# Bering Sea Non-native Marine Species Status Reports

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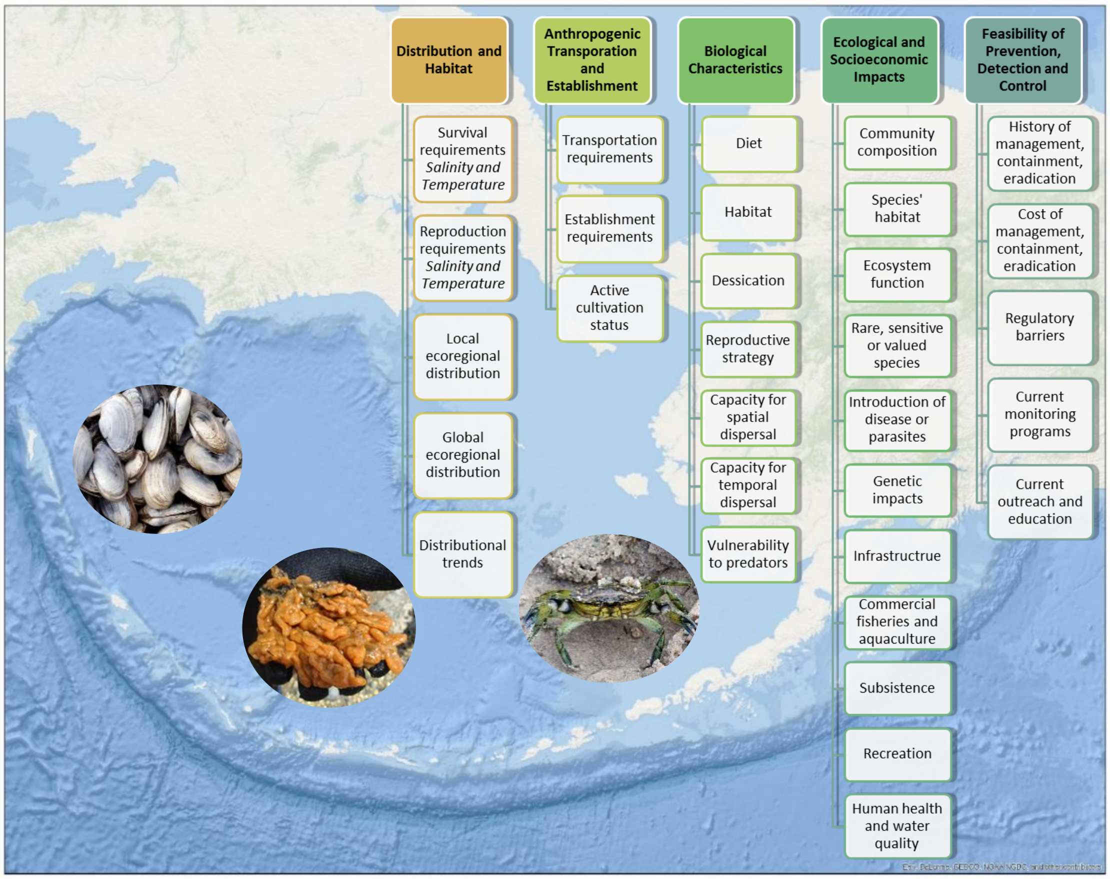


To evaluate the risk of non-native species to the Bering Sea, we developed a semi-quantitative ranking system consisting of 31 questions grouped into five categories. The first four categories evaluate a species' ability to arrive and establish in the Bering Sea, its reliance on humans for introductions, its biology, and its impacts on ecological and human systems. The fifth category is not included in the total ranking score, but provides information on management considerations. The ranking system has methods to account for data deficiencies and calculates these deficiencies to allow readers to weigh the lack of knowledge with the ranking score. Cumulative scores produce an index value that may be used to rank species such that managers and researchers may prioritize species for action.

This atlas is a companion document to NPRB project 1532, The Pervasive Invasive: Assessing the Risk of Non-native Marine Species in the Bering Sea.

Detailed methods and project information are presented in the final project report: Reimer, J.P., A. Droghini, A. Fischbach, J.T. Watson, B. Bernard, and A. Poe. 2017. Assessing the Risk of Non-Native Marine Species in the Bering Sea. Alaska Center for Conservation Science, University of Alaska Anchorage, AK. 40 pp.

Digital copies of all spatial data and publications associated with this project are available online: [www.beringinvaders.org](www.beringinvaders.org)

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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Hediste diadroma*

**Common Name** *a clam worm*

| | |
|---|---|
| Phylum | Annelida |
| Class | Polychaeta |
| Order | Phyllodocida |
| Family | Nereididae |

**Final Rank** 38.83

**Data Deficiency:** 10.50

## Species Occurrence by Ecoregion

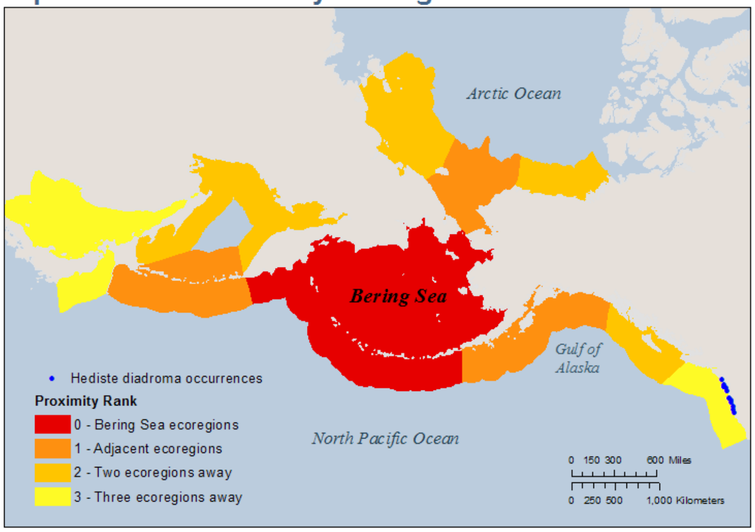


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 9.75 | 30 | 0 |
| Anthropogenic Influence: | 4.75 | 10 | 0 |
| Biological Characteristics: | 18.75 | 25 | 5.00 |
| Impacts: | 1.5 | 25 | 5.50 |
| **Totals:** | 34.75 | 89.50 | 10.50 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | NA | Minimum Salinity (ppt) | 4 |
| Maximum Temperature (°C) | NA | Maximum Salinity (ppt) | 34 |
| Minimum Reproductive Temperature (°C) | 18 | Minimum Reproductive Salinity (ppt) | 4 |
| Maximum Reproductive Temperature (°C) | NA | Maximum Reproductive Salinity (ppt) | 20 |

### Additional Notes

Hediste diadroma is a polychaete worm with an elongated, cylindrical body that gradually tapers towards the posterior end. In their native range (Japan), individuals are up to 150 mm in length (Sato and Nakashima 2003), but the largest specimen observed in North America is 43 mm (Nishizawa et al. 2014). Females are green in color and males are yellow and white with a prominent dorsal blood vessel (Hanafiah et al. 2006). When breeding, H. diadroma undergoes a morphological change, as the body wall becomes thin and transparent. Morphological identification of sexually immature Hediste spp. is very difficult. H. diadroma is Native to the Northwest Pacific (Japan). The first reported introduction to North America was on the west coast of Washington and Oregon in 2009. Its abundance, geographical distribution, and ecological impacts in North American waters is unknown.

# 1. Distribution and Habitat



### 1.1 Survival requirements - Water temperature

**Choice:** C — Little overlap – A small area (<25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 1.25 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Temperature thresholds required for survival are unknown. Because this species can reproduce in cold waters, we assume that there is at least some suitable year-round habitat in the Bering Sea. We therefore ranked this species as "Little overlap" with "High Uncertainty".

**Background Information:**
General surival requirements were not available in the literature. Reproductive temperature range is from 5 to 20°C (Hanafia et al. 2006, qtd. in Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 1.2 Survival requirements - Water salinity

**Choice:** A — Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea. We ranked this question with "High Uncertainty" to indicate disagreements in model estimates.

**Background Information:**
Based on field observations, salinity range for H. diadroma is 4 to 34 ppt (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 1.3 Establishment requirements - Water temperature

**Choice:** D — No overlap – Temperatures required for reproduction do not exist in the Bering Sea

**Score:** 0 of 3.75

**Ranking Rationale:**
Temperatures required for metamorphosis do not exist in the Bering Sea.

**Background Information:**
The temperature range required for reproduction of H. diadroma is 5°C to 20°C (Hanafia et al. 2006 as qtd. in Fofonoff et al. 2003). In a laboratory setting, immature animals required temperatures of 18°C for metamorphosis (Nishizawa et al 2014).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Nishizawa et al. 2014

### 1.4 Establishment requirements - Water salinity

**Choice:** D — No overlap – Salinities required for reproduction do not exist in the Bering Sea

**Score:** 0 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Physiological salinity requirements are unknown. However, this species appears to undergo early life stages in brackish waters < 20 ppt. These salinities do not exist in the Bering Sea.

**Background Information:**
H. diadroma are typically found in brackish waters during reproduction and immature worms are most abundant in mesohalinehabitats of 4 to 19 ppt.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.5 Local ecoregional distribution*

**Choice: D** Present in an ecoregion greater than two regions away from the Bering Sea

**Score:** 1.25 of 5

**Ranking Rationale:**
Washington is the closest known occurrence record to the Bering Sea.

**Background Information:**
H. diadroma has been observed in Washington, Oregon and California (NEMESIS; Fofonoff et al 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.6 Global ecoregional distribution*

**Choice: C** In few ecoregions globally

**Score:** 1.75 of 5

**Ranking Rationale:**
Limited distribution.

**Background Information:**
H. diadroma is native to the Northwest Pacific (China and Japan). The first reported introduction to North America was on the west coast of Washington and Oregon in 2009. It has been reported in Washington, Oregon and at least one location in California (NEMESIS; Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.7 Current distribution trends*

**Choice: C** Established outside of native range, but no evidence of rapid expansion or long-distance dispersal

**Score:** 1.75 of 5

**Ranking Rationale:**
Well established in North America but is limited by its dispersal ability

**Background Information:**
Range expansion along the west coast of North America is likely the result of repeated introductions from its native range to the U.S. (Tosuji and Furota 2016). No information was found on natural dispersal distances in the literature.

**Sources:**
Torchin et al. 2005 Tosuji and Furota 2016

| | |
|---|---|
| **Section Total - Scored Points:** | 9.75 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 2. Anthropogenic Transportation and Establishment

4

### 2.1 *Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice: B** Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 **of** 4

**Ranking Rationale:**
Transportation has been observed in ballast water, however dispersal away from ports has not been observed.

**Background Information:**
The introduction of H. diadroma to the western U.S. is thought to be the result of transportation by ballast water (Nishizawa et al. 2014).

**Sources:**
Nishizawa et al. 2014

### 2.2 *Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice: B** Readily establishes in areas with anthropogenic disturbance/infrastructure; occasionally establishes in undisturbed areas

**Score:** 2.75 **of** 4

**High uncertainty?** ☑

**Ranking Rationale:**
Information is lacking on the distribution and dispersal of this species in its introduced range. This species can establish in natural habitats away from anthropogenic infrastructure, but the extent to which it does that is unknown.

**Background Information:**
This species can spread outside of major international shipping areas where it is likely to have been introduced (Nishizawa et al. 2014). Nishizawa et al. (2014) sampled six sites in Oregon and Washington. All of these sites were near roads, but one was near the relatively remote Willapa National Wildlife Refuge.

**Sources:**
Nishizawa et al. 2014

### 2.3 *Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice: B** No

**Score:** 0 **of** 2

**Ranking Rationale:**

**Background Information:**
H. diadroma is not currently farmed or intentionally cultivated.

**Sources:**
None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 4.75 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics



### *3.1 Dietary specialization*

**Choice:** **A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Can feed on a variety of things found readily in the Bering Sea.

**Background Information:**
H. diadroma is a surface-deposit feeder that feeds on detritus, benthic microalgae and settling phytoplankton (Kanaya et al. 2008). It has the ability to secrete a mucous net that is used to trap planktonic particles for food (Toba and Sato 2013).

**Sources:**
Kanaya et al. 2008 Toba and Sato 2013

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **B** Requires specialized habitat for some life stages (e.g., reproduction)

**Score:** 3.25 of 5

**Ranking Rationale:**
Requires estuaries with sandy or muddy tidal flats for adult life stages.

**Background Information:**
In its native range, H. diadroma is found in estuaries where it burrows into sandy or muddy tidal flats. H. diadroma is tolerant of a wide range of salinities (Sato and Nakashima 2003) and temperatures, with different habitats used during different life stages.

Embryos and larvae are planktonic and need high salinities (>20 ppt) during development; at these life stages, individuals are found in the sea. Young return to brackish waters ~1 month after fertilization, where they adopt a benthic lifestyle (Sato and Nakashima 2003).

Changes in the spatial distribution of H. diadroma following the 2011 tsunami suggests that this species preferred sandy, oxidized substrates (post-tsunami), rather than the pre-tsunami habitat, a hypertrophic lagoon whose muddy substrate was high in hydrogen sulfide (Kanaya et al. 2015).

**Sources:**
Sato and Nakashima 2003 Kanaya et al. 2015

### *3.3 Desiccation tolerance*

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *3.4 Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice:** **A** High – Exhibits three or four of the above characteristics

**Score:** 5 of 5

**Ranking Rationale:**
High fecundity, low parental investment and external fertilization, and short generation time.

**Background Information:**
H. diadroma has a diadromous, migratory lifecycle. Individuals exhibit reproductive swarming behavior during the spawning season which occurs during winter or early spring (January to April). Swarming has been reported as late as June in northern Japan (Sato and Nakashima 2003). Gametes release and fertilization occur in salt water near river entrances. Females release 10,000 to 1 million eggs per individual, and adults die after spawning (lifespan: 1 year).

**Sources:**
Sato and Nakashima 2003

### *3.5 Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice:** **A** Disperses long (>10 km) distances

**Score:** 2.5 of 2.5

**Ranking Rationale:**
Dispersal primarily occurs during the larval stage and can travel using tides, up to distance of 45 km.

**Background Information:**
Adults are largely sessile for majority of their life, living in self-constructed burrows. Adults engage in migratory, seaward movements when it is time to spawn, but the distance they travel during those movements is unknown. Based on sampling distances and study area description, distances of up to 45 km are possible, and coincide with tidal movements (Kikuchi and Yasuda 2006). Larval stage is long-lived and planktonic, and resides in the sea.

**Sources:**
Kikuchi and Yasda 2006

### *3.6 Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice:** **B** Moderate – Exhibits one of the above characteristics

**Score:** 1.75 of 2.5

**Ranking Rationale:**
Dispersal occurs primarily during one lifestage (larval), however, that stage is relatively long (1 month).

**Background Information:**
In the Nanakita River estuary in northeastern Japan, the life cycle of H. diadroma includes several movements along a salinity gradient: (1) benthic adults in euryhaline estuaries, (2) reproductive swarming of mature adults around river mouths, (3) small eggs developing into free-swimming larvae under relatively high salinity (favorable salinity 22–30 psu), (4) planktonic larval life at sea, lasting 1 month, and (5) upstream migrations and settlement of larvae into brackish waters.
Besides their reproductive swarming behaviour, adults are likely relatively sedentary, living in burrows that they construct

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *3.7 Vulnerability to predators*



**Choice: D** — Multiple predators present in the Bering Sea or neighboring regions

**Score:** 1.25 of 5

**Ranking Rationale:**
H. diadroma has numerous predators, many of which exist in the Bering Sea.

**Background Information:**
In its native range, H. diadroma is a major dietary component of five migratory shorebirds (Iwamatsu et al. 2007 as qtd. In Fofonoff et al. 2003).
H. diversicolor, which is a closely related species in Europe, is highly prone to predation by birds, large crabs (Carcinus maenas), shrimps and small fish (gobies) that migrate onto the mudflats from lower tidal levels (Scaps 2002).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Scaps 2002

| | |
|---|---|
| **Section Total - Scored Points:** | 18.75 |
| **Section Total - Possible Points:** | 25 |
| **Section Total -Data Deficient Points:** | 5 |

## 4. Ecological and Socioeconomic Impacts



### 4.1 *Impact on community composition*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No literature to suggest that H. diadroma, or closely related species have an impact on community composition.

**Background Information:**
H. diversicolor, a closely related European species, is associated with large numbers of heterotrophic bacteria and a higher concentration of chlorophyll a. Oxygen availability in burrow environments may affect growth and population sizes of associated organisms. A study on the island of Sylt found that the density of small, benthic organisms near burrows was nearly 8X greater than reference (non-burrow) sites at the same sediment depth. Diversity was not affected by H. diversicolor burrows.

In OR and WA, H. diadroma co-occurs with a native species H. limnicola (Nishizawa et al. 2014). At many sites, Hediste diadroma has replaced H. limnicola in the more saline intertidal portions of estuaries, while H. limnicola remains dominant at salinities below 5 PSU and in subtidal habitats (Tosuji and Furota 2016, qtd. in Fofonoff et al. 2003)

**Sources:**
Anderson and Meadows 1978   Nishizawa et al. 2014   NEMESIS; Fofonoff et al. 2003

### 4.2 *Impact on habitat for other species*

**Choice:** **C** Limited – Has limited potential to cause changes in one or more habitats

**Score:** 0.75 of 2.5

**Ranking Rationale:**
May increase biogeochemical cycling.

**Background Information:**
H. diadroma is a burrowing species which may have a limited effect on habitat for other species by increasing oxygen and sediment transport in areas it inhabits (Kristensen and Hansen 1999).

**Sources:**
Kristensen and Hansen 1999

### 4.3 *Impact on ecosystem function and processes*

**Choice:** **C** Limited – Causes or potentially causes changes to food webs and/or ecosystem functions, with limited impact and/or within a very limited region

**Score:** 0.75 of 2.5

**High uncertainty?** ☑

**Ranking Rationale:**
If H. diadroma is similar to H. diversicolor, it may alter sediment biogeochemistry and element cycling in small areas.

**Background Information:**
H. diversicolor, a closely related European species, affects ecosystem processes through its feeding and burrowing behaviors, which transport solutes and water, and promote oxygenation and microbial growth. This aids in the release of carbon dioxide and ammonium (Kristensen and Hansen 1999). Also increases nutrient and heavy metal fluxes in the water column (Scaps 2002).

**Sources:**
Kristensen and Hansen 1999   Scaps 2002

### 4.4 Impact on high-value, rare, or sensitive species and/or communities

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
To date, no impacts on high-value, rare, or sensitive species have been reported for H. diadroma.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 4.5 Introduction of diseases, parasites, or travelers

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 4.6 Level of genetic impact on native species

Can this invasive species hybridize with native species?

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
To date, no impacts on genetic hybridization have been reported for H. diadroma.

**Background Information:**
No genetic hybridization has been reported for H. diadroma in the literature.

**Sources:**
None listed

### 4.7 Infrastructure

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 4.8 Commercial fisheries and aquaculture

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on commercial fisheries and aquaculture have been reported, and given the ecology of H. diadroma, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 4.9 Subsistence

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on subsistence activities have been reported for H. diadroma, and given the ecology of H. diadroma, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 4.101 Recreation

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on recreation have been reported for H. diadroma, and given the ecology of H. diadroma, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 4.11 Human health and water quality

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on human health or water quality have been reported for H. diadroma, and given the ecology of H. diadroma, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 1.5 |
| **Section Total - Possible Points:** | 24.5 |
| **Section Total -Data Deficient Points:** | 5.5 |

# 5. Feasibility of prevention, detection and control



### *5.1 History of management, containment, and eradication*

**Choice:** **B** Not attempted

**Score:** of

**Ranking Rationale:**

**Background Information:**
No attempts to manage, contain or eradicate H. diadroma are mentioned in the literature.

**Sources:**
None listed

### *5.2 Cost and methods of management, containment, and eradication*

**Choice:** **B** Major short-term and/or moderate long-term investment

**Score:** of

**Ranking Rationale:**
To comply with ballast water regulations, vessels will have to equip themselves with an onboard ballast water treatment system. These systems represent a major short-term cost for vessel owners (up to $3 million), with additional costs over time to maintain and replace equipment (e.g. chemicals, filters, UV light bulbs).

**Background Information:**
No species-specific methods have been reported in the literature. However, methods to deatil with ballast water have been tested.

The costs associated with purchasing a ballast water treatment system depend on the volume of water that needs to be treated. Systems with a pump capacity of 200-250 $m^3/h$ can cost from $175,000 to $490,000. The estimated price for larger systems with a pump capacity of around 2000 $m^3/h$ range from $650,000 to nearly $3 million.

**Sources:**
Zagdan 2010

### *5.3 Regulatory barriers to prevent introductions and transport*

**Choice:** **C** Regulatory oversight and/or trade restrictions

**Score:** of

**Ranking Rationale:**
Alaska does not have state regulations on ballast water management, but two federal regulations (USCG and EPA) require mandatory reporting and either exchange or treatment of ballast water.

**Background Information:**
State regulations: Alaska does not have a state regulations related to the management of aquatic invasive species in discharged ballast water. It relies on the U.S. Coast Guard (USCG) to enforce national standards. In Alaska, data from 2009-2012 show moderate to high compliance with USCG reporting requirements (qtd. in Verna et al. 2016).

Federal regulations: In the U.S., ballast water management (treatment or exchange) and record-keeping is mandatory and regulated by the USCG, with additional permitting by the Environmental Protection Agency (EPA). Certain vessels (e.g. small vessels or those traveling within 1 Captain of the Port Zone) are exempt from USCG and EPA regulations

**Sources:**
EPA 2013 Verna et al. 2016

### *5.4 Presence and frequency of monitoring programs*



**Choice:** **A** No surveillance takes place

**Score:** of

**Ranking Rationale:**
No species-specific monitoring exists for H. diadroma.

**Background Information:**

**Sources:**
None listed

### *5.5 Current efforts for outreach and education*

**Choice:** **A** No education or outreach takes place

**Score:** of

**Ranking Rationale:**
No species-specific educational materials were found for H. diadroma.

**Background Information:**

**Sources:**
None listed

**Section Total - Scored Points:**
**Section Total - Possible Points:**
**Section Total -Data Deficient Points:**

## Literature Cited for *Hediste diadroma*


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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Polydora cornuta*

**Common Name** *whip mudworm*

| | |
|---|---|
| **Phylum** | Annelida |
| **Class** | Polychaeta |
| **Order** | Canalipalpata |
| **Family** | Spionidae |

**Final Rank** 51.25

**Data Deficiency:** 0.00

## Species Occurrence by Ecoregion

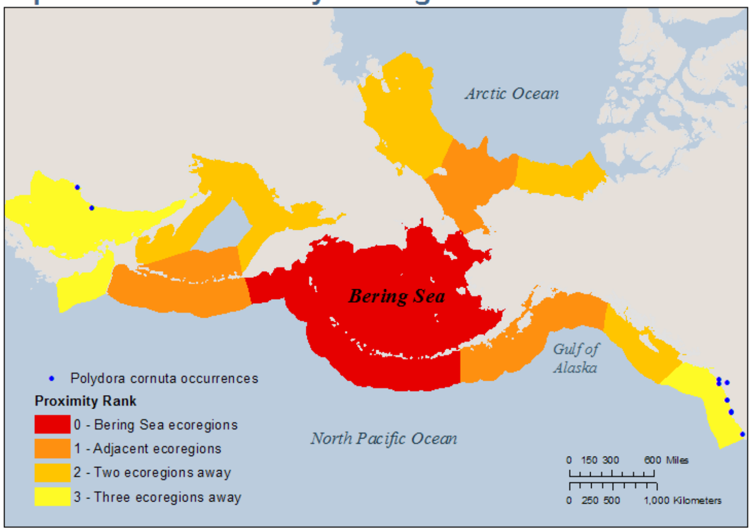


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 20.5 | 30 | 0 |
| Anthropogenic Influence: | 4.75 | 10 | 0 |
| Biological Characteristics: | 23 | 30 | 0 |
| Impacts: | 3 | 30 | 0 |
| **Totals:** | 51.25 | 100.00 | 0.00 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | -2 | Minimum Salinity (ppt) | 2 |
| Maximum Temperature (°C) | 29 | Maximum Salinity (ppt) | 75 |
| Minimum Reproductive Temperature (°C) | 10 | Minimum Reproductive Salinity (ppt) | 5 |
| Maximum Reproductive Temperature (°C) | 29 | Maximum Reproductive Salinity (ppt) | 75 |

### Additional Notes

Polydora cornuta is a species complex of tube-building polychaete worms. Adult individuals have up to 90 segments, can be between 12 to 32 mm long, and are light tan in color.

## 1. Distribution and Habitat



### *1.1 Survival requirements - Water temperature*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 3.75 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Temperatures required for year-round survival occur over a large (>75%) area of the Bering Sea. Thresholds are based on geographic distribution, which may not represent physiological tolerances; we therefore ranked this question with "High uncertainty".

**Background Information:**
This species' temperature range is from -2 to 29˚C (based on geographic distribution), though it can probably tolerate warmer temperatures.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.2 Survival requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
This species has been collected in water with salinities between 2 and 75 PSU. It is abundant at salinities above 5 PSU.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.3 Establishment requirements - Water temperature*

**Choice:** **C** Little overlap – A small area (<25%) of the Bering Sea has temperatures suitable for reproduction

**Score:** 1.25 of 3.75

**Ranking Rationale:**
Temperatures required for reproduction occur in a limited area (<25%) of the Bering Sea.

**Background Information:**
This species requires a minimum reproductive temperature of 10˚C (based on laboratory experiments; Orth 1971 qtd. in Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.4 Establishment requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Although upper salinity thresholds are unknown, this species is a marine organism that does not require freshwater to reproduce. We therefore assume that this species can reproduce in saltwater (31 to 35 ppt). These salinities occur in a large (>75%) portion of the Bering Sea.

**Background Information:**
This species requires a minimum reproductive salinity of 5 PSU.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.5 Local ecoregional distribution*

**Choice: D** Present in an ecoregion greater than two regions away from the Bering Sea

**Score:** 1.25 of 5

**Ranking Rationale:**
This species is currently found from California to southern British Columbia.

**Background Information:**
This species is currently found in southern BC, and in the U.S. Pacific Northwest from WA to CA.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.6 Global ecoregional distribution*

**Choice: A** In many ecoregions globally

**Score:** 5 of 5

**Ranking Rationale:**
Polydora cornuta has a global distribution. It is found on both coasts of North America, in Europe, South America, parts of Asia, Australia, and New Zealand.

**Background Information:**
This species' is found in cold- to warm-temperate waters around the world. It is considered cryptogenic in eastern North America, where it occurs from Quebec and Newfoundland south to the Caribbean; it is also considered cryptogenic in Atlantic Europe, where it is found in the Netherlands, Germany, and the U.K., south to Portgual. In Europe, it has also been reported in the Mediterranean, Aegean, and Black Seas. In the southern hemisphere, it is found in South America, Australia, New Zealand. In Asia, it occurs from Taiwan to southern Russia (Peter the Great Bay). It is invasive on the western coast of North America, where it occurs from southern British Columbia to Mexico.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.7 Current distribution trends*

**Choice: C** Established outside of native range, but no evidence of rapid expansion or long-distance dispersal

**Score:** 1.75 of 5

**Ranking Rationale:**
Although this species has a widespread distribution, accounts of its geographic spread suggest that its dispersal is likely due to introductions by human vectors.

**Background Information:**
This species is being introduced worldwide via ballast waster and hull fouling, and has been transported extensively as a result of human activities (Radashevsky and Selifonova 2013).

**Sources:**
Radashevsky and Selifonova 2013

| | |
|---|---|
| **Section Total - Scored Points:** | 20.5 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 2. Anthropogenic Transportation and Establishment



### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice: B** — Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 of 4

**Ranking Rationale:**
This species can transport by ballast water, hull fouling, and hitchhiking. Its geographic spread is attributed to introduction by humans (Radashevsky and Selifonova 2013).

**Background Information:**
Polydora cornuta was initially introduced to the west coast of North America with introductions of Eastern oysters (Crassostrea virginica). Nowadays, the most likely vectors of introductions are via hull fouling and ballast water (Radashevsky and Selifonova 2013).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Radashevsky and Selifonova 2013

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice: B** — Readily establishes in areas with anthropogenic disturbance/infrastructure; occasionally establishes in undisturbed areas

**Score:** 2.75 of 4

**Ranking Rationale:**
In its introduce range, this species is more commonly associated with anthropogenic substrates than natural habitats.

**Background Information:**
This species is most often associated with anthropogenic habitats, although it can also settle on natural habitats such as soft-bottom substrates and oyster reefs. A survey of 174 invertebrate species in southern Brazil only found Polydora cornuta on artificial substrates (Bumbeer and da Rocha 2016). This species is tolerant of disturbance and polluted areas, which may facilitate its establishment in anthropogenic areas (Radashevsky and Selifonova 2013).

**Sources:**
Bumbeer and da Rocha 2016   NEMESIS; Fofonoff et al. 2003   Radashevsky and Selifonova 2013

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice: B** — No

**Score:** 0 of 2

**Ranking Rationale:**
This species is not farmed or intentionally cultivated.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 4.75 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

# 3. Biological Characteristics



### *3.1 Dietary specialization*

**Choice:** **A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
This species has broad dietary preferences, and foods are readily available in the Bering Sea.

**Background Information:**
Larvae feed on phytoplankton, while adults switch between suspension and deposit feeding, consuming detritus, microalgae, and plankton. Predation on bivalve veligers has also been records.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **A** Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 of 5

**Ranking Rationale:**
This species exhibits a broad range of habitat and water tolerances.

**Background Information:**
This species can tolerate a wide range of temperatures and salinities, and can establish in disturbed or polluted areas (Radashevsky and Selifonova 2013). It can also tolerate hypoxic conditions and is often exposed to environmental extremes.

**Sources:**
Radashevsky and Selifonova 2013 NEMESIS; Fofonoff et al. 2003

### *3.3 Desiccation tolerance*

**Choice:** **C** Little to no tolerance (<1 day) of desiccation during its life cycle

**High uncertainty?** ☑

**Score:** 1.75 of 5

**Ranking Rationale:**
The desiccation tolerance of this species is unknown, but studies on related spionid polychaetes suggests that this group has a low tolerance to air exposure.

**Background Information:**
No species-specific information has been found. In Tasmania, infestation of abalones by two polychaetes (Boccardia knoxi and Polydora hoplura) was significantly reduced when fouled abalones were exposed to air for 3 to 8 hours (Lleonart et al. 2003). On average, less than 4 individuals of B. knoxi survived after being exposed to air for 8 hours.

**Sources:**
Lleonart et al. 2003

### 3.4 *Likelihood of success for reproductive strategy*



i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice:** **A** High – Exhibits three or four of the above characteristics

**Score:** 5 **of** 5

**Ranking Rationale:**

This species exhibits external fertilization, high fecundity, and short generation time. Reproduction is sexual and sexes are separate.

**Background Information:**

Sexes are separate. Sperm is released in packets called spermatophores; these packets are then taken by females to fertilize her deposited eggs. Eggs are brooded in tubes built by females (Levin 1984). Females can store sperm, and a single spermatophore packet can fertilize several spawning events (Rice et al. 2008). Although single brood sizes are small (between 50 and 200 eggs; Levin 1984), Rice et al. (2008) estimated that P. cornuta females could produce between 26 000 and >31 000 eggs in 90 days under laboratory conditions. Larvae are planktonic. Development rates are affected by temperature and food supply. At 10°C, larvae settled within 60 days; time to settlement decreased to 16-28 days at 12°C, and 12 days at 28°C (qtd. in Fofonoff et al. 2003). Under laboratory conditions, sexual maturity occurred within 33 days at 18°C. Average adult survival was 13 months under controlled conditions.

**Sources:**

NEMESIS; Fofonoff et al. 2003 Rice et al. 2008 Levin 1984

### 3.5 *Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice:** **A** Disperses long (>10 km) distances

**Score:** 2.5 **of** 2.5

**High uncertainty?** ☑

**Ranking Rationale:**

P. cornuta is considered capable of long-distance dispersal, but no quantitative estimates are provided.

**Background Information:**

Levin (1984) identified the planktonic larval stage as this species' main mode of dispersal. While she considers P. cornuta as a long-distance disperser, she does not define or estimate "long-distance".

**Sources:**

Levin 1984

### *3.6 Likelihood of dispersal or movement events during multiple life stages*

20

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: A** High – Exhibits two or three of the above characteristics

**Score:** 2.5 of 2.5

**Ranking Rationale:**
Larvae are free-swimming and long-lived. Smaller individuals may be dispersed via sediment transport. Adults are sessile and live in tubes; eggs are laid and fertilized in these tubes.

**Background Information:**
The larval stage is planktonic and long-lived: larvae can remain in the water column for up to 60 days at 10°C, and at least 1 week at 20°C. Levin (1984) considered the larval stage as this species' main dispersal stage, but Shull (1997) documented dispersal of small, recently settled individuals via bedload transport. Adults live in tubes that they build in the substrates, and eggs are deposited and fertilized in these tubes (Rice et al. 2008).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Rice et al. 2008 Levin 1984 Shull 1997

### *3.7 Vulnerability to predators*

**Choice: D** Multiple predators present in the Bering Sea or neighboring regions

**Score:** 1.25 of 5

**Ranking Rationale:**
This species is preyed upon by several species present in the Bering Sea ecoregion.

**Background Information:**
P. cornuta is preyed upon by fishes and invertebrates including shrimps and crabs.

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 23 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

# 4. Ecological and Socioeconomic Impacts

## *4.1 Impact on community composition*

**Choice: C** Limited – Single trophic level; may cause decline but not extirpation

**Score:** 0.75 of 2.5

**Ranking Rationale:**
Although P. cornuta can become a dominant species in certain habitats, its presence has not been linked to the decline or extirpation of other species. At high densities, similar species are known to compete with native polychaetes.

**Background Information:**
P. cornuta fouls bivalve shells and has been documented feeding on oyster larvae (although species ID is tentative; Breese and Phibbs 1972); however, the effect on oyster fitness and populations is unknown (Fofonoff et al. 2003).

Polydora cornuta is tolerant of polluted sites, and is thus a strong competitor in eutrophic habitats. Once introduced, it can quickly become the dominant species in polluted habitats (Dagli and Ergen 2008; Karhan et al. 2008) and can occur at high densities of several thousand individuals/m2 (Karhan et al. 2008). However, the competitive abilities of P. cornuta in these sites are difficult to determine, because many other polychaetes perform poorly in polluted water (Fofonoff et al. 2003).

A similar tube-building species, Polydora limicola, competed with at least three native species in the Black Sea where it was introduced and became dominant (Losovskaya and Zolotarev 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Breese and Phibbs 1972 Dagli and Ergen 2008 Karhan et al. 2008 Losovskaya and Zolotarev 2003

## *4.2 Impact on habitat for other species*

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
Impacts on habitat have not been reported for this species.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003 Losovskaya and Zolotarev 2003

## *4.3 Impact on ecosystem function and processes*

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
Impacts on ecosystem functions or processes have not been reported for this species.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.4 *Impact on high-value, rare, or sensitive species and/or communities*



**Choice: C** Limited – Has limited potential to cause degradation of one more species or communities, with limited impact and/or within a very limited region

**Score:** 0.75 of 2.5

**High uncertainty?** ✔

**Ranking Rationale:**
Although it may feed on oyster larvae, Polydora cornuta has not been shown to affect population numbers, and no reports exist from natural settings.

**Background Information:**
Breese and Phipps (1972) claimed that P. cornuta ate significant amounts of oyster larvae in a hatchery facility. However, the identification of the polychaete worm was uncertain.

**Sources:**
Breese and Phibbs 1972

### 4.5 *Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not known to introduce parasites, diseases or hitchhikers.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.6 *Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice: D** No impact

**Score:** 0 of 2.5

**High uncertainty?** ✔

**Ranking Rationale:**
Geographically distinct populations of P. cornuta are able to hybridize under controlled conditions. The ability for P. cornuta to hybridize with other species is unknown, as is the effect of hybridization on populations. Alaska is home to ~50 species of tube-building polychaetes.

**Background Information:**
The taxonomy of this species complex remains unresolved. In some cases, individuals from geographically distinct populations (e.g., California and Florida) can hybridize under experimental conditions (Rice et al. 2008).

**Sources:**
Rice et al. 2008 AFSC 2016

### 4.7 Infrastructure



**Choice: B** Moderate – Causes or has the potential to cause degradation to infrastructure, with moderate impact and/or within only a portion of the region

**Score:** 1.5 of 3

**Ranking Rationale:**
P. cornuta is a common fouling organism. Fouling organisms impose substantial economic costs for shipping and other marine industries.

**Background Information:**
P. cornuta is a common and abundant fouler of docks, ships, and other infrastructure. Fouling organisms cost the U.S. Navy over $50 million a year in fuel costs due to drag (Cleere 2001).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Cleere 2001

### 4.8 Commercial fisheries and aquaculture

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not predicted to impact commercial fisheries in the Bering Sea.

**Background Information:**
Although P. cornuta feeds on oyster larvae (Breese and Phibbs 1972), impacts to the fishing or shellfish industry have not been reported (Fofonoff et al. 2003).

**Sources:**
Breese and Phibbs 1972 NEMESIS; Fofonoff et al. 2003

### 4.9 Subsistence

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not predicted to impact subsistence resources in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.101 Recreation

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not predicted to impact recreational activities in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.11 Human health and water quality*

24

**Choice:** **D** No impact

**Score:** **0** of **3**

**Ranking Rationale:**
This species is not predicted to impact human health or water quality in the Bering Sea.

**Background Information:**
No impacts have been reported. This species is considered a pollution indicator because of its ability to tolerate polluted areas.

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 3 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 5. Feasibility of prevention, detection and control

25

### *5.1 History of management, containment, and eradication*

**Choice:** **C** Attempted; control methods are currently in development/being studied

**Score:** of

**Ranking Rationale:**
Methods to control Polydora worms are being tested.

**Background Information:**
Several methods to control Polydora worms have been tested, including exposure to air and freshwater, chemical methods, and physical removal (Haskin and Calvo 2014).

**Sources:**
Haskin and Calvo 2014

### *5.2 Cost and methods of management, containment, and eradication*

**Choice:** **B** Major short-term and/or moderate long-term investment

**Score:** of

**Ranking Rationale:**
Control of Polydora sp. infestation on oyster farms requires a moderate investment sustained over time. To date, treatment methods are not fully effective at controlling infestations.

**Background Information:**
For a mid-sized oyster farm, controlling Polydora sp. infestation requires approximately 700 hours of labor, and an additional $2000 per year for equipment and supplies (Haskin and Calvo 2014). Treatments are still being developed and need to be repeated (Haskin and Calvo 2014).

**Sources:**
Haskin and Calvo 2014

### *5.3 Regulatory barriers to prevent introductions and transport*

**Choice:** **B** Regulatory oversight, but compliance is voluntary

**Score:** of

**Ranking Rationale:**
This species is transported by numerous vectors and no species-specific regulations are currently in place. Although there are federal regulations for both ballast water and hull fouling, compliance with federal fouling regulations remains voluntary.

**Background Information:**

**Sources:**
CFR 2017 Hagan et al. 2014

### *5.4 Presence and frequency of monitoring programs*

**Choice:** **A** No surveillance takes place

**Score:** of

**Ranking Rationale:**
We did not find any information to suggest that Polydora cornuta is being monitored in Alaska.

**Background Information:**

**Sources:**
None listed

### *5.5 Current efforts for outreach and education*

26

**Choice:** **A** — No education or outreach takes place

**Score:** of

**Ranking Rationale:**
We did not find any information on outreach or education programs for this species.

**Background Information:**

**Sources:**
None listed

**Section Total - Scored Points:**
**Section Total - Possible Points:**
**Section Total -Data Deficient Points:**

## Literature Cited for *Polydora cornuta*


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- Shull, D. H. 1997. Mechanisms of infaunal polychaete dispersal and colonization in an intertidal sandflat. Journal of Marine Research 55:153 179.

# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Pseudopolydora cf. kempi*

**Common Name** *spionid worm*

| | |
|---|---|
| **Phylum** | Annelida |
| **Class** | Polychaeta |
| **Order** | Canalipalpata |
| **Family** | Spionidae |

**Final Rank** 47.40

**Data Deficiency:** 8.75

## Species Occurrence by Ecoregion

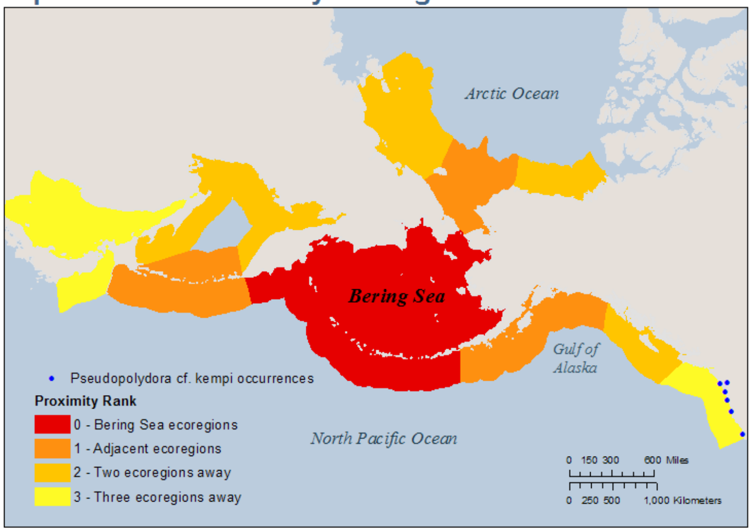


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

### Category Scores and Data Deficiencies

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 20 | 26 | 3.75 |
| Anthropogenic Influence: | 4.75 | 10 | 0 |
| Biological Characteristics: | 16 | 25 | 5.00 |
| Impacts: | 2.5 | 30 | 0 |
| **Totals:** | 43.25 | 91.25 | 8.75 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | NA | Minimum Salinity (ppt) | 1.6 |
| Maximum Temperature (°C) | 29 | Maximum Salinity (ppt) | 37 |
| Minimum Reproductive Temperature (°C) | NA | Minimum Reproductive Salinity (ppt) | 31* |
| Maximum Reproductive Temperature (°C) | NA | Maximum Reproductive Salinity (ppt) | 35* |

### Additional Notes

A species complex of tube-building polychaetes (segmented worms). Maximum reported length ranges from 6.5 to 22 mm. The worms are white to tan in color, with black pigments towards the front of their body, and sometimes with a pair of dorsal spots on the chaetigers. Populations from different localities show small differences in morphology. Populations from India, the Sea of Japan, and California differ in the number and size of nurse eggs providing food for developing embryos, and in the length of the planktonic larval stage (Blake and Woodwick 1975; Myohara 1979; Rdashevsky 1985; Blake and Ruff 2007). Pseudopolydora cf. kempi is a tube-building suspension and deposit feeder. Has been subdivided into several subspecies, which show differences in adult morphology and larval development. The status of these subspecies is unresolved. Its native range is believed to be the Indo-Pacific with introduced populations in Europe, Australia, New Zealand, Central America and the West Coast of the US (British Columbia to California). It is typically found in intertidal mudflats and shallow, muddy subtidal waters, often with low or variable salinity.

# 1. Distribution and Habitat

### *1.1 Survival requirements - Water temperature*

**Choice:** **C** Little overlap – A small area (<25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 1.25 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
The minimum temperature threshold is not known, but this species currently exists at northern latitudes in Russia. We therefore ranked this species as "Little overlap" with "High uncertainity".

**Background Information:**
Broad temperature range, from cold-temperate to tropical. Maximum Temperature: 29º C (Chollet and Bone 2007). Found at similar northern latitudes in Russia. A minimum temperature threshold was not found in the literature for P. cf. kempi.

**Sources:**
Chollet and Bone 2007

### *1.2 Survival requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
P. cf. kempi has a salinity tolerance of 1.6 to 35 PSU (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.3 Establishment requirements - Water temperature*

**Choice:** **U** Unknown/Data Deficient

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information is available in the literature for temperature thresholds for the reproduction of P. cf. kempi. Growth rates for this species depend upon temperature (Blake and Woodwick 1975)

**Sources:**
Blake and Woodwick 1975

### *1.4 Establishment requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Although salinity thresholds are unknown, this species is a marine organism that does not require freshwater to reproduce. We therefore assume that this species can reproduce in saltwater (31 to 35 ppt). These salinities occur in a large (>75%) portion of the Bering Sea.

**Background Information:**
No information found.

**Sources:**
None listed

### *1.5 Local ecoregional distribution*

**Choice: D** Present in an ecoregion greater than two regions away from the Bering Sea

**Score:** 1.25 of 5

**Ranking Rationale:**
Washington is closest known occurrence of P. cf. kempi to the Bering Sea.

**Background Information:**
Found along the west coast of North America in California, Oregon and Washington (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.6 Global ecoregional distribution*

**Choice: A** In many ecoregions globally

**Score:** 5 of 5

**Ranking Rationale:**
Has a wide global distribution.

**Background Information:**
First described from Kolkata, India and has a wide global distribution. Its native range is believed to be the Indo-Pacific with introduced populations in Europe, Australia, New Zealand, Central America and the West Coast of the US (British Columbia to California). Also reported from Venezuela and Mozambique. Further molecular and morphological studies are needed to verify the identity of these

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.7 Current distribution trends*

**Choice: A** Recent rapid range expansion and/or long-distance dispersal (within the last ten years)

**Score:** 5 of 5

**Ranking Rationale:**
Recent documentation of long-distance dispersal and range expansion.

**Background Information:**
Reported in numerous locations from 1975 to 2015. Long-distance dispersal due to anthropogenic vectors.

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 20 |
| **Section Total - Possible Points:** | 26.25 |
| **Section Total -Data Deficient Points:** | 3.75 |

## 2. Anthropogenic Transportation and Establishment



### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice:** **B** Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 **of** 4

**Ranking Rationale:**
Has been observed using anthropogenic vectors but no information exists for movements independent of anthropogenic vectors once introduced.

**Background Information:**
The absence of Pseudopolydora cf. kempi in early polychaete surveys strongly supports introduced status for West Coast populations (Carlton 1979; Cohen and Carlton 1995). A likely source of these populations is northeastern Japan, from where the Miyagi strain of Pacific Oysters (Crassostrea gigas) was imported (Fofonoff et al. 2003). Ballast water discharge and ship fouling are also likely sources (Cohen 1998).

**Sources:**
Carlton 1979   Cohen and Carlton 1995   NEMESIS; Fofonoff et al. 2003   Cohen 1998

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice:** **B** Readily establishes in areas with anthropogenic disturbance/infrastructure; occasionally establishes in undisturbed areas

**Score:** 2.75 **of** 4

**High uncertainty?** ✔

**Ranking Rationale:**
In its introduced range, may be more common in anthropogenic areas due to its limited dispersal abilities. Information is lacking for this species.

**Background Information:**
Occurs on intertidal mudflats and soft sand or mud substrates (Blake and Woodwick 1975). Several specimens have been collected in harbors, on pilings, and in polluted areas (Barnard 1958; Blake and Woodwick 1975). This species lives in substrates and has limited natural dispersal abilities (Blake and Woodwick 1975).

**Sources:**
Blake and Woodwick 1975   Barnard 1958

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice:** **B** No

**Score:** 0 **of** 2

**Ranking Rationale:**

**Background Information:**
P. cf. kempi is not currently farmed or intentionally cultivated.

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 4.75 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics

### *3.1 Dietary specialization*

**Choice:** **A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Deposit feeder that can shift to suspension feeding when the environment dictates a need.

**Background Information:**
P. cf. kempi is primarily a deposit feeder that consumes benthic microalgae, detritus, and phytoplankton (Gallagher and Wells 1983 as qtd. In Fofonoff et al. 2003;Hentschel 1998). Can shift to suspension feeding when water currents increase by forming palps in helical shapes (Hiebert 2015).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Hentschel 1998 Hiebert 2015

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **A** Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 of 5

**Ranking Rationale:**
Tolerates a wide range of temperatures and salinities and utilizes numerous habitat types.

**Background Information:**
P. cf. kempi is typically found in intertidal mudflats and shallow, muddy subtidal waters, often with low or variable salinity. General habitats include: unstructured bottom mudflats, salt-brackish marshes and canals. B P. cf. kempi tolerates a broad temperature range, from cold-temperate to tropical. It has been reported from brackish estuaries and coastal waters in cold-temperate to tropical waters (Berkeley and Berkeley 1951; Srikrishnada and Ramamoorthi 1977; Light 1978; as qtd. In Fofonoff et al. 2003). It also exhibits a broad salinity range, from Mesohaline to Euhaline (1.6 -34.8 PSU) and seems fairly tolerant of contamination by industrial wastes in native ranges. It is an early successional species after a disturbance (Lu and Wu 2007).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Lu and Wu 2007

### *3.3 Desiccation tolerance*

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 3.4 *Likelihood of success for reproductive strategy*



i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice: B** Moderate – Exhibits one or two of the above characteristics

**Score:** 3.25 of 5

**Ranking Rationale:**
P. cf. kempi have sexual reporduction, moderate fecudity, short generation time, and low parental investment.

**Background Information:**
P. cf. kempi occurs in estuarine habitats in constructed mud and mucus tubes. There are two sexes. The females lay 15-20 eggs in the tubes (Myohara 1979). The planktonic larval stage lasts from a few days to 4 weeks. The length of the larval stage varies by population. Populations in India hatch at an earlier stage and spend 2-4 weeks as larvae (Myohara 1979, Srikrishanda and Ramamoorthi 1977, Radshevsky 1985 as qtd. in Fofonoff et al. 2003). California populations hatch at a later stage and spend only a few days as larvae (Blake and Woodwick 1975).

**Sources:**
Myohara 1979 NEMESIS; Fofonoff et al. 2003 Blake and Woodwick 1975 Hiebert 2015

### 3.5 *Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice: C** Disperses short (< 1 km) distances

**Score:** 0.75 of 2.5

**Ranking Rationale:**
Natural dispersal occurs only at one life stage that lasts a short time.

**Background Information:**
P. cf kempi is more mobile during short larval phase as plankton, with adults and eggs being benthic. The mobile plankton stage exists for a only a short time before larvae settle into a benthic life (Blake and Woodwick 1975).

**Sources:**
Blake and Woodwick 1975

### 3.6 *Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: C** Low – Exhibits none of the above characteristics

**Score:** 0.75 of 2.5

**Ranking Rationale:**
Has only one short mobile phase as a larvae.

**Background Information:**
Benthic for majority of its life. Mobile for a very short period as planktonic larvae.

**Sources:**
Blake and Woodwick 1975

### *3.7 Vulnerability to predators*



**Choice: D** Multiple predators present in the Bering Sea or neighboring regions

**Score:** 1.25 **of** 5

**Ranking Rationale:**
Numerous predators, many of which exist in the Bering Sea.

**Background Information:**
P. cf. kempi is a potential prey item for fishes, shorebirds and other predators (Tomiyama et al. 2007).

**Sources:**
Tomiyama et al. 2007

| | |
|---|---|
| **Section Total - Scored Points:** | 16 |
| **Section Total - Possible Points:** | 25 |
| **Section Total -Data Deficient Points:** | 5 |

## 4. Ecological and Socioeconomic Impacts



### *4.1 Impact on community composition*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
Has few, minor impacts.

**Background Information:**
In native ranges, facilitates recruitment of other invertebrates and provides forage for vertebrates. No evidence of declines detected.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.2 Impact on habitat for other species*

**Choice:** **B** Moderate – Causes or has potential to cause changes to one or more habitats

**Score:** 1.75 of 2.5

**Ranking Rationale:**
Alters the structure of the benthic habitat which facilitates the recruitment of other invertebrates.

**Background Information:**
Tube building invertebrates including P. cf. kempi have impacts on mudflats and other soft substrates through their burrowing behaviors. This adds structure to relatively soft and homogenous environments and aids in the recruitment of other invertebrate taxa (Gallagher et al 1983).

**Sources:**
Gallagher et al. 1983 NEMESIS; Fofonoff et al. 2003 Hiebert 2015

### *4.3 Impact on ecosystem function and processes*

**Choice:** **C** Limited – Causes or potentially causes changes to food webs and/or ecosystem functions, with limited impact and/or within a very limited region

**Score:** 0.75 of 2.5

**Ranking Rationale:**
Is a potential prey item. It's burrowing activities facilitate recruitment of other invertebrates.

**Background Information:**
The impacts of exotic polychaetes are varied, with many having no reported impact, but some species can reach high densities and are known to increase erosion or foul aquaculture species and maritime equipment. The ecological impacts of Pseudopolydora cf. kempi are not well known.

Pseudopolydora cf. kempi is frequently abundant in subtidal brackish waters in Asian waters and the West Coast of North America. It is a potential prey item for fishes and other predators (Tomiyama et al. 2007). Together with other tube-building invertebrates, this worm has an ecological impact in mudflats and soft-substrate habitats by adding structure to relatively homogeneous environments, facilitating the recruitment of other invertebrates (Gallagher et al. 1983).

**Sources:**
Tomiyama et al. 2007 Gallagher et al. 1983 NEMESIS; Fofonoff et al. 2003

### *4.4 Impact on high-value, rare, or sensitive species and/or communities*



**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
To date, no impacts on high-value, rare, or sensitive species have been reported for P. cf. kempi.

**Background Information:**
No information available in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.5 Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
To date, no known diseases or parasites have been reported for P. cf. kempi.

**Background Information:**
No information available in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Hiebert 2015

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No evidence exists for hybridization with native species.

**Background Information:**
No evidence of hybridization with native species detected. Genetics of this species still poorly understood. Pseudopolydora cf. kempi has been subdivided into several subspecies, which show differences in adult morphology and larval development. The status of these subspecies is unresolved, due to scanty descriptions and the absence of type specimens. With future work, this taxon may be split into several cryptic species (Radashevsky and Hsieh 2000; Sato-Okoshi 2000).

**Sources:**
Hiebert 2015 NEMESIS; Fofonoff et al. 2003

### *4.7 Infrastructure*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on infrastucture have been reported for P. cf. kempi.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 4.8 *Commercial fisheries and aquaculture*



**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
Is an important prey species in it's native range, impact in introduced ranges unknown.

**Background Information:**
P. cf. kempi may be important to fish and benthic invertebrates as prey. In Japan, predators (particularly flounders) engaged in sublethal predation of this species. The predators bite off chunks of the worms that the worms would then regenerate (Tomiyama et al. 2007). This has helped maintain the near optimal conditions for the high growth rates of stone flounders observed in Japan. Information not known in non-native regions.

**Sources:**
Tomiyama et al. 2007   NEMESIS; Fofonoff et al. 2003

### 4.9 *Subsistence*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on subsistence have been reported for P. cf. kempi.

**Background Information:**
No information available in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.101 *Recreation*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on recreation have been reported for P. cf. kempi.

**Background Information:**
No information found in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.11 *Human health and water quality*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on human health or water quality have been reported for P. cf. kempi.

**Background Information:**
No information available in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003   Hiebert 2015

| | |
|---|---|
| **Section Total - Scored Points:** | 2.5 38 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 5. Feasibility of prevention, detection and control

39

### 5.1 History of management, containment, and eradication

**Choice:** **C** Attempted; control methods are currently in development/being studied

**Score:** of

**Ranking Rationale:**

**Background Information:**
Increased awareness and regulation of transportation methods of exotic species (oyster farming and ship ballast water discharge are primary sources of Pseudopolydora cf. kempi), global efforts to identify non-native polychaetes but no direct efforts to manage or eradicate Pseudopolydora cf. kempi found.

**Sources:**
Hiebert 2015 NEMESIS; Fofonoff et al. 2003

### 5.2 Cost and methods of management, containment, and eradication

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**

**Sources:**
None listed

### 5.3 Regulatory barriers to prevent introductions and transport

**Choice:** **C** Regulatory oversight and/or trade restrictions

**Score:** of

**High uncertainty?** ✔

**Ranking Rationale:**
Regulations exist for oyster seed to be certified diesase free, but it is not clear if the presence of P. cf. kempi is included in this restriction.

**Background Information:**
The distribution and release of the hatchery products (including oysters) are a matter of state regulations and control as well as the practices outlined in the National Shellfish Sanitation Program (NSSP) Guide for the Control of Molluscan Shellfish – Section II, Chapter VI (FDA 2011). In 1989 the State of Alaska passed legislation permitting the farming of approved shellfish species in coastal waters. The state of Alaska requires oyster seed sources to be certified disease free, but it is not clear if species like Pseudopolydora kempi could still be present in certified seed or spat (ADF&G 2016). Alaska does not have a formal program for the management of aquatic species in ballast water discharges. It relies on the U.S. Coast Guard to enforce national standards (ADF&G 2016).

**Sources:**
NEMESIS; Fofonoff et al. 2003 ADF&G 2016

### *5.4 Presence and frequency of monitoring programs*

40

**Choice:** **A** No surveillance takes place

**Score:** of

**Ranking Rationale:**

**Background Information:**
No specific efforts for Pseudopolydora kempi found.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *5.5 Current efforts for outreach and education*

**Choice:** **A** No education or outreach takes place

**Score:** of

**Ranking Rationale:**

**Background Information:**
No specific efforts for Pseudopolydora kempi found.

**Sources:**
None listed

**Section Total - Scored Points:**

**Section Total - Possible Points:**

**Section Total -Data Deficient Points:**

## Literature Cited for *Pseudopolydora cf. kempi*


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- Myohara, M. 1979. Reproduction and development of Pseudopolydora kempi japonica (Polychaeta: Spionidae), with special reference to the polar lobe formation. Journal of the Faculty of Science Hokkaido University Series VI, Zoology 21(4):355-364.

# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Bugula neritina*

**Common Name** *brown bryozoan*

| | |
|---|---|
| **Phylum** | Bryozoa |
| **Class** | Gymnolaemata |
| **Order** | Cheilostomatida |
| **Family** | Bugulidae |

**Final Rank** 62.63

**Data Deficiency:** 5.00

## Species Occurrence by Ecoregion

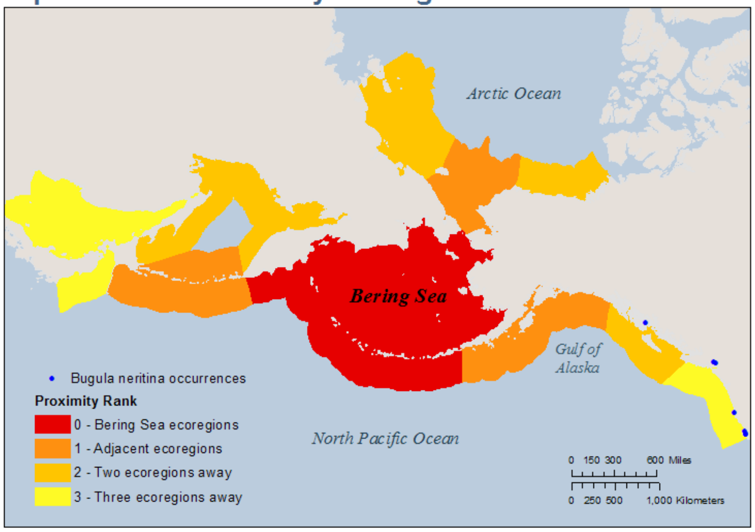


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 25 | 30 | 0 |
| Anthropogenic Influence: | 6 | 10 | 0 |
| Biological Characteristics: | 21.5 | 25 | 5.00 |
| Impacts: | 7 | 30 | 0 |
| **Totals:** | 59.50 | 95.00 | 5.00 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | 2 | Minimum Salinity (ppt) | 18 |
| Maximum Temperature (°C) | 30.6 | Maximum Salinity (ppt) | 40 |
| Minimum Reproductive Temperature (°C) | 7 | Minimum Reproductive Salinity (ppt) | 31* |
| Maximum Reproductive Temperature (°C) | NA | Maximum Reproductive Salinity (ppt) | 35* |

### Additional Notes

Bugula neritina is a widespread, colonial bryozoan and a common fouling organism. It is a species complex comprised of at least three species that can only be distinguished through molecular work. Colonies branch out in a shrub-like pattern and are dark red to purple or brown. They can grow over 100 mm in height.

**Reviewed by** Linda McCann, Research Technician, Smithsonian Environmental Research Center, Tiburon, CA

**Review Date:** 12/15/2017

# 1. Distribution and Habitat



### 1.1 *Survival requirements - Water temperature*

**Choice: C** Little overlap – A small area (<25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 1.25 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Temperatures required for year-round survival occur in a limited area (<25%) of the Bering Sea. Thresholds are based on geographic distribution, which may not represent physiological tolerances; we therefore ranked this question with "High uncertainty".

**Background Information:**
Based on geographic distribution, this species is thought to tolerate temperatures from 2°C to 30.6°C (Zerebecki and Sorte 2011). Populations of this species have different temperature tolerances depending on where they live. Populations from Massachusetts had a higher temperature threshold than populations from California (26.4°C versus 24.4°C; Sorte et al. 2011).

**Sources:**
Zerebecki and Sorte 2011 Sorte et al. 2011

### 1.2 *Survival requirements - Water salinity*

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea. Thresholds are based on geographic distribution, which may not represent physiological tolerances; we therefore ranked this question with "High uncertainty".

**Background Information:**
B. neritina is a marine species that can tolerate salinities from 18 to 40 ppt (based on geographic distribution).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 1.3 *Establishment requirements - Water temperature*

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has temperatures suitable for reproduction

**Score:** 3.75 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Because this species is reported from warm-temperate to tropical waters, upper reproductive limits are unlikely to be exceeded in the Bering Sea. Temperature requirements for maturation of gametes and spawning are unknown, but larvae can metamorphose at temperatures as low as 7°C. We ranked this species as "High Uncertainty" to indicate lack of data, as well as disagreements in model estimates.

**Background Information:**
Based on laboratory experiments, Lynch (1947) determined that the optimal temperature for larvae was 16°C. Larvae survived and metamorphosed in 7°C water (lowest treatment tested), but exhibited behavioral changes, a prolonged free-swimming period (from < 1 hour to 5+ hours), and greatly reduced activity levels (Lynch 1947).

**Sources:**
Lynch 1947

## *1.4 Establishment requirements - Water salinity*



**Choice:** **A**

Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 **of** 3.75

**High uncertainty?** ✔

**Ranking Rationale:**

Although salinity thresholds are unknown, this species is a marine organism that does not require freshwater to reproduce. We therefore assume that this species can reproduce in saltwater (31 to 35 ppt). These salinities occur in a large (>75%) portion of the Bering Sea.

**Background Information:**

Larvae placed in seawater exhibited normal behaviours (Lynch 1947). B. neritina is a marine species that does not require fresh or brackish water to spawn (Fofonoff et al. 2003).

**Sources:**

Lynch 1947   NEMESIS; Fofonoff et al. 2003

## *1.5 Local ecoregional distribution*

**Choice:** **C**

Present in an ecoregion two regions away from the Bering Sea (i.e. adjacent to an adjacent ecoregion)

**Score:** 2.5 **of** 5

**Ranking Rationale:**

This species was recently found in Ketchikan, AK.

**Background Information:**

On the West Coast of North America, this species occurs from Mexico to Oregon (Fofonoff et al. 2003). It was reported in Washington state in 1994, but it is unclear whether it is established there (Cohen 2011). B. neritina was discovered in Ketchikan, AK in 2016, but has not been found since (Jurgens et al. 2018; L. McCann, pers. comm.). It is therefore unclear whether this species is established in southeast AK (L. McCann, pers. comm.).

**Sources:**

Jurgens et al. 2018   NEMESIS; Fofonoff et al. 2003   Cohen 2011

## *1.6 Global ecoregional distribution*

**Choice:** **A**

In many ecoregions globally

**Score:** 5 **of** 5

**Ranking Rationale:**

This species is widespread and is found on every continent except Antarctica.

**Background Information:**

The native range of this species is unknown, but it is thought to be native to warm-temperate and tropical waters of Central and South America, the Mediterranean, and along the Atlantic coast of Africa. It is also considered cryptogenic in the northwestern Pacific (from Japan to Hong Kong), in India and in the Middle East. In western North America, it is considered introduced from CA to AK, and in the east from MA to VA. It is considered introduced in southern Africa (Namibia, South Africa), in Atlantic Europe (U.K. to Spain), and on several Pacific islands including New Zealand, Australia, and Hawaii.

**Sources:**

NEMESIS; Fofonoff et al. 2003

### *1.7 Current distribution trends*

**Choice: A** Recent rapid range expansion and/or long-distance dispersal (within the last ten years)

**Score:** 5 **of** 5

**Ranking Rationale:**
This species has been rapidly expanding its range worldwide. It was recently found in Ketchikan, AK.

**Background Information:**
This species has been expanding its range for the past 60 years (Ryland et al. 2011). On the West Coast of North America, it was first collected in San Francisco Bay in the 1980s, and has expanded its range northward since then, reaching Oregon by 1986 (Fofonoff et al. 2003). Although reported from Washington state, it is unclear whether it is established there (Cohen 2011). It was recently discovered in Ketchikan, AK, which is the northernmost record in North America and perhaps worldwide (Jurgens et al. 2018).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Ryland et al. 2011 Jurgens et al. 2018 Cohen 2011

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| **Section Total - Scored Points:** | 25 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 2. Anthropogenic Transportation and Establishment

### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice: B** Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 of 4

**Ranking Rationale:**
This species has been introduced worldwide by anthropogenic vectors. Because adults are sessile and the free-swimming larval stage is very short-lived, it is unlikely that this species can travel long distances on its own.

**Background Information:**
This species has been transported globally by ship fouling and hitchhiking on oysters (Mackie et al. 2006; Cohen 2011; Ryland et al. 2011). Marine debris, including tsunami debris, is also a potential transport vector (L. McCann, pers. comm.). Because the free-swimming larval stage is short-lived (2 to 10 hours), it is unlikely to be transported in ballast water (Cohen 2011).

**Sources:**
Cohen 2011   Ryland et al. 2011   Mackie et al. 2006

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice: A** Readily establishes in areas with anthropogenic disturbance/infrastructure and in natural, undisturbed areas

**Score:** 4 of 4

**Ranking Rationale:**
This species can establish on both natural and anthropogenic substrates.

**Background Information:**
This species has been reported from several anthropogenic and natural substrates, including oysters, seaweed, tunicates, rocks, ship hulls, and docks (Walters 1992; Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Walters 1992

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice: B** No

**Score:** 0 of 2

**Ranking Rationale:**
This species is not farmed or cultivated.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

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|---|---|
| **Section Total - Scored Points:** | 6 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics

### *3.1 Dietary specialization*

**Choice:** **A**

Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Food items for this species are readily available in the Bering Sea.

**Background Information:**
B. neritina is a suspension feeder. It uses its tentacles to capture phytoplankton and organic particles.

**Sources:**
NEMESIS; Fofonoff et al. 2003   CABI 2017

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **A**

Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 of 5

**Ranking Rationale:**
This species has a global distribution, and has been reported on a variety of substrates. It is not known to have specific habitat requirements.

**Background Information:**
This species has been reported from many types of substrates, including ship hulls, docks, bivalve shells, and rocks (Fofonoff et al. 2003). Larvae are planktonic, and prefer to settle on heterogeneous surfaces such as bumpy or rough surfaces with many refuges (Walters 1992; Marshall and Keough 2003). This species is usually found at shallow depths up to 12 m (depending on light penetration; Conradi et al. 2000). B. neritina is tolerant of a range of salinities (Fofonoff et al. 2003). It has a high tolerance to copper, which is used in antifouling paints (Piola and Johnston 2006).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Marshall and Keough 2003   Piola and Johnston 2006   Conradi et al. 2000   Walters 1992

### *3.3 Desiccation tolerance*

**Choice:** **U**

Unknown

**Score:** of

**Ranking Rationale:**
No information found.

**Background Information:**
Anecdotal evidence from San Francisco, CA suggest that this species is fairly tolerant of desiccation (L. McCann, pers. comm.). An assessment for B. turbinata, which is also a branching bryozoan, believed B. turbinata was likely highly intolerant to air exposure, but no tests have been conducted (Tyler-Walters 2005).

**Sources:**
Tyler-Walters 2005

### *3.4 Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice: A** High – Exhibits three or four of the above characteristics

**Score:** 5 of 5

**Ranking Rationale:**

This species can reproduce asexually and is hermaphroditic. Fertilization is internal, but parental investment is otherwise low. Colonies are highly fecund and likely produce hundreds of planktonic larvae, which become sexually mature within a few weeks.

**Background Information:**

This species can reproduce asexually and is hermaphroditic (Fofonoff et al. 2003) and exhibits internal fertilization (Walters 1992). Only one larva is brooded per zooid (Walters 1992). As a proxy for fecundity, Mathew et al. (2016) estimated ~700 ovicells per colony, while Burgess and Marshall (2011) estimated a maximum of 631 ovicells, and estimated that populations increased by 187 to 210 zooids for every additional individual produced. Individuals reach sexual maturity within 2-4 weeks (Wendt 1998; Keough and Chernoff 1987). Colonies can live anywhere from 5-6 weeks to > 1 year (Wendt 1998; Cohen 2011).

**Sources:**

NEMESIS; Fofonoff et al. 2003 Walters 1992 Mathew et al. 2016 Burgess and Marshall 2011 Wendt 1998 Keough and Chernoff 1987 Cohen 2011

### *3.5 Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice: C** Disperses short (< 1 km) distances

**Score:** 0.75 of 2.5

**Ranking Rationale:**

This species has a short-lived planktonic stage. Its spatial distribution suggests that dispersal is highly limited.

**Background Information:**

Keough (1989) observed a strongly clumped spatial distribution in both adult and juveniles, and he suggested that this species has limited dispersal abilities. In some cases, Keough and Chernoff (1987) did not find any individuals on suitable substrate (seagrass), even though large populations were present < 100 m away. Larvae are non-feeding, planktonic and short-lived. Most larvae settle on suitable substrates within a few hours (Keough 1989; Walters 1992). In a field study by Burgess and Marshall (2011), less than 19% of individuals had a long larval stage (> 6.5 hours), with a maximum of 32 hours.

**Sources:**

Keough 1989 Keough and Chernoff 1987 Walters 1992 Burgess and Marshall 2011

### *3.6 Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice:** **C** Low – Exhibits none of the above characteristics

**Score:** **0.75** of **2.5**

**Ranking Rationale:**
Only the short-lived larval stage is free-swimming. Adults are sessile. Natural dispersal in this species is very limited.

**Background Information:**
Adults are sessile and eggs are brooded internally (Walters 1992). The larval stage is free-swimming but short-lived, with most individuals settling on substrates within a few hours of release (Keough 1989; Walters 1992). This species is highly patchy, both spatially and temporally, and very likely has limited natural dispersal abilities (Keough and Chernoff 1987; Keough 1989).

**Sources:**
Walters 1992 Keough 1989 Keough and Chernoff 1987

### *3.7 Vulnerability to predators*

**Choice:** **A** Lacks natural predators

**Score:** **5** of **5**

**Ranking Rationale:**
This species is preyed upon by several taxa found in the Bering Sea.

**Background Information:**
This species is predated upon by fish, sea urchins, crabs, and shrimp (Keough and Chernoff 1987; Walters 1992; Mcgovern and Hellberg 2003; Dumont et al. 2011).

**Sources:**
Keough and Chernoff 1987 Walters 1992

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| **Section Total - Scored Points:** | 21.5 |
| **Section Total - Possible Points:** | 25 |
| **Section Total -Data Deficient Points:** | 5 |

## 4. Ecological and Socioeconomic Impacts

50

### 4.1 *Impact on community composition*

**Choice:** **C** Limited – Single trophic level; may cause decline but not extirpation

**Score:** 0.75 of 2.5

**High uncertainty?** ☑

**Ranking Rationale:**
No impacts on natural communities have been reported to date; however, several studies highlight the strong competitive abilities of B. neritina, which suggests that this species may be able to outcompete other bryozoans or fouling organisms in the Bering Sea. Warming sea temperatures may increase the competitive ability of this species.

**Background Information:**
B. neritina is a dominant and highly competitive member of the fouling community (Sorte and Stachowicz 2011; Hart and Marshall 2013). In an examination of fouling plates around the world, B. neritina was a consistently strong competitor, exhibiting high growth even when space was limited (Lord 2017). However, this species was more present on panels at warm sea temperatures (20 to 24°C) than at cooler sites (Lord 2017). B. neritina Both field and laboratory studies suggest that, in introduced parts of its range, warming sea temperatures may give B. neritina a competitive advantage over native species by enhancing growth and recruitment (Sorte et al. 2010, Sorte and Stachowicz 2011). In Bodega Harbor, CA B. neritina has become more abundant than its native counterpart, Bugula californica (Sorte et al. 2010), though competition between the two species has not been documented.

**Sources:**
Hart and Marshall   Sorte and Stachowicz 2011   Lord 2017   Sorte et al. 2010

### 4.2 *Impact on habitat for other species*

**Choice:** **B** Moderate – Causes or has potential to cause changes to one or more habitats

**Score:** 1.75 of 2.5

**Ranking Rationale:**
By fouling substrates, this species may reduce available habitat for some organisms through competition for space. Conversely, it may create secondary settlement habitat for others. Several species are known to use B. neritina as habitat.

**Background Information:**
In Algeciras Bay, Spain, several crustaceans were found living on B. neritina, including tanaids, cumaceans, and the invasive amphipod Jassa marmorata (Conradi et al. 2000). The polychaete Hydroides elegans was found on B. neritina in Hong Kong (Bryan et al. 1998).

**Sources:**
Conradi et al. 2000   Bryan et al. 1998

### 4.3 *Impact on ecosystem function and processes*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not expected to impact ecosystem function in the Bering Sea.

**Background Information:**
No information found.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.4 *Impact on high-value, rare, or sensitive species and/or communities*



**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not expected to impact ecologically valuable species in the Bering Sea.

**Background Information:**
No information found.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.5 *Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice: C** Limited – Has limited potential to spread one or more organisms, with limited impact and/or within a very limited region

**High uncertainty?** ☑

**Score:** 0.75 of 2.5

**Ranking Rationale:**
B. neritina may inadvertently facilitate the transport of other species that live on it.

**Background Information:**
B. neritina has symbiotic relationships with bacteria that produce chemical compounds known as bryostatins (Mcgovern and Hellberg 2003). Several taxa have been found living on B. neritina, including amphipods, cumaceans and polychaetes (Bryan et al. 1998; Conradi et al. 2000). The invasive amphipod Jassa marmorata has been found on B. neritina (Conradi et al. 2000).

**Sources:**
Mcgovern and Hellberg 2003 Bryan et al. 1998 Conradi et al. 2000

### 4.6 *Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not expected to hybridize with native species in the Bering Sea.

**Background Information:**
No information found.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.7 Infrastructure*

**Choice: B** — Moderate – Causes or has the potential to cause degradation to infrastructure, with moderate impact and/or within only a portion of the region

**Score:** 1.5 of 3

**Ranking Rationale:**
Moderate impacts on infrastructure are expected given its abundance as a fouling organism.

**Background Information:**
This species is a common member of the fouling community and has been reported on ship hulls, pilings, docks, and power plants (Fofonoff et al. 2003). This species is highly resistant to copper, which is used in many anti-fouling paints (Piola and Johnston 2006). Fouling organisms on ships cause drag and reduce maneuverability. They are estimated to cost the U.S. Navy over $50 million a year in fuel costs due to increased drag (Cleere 2001).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Piola and Johnston 2006   Cleere 2001

### *4.8 Commercial fisheries and aquaculture*

**Choice: C** — Limited – Has limited potential to cause degradation to fisheries and aquaculture, and/or is restricted to a limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
By fouling mussels and equipment, this species can negatively affect the weight and growth of economically important shellfish species. Shellfish aquaculture is currently a small industry in Alaska that occurs only in a restricted area of the Bering Sea.

**Background Information:**
In southeastern Brazil, B. neritina was one of the most abundant fouling organisms on Perna perna mussels (de Sá et al. 2007). Mussels that were fouled were shorter and smaller than cleaned mussels, though the difference, according to the authors, was small: 5.4 mm in final length and 1.7 g in weight of the meat (de Sá et al. 2007). Antoniadou et al. (2013) also reported B. neritina as a common fouling organism on the shells of the Mediterranean mussel Mytilus galloprovincialis. Similarly to de Sá et al. (2007), they observed a negative, but weak, effect of fouling on mussel condition (Antoniadou et al. 2013).

According to the Pacific Shellfish Institute, the shellfish industry in Alaska is estimated at $1 million. Revenues from shellfish are most important in southeast (Gulf of Alaska, Wrangell to Haines) and southwest Alaska (Aleutians East through Lake and Peninsula; Mathis et al. 2015).

**Sources:**
Antoniadou et al. 2013   Mathis et al. 2015   de Sá et al. 2007   PSI Alaska 2017

### 4.9 Subsistence

**Choice: C** Limited – Has limited potential to cause degradation to subsistence resources, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
This species may negatively affect the growth of bivalves by fouling shells and equipment such as mussel lines.

**Background Information:**
In southeastern Brazil, B. neritina was one of the most abundant fouling organisms on Perna perna mussels (de Sá et al. 2007). Mussels that were fouled were shorter and smaller than cleaned mussels, though the difference, according to the authors, was small: 5.4 mm in final length and 1.7 g in weight of the meat (de Sá et al. 2007). Antoniadou et al. (2013) also reported B. neritina as a common fouling organism on the shells of the Mediterranean mussel Mytilus galloprovincialis. Similarly to de Sá et al. (2007), they observed a negative, but weak, effect of fouling on mussel condition (Antoniadou et al. 2013).

Compared to salmon and finfish, shellfish such as oysters, clams, and mussels comprise a smaller percentage of subsistence catch in the Bering Sea (when measured by weight; Mathis et al. 2015). Although shellfish comprised almost 20% of subsistence catch in the Aleutians West, most municipalities in the Bering Sea recorded low percentages (< 5%).

**Sources:**
Antoniadou et al. 2013   Mathis et al. 2015   de Sá et al. 2007

### 4.101 Recreation

**Choice: C** Limited – Has limited potential to cause degradation to recreation opportunities, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
B. neritina may negatively affect mussel growth by fouling shells and may consequently degrade recreational harvest opportunities.

**Background Information:**
In southeastern Brazil, B. neritina was one of the most abundant fouling organisms on Perna perna mussels (de Sá et al. 2007). Mussels that were fouled were shorter and smaller than cleaned mussels, though the difference, according to the authors, was small: 5.4 mm in final length and 1.7 g in weight of the meat (de Sá et al. 2007). Antoniadou et al. (2013) also reported B. neritina as a common fouling organism on the shells of the Mediterranean mussel Mytilus galloprovincialis. Similarly to de Sá et al. (2007), they observed a negative, but weak, effect of fouling on mussel condition (Antoniadou et al. 2013).

**Sources:**
de Sá et al. 2007   Antoniadou et al. 2013

### 4.11 Human health and water quality

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to negatively impact human health or water quality in the Bering Sea.

**Background Information:**
Bacteria found in Bugula neritina produce chemical compounds known as bryostatins. These compounds are being studied for use in cancer and HIV treatments.

**Sources:**
NEMESIS; Fofonoff et al. 2003   Mcgovern and Hellberg 2003

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| **Section Total - Scored Points:** | 7 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

54

# 5. Feasibility of prevention, detection and control

### *5.1 History of management, containment, and eradication*

**Choice:** **C** Attempted; control methods are currently in development/being studied

**Score:** of

**Ranking Rationale:**
Methods to control species that foul bivalves, aquaculture equipment, and/or ship hulls are currently being studied.

**Background Information:**
Control of B. neritina and other fouling species has been attempted on mussel farms in New Zealand using acetic acid treatments (Forrest et al. 2007). B. neritina is thought to have been introduced worldwide by ship fouling, and it is tolerant to copper, which is used as an agent in many anti-fouling paints (Piola and Johnston 2006; Ryland et al. 2011). Hull fouling technologies that treat and/or safely dispose of marine organisms, without being toxic to the environment, are currently being studied (Hagan et al. 2014).

**Sources:**
Piola and Johnston 2006 Ryland 1977 Hagan et al. 2014 Forrest et al. 2007

### *5.2 Cost and methods of management, containment, and eradication*

**Choice:** **A** Major long-term investment, or is not feasible at this time

**Score:** 0 of

**Ranking Rationale:**
Given the weak effect of B. neritina on mussel growth, the costs of cleaning would have to be weighed against the lost profits arising from smaller mussels. Current technologies to prevent the transport of marine invasive species are being developed, and require major long-term investments.

**Background Information:**
This species can be transported via several anthropogenic vectors, including fouling, hitchhiking, and marine debris. Methods to control the spread of marine invasive species are being studied, and currently necessitate major long-term investments (Zagdan 2010; Hagan et al. 2014). On shellfish farms, B. neritina was still alive on ropes treated with 2% acetic acid, but no individuals were found when ropes were treated with a 4% solution (Forrest et al. 2007). Because B. neritina had only a small effect on mussel growth, de Sá et al. (2007) wondered whether physical removal is a cost-effective method for shellfish growers.

**Sources:**
Forrest et al. 2007 de Sá et al. 2007 Zagdan 2010 Hagan et al. 2014

### *5.3 Regulatory barriers to prevent introductions and transport*

**Choice:** **A** Little to no regulatory restrictions

**Score:** of

**Ranking Rationale:**
Compliance with hull fouling regulations is voluntary. No regulations exist to prevent the spread of invasive species by hitchhiking.

**Background Information:**
In the U.S., Coast Guard regulations require masters and ship owners to clean vessels and related infrastructure on a “regular” basis (CFR 33 § 151.2050). However, because the word “regular” is not defined, regulations are hard to enforce and compliance remains largely voluntary (Hagan et al. 2014). Cleaning of recreational vessels is also largely voluntary, although state and federal programs are in place to encourage owners to clean their boats (e.g. Davis 2016).

**Sources:**
CFR 2017 Hagan et al. 2014 Davis 2016

## *5.4 Presence and frequency of monitoring programs*

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**Choice: B** Surveillance takes place, but is largely conducted by non-governmental environmental organizations (e.g., citizen science programs)

**Score:** of

**Ranking Rationale:**

Monitoring for invasive tunicates is conducted by Plate Watch and KBNERR, which are non-governmental agencies.

**Background Information:**

In Alaska, Plate Watch and Kachemak Bay National Estuarine Research Reserve (KBNERR) conduct monitoring for non-native tunicates and other invasive or harmful species. These programs involve teachers, students, outdoor enthusiasts, environmental groups and professional biologists to detect invasive species. Plate Watch found B. neritina on one of its fouling plates in Ketchikan, AK in 2016 (Jurgens et al. 2018; L. McCann, pers. comm.).

**Sources:**

Jurgens et al. 2018   iTunicate Plate Watch 2016

## *5.5 Current efforts for outreach and education*

**Choice: C** Educational materials are available and outreach occurs only sporadically in the Bering Sea or adjacent regions

**Score:** 0 of

**Ranking Rationale:**

Following the discovery of B. neritina on a fouling plate in southeastern Alaska, Plate Watch wrote an article about this species, with photos and tips for identification, in its March 2017 newsletter.

**Background Information:**

Plate Watch and the Kachemak Bay National Estuarine Research Reserve (KBNERR) provide training opportunities for identifying and detecting non-native fouling organisms, and public education events on coastal and marine ecosystems more generally. "Bioblitzes" were held in Southeast AK in 2010 and 2012; these events engage and educate the public on marine invasive species. Outreach activities were conducted on the Pribilof Islands for Bering Sea Days in 2017. Field identification guides for native and non-native tunicates, as well as common fouling organisms, are readily available.

**Sources:**

McCann 2017   iTunicate Plate Watch 2016

| | |
|---|---|
| **Section Total - Scored Points:** | 0 |
| **Section Total - Possible Points:** | |
| **Section Total -Data Deficient Points:** | |

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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Schizoporella japonica*

**Common Name** *orange ripple bryozoan*

**Phylum** Bryozoa

**Class** Gymnolaemata

**Order** Cheilostomatida

**Family** Schizoporellidae

**Final Rank** 51.78

**Data Deficiency:** 8.75

## Species Occurrence by Ecoregion

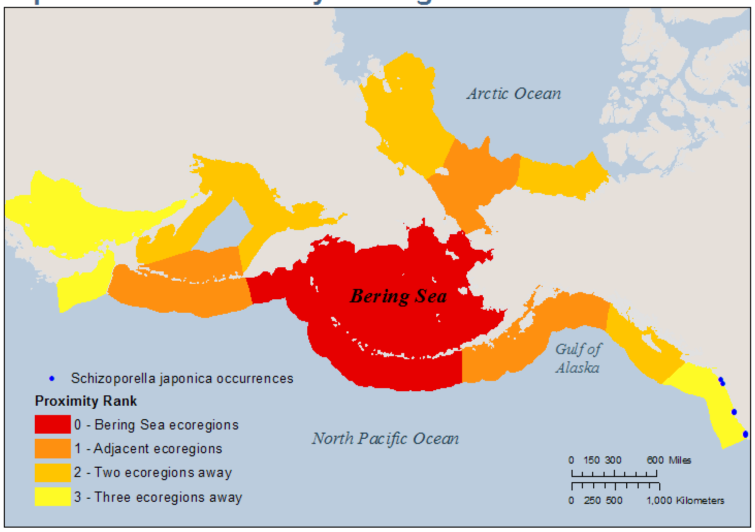


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 19.5 | 26 | 3.75 |
| Anthropogenic Influence: | 6 | 10 | 0 |
| Biological Characteristics: | 17 | 25 | 5.00 |
| Impacts: | 4.75 | 30 | 0 |
| **Totals:** | 47.25 | 91.25 | 8.75 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | 7 | Minimum Salinity (ppt) | 15 |
| Maximum Temperature (°C) | 19 | Maximum Salinity (ppt) | 35* |
| Minimum Reproductive Temperature (°C) | NA | Minimum Reproductive Salinity (ppt) | 31* |
| Maximum Reproductive Temperature (°C) | NA | Maximum Reproductive Salinity (ppt) | 35* |

### Additional Notes

Schizoporella japonica is a colonial bryozoan. It is usually an encrusting species, though colonies can occasionally form leaf-like lobes that are free from the substrate. Colonies range in color from light pink to dark red, and can grow up to 20 cm in diameter. There is taxonomic confusion between S. unicornis and S. japonica. An examination of Alaskan specimens by Dick et al. (2005) recommended elevating S. unicornis var. japonica to species status.

**Reviewed by** Linda McCann, Research Technician, Smithsonian Environmental Research Center, Tiburon, CA

**Review Date:** 12/15/2017

# 1. Distribution and Habitat



### 1.1 *Survival requirements - Water temperature*

**Choice: D** No overlap – Temperatures required for survival do not exist in the Bering Sea

**Score:** 0 of 3.75

**Ranking Rationale:**
Year-round temperature requirements do not exist in the Bering Sea.

**Background Information:**
Wood (2016) claims that this species can tolerate temperatures between 7 and 19°C.

**Sources:**
Wood 2016

### 1.2 *Survival requirements - Water salinity*

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**Ranking Rationale:**
This species has been found in waters > 15 ppt, and in marine waters (e.g. the Gulf of Alaska). Although upper salinity tolerances are unknown, we assume that this species can tolerate salinities up to 35 ppt. Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
In Washington and in British Columbia, S. japonica has been found in brackish waters (Powell 1970; Powell et al. 1970). In Willapa Bay, WA salinities were above 15 ppt (Powell et al. 1970). In Scotland, S. japonica was not found in harbors near freshwater outflow with salinities < 10 (Nall et al. 2015). This species has been found in the Gulf of Alaska (Hines and Ruiz 2000).

**Sources:**
Powell 1970   Powell et al. 1970   Nall et al. 2015   Hines and Ruiz 2001

### 1.3 *Establishment requirements - Water temperature*

**Choice: U** Unknown/Data Deficient

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information found.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 1.4 *Establishment requirements - Water salinity*

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**High uncertainty?** ✔

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Although salinity thresholds are unknown, this species is a marine organism that does not require freshwater to reproduce. We therefore assume that this species can reproduce in saltwater (31 to 35 ppt). These salinities occur in a large (>75%) portion of the Bering Sea.

**Background Information:**
No information found.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.5 Local ecoregional distribution*



**Choice: B** Present in an ecoregion adjacent to the Bering Sea

**Score:** 3.75 of 5

**Ranking Rationale:**
S. japonica was found in the Gulf of Alaska.

**Background Information:**
This species is found in Tatitlek, AK (Hines and Ruiz 2000), as well as Ketchikan (Dick et al. 2005).

**Sources:**
Hines and Ruiz 2001 Dick et al. 2005

### *1.6 Global ecoregional distribution*

**Choice: B** In a moderate number of ecoregions globally

**Score:** 3.25 of 5

**Ranking Rationale:**
S. japonica is native to western Asia. It has been introduced to the western coast of North America, and to northwestern Europe.

**Background Information:**
Its global distribution is uncertain because of confusion with other Schizoporella species (Fofonoff et al. 2003). It is native to western Asia (China to northern Japan; Dick et al. 2005). S. japonica is considered introduced on the West Coast of North America, where it is found from AK to CA. It has recently been discovered on the Atlantic coast of Europe, including Norway, Scotland, and Wales (Fofonoff et al. 2003; Ryland et al. 2014).

**Sources:**
Dick et al. 2005 NEMESIS; Fofonoff et al. 2003 Ryland et al. 2014

### *1.7 Current distribution trends*

**Choice: A** Recent rapid range expansion and/or long-distance dispersal (within the last ten years)

**Score:** 5 of 5

**Ranking Rationale:**
Rapidly spreading in the UK, where it was first documented in 2011.

**Background Information:**
S. japonica was first discovered in western Europe in 2011 (Ryland et al. 2014). Since then, it is undergoing a rapid range expasion in the UK (Nall et al. 2015).

**Sources:**
Nall et al. 2015 Ryland et al. 2014

| | |
|---|---|
| **Section Total - Scored Points:** | 19.5 |
| **Section Total - Possible Points:** | 26.25 |
| **Section Total -Data Deficient Points:** | 3.75 |

## 2. Anthropogenic Transportation and Establishment

### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice: B** Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 of 4

**Ranking Rationale:**
This species uses anthropogenic vectors for transport. Given its low dispersal potential, introductions are likely the result of transport by human vectors.

**Background Information:**
Introduced to the west coast of North America by hitchhiking on Pacific oysters imported from Japan. It likely arrrived in western Europe via hull fouling (Nall et al. 2015). Marine debris, including tsunami debris, is also a potential transport vector (L. McCann, pers. comm.). This species has low dispersal potential and expansions in its distributions are likely result from transport by humans (Nall et al. 2015).

**Sources:**
Nall et al. 2015

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice: A** Readily establishes in areas with anthropogenic disturbance/infrastructure and in natural, undisturbed areas

**Score:** 4 of 4

**Ranking Rationale:**
This species grows readily on both natural and anthropogenic substrates.

**Background Information:**
In Ketchikan, AK, it was found at high densities in natural habitats on rocks and underneath boulders (Dick et al. 2005). It has also been reported growing on buoys, boats, and other floating structures (Ryland et al. 2014).

**Sources:**
Dick et al. 2005 Ryland et al. 2014

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice: B** No

**Score:** 0 of 2

**Ranking Rationale:**
This species is not farmed or cultivated.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 6 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

# 3. Biological Characteristics



### 3.1 Dietary specialization

**Choice:** **A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Phytoplankton is readily available in the Bering Sea.

**Background Information:**
S. japonica feeds on phytoplankton.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 3.2 Habitat specialization and water tolerances

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **A** Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 of 5

**Ranking Rationale:**
S. japonica has a wide salinity tolerance and has been reported from a variety of habitats and water depths.

**Background Information:**
This species has a wide range of salinity tolerances, and has been found in brackish waters (Powell 1970; Powell et al. 1970). It has been found growing on both natural and anthropogenic substrates (Dick et al. 2005; Ryland et al. 2014). In the UK, structures were treated with lethal doses of calcium hypochlorite to control for another bryozoan, Didemnum vexillum (Ryland et al. 2014). Colonization of these structures by S. japonica was observed within three years (Ryland et al. 2014). This species has been observed at both subtidal and intertidal water depths (Nall et al. 2015).

**Sources:**
Powell 1970   Powell et al. 1970   Dick et al. 2005   Ryland et al. 2014   Nall et al. 2015

### 3.3 Desiccation tolerance

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**
The desiccation tolerance of this species is unknown.

**Background Information:**
No information found.

**Sources:**
None listed

### 3.4 *Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice: B** Moderate – Exhibits one or two of the above characteristics

**Score:** 3.25 of 5

**High uncertainty?** ☑

**Ranking Rationale:**

This species exhibits both sexual and asexual reproduction, and internal fertilization. Estimates of fecundity are unkown; however, because larvae are lecithotrophic, some parental investment is required and the number of eggs produced per spawning event is probably not extremely high. Information on related species suggests that this species may die off annually and thus have a short generation time.

**Background Information:**

Bryozoans can reproduce both sexually and asexually. Sperm are released externally, and taken up by females; eggs are brooded inside the female zooid (Temkin 1994; Ostrovsky 2014). Studies on Schizoporella errata, a closely related species, suggests a short generation time - most colonies die within a year, although some may survive through the winter (Schopf 1974).

**Sources:**

Temkin 1994 Ostrovsky 2014 Schopf 1974

### 3.5 *Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice: C** Disperses short (< 1 km) distances

**Score:** 0.75 of 2.5

**High uncertainty?** ☑

**Ranking Rationale:**

Given the short-lived, non-feeding larval stage and internal fertilization, this species probably has low dispersal potential (<1 km). Events such as rafting and fragmentation may help disperse this species further; however, the frequency of these events and its effects on overall spread are unknown.

**Background Information:**

Larvae are non-feeding and settle within a day (Schopf 1974; Fofonoff et al. 2003). In a study on Schizoporella errata, a closely related species, Schopf (1974) believed that larval dispersal distance was probably (much) less than 1 km. Nall et al. (2015) claims S. japonica has low dispersal potential.

**Sources:**

Schopf 1974 NEMESIS; Fofonoff et al. 2003 Nall et al. 2015

### 3.6 *Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: B** Moderate – Exhibits one of the above characteristics

**Score:** 1.75 of 2.5

**Ranking Rationale:**

This species has limited dispersal potential and a short-lived larval stage. Larvae and sperm may disperse short distances. Fragments may also break off and be transported passively through the water column.

**Background Information:**

Larvae are lecithotrophic and short-lived (on the scale of hours) (Gooch and Schopf 1971; Nall et al. 2015). Adults are sessile, and fertilized eggs are brooded inside the female zooid (Temkin 1994). Dispersal is limited, but zooid fragments can break off the main colony and spread passively in the water column.

**Sources:**

Nall et al. 2015 Gooch and Schopf 1971 Temkin 1994

### *3.7 Vulnerability to predators*



**Choice:** **D** Multiple predators present in the Bering Sea or neighboring regions

**Score:** 1.25 **of** 5

**Ranking Rationale:**

This species is predated upon by several taxa found in the Bering Sea.

**Background Information:**

Bryozoans in general are preyed on by grazing organisms such as marine arthropods, sea urchins, nudibranchs and fish. They are also subject to competition and overgrowth from sponges, algae, and tunicates.

**Sources:**

U.S. Geological Survey; Fuller and Benson 2017 Ryland 1977

| | |
|---|---|
| **Section Total - Scored Points:** | 17 |
| **Section Total - Possible Points:** | 25 |
| **Section Total -Data Deficient Points:** | 5 |

# 4. Ecological and Socioeconomic Impacts



### 4.1 *Impact on community composition*

**Choice:** **C** Limited – Single trophic level; may cause decline but not extirpation

**Score:** 0.75 of 2.5

**Ranking Rationale:**
Through overgrowth and competition for space, this species may prevent other organisms (e.g., native bryozoans, tunicates, sponges) from settling.

**Background Information:**
This species can overgrow algae and bivalves on which it settles. In southeast Alaska, Dick et al. (2005) reported S. japonica competing for space with a native bryozoan, Tegella aquilirostris. Surveys in the UK, where S. japonica has been recently introduced, have reported it as a dominant species in harbours (Ryland et al. 2014; Nall et al. 2015). Schizoporella species may prevent other organisms from establishing, leading to relatively fewer species at sites dominated by Schizoporella (Sutherland 1978).

**Sources:**
Dick et al. 2005   Ryland 1977   Nall et al. 2015   Sutherland 1978

### 4.2 *Impact on habitat for other species*

**Choice:** **B** Moderate – Causes or has potential to cause changes to one or more habitats

**Score:** 1.75 of 2.5

**Ranking Rationale:**
This species forms encrustations, which can grow very large and can be three-dimensional. These structures can create habitat for some species, but can also limit habitat for others.

**Background Information:**
S. japonica has been reported to form colonies up to 20 cm in diameter, and to occur at high densities (Ryland et al. 2014). Schizoporella species can form giant colonies, resulting in large three-dimensional masses or "build-ups" (Cocito et al. 2000). Build-ups of S. errata in La Spezia, Italy provided habitat for several taxa including barnacles, algae, polychaetes, and hydroids (Cocito et al. 2000).

**Sources:**
Ryland et al. 2014   Cocito et al. 2000

### 4.3 *Impact on ecosystem function and processes*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No impacts have been reported for this species. A long-term study on a similar species found that the effects of S. errata on community composition were short-lived. We therefore expect limited consequences on ecosystem functions and processes.

**Background Information:**
Field experiments on a closely related species, Schizoporella errata, found that this species was able to invade new sites and grow rapidly, preventing other species from establishing (Sutherland 1978). While these traits may reduce species' richness and change community composition, Sutherland (1978) remarked that S. errata's competitive abilities were short-lived. Within two years, colonie were outcompeted and played a minor role in the community.

**Sources:**
Sutherland 1978

### *4.4 Impact on high-value, rare, or sensitive species and/or communities*

**Choice: C** Limited – Has limited potential to cause degradation of one more species or communities, with limited impact and/or within a very limited region

**Score:** 0.75 of 2.5

**Ranking Rationale:**
No impacts have been reported for this species. Through overgrowth and competition, may affect native bryozoans.

**Background Information:**
Alaska is home to a high diversity of native bryozoa (Dick et al. 2005). The Aleutian Islands has the highest diversity of Monoporella species, with six new species described in the last decade (Dick 2008). S. japonica is known to compete with native bryozoans in Southeast Alaska (Dick et al. 2005). Although it may grow on bivalves, it does not seem cause to significant damage (Fofonoff et al. 2003).

**Sources:**
Dick et al. 2005 Dick 2008 NEMESIS; Fofonoff et al. 2003

### *4.5 Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not known to transport diseases, parasites, or hitchhikers.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
Hybridization in bryozoans is poorly studied and rendered difficult by the lack of taxonomic resolution. There are no native Schizoporella species in the Bering Sea. No impacts of hybridization have been reported for this or other Schizoporella species.

**Background Information:**
Little is known about the frequency of hybridization in bryozoans (Lidgard and Buckley 1994). Studying hybridization in Schizoporella may be complicated by the taxonomic confusion that exists amongst species (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Lidgard and Buckley 1994 O'Clair and O'Clair 1998

### 4.7 *Infrastructure*

**Choice: B** Moderate – Causes or has the potential to cause degradation to infrastructure, with moderate impact and/or within only a portion of the region

**Score:** 1.5 of 3

**Ranking Rationale:**
S. japonica is a common fouling organism. Fouling organisms on ships can cause drag and reduce maneuverability.

**Background Information:**
This species has been reported at high densities on many anthropogenic structures, including buoys, docks, and ships (Fofonoff et al. 2003; Ryland et al. 2014). Fouling organisms are estimated to cost the U.S. Navy over $50 million a year in fuel costs due to increased drag (Cleere 2001).

**Sources:**
Ryland et al. 2014 NEMESIS; Fofonoff et al. 2003

### 4.8 *Commercial fisheries and aquaculture*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact commercial fisheries in the Bering Sea.

**Background Information:**
Powell (1970) observed that S. japonica preferred to settle on dead, rather than live, oyster shells, and predicted that this species would therefore have little effect on the commercial shellfish industry. No impacts on fisheries have been reported, although S. japonica can foul fishing gear (Fofonoff et al. 2003).

**Sources:**
Powell 1970 NEMESIS; Fofonoff et al. 2003

### 4.9 *Subsistence*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact subsistence resources in the Bering Sea.

**Background Information:**
Powell (1970) observed that S. japonica preferred to settle on dead, rather than live, oyster shells, and predicted that this species would therefore have little effect on the shellfish industry. No impacts on fish or fish habitat have been reported, although S. japonica can foul fishing gear (Fofonoff et al. 2003).

**Sources:**
Powell 1970 NEMESIS; Fofonoff et al. 2003

### *4.101 Recreation*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to affect recreational opportunities in the Bering Sea.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.11 Human health and water quality*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
No impacts on human health or water quality have been reported.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 4.75 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 5. Feasibility of prevention, detection and control

### 5.1 History of management, containment, and eradication

**Choice: B** Not attempted

**Score:** of

**Ranking Rationale:**
Control or eradication has not been attempted for this species.

**Background Information:**

**Sources:**
Molnar et al. 2008

### 5.2 Cost and methods of management, containment, and eradication

**Choice: A** Major long-term investment, or is not feasible at this time

**Score:** of

**Ranking Rationale:**
Methods to control the spread of marine invasive species are being developed, and currently require major long-term investments.

**Background Information:**
This species can be transported via several anthropogenic vectors, including ballast water, fouling, hitchhiking, and marine debris. Methods to control the spread of marine invasive species are being studied, and currently necessitate major long-term investments (Zagdan 2010; Hagan et al. 2014).

**Sources:**
Zagdan 2010 Hagan et al. 2014

### 5.3 Regulatory barriers to prevent introductions and transport

**Choice: B** Regulatory oversight, but compliance is voluntary

**Score:** of

**Ranking Rationale:**
This species can be transported via ballast water, fouling, and hitchhiking. No species-specific regulations are currently in place. Although there are federal regulations for both ballast water and hull fouling, compliance with federal fouling regulations remains voluntary.

**Background Information:**

**Sources:**
CFR 2017

### 5.4 *Presence and frequency of monitoring programs*

**Choice: B** Surveillance takes place, but is largely conducted by non-governmental environmental organizations (e.g., citizen science programs)

**Score:** of

**Ranking Rationale:**
Monitoring for invasive tunicates is conducted by Plate Watch and KBNERR, which are non-governmental agencies.

**Background Information:**
In Alaska, Plate Watch and Kachemak Bay National Estuarine Research Reserve (KBNERR) conduct monitoring for non-native tunicates and other invasive or harmful species. These programs involve teachers, students, outdoor enthusiasts, environmental groups and professional biologists to detect invasive species.

**Sources:**
iTunicate Plate Watch 2016

### 5.5 *Current efforts for outreach and education*

**Choice: C** Educational materials are available and outreach occurs only sporadically in the Bering Sea or adjacent regions

**Score:** 0 of

**Ranking Rationale:**
Identification guides are available, but outreach activities occur sporadically.

**Background Information:**
Plate Watch and the Kachemak Bay National Estuarine Research Reserve (KBNERR) provide training opportunities for identifying and detecting non-native fouling organisms, and public education events on coastal and marine ecosystems more generally. "Bioblitzes" were held in Southeast AK in 2010 and 2012; these events engage and educate the public on marine invasive species. Outreach activities were conducted on the Pribilof Islands for Bering Sea Days in 2017. Field identification guides for native and non-native tunicates, as well as common fouling organisms, are readily available.

**Sources:**
iTunicate Plate Watch 2016

| | |
|---|---|
| **Section Total - Scored Points:** | 0 |
| **Section Total - Possible Points:** | |
| **Section Total -Data Deficient Points:** | |

## Literature Cited for *Schizoporella japonica*


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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Watersipora subtorquata complex*

**Common Name** *red-rust bryozoan*

| | |
|---|---|
| **Phylum** | Bryozoa |
| **Class** | Gymnolaemata |
| **Order** | Cheilostomatida |
| **Family** | Watersiporidae |

### Species Occurrence by Ecoregion

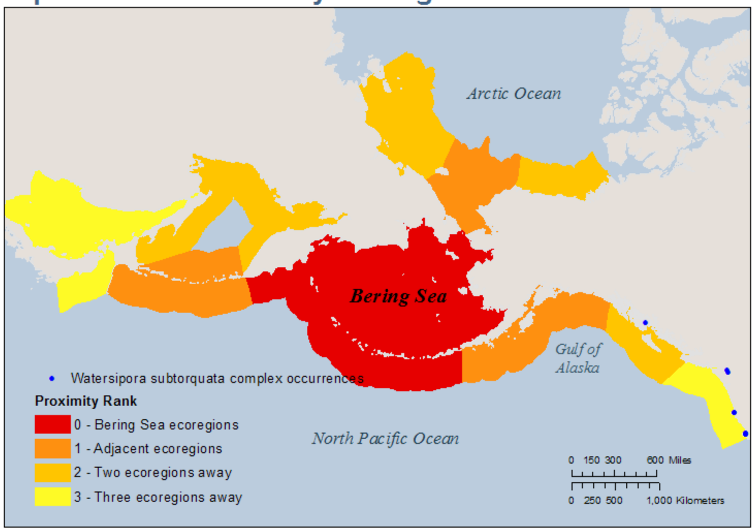


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Final Rank** 58.51

**Data Deficiency:** 16.25

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 20 | 26 | 3.75 |
| Anthropogenic Influence: | 3.25 | 10 | 0 |
| Biological Characteristics: | 19 | 25 | 5.00 |
| Impacts: | 6.75 | 23 | 7.50 |
| **Totals:** | 49.00 | 83.75 | 16.25 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | 6.7 | Minimum Salinity (ppt) | 25 |
| Maximum Temperature (°C) | 30.6 | Maximum Salinity (ppt) | 40 |
| Minimum Reproductive Temperature (°C) | NA | Minimum Reproductive Salinity (ppt) | 31* |
| Maximum Reproductive Temperature (°C) | NA | Maximum Reproductive Salinity (ppt) | 35* |

### Additional Notes

Colonial bryozoan that is red or orange in color. Its native range is unknown. Watersipora subtorquata is a species complex that has not been taxonomically resolved.

**Reviewed by** Linda McCann, Research Technician, Smithsonian Environmental Research Center, Tiburon, CA

**Review Date:** 12/15/2017

# 1. Distribution and Habitat

### *1.1 Survival requirements - Water temperature*

**Choice:** **D**

No overlap – Temperatures required for survival do not exist in the Bering Sea

**Score:** 0 of 3.75

**Ranking Rationale:**
Year-round temperature requirements do not exist in the Bering Sea.

**Background Information:**
The temperature range for survival is 6.7°C to 30.6°C (Zerebecki and Sorte 2011).

**Sources:**
Zerebecki and Sorte 2011 NEMESIS; Fofonoff et al. 2003

### *1.2 Survival requirements - Water salinity*

**Choice:** **A**

Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
This species has a salinity range of 25 to 40 ppt (Cohen 2011; Wyatt et al. 2005).

**Sources:**
Cohen 2011 Wyatt et al. 2005

### *1.3 Establishment requirements - Water temperature*

**Choice:** **U**

Unknown/Data Deficient

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *1.4 Establishment requirements - Water salinity*

**Choice:** **A**

Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Although salinity thresholds are unknown, this species is a marine organism that does not require freshwater to reproduce. We therefore assume that this species can reproduce in saltwater (31 to 35 ppt). These salinities occur in a large (>75%) portion of the Bering Sea.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *1.5 Local ecoregional distribution*

**Choice: C** Present in an ecoregion two regions away from the Bering Sea (i.e. adjacent to an adjacent ecoregion)

**Score:** 2.5 **of** 5

**Ranking Rationale:**
Present in Southeast Alaska.

**Background Information:**
Discovered in Ketchikan, AK in 2010 (Ashton et al. 2014).

**Sources:**
Ashton et al. 2014

### *1.6 Global ecoregional distribution*

**Choice: A** In many ecoregions globally

**Score:** 5 **of** 5

**Ranking Rationale:**
Wide global distribution.

**Background Information:**
Globally distributed. In North America, it is widely distributed in California; it also occurs in OR and WA, and north to Ketchikan, AK. Also found in Florida, Jamaica, Puerto Rico, Hawaii, and Brazil. In Europe, has been found in England and France. Also reported in the Middle East (Egypt, Lebanon). In Asia, found along the coasts of Japan, Korea, and China, including the Sea of Japan and East China Sea. In the Southern Hemisphere, it is found in South Africa, Australia, and New Zealand.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.7 Current distribution trends*

**Choice: A** Recent rapid range expansion and/or long-distance dispersal (within the last ten years)

**Score:** 5 **of** 5

**Ranking Rationale:**
Recent documentation of range expansion and long-distance dispersal.

**Background Information:**
Where introduced, is able to become a dominant species in a relatively short period of time. In 1970-1971 was listed as one of seven rare non-native species off the coast of California. In 2006 it was listed as one of the eight most abundant species with potential for rapid growth and expansion (Lonhart 2012).

**Sources:**
Lonhart 2012 NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 20 |
| **Section Total - Possible Points:** | 26.25 |
| **Section Total -Data Deficient Points:** | 3.75 |

## 2. Anthropogenic Transportation and Establishment



### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice: B**

Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 of 4

**Ranking Rationale:**

Readily transported via fouling, but natural dispersal is limited.

**Background Information:**

Long-distance dispersal is likely due to fouling as W. subtorquata has a short mobile life stage (Ryland et al. 2009). Marine debris, including tsunami debris, is also a potential transport vector (L. McCann, pers. comm.).

**Sources:**

Ryland et al. 2009   NEMESIS; Fofonoff et al. 2003

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice: C**

Uses anthropogenic disturbance/infrastructure to establish; never observed establishing in undisturbed areas

**Score:** 1.25 of 4

**Ranking Rationale:**

Typically associated with anthropogenic substrates.

**Background Information:**

W. subtorquata establishes itself on hard substrates. It has been observed on several anthropogenic structures such as pilings, floats, oil platforms, ships' hulls, and fouling plates (Mackie et al. 2006; Page et al. 2006; Cohen and Zabin 2009; Ryland et al. 2009).

**Sources:**

Mackie et al. 2006   Page et al. 2006   Cohen and Zabin 2009   Ryland et al. 2009   NEMESIS; Fofonoff et al. 2003

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice: B**

No

**Score:** 0 of 2

**Ranking Rationale:**

This species is not farmed or cultivated.

**Background Information:**

**Sources:**

None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 3.25 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics



### *3.1 Dietary specialization*

**Choice:** **A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Feeds on taxa readily available in the Bering Sea.

**Background Information:**
Larvae are lecithotrophic, adults are suspension feeders consuming primarily phytoplankton (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **A** Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 of 5

**Ranking Rationale:**
Tolerates a wide range of temperatures and uses numerous habitat types. Can enter a dormancy during periods of poor conditions.

**Background Information:**
Requires hard substrates to establish itself. Has been observed on pilings, rocks, shells, floats, oil platforms, ships' hulls, and fouling plates (Mackie et al. 2006; Page et al. 2006; Cohen and Zabin 2009; Ryland et al. 2009).
Can lie dormant in toxic conditions and recover as conditions improves (Piola and Johnston 2006).
Has a wide temperature range and moderate salinity range

**Sources:**
Mackie et al. 2006   Page et al. 2006   Cohen and Zabin 2009   Ryland et al. 2009   Piola and Johnston 2006   NEMESIS; Fofonoff et al. 2003

### *3.3 Desiccation tolerance*

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 3.4 *Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice: A** High – Exhibits three or four of the above characteristics

**Score:** 5 of 5

**Ranking Rationale:**
Asexual and hermophroditic with low parental investment.

**Background Information:**
Asexual reproduction through budding. Colonies are hermaphroditic, and capable of sexual reproduction. Eggs are brooded and released once mature. No parental care exists beyond that. Lifespan and age at maturity is unknown. Able to lie dormant in unsuitable (e.g. toxic) conditions and recover as conditions improve.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 3.5 *Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice: C** Disperses short (< 1 km) distances

**Score:** 0.75 of 2.5

**Ranking Rationale:**
Natural dispersal only occurs at one life stage that lasts a short time.

**Background Information:**
Larvae is free-swimming, but shorted live (≤1 day). Adult is sessile and attached to a hard substrate.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 3.6 *Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: C** Low – Exhibits none of the above characteristics

**Score:** 0.75 of 2.5

**Ranking Rationale:**
Has only one short mobile phase as a larvae.

**Background Information:**
Larvae are free-swimming, but short-lived, settling on substrate within a day or less. Adults are sessile.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *3.7 Vulnerability to predators*



**Choice:** **C** Few predators suspected present in the Bering Sea and neighboring regions, and/or multiple predators in native range

**Score:** 2.5 **of** 5

**High uncertainty?** ✔

**Ranking Rationale:**

Expected to have few predators in the Bering Sea.

**Background Information:**

Predators include sea slugs and sea spiders, and occasionally sea urchins and chitons. However, calcareous crusts are not readily eaten by most predators (O'Clair and O'Clair 1998).

**Sources:**

O'Clair and O'Clair 1998

| | |
|---|---|
| **Section Total - Scored Points:** | 19 |
| **Section Total - Possible Points:** | 25 |
| **Section Total -Data Deficient Points:** | 5 |

# 4. Ecological and Socioeconomic Impacts

## *4.1 Impact on community composition*

**Choice: B** Moderate – More than one trophic level; may cause declines but not extirpation

**Score:** 1.75 of 2.5

**Ranking Rationale:**
By creating habitat for other species, is known to cause changes in community composition in warm-temperate climates.

**Background Information:**
Displaces local Watersipora species to become dominant species as seen in New Zealand (Gordon and Mawatari 1992), Australia (Keough and Ross 1999 as qtd. in Fofonoff et al. 2003), and Southern California (Geller et al. 2008 as qtd. in Fofonoff et al. 2003; Banta 1969).

W. subtorquata has a sessile three dimensional growth form that increases species richness by providing a habitat for other species (Sellheim et al. 2010).

**Sources:**
Gordon and Mawatari 1992 Banta 1969 Sellheim et al. 2010 NEMESIS; Fofonoff et al. 2003

## *4.2 Impact on habitat for other species*

**Choice: B** Moderate – Causes or has potential to cause changes to one or more habitats

**Score:** 1.75 of 2.5

**Ranking Rationale:**
Because of its colonial habitat and leaf-like growth structure, W. subtorquata spp. creates habitat for other species to settle on.

**Background Information:**
Can grow in large colonies on hard substrates providing habitat for other organisms. Often grows leaf-like folds above the substrate creating additional habitat space. Due to its resistance to heavy metals found in anti-fouling plates, it provides habitat for more sensitive species to settle (Floerl et al. 2004).

**Sources:**
Floerl et al. 2004 NEMESIS; Fofonoff et al. 2003

## *4.3 Impact on ecosystem function and processes*

**Choice: U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.4 Impact on high-value, rare, or sensitive species and/or communities*

**Choice: U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.5 Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice: B** Moderate – Spreads or has potential to spread one or more organisms, with moderate impact and/or within only a portion of region

**Score:** 1.75 of 2.5

**Ranking Rationale:**
Because it provides habitat for other species to settle on, it may introduce "hitchhikers" into new areas.

**Background Information:**
Facilitates spread of other invasive species by providing a non-toxic surface settle on (Wisely 1958; Allen 1959 as qtd in GISD 2016).

**Sources:**
GISD 2016

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice: U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.7 Infrastructure*

**Choice: B** Moderate – Causes or has the potential to cause degradation to infrastructure, with moderate impact and/or within only a portion of the region

**Score:** 1.5 of 3

**Ranking Rationale:**
Grows on infrastructure but is not destructive.

**Background Information:**
Fouls ship hulls, docks, and pilings (Fofonoff et al. 2003). Its resistance to copper-based antifouling paints makes it hard to control (Fofonoff et al. 2003; Piola and Johnston 2006). Once established, it provides a relatively non-toxic surface for other organisms to establish. Hull foulers have negative impacts on ship speed and efficiency (Floerl et al. 2004).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Floerl et al. 2004

### 4.8 Commercial fisheries and aquaculture

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
No impacts have been reported. Given its ecology, we do not expect this species to impact recreational opportunities in the Bering Sea.

**Background Information:**
No information found.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.9 Subsistence

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
No impacts have been reported. Given its ecology, we do not expect this species to impact recreational opportunities in the Bering Sea.

**Background Information:**
No information available in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.101 Recreation

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
No impacts have been reported. Given its ecology, we do not expect this species to impact recreational opportunities in the Bering Sea.

**Background Information:**
No information found.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.11 Human health and water quality

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
No impacts have been reported. Given its ecology, we do not expect this species to impact human health or water quality in the Bering Sea.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 6.75 |
| **Section Total - Possible Points:** | 22.5 |
| **Section Total -Data Deficient Points:** | 7.5 |

## 5. Feasibility of prevention, detection and control



### *5.1 History of management, containment, and eradication*

**Choice:** **A** Attempted; control methods are not successful

**Score:** of

**Ranking Rationale:**
Methods of control have been performed and were unsuccessful.

**Background Information:**
Tolerant of copper and mercury in antifouling paint, making it difficult to control or eliminate (Allen 1953; Ryland 1971 as qtd. in Fofonoff et al. 2003; Piola and Johnston 2006). Since its populations are usually fairly widespread, local population control using are deemed ineffective (Hayes et al. 2005). Physical removal or chemical treatment options are not yet cost-effective.

**Sources:**
Allen 1953   NEMESIS; Fofonoff et al. 2003   Piola and Johnston 2006   Hayes et al. 2005

### *5.2 Cost and methods of management, containment, and eradication*

**Choice:** **A** Major long-term investment, or is not feasible at this time

**Score:** of

**Ranking Rationale:**
Current technologies to prevent the transport of marine invasive species are being developed, and require major long-term investments. Resistant to copper-based anti-fouling paints.

**Background Information:**
This species can be transported via several anthropogenic vectors, including fouling, hitchhiking, and marine debris. Methods to control the spread of marine invasive species are being studied, and currently require major long-term investments (Zagdan 2010; Hagan et al. 2014). This species is resistant to anti-fouling paints (Hayes et al. 2005).

**Sources:**
Hayes et al. 2005   Zagdan 2010   Hagan et al. 2014

### *5.3 Regulatory barriers to prevent introductions and transport*

**Choice:** **B** Regulatory oversight, but compliance is voluntary

**Score:** of

**Ranking Rationale:**
Compliance with fouling regulations are voluntary.

**Background Information:**
In the U.S., Coast Guard regulations require masters and ship owners to engage in practices that will reduce the spread of invasive species, including cleaning ballast tanks and removing fouling organisms from hulls, anchors, and other infrastructure on a “regular” basis (CFR 33 § 151.2050). Failure to remove fouling organisms is punishable with a fine (up to $27 500). However, the word “regular” is not defined, which makes the regulations hard to enforce. As a result of this technical ambiguity, compliance with ship fouling regulations remains largely voluntary (Hagan et al. 2014).

Cleaning of recreational vessels is also voluntary, although state and federal programs are in place to encourage owners to clean their boats. Boat inspection is mandatory on some lakes (e.g. Lake Tahoe in CA/NV, Lake George in NY). In summer 2016, state and federal agencies conducted voluntary inspections for aquatic invasive species on trailered boats entering the state of Alaska (Davis 2016).

**Sources:**
CFR 2017   Hagan et al. 2014   Davis 2016

### 5.4 *Presence and frequency of monitoring programs*

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**Choice: B** — Surveillance takes place, but is largely conducted by non-governmental environmental organizations (e.g., citizen science programs)

**Score:** of

**Ranking Rationale:**
Monitoring for invasive tunicates is conducted by Plate Watch and KBNERR, which are non-governmental agencies.

**Background Information:**
In Alaska, Plate Watch and Kachemak Bay National Estuarine Research Reserve (KBNERR) conduct monitoring for non-native tunicates and other invasive or harmful species. These programs involve teachers, students, outdoor enthusiasts, environmental groups and professional biologists to detect invasive species. W. subtorquata is listed as a species to look for, and has an ID fact sheet.

**Sources:**
iTunicate Plate Watch 2016

### 5.5 *Current efforts for outreach and education*

**Choice: C** — Educational materials are available and outreach occurs only sporadically in the Bering Sea or adjacent regions

**Score:** 0 of

**Ranking Rationale:**
Identification guides are available, but outreach activities occur sporadically.

**Background Information:**
Plate Watch and the Kachemak Bay National Estuarine Research Reserve (KBNERR) provide training opportunities for identifying and detecting non-native fouling organisms, and public education events on coastal and marine ecosystems more generally. "Bioblitzes" were held in Southeast AK in 2010 and 2012; these events engage and educate the public on marine invasive species. Outreach activities were conducted on the Pribilof Islands for Bering Sea Days in 2017. Field identification guides for native and non-native tunicates, as well as common fouling organisms, are readily available.

**Sources:**
iTunicate Plate Watch 2016

| | |
|---|---|
| **Section Total - Scored Points:** | 0 |
| **Section Total - Possible Points:** | |
| **Section Total -Data Deficient Points:** | |

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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Alosa sapidissima*

**Common Name** *American shad*

| | |
|---|---|
| **Phylum** | Chordata |
| **Class** | Actinopterygii |
| **Order** | Clupeiformes |
| **Family** | Clupeidae |

**Final Rank** 49.25

**Data Deficiency:** 0.00

**Species Occurrence by Ecoregion**

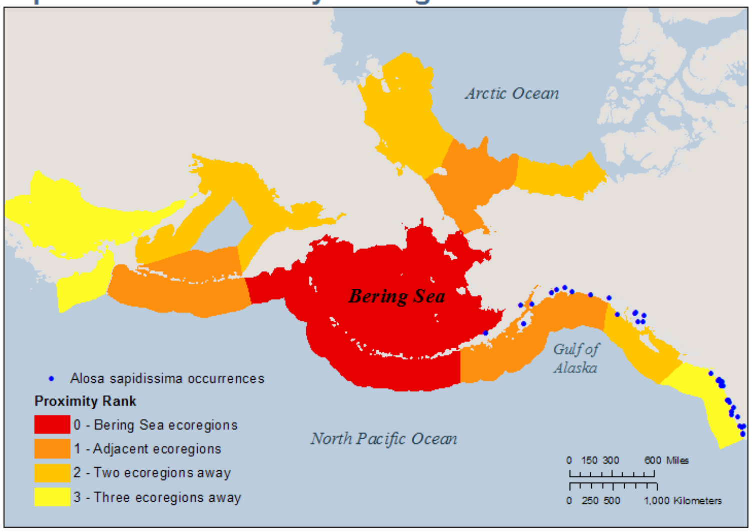


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 13.75 | 30 | 0 |
| Anthropogenic Influence: | 10 | 10 | 0 |
| Biological Characteristics: | 20.75 | 30 | 0 |
| Impacts: | 4.75 | 30 | 0 |
| **Totals:** | 49.25 | 100.00 | 0.00 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | 2 | Minimum Salinity (ppt) | 5 |
| Maximum Temperature (°C) | 26 | Maximum Salinity (ppt) | 33 |
| Minimum Reproductive Temperature (°C) | 8 | Minimum Reproductive Salinity (ppt) | 0 |
| Maximum Reproductive Temperature (°C) | 26 | Maximum Reproductive Salinity (ppt) | 7.6 |

### Additional Notes

The American Shad has a silver, metallic body with a deeply forked tail fin and iridescent coloring that can vary from greenish to dark blue. Its large dark shoulder spot may be followed by several paler spots. It is an anadromous, schooling fish that spends most of its life at sea. Adults enter freshwater in the spring to spawn, and many return to their natal river. A thorough risk assessment for this species must therefore consider compatibility with freshwater as well as marine conditions. However, in keeping with the scope of this project (i.e. the Bering Sea ecosystem), we assess this species' impacts and establishment potential only with respect to its marine life phase. American Shad is a species of concern in its native range along the Atlantic Coast of North America, where populations are declining.

**Reviewed by** Peter Westley, Assistant Professor, College of Fisheries and Ocean Sciences, UAF, Fairbanks AK

**Review Date:** 9/6/2017

# 1. Distribution and Habitat

90

### *1.1 Survival requirements - Water temperature*

**Choice:** **C** Little overlap – A small area (<25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 1.25 of 3.75

**Ranking Rationale:**
Temperatures required for year-round survival occur in a limited area (<25%) of the Bering Sea.

**Background Information:**
Optimal sea surface temperatures are between 13 to 18°C (Pearcy and Fisher 2011; Hasselman et al. 2012a). On the East Coast, A. sapidissima has been caught in waters with surface temperatures as low as 2°C (Neves and Depres 1978).

**Sources:**
FishBase 2016   Pearcy and Fisher 2011   Hasselman et al. 2012a   Neves and Depres 1978   Greene et al. 2009

### *1.2 Survival requirements - Water salinity*

**Choice:** **B** Moderate overlap – A moderate area (≥25%) of the Bering Sea has salinities suitable for year-round survival

**High uncertainty?** ☑

**Score:** 2.5 of 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur in a moderate area (≥25%) of the Bering Sea. We ranked this question with "High Uncertainty" to indicate disagreements in model estimates.

**Background Information:**
While in the ocean, American shad will live in seawater that is approximately 33 ppt.

**Sources:**
Greene et al. 2009

### *1.3 Establishment requirements - Water temperature*

**Choice:** **D** No overlap – Temperatures required for reproduction do not exist in the Bering Sea

**Score:** 0 of 3.75

**Ranking Rationale:**
This species requires freshwater to spawn.

**Background Information:**
Spawning has been reported from 8 to 26°C, and generally occurs between 12 and 21°C.

**Sources:**
Greene et al. 2009   Morrow 1980

### *1.4 Establishment requirements - Water salinity*

**Choice:** **D** No overlap – Salinities required for reproduction do not exist in the Bering Sea

**Score:** 0 of 3.75

**Ranking Rationale:**
This species requires freshwater to spawn.

**Background Information:**
Spawning and embryos require freshwater. Juveniles can tolerate a wide range of salinities (5 to 33 ppt).

**Sources:**
Greene et al. 2009

### 1.5 *Local ecoregional distribution*



**Choice: A** Present in the Bering Sea

**Score:** 5 of 5

**Ranking Rationale:**
This species has been found in the Bering Sea.

**Background Information:**
American Shad have been documented northeast of Port Moller (Aleutians East), and in the Gulf of Alaska (Mecklenburg et al. 2002). Individuals have been found in Alaska as far back as 1891 (Smith 1896, qtd. in Mecklenburg et al. 2002). American Shad are considered "strays" in Alaska and there are no established populations in the state (Morrow 1980).

**Sources:**
Morrow 1980 Mecklenburg et al. 2002

### 1.6 *Global ecoregional distribution*

**Choice: C** In few ecoregions globally

**Score:** 1.75 of 5

**Ranking Rationale:**
With the exception of records off the Russian coast, does not occur outside of North America.

**Background Information:**
American Shad are native to the Atlantic coast of North America from Labrador (Canada) to Florida. They were introduced to San Francisco Bay in 1871, and rapidly spread northward along the Pacific Coast. Spawning has been reported at least as far north as the Columbia River (WA) (Cohen and Carlton 1995). Feeding adults have been caught as far south as Baja California (Mexico), and as far north as Cook Inlet and the Kamchatka Peninsula (Center for Aquatic Resource Studies 2005).

**Sources:**
Ruiz et al. 2006 Hasselman et al. 2012a

### 1.7 *Current distribution trends*

**Choice: B** History of rapid expansion or long-distance dispersal (prior to the last ten years)

**Score:** 3.25 of 5

**Ranking Rationale:**
No evidence of rapid range expansion has been reported in the past 10 years. Rapid range expansion via natural long-distance dispersal was documented along the Pacific Coast after this species' initial introduction to California in 1871.

**Background Information:**
American shad are capable of long-distance dispersal. This species underwent a rapid northward expansion following its introduction in California in 1871 (Hasselman et al. 2012a). By 1891, it had spread all along the Pacific coast, north to AK. Reports of shad from Russia and Alaska are sporadic (Mecklenburg et al. 2002). There are currently no established populations in Alaska.

**Sources:**
Hasselman et al. 2012a Hasselman et al. 2012b Mecklenburg et al. 2002

| | |
|---|---|
| **Section Total - Scored Points:** | 13.75 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 2. Anthropogenic Transportation and Establishment



### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice:** **A** Has been observed using anthropogenic vectors for transport and transports independent of any anthropogenic vector once introduced

**Score:** 4 **of** 4

**Ranking Rationale:**
Intentionally stocked as a sport fish, and can disperse naturally once introduced.

**Background Information:**
American Shad have been intentionally stocked as a sport fish. Following its introduction to California in 1871, American Shad dispersed naturally along the Pacific Coast, north to AK (Ruiz et al. 2006).

**Sources:**
Animal Diversity Web 2017   U. S. Geological Survey 2017   Ruiz et al. 2006

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice:** **A** Readily establishes in areas with anthropogenic disturbance/infrastructure and in natural, undisturbed areas

**Score:** 4 **of** 4

**Ranking Rationale:**
Lives in open water and does not require anthropogenic vectors to establish. Human disturbance may facilitate establishment by providing access to more spawning habitat.

**Background Information:**
This species does not require anthropogenic vectors to establish. Human disturbance (e.g. construction of dams) in the Columbia River may have allowed the American Shad to enter previously inaccessible spawning habitat (Hasselman et al. 2012a)

**Sources:**
Hasselman et al. 2012a

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice:** **A** Yes

**Score:** 2 **of** 2

**Ranking Rationale:**
This species supports commercial, subsistence, and sport fisheries.

**Background Information:**
American Shad have been introduced for forage, food, sport and commercial fishing. In its native range, American Shad are being reared in hatcheries to boost local populations; but there are no hatchery programs outside the native range (although one did operate in Oregon from 1906 to 1920; Hasselman et al. 2012a).

**Sources:**
ASFMC 2007   U. S. Geological Survey 2017   Hasselman et al. 2012a

| | |
|---|---|
| **Section Total - Scored Points:** | 10 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

# 3. Biological Characteristics



### 3.1 *Dietary specialization*

**Choice:** **A** — Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Generalist diet across all life stages. Prey items are readily available in the Bering Sea.

**Background Information:**
At sea, American Shad feed on plankton, crustaceans and small fish. Adults are believed to stop feeding once they begin their upstream spawning migration; however, a recent stomach content analysis found freshwater copepods and crustaceans in adults that had just spawned (Walters and Olney 2003, qtd. in Greene et al. 2009). Juveniles feed on zooplankton, copepods, adults and immature insects (both aquatic and terrestrial).

**Sources:**
Greene et al. 2009

### 3.2 *Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **B** — Requires specialized habitat for some life stages (e.g., reproduction)

**Score:** 3.25 of 5

**Ranking Rationale:**
American Shad require freshwater for spawning.

**Background Information:**
American Shad spend most of their adult life in the open sea, at average water depths of 125 m (range: 0 to 375 m). They require well-oxygenated waters throughout their life history, but adults appear to be tolerant to turbid water conditions (Greene et al. 2009). Larvae and adults can tolerate a wide range of salinities between 5 to 33 ppt (Greene et al. 2009). Spawning typically occurs in freshwater.

**Sources:**
Greene et al. 2009   Animal Diversity Web 2017

### 3.3 *Desiccation tolerance*

**Choice:** **C** — Little to no tolerance (<1 day) of desiccation during its life cycle

**Score:** 1.75 of 5

**Ranking Rationale:**
American Shad cannot survive out of water for extended periods of time.

**Background Information:**
A. sapidissima is a ray-finned fish that requires water for respiration.

**Sources:**
Randall 1970

### *3.4 Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice:** **B** Moderate – Exhibits one or two of the above characteristics

**Score:** 3.25 of 5

**Ranking Rationale:**

American Shad exhibit high fecundity, external fertilization and low parental investment, but time to sexual maturity is long. Sexes are separate.

**Background Information:**

Dioecious, sexual reproduction. Fertilization is external, and adults do not provide any care for the eggs or larvae after fertilization. American Shad spawn in rivers during late winter or early spring. Most return to their natal rivers and tributaries to spawn, but some populations exhibit low site fidelity (e.g. Cumberland Basin population; Melvin et al. 1986). On average, larvae hatch in 10 days. Fecundity estimates vary from 116,000 to >600,000 eggs per female (Morrow 1980). Estimates of egg production in York River, Virginia, are 20,000 to 70,000 eggs per kg of somatic weight, spawned every four days (Olney et al. 2001, qtd. in Greene et al. 2009). American Shad breed once a year, but exhibit regional differences in lifetime spawning frequency. Some populations are iteroparous (repeat spawners), while others are semelparous (die after one spawning season) (Leggett and Carscadden 1978).

Average lifespan: 9 years
Sexual maturity: 3 to 7 years for females

**Sources:**

Greene et al. 2009 Melvin et al. 1986 Animal Diversity Web 2017 Morrow 1980 Leggett and Carscadden 1978

### *3.5 Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice:** **A** Disperses long (>10 km) distances

**Score:** 2.5 of 2.5

**Ranking Rationale:**

While eggs and larvae may only disperse a few metres within a waterway, adults can undergo extensive migrations, travelling hundreds to thousands of kilometers in one season.

**Background Information:**

Larvae, eggs, and juveniles can be passively dispersed by water currents. Eggs have been observed traveling a distance of 5 to 35 m downstream before sinking (qtd. in Greene et al. 2009). Bilkovic et al. (2002) found that larvae were transported throughout a larger portion of the water body than eggs. The oceanic Davidson Current may have enabled juvenile shad to move northwards from Sacramento at a rate of 24.9 km/day (Burt and Wyatt 1964, qtd. in Hasselman et al. 2012a). Hasselman et al. (2012a) propose that this mechanism was responsible for the rapid northward expansion of American shad at the end of the 19th century. Adults undergo extensive ocean migrations of sometimes thousands of kilometers in one season (Pearcy and Fisher 2011). Leggett (1977, qtd in. Melvin et al. 1986) determined a maximum migration rate of 25 km/day for adult shad during their spring coastal movements. Most American Shad populations return to their natal river to spawn (Melvin et al. 1986).

**Sources:**

Greene et al. 2009 Melvin et al. 1986 Bilkovic et al. 2002 Animal Diversity Web 2017 Pearcy and Fisher 2011 Hasselman et al. 2012a

### *3.6 Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: A** High – Exhibits two or three of the above characteristics

**Score:** 2.5 of 2.5

**Ranking Rationale:**
All life stages (eggs, larvae, juveniles, and adults) can disperse. Juveniles and adults are highly mobile and free-swimming. Eggs and larvae can be passively dispersed by water currents.

**Background Information:**

**Sources:**
Hasselman et al. 2012a Greene et al. 2009

### *3.7 Vulnerability to predators*

**Choice: C** Few predators suspected present in the Bering Sea and neighboring regions, and/or multiple predators in native range

**Score:** 2.5 of 5

**Ranking Rationale:**
Several taxa including birds, fishes, and marine mammals prey upon adult American Shad. Predators known to eat eggs and larvae are not present in the Bering Sea.

**Background Information:**
Adults are eaten by seals, double-crested cormorant, dolphins, otters, and herons. Eggs and larvae are preyed upon primarily by American eel and fish including striped bass, king mackerel, and catfish.

**Sources:**
Greene et al. 2009

| | |
|---|---|
| **Section Total - Scored Points:** | 20.75 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 4. Ecological and Socioeconomic Impacts



### 4.1 *Impact on community composition*

**Choice:** **C** Limited – Single trophic level; may cause decline but not extirpation

**Score:** 0.75 of 2.5

**Ranking Rationale:**
A negative correlation between American Shad and zooplankton abundances has been reported in the Columbia River, where shad occurs at large densities. At high densities, American Shad may also affect salmon behaviour by blocking their migratory movement. However, population-level effects of shad on salmon (or other fish species) have not yet been documented.

**Background Information:**
Shad have been reported from several rivers in the Pacific Northwest that contain evolutionarily significant populations of salmon and steelhead. Although some authors have suggested that shad may negatively affect Pacific coastal ecosystems and native salmon populations, this hypothesis has not been empirically tested (Hasselman et al. 2012b).

Shad may compete with indigenous taxa for space and impede the migration of other anadromous fishes (Hasselman et al. 2012b). Accumulations of large numbers of adult shad have impeded the migration of salmon at fish ladder entrances on the Columbia River (Monk et al. 1989, qtd. in Hasselman et al. 2012b).

Competition for zooplankton by young: In the Columbia River, where shad occur at high densities, larval and juvenile shad feed primarily on zooplankton. Haskell et al. (2013) observed strong predation by shad on zooplankton, and concomitant decreases in the abundance and size of Daphnia spp. Through their effect on zooplankton, American shad may have negative consequences on native fish such as Pacific salmon that also rely on this resource (Haskell et al. 2013).

**Sources:**
Hasselman et al. 2012b   Haskell et al. 2013   U. S. Geological Survey 2017

### 4.2 *Impact on habitat for other species*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No impacts have been reported. Given its ecology, we do not expect American Shad to impact habitat in the Bering Sea.

**Background Information:**
No information found.

**Sources:**
Hasselman et al. 2012b   U. S. Geological Survey 2017

### 4.3 *Impact on ecosystem function and processes*



**Choice:** **C**

Limited – Causes or potentially causes changes to food webs and/or ecosystem functions, with limited impact and/or within a very limited region

**Score:** 0.75 **of** 2.5

**Ranking Rationale:**

Ecosystem effects are largely speculative, or restricted to areas where American Shad occur at high densities.

**Background Information:**

Apparent competition: Shad may indirectly affect native salmon through apparent competition. In areas where American Shad occur at high densities, larvae and juveniles may provide an important food source for double-crested cormorants, and fishes such as northern pike minnow, smallmouth bass, and walleye. The population of these fish species may increase as a result, which may in turn lead to increased predation on juvenile salmon (Hasselman et al. 2012b).

In south Atlantic coastal rivers, where most individuals die after spawning, shad carcasses may contribute significant nutrient input from marine to freshwater ecosystems (ASMFC 1999, qtd. in Greene et al. 2009).

**Sources:**

Hasselman et al. 2012b   Greene et al. 2009

### 4.4 *Impact on high-value, rare, or sensitive species and/or communities*

**Choice:** **C**

Limited – Has limited potential to cause degradation of one more species or communities, with limited impact and/or within a very limited region

**Score:** 0.75 **of** 2.5

**High uncertainty?** ☑

**Ranking Rationale:**

Although this species has the potential to affect native Pacific salmon populations, effects have not yet been documented.

**Background Information:**

Shad have been reported from several rivers in the Pacific Northwest that contain evolutionarily significant populations of salmon and steelhead. Although some authors have suggested that shad may negatively affect Pacific coastal ecosystems and native salmon populations, this hypothesis has not been empirically tested (Hasselman et al. 2012b).

**Sources:**

Hasselman et al. 2012b

### *4.5 Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice: B** Moderate – Spreads or has potential to spread one or more organisms, with moderate impact and/or within only a portion of region

**Score:** 1.75 of 2.5

**Ranking Rationale:**

American Shad is host to several parasites, some of which affect other fish species and/or can be transmitted to higher trophic levels. The introduction or increased abundance of American Shad has been linked to the outbreak and spread of Ichthyophonus and Anisakis simplex parasites.

**Background Information:**

American Shad are hosts to a variety of parasites, including nematodes (Anisakis simplex, Hysterothylacium aduncum), cestodes (Scolex pleuronectis), and trematodes (Genitocotyle atlantica). Anisakis simplex was historically restricted to marine environments and its native herring (Clupea harengus) host. The introduction of American shad has enabled A. simplex to expand into freshwater systems. A. simplex can be transmitted to mammalian predators including otters and humans. American shad are also hosts to Ichthyophonus spp., a parasite of wild marine fishes. Ichthyophonus is native to the Pacific Northwest and infects salmon, which then introduce the parasite into freshwater systems. However, an outbreak of this parasite in the Columbia River in 2007 was linked to the high abundance of shad in the river.

**Sources:**

Hasselman et al. 2012b

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**

No instances of hybridization between American Shad and other fish species have been reported. There are no native Clupeidae species in Alaska.

**Background Information:**

No information found to suggest that A. sapidissima hybridizes with native species. Instances of hybridization have been reported between other Alosa species (A. alosa × A. fallax in Jolly et al. 2011; A. pseudoharengus × A. aestivalis in Hasselman et al. 2014).

**Sources:**

Jolly et al. 2011 Hasselman et al. 2014

### *4.7 Infrastructure*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**

No impacts have been reported. Given its ecology, we do not expect American Shad to impact infrastructure in the Bering Sea.

**Background Information:**

No information found.

**Sources:**

Hasselman et al. 2012b

### 4.8 Commercial fisheries and aquaculture

**Choice:** **D** No impact

**Score:** 0 of 3

**High uncertainty?** ☑

**Ranking Rationale:**
Some authors have suggested that American Shad may compete with native Pacific salmon species, but this assertion has not yet been supported by empirical data.

**Background Information:**
No impacts have been reported.

**Sources:**
Hasselman et al. 2012b U. S. Geological Survey 2017

### 4.9 Subsistence

**Choice:** **D** No impact

**Score:** 0 of 3

**High uncertainty?** ☑

**Ranking Rationale:**
Some authors have suggested that American Shad may compete with native Pacific salmon species, but this assertion has not yet been supported by empirical data.

**Background Information:**
No impacts have been reported.

**Sources:**
Hasselman et al. 2012b U. S. Geological Survey 2017

### 4.101 Recreation

**Choice:** **D** No impact

**Score:** 0 of 3

**High uncertainty?** ☑

**Ranking Rationale:**
Some authors have suggested that American Shad may compete with native Pacific salmon species, but this assertion has not yet been supported by empirical data.

**Background Information:**
No impacts have been reported.

**Sources:**
Hasselman et al. 2012b U. S. Geological Survey 2017

### 4.11 Human health and water quality

**Choice:** **C** Limited – Has limited potential to pose a threat to human health, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
To prevent anisakiasis, the CDC recommends avoiding to eat raw or undercooked fish. Anisakiasis is most commonly found in areas where eating raw fish is popular. Japan has the greatest number of reported cases of anisakiasis, with over 1000 cases reported per year (Beaudry 2012).

**Background Information:**
American shad are hosts to the nematode Anisakis simplex. Anisakis simplex is not specific to American Shad, and can also infect herring, cod, salmon, and cephalopods (e.g., squid, cuttlefish). This parasite can pose a health risk to humans if humans consume undercooked, infected fish. Because Anisakis larvae cannot survive in humans, larvae will eventually die. In extreme cases, ingesting A. simplex can trigger severe allergic reactions, and treating an Anisakis infection may require surgery. This infection cannot be transmitted from human to human.

**Sources:**
CDC 2017 U. S. Geological Survey 2017 Beaudry 2012

| | |
|---|---|
| **Section Total - Scored Points:** | 4.75 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

# 5. Feasibility of prevention, detection and control

### *5.1 History of management, containment, and eradication*

**Choice:** **B** Not attempted

**Score:** of

**Ranking Rationale:**
There have been no attempts to control or eradicate American shad.

**Background Information:**
There have been no attempts to control or eradicate American shad, but intentional introductions to the Pacific coast have stopped (Hasselman et al. 2012a). In the Atlantic states where American shad is native, management efforts are hoping to increase population size (ASFMC 2007).

**Sources:**
ASFMC 2007 Hasselman et al. 2012a

### *5.2 Cost and methods of management, containment, and eradication*

**Choice:** **B** Major short-term and/or moderate long-term investment

**Score:** of

**Ranking Rationale:**
Although few estimates are available, control or eradication of American Shad would likely require millions of dollars over several years.

**Background Information:**
Few management plans discuss the control or eradication of American Shad. However, Huppert and Fluharty (1995, qtd. in Petersen et al. 2003) estimated that removing American Shad from the Snake River would cost $1 million per year over five years.

**Sources:**
Petersen et al. 2003

### *5.3 Regulatory barriers to prevent introductions and transport*

**Choice:** **C** Regulatory oversight and/or trade restrictions

**Score:** of

**Ranking Rationale:**
The transport and trade of live fish is regulated in Alaska.

**Background Information:**
According to the Alaska Administrative Code, “No person may transport, possess, export from the state, or release into the waters of the state, any live fish unless the person holds a fish transport permit […] and the person is in compliance with all conditions of the permit and the provisions of this chapter.” Permits are issued by the Alaska Department of Fish & Game and are project- and time-specific.

**Sources:**
AAC 2017

### 5.4 *Presence and frequency of monitoring programs*

**Choice: A** No surveillance takes place

**Score:** of

**Ranking Rationale:**
Although monitoring of American Shad population is being conducted in its native range (where the goal is to increase populations), no monitoring is being conducted in Alaska or in states where it is invasive.

**Background Information:**
State monitoring programs exist in this species' native range, where management efforts are underway to increase populations. In its invasive range, no monitoring plans are in place. In its introduced range, counts are conducted at some dams on the Columbia River during migration. Management plans for the Columbia River basin do not mention American Shad as a potential threat to salmon or to the ecosystem (Petersen et al. 2003).

**Sources:**
Greene et al. 2009 Petersen et al. 2003

### 5.5 *Current efforts for outreach and education*

**Choice: A** No education or outreach takes place

**Score:** of

**Ranking Rationale:**
No outreach or education is being conducted for this species.

**Background Information:**
An online search returned no results for outreach and education programs on the invasive status of American Shad.

**Sources:**
None listed

**Section Total - Scored Points:**

**Section Total - Possible Points:**

**Section Total -Data Deficient Points:**

## Literature Cited for *Alosa sapidissima*


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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Salmo salar*

**Common Name** *Atlantic salmon*

| | |
|---|---|
| **Phylum** | Chordata |
| **Class** | Actinopterygii |
| **Order** | Salmoniformes |
| **Family** | Salmonidae |

**Final Rank** 49.25

**Data Deficiency:** 0.00

Species Occurrence by Ecoregion

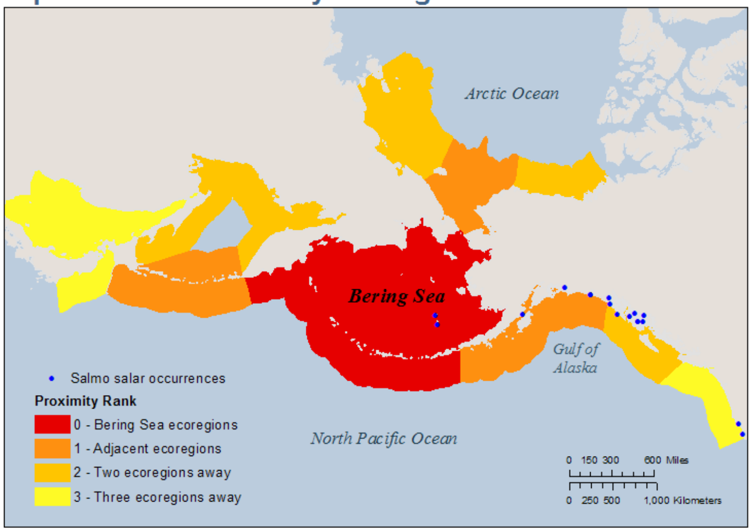


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 16.25 | 30 | 0 |
| Anthropogenic Influence: | 7.25 | 10 | 0 |
| Biological Characteristics: | 18.75 | 30 | 0 |
| Impacts: | 7 | 30 | 0 |
| **Totals:** | 49.25 | 100.00 | 0.00 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | -0.7 | Minimum Salinity (ppt) | 0 |
| Maximum Temperature (°C) | 27.8 | Maximum Salinity (ppt) | 35.3 |
| Minimum Reproductive Temperature (°C) | 7.2 | Minimum Reproductive Salinity (ppt) | 0 |
| Maximum Reproductive Temperature (°C) | 10 | Maximum Reproductive Salinity (ppt) | 0 |

### Additional Notes

Atlantic salmon are anadromous fish native to the North Atlantic Ocean. Introductions in Alaska are largely the result of escaped individuals from fish farms in B.C. and Washington. Several significant escape events have been noted; for example, in August 2017, >145 000 fish escaped from a net pen on Cypress Island, WA. Atlantic salmon require freshwater to spawn. A thorough risk assessment for this species must therefore consider compatibility with freshwater as well as marine conditions. However, in keeping with the scope of this project (i.e. the Bering Sea ecosystem), we assess this species' impacts and establishment potential only with respect to its marine life phase.

**Reviewed by** Peter Westley, Assistant Professor, College of Fisheries and Ocean Sciences, UAF, Fairbanks AK

**Review Date:** 9/6/2017

# 1. Distribution and Habitat

### *1.1 Survival requirements - Water temperature*

**Choice: B** Moderate overlap – A moderate area (≥25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 2.5 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Temperatures required for year-round survival occur in a moderate area (≥25%) of the Bering Sea. We ranked this question with "High Uncertainty" to indicate disagreements in model estimates.

**Background Information:**
The optimal temperature range for survival is 4°C to 12°C (NAS; USGS 2016). The lower lethal temperature limit is -0.7°C, upper limit is 27.8°C (Bigelow 1963).

**Sources:**
NAS database, USGS 2017   Bigelow 1963

### *1.2 Survival requirements - Water salinity*

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
Freshwater is required for reproduction and very young individuals. Adaptability to seawater typically increases during parr-smolt transformation, though large parr (> 120 mm) can tolerate salinities up to 31 ppt (Farmer et al. 1978; Danie et al. 1984). Post-smolts in the Norwegian Sea were caught at salinities between 34 and 35.3 ppt (Holm et al. 2000).

**Sources:**
Holm et al. 2000   NAS database, USGS 2017   Danie et al. 1984   Farmer et al. 1978

### *1.3 Establishment requirements - Water temperature*

**Choice: D** No overlap – Temperatures required for reproduction do not exist in the Bering Sea

**Score:** 0 of 3.75

**Ranking Rationale:**
Atlantic salmon require freshwater to spawn.

**Background Information:**
Requires freshwater for spawning and juvenile life stages (NAS; USGS 2017).

**Sources:**
NAS database, USGS 2017

### *1.4 Establishment requirements - Water salinity*

**Choice: D** No overlap – Salinities required for reproduction do not exist in the Bering Sea

**Score:** 0 of 3.75

**Ranking Rationale:**
Atlantic salmon require freshwater to spawn.

**Background Information:**
Requires freshwater for spawning and juvenile life stages (NAS; USGS 2017).

**Sources:**
NAS database, USGS 2017

### 1.5 *Local ecoregional distribution*



**Choice: A** Present in the Bering Sea

**Score:** 5 of 5

**Ranking Rationale:**
Occasionally observed in the Bering Sea.

**Background Information:**
Individuals have been documented primarily in southeast Alaska, but have also been caught in the Gulf of Alaska and in the Bering Sea (Wing et al. 1992, Brodeur and Busby 1998, Gross 1998). The first recorded instance of S. salar in the Bering Sea was in September 1997, when an individual was captured in a bottom trawl south of the Pribilof Islands (Brodeur and Busby 1998).

**Sources:**
NAS database, USGS 2017   Brodeur and Busby 1998   Gross 1998   Wing et al. 1992

### 1.6 *Global ecoregional distribution*

**Choice: A** In many ecoregions globally

**Score:** 5 of 5

**Ranking Rationale:**
Wide global distribution.

**Background Information:**
Found in both polar and temperate waters, on both the Eastern and Western coasts of North America, and in Europe's Atlantic Ocean (as far south as Portugal). Has been introduced in Argentina, Australia, Chile, and New Zealand (WCMC 1996). Despite these extensive introduction efforts, there are no self-sustaining anadromous populations of Atlantic salmon outside the species' native range, and only a few self-sustaining landlocked populations (Thorstad et al. 2011).

**Sources:**
WCMC 1996   Thorstad et al. 2011

### 1.7 *Current distribution trends*

**Choice: D** Not well established outside of native range

**Score:** 0 of 5

**Ranking Rationale:**
Capable of long-distance dispersal, but dispersals and introduction efforts have not resulted in established populations.

**Background Information:**
Atlantic Salmon have been introduced worldwide and are capable of long-distance dispersal of 1500 km or more (Hansen and Youngson 2010). However, despite extensive introduction efforts, there are no self-sustaining anadromous populations of Atlantic salmon outside the species' native range, and only a few self-sustaining landlocked populations (Thorstad et al. 2011).

**Sources:**
Hansen and Youngson 2010   Thorstad et al. 2011

| | |
|---|---|
| **Section Total - Scored Points:** | 16.25 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 2. Anthropogenic Transportation and Establishment



### 2.1 *Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice: A** — Has been observed using anthropogenic vectors for transport and transports independent of any anthropogenic vector once introduced

**Score:** 4 of 4

**Ranking Rationale:**
Intentionally moved for aquaculture or recreational purposes. Can disperse naturally after initial introduction.

**Background Information:**
Anthropogenic transportation is restricted to intentional introductions. Once introduced, S. salar can undergo long distance dispersal without human assistance (NAS, USGS 2017).

**Sources:**
NAS database, USGS 2017

### 2.2 *Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice: C** — Uses anthropogenic disturbance/infrastructure to establish; never observed establishing in undisturbed areas

**Score:** 1.25 of 4

**Ranking Rationale:**
Although populations have been introduced worldwide for aquaculture and recreation, very few have become self-sustaining.

**Background Information:**
Once Atlantic salmon escape from their mariculture infrastructure, they can disperse to and survive in pristine, natural areas (Gross 1998). Natural spawning has been observed among 'escaped' Atlantic salmon in British Columbia (Volpe et al. 2000); however, this species rarely establishes self-sustaining populations outside of its native range (Thorstad et al. 2011).

**Sources:**
Gross 1998   Volpe et al. 2000   Thorstad et al. 2011

### 2.3 *Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice: A** — Yes

**Score:** 2 of 2

**Ranking Rationale:**
Atlantic salmon is one of the most important commercially farmed fin fish in the world. It has also been intentionally introduced for sportfishing.

**Background Information:**
Atlantic Salmon have a long history of being stocked and farmed in areas outside of their historic range. Salmon mariculture is practiced in many parts of the world including the UK, Ireland, Faroe Island, Canada, USA, Chile, Australia, New Zealand, France and Spain (reviewed in FAO 2017b). In 2014, worldwide production of farmed Atlantic salmon was estimated at 2.3 million tonnes (FAO 2017b).

**Sources:**
FAO 2017b

| | |
|---|---|
| **Section Total - Scored Points:** | 7.25 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics



### *3.1 Dietary specialization*

**Choice: A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Generalist at all life stages.

**Background Information:**
Young salmon feed on aquatic and terrestrial insects. Adults feed on crustaceans and other fish. At the population level, Atlantic Salmon are considered as generalist feeders, even though individuals may specialize on only a few food items (Jorgensen et al. 2000).

**Sources:**
Jorgensen et al. 2000

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice: B** Requires specialized habitat for some life stages (e.g., reproduction)

**Score:** 3.25 of 5

**Ranking Rationale:**
Requires freshwater for spawning and juvenile development.

**Background Information:**
Atlantic Salmon are anadromous and require freshwater for spawning and during the juvenile life stage (Thorpe 1994; NAS, USGS 2016).

**Sources:**
NAS database, USGS 2017 Thorpe 1994

### *3.3 Desiccation tolerance*

**Choice: C** Little to no tolerance (<1 day) of desiccation during its life cycle

**Score:** 1.75 of 5

**Ranking Rationale:**
Atlantic salmon cannot survive out of water for extended periods of time.

**Background Information:**
S. salar is a ray-finned fish that requires water for respiration.

**Sources:**
Randall 1970

### *3.4 Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice: B** Moderate – Exhibits one or two of the above characteristics

**Score:** 3.25 of 5

**Ranking Rationale:**
Exhibit low parental investment and external fertilization. However, reproduction is sexual, fecundity is low, and they do not have a short generation time.

**Background Information:**
Life span is 4 - 6 years, half in freshwater, half in a marine environment (NOAA 2016). Females produce 1,500 to 1,800 eggs/kg and are capable of spawning more than once during their life time. There is no parental investment after eggs have been covered and nesting is complete.

**Sources:**
NOAA 2016

### *3.5 Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice: A** Disperses long (>10 km) distances

**Score:** 2.5 of 2.5

**Ranking Rationale:**
Capable of long-distance movements.

**Background Information:**
Adults are capable of moving large distances (1500 km; Hansen and Youngson 2010).

**Sources:**
Hansen and Youngson 2010

### *3.6 Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: B** Moderate – Exhibits one of the above characteristics

**Score:** 1.75 of 2.5

**Ranking Rationale:**
Although larval viability is long, dispersal only occurs with the adult lifestage. Individuals show high natal site fidelity.

**Background Information:**
Dispersal events occur only at smolt and post-smolt life stages. Younger life stages remain in the freshwater body in which they were born until they are ready to migrate to sea. Anadramous populations tend to return to the same freshwater site year after year (NOAA 2016).

**Sources:**
NOAA 2016

### *3.7 Vulnerability to predators*

**Choice:** **D** Multiple predators present in the Bering Sea or neighboring regions

**Score:** 1.25 **of** 5

**Ranking Rationale:**
Several taxa including birds, fishes, and marine mammals prey upon Atlantic Salmon.

**Background Information:**
Atlantic Salmon are predated upon by birds (Montevecchi et al. 2002), fish (Hvidsten and Lund 1988), and marine mammals (Carss et al. 1990).

**Sources:**
Montevecchi et al. 2009 Hvidsten and Lund 1988 Carss et al. 1990

| | |
|---|---|
| **Section Total - Scored Points:** | 18.75 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 4. Ecological and Socioeconomic Impacts



### *4.1 Impact on community composition*

**Choice: C** Limited – Single trophic level; may cause decline but not extirpation

**Score:** 0.75 of 2.5

**Ranking Rationale:**
May compete with native salmon species.

**Background Information:**
Farmed Atlantic salmon may compete with native salmon populations for resources such as habitat, mating partners and prey. Farmed Atlantic salmon can have significant and negative impacts on wild Atlantic salmon (e.g. Fleming and Einum 1997; Fleming et al. 2000; McGinnity et al. 2003; reviewed in Glover et al. 2017), but their impacts on Pacific salmon appear limited (Naylor et al. 2005; Nielsen et al. 2013).

**Sources:**
Naylor et al. 2005 Fleming and Einum 1997 Fleming et al. 2000 McGinnity et al. 2003 Nielsen et al. 2013 Glover et al. 2017

### *4.2 Impact on habitat for other species*

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No impacts have been reported. Given its ecology, we do not expect Atlantic Salmon to impact habitat in the Bering Sea.

**Background Information:**
No information found.

**Sources:**
None listed

### *4.3 Impact on ecosystem function and processes*

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No impacts have been reported.

**Background Information:**
No information found.

**Sources:**
None listed

### 4.4 *Impact on high-value, rare, or sensitive species and/or communities*



**Choice: C** Limited – Has limited potential to cause degradation of one more species or communities, with limited impact and/or within a very limited region

**Score:** 0.75 **of** 2.5

**Ranking Rationale:**
May have limited impact on Pacific salmon populations.

**Background Information:**
Competition may occur between Atlantic and Pacific salmon populations for resources such as habitat, mating partners and prey. Atlantic salmon may also inter-breed and introduce disease into natural salmon populations. However, the likelihood of these scenarios appears low (Naylor et al. 2005), and historical evidence suggests that Pacific salmon may have a compeittive advantage over Atlantic salmon in high-latitude ecosystems (Nielsen et al. 2013).

**Sources:**
Naylor et al. 2005   Nielsen et al. 2013

### 4.5 *Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice: A** High – Is known to spread multiple organisms and/or is expected to have severe impacts and/or will impact the entire region

**Score:** 2.5 **of** 2.5

**Ranking Rationale:**
Can spread numerous bacteria, viruses and disease with moderate impacts to native salmonids.

**Background Information:**
Farmed Atlantic salmon can transmit several bacteria, viruses or parasites including furunculosis, sea lice, infectious salmon anemia virus (ISA), and piscine reovirus (PRV) (Johnsen and Jensen 1994; Naylor et al. 2005; Phillips 2005; Marty et al. 2010). PRV has recently been correlated with instances of heart and skeletal muscle inflammation (HSMI) in farmed Atlantic salmon in British Columbia (Di Cicco et al. 2017).

**Sources:**
Naylor et al. 2005   Johnsen and Jensen 1994   Phillips 2005   Marty et al. 2010   Di Cicco et al. 2017

### 4.6 *Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice: C** Limited – Has limited potential to cause genetic changes in one or more species, with limited impact and/or within a very limited region

**Score:** 0.75 **of** 2.5

**High uncertainty?** ✔

**Ranking Rationale:**
Limited potential to interbreed with native Pacific salmon. Discrepancies exist regarding impacts.

**Background Information:**
It is very difficult, even under optimal laboratory conditions, to cross-breed between Pacific and Atlantic salmon and produce viable offspring (reviewed in WDFW 2016). Even if this event were to occur in the wild, the offspring would be functionally sterile and incapable of reproduction. However, some literature suggests that cross-breeding of farmed and native salmon species has occurred in spawning areas; the extent to which this interbreeding affects long-term fitness and productivity is uncertain (reviewed in Naylor 2005).

**Sources:**
Naylor et al. 2005   WDFW 2016

### *4.7 Infrastructure*



**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
No impacts have been reported. Given its ecology, we do not expect Atlantic Salmon to impact infrastructure in the Bering Sea.

**Background Information:**
No information found.

**Sources:**
None listed

### *4.8 Commercial fisheries and aquaculture*

**Choice: C** Limited – Has limited potential to cause degradation to fisheries and aquaculture, and/or is restricted to a limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
May have limited impact on Pacific salmon.

**Background Information:**
Farmed Atlantic salmon can have significant and negative impacts on wild Atlantic salmon (e.g. Fleming and Einum 1997; Fleming et al. 2000; McGinnity et al. 2003; reviewed in Glover et al. 2017), but impacts on Pacific salmon (e.g. competition, hybridization, parasite transmission) appear limited (Naylor et al. 2005; Nielsen et al. 2013; WDFW 2016).

**Sources:**
WDFW 2016   Naylor et al. 2005   Nielsen et al. 2013   Fleming and Einum 1997   Fleming et al. 2000   McGinnity et al. 2003   Glover et al. 2017

### *4.9 Subsistence*

**Choice: C** Limited – Has limited potential to cause degradation to subsistence resources, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
May have limited impact on local salmon populations.

**Background Information:**
Farmed Atlantic salmon can have significant and negative impacts on wild Atlantic salmon (e.g. Fleming and Einum 1997; Fleming et al. 2000; McGinnity et al. 2003; reviewed in Glover et al. 2017), but impacts on Pacific salmon appear limited (Naylor et al. 2005; Nielsen et al. 2013; WDFW 2016).

**Sources:**
WDFW 2016   Fleming and Einum 1997   Fleming et al. 2000   McGinnity et al. 2003   Glover et al. 2017   Naylor et al. 2005   Nielsen et al. 2013

### *4.101 Recreation*

**Choice: C** Limited – Has limited potential to cause degradation to recreation opportunities, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
Atlantic Salmon has limited potential to degrade local salmonid populations (WDFW 2016).

**Background Information:**
Farmed Atlantic salmon can have significant and negative impacts on wild Atlantic salmon (e.g. Fleming and Einum 1997; Fleming et al. 2000; McGinnity et al. 2003; reviewed in Glover et al. 2017), but impacts on Pacific salmon appear limited (Naylor et al. 2005; Nielsen et al. 2013; WDFW 2016).

**Sources:**
WDFW 2016 Fleming and Einum 1997 Fleming et al. 2000 McGinnity et al. 2003 Glover et al. 2017 Nielsen et al. 2013 Naylor et al. 2005

### *4.11 Human health and water quality*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
No impacts reported.

**Background Information:**
Atlantic Salmon require high water quality for survival (Staurnes et al. 1995) and are not reported to carry disease that would impact human health.

**Sources:**
Staurnes et al. 1995.

| | |
|---|---|
| **Section Total - Scored Points:** | 7 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

# 5. Feasibility of prevention, detection and control

116

### *5.1 History of management, containment, and eradication*

**Choice:** **C** Attempted; control methods are currently in development/being studied

**Score:** of

**Ranking Rationale:**
Current methods to contain Atlantic Salmon within fish farms, and reduce the incidence of sea lice, are being studied. Efforts to reduce the incidence of escaped individuals have been relatively successful, but major incidents still occur.

**Background Information:**
There are regulations in place in British Columbia and in Washington to prevent the escape of farmed fish and to lower incidence of disease. The number of escaped Atlantic Salmon caught in Alaska has declined (Piccolo and Orlikowska 2012), but escapes still occur. Recently (August 2017), more than 145 000 salmon escaped from a net pen on Cypress Island, WA (DNR WA 2017). Methods to control incidence of diseases and sea lice are being studied (e.g. using closed cages Nilsen et al. 2017 or lumpfish as biocontrol Powell et al. 2017).

**Sources:**
Piccolo and Orlikowska 2012   Nilsen et al. 2017   DNR WA 2017   Powell et al. 2017

### *5.2 Cost and methods of management, containment, and eradication*

**Choice:** **B** Major short-term and/or moderate long-term investment

**Score:** of

**Ranking Rationale:**
No cost estimates found; however, current containment methods and commonly used methods for fish eradication likely require major short-term and/or moderate long-term investments.

**Background Information:**
There are strict regulations in place in British Columbia and in Washington to contain farmed fish (Piccolo and Orlikowska 2012). We have not found studies of eradication programs in areas where Atlantic Salmon have been introduced, but several methods to control or eradicate invasive fish are available, including chemical methods, physical removal (e.g., by seining or netting), or draining.

**Sources:**
Piccolo and Orlikowska 2012

### *5.3 Regulatory barriers to prevent introductions and transport*

**Choice:** **C** Regulatory oversight and/or trade restrictions

**Score:** of

**Ranking Rationale:**
The transport and trade of live fish is regulated in Alaska. Finfish farming is illegal in Alaska.

**Background Information:**
According to the Alaska Administrative Code, “No person may transport, possess, export from the state, or release into the waters of the state, any live fish unless the person holds a fish transport permit […] and the person is in compliance with all conditions of the permit and the provisions of this chapter.” Permits are issued by the Alaska Department of Fish & Game and are project- and time-specific. AAC 16.40.210 prohibits finfish farming.

**Sources:**
AAC 2017

### *5.4 Presence and frequency of monitoring programs*

**Choice: D** State and/or federal monitoring programs exist, and monitoring is conducted frequently

**Score:** of

**Ranking Rationale:**
State monitoring programs exist.

**Background Information:**
The Alaska Department of Fish and Game is monitoring for escaped Atlantic salmon by sampling commercial catches, conducting snorkel surveys, and asking fishermen to report any Atlantic salmon they might catch (Senkowsky 2004, Carroll 2005).

**Sources:**
Senkowsky 2004 Carroll 2005

### *5.5 Current efforts for outreach and education*

**Choice: C** Educational materials are available and outreach occurs only sporadically in the Bering Sea or adjacent regions

**Score:** of

**Ranking Rationale:**
Educational materials exists and occasional outreach events are held.

**Background Information:**
Atlantic Salmon is currently listed as an invasive species in AK and educational materials are available online (Carroll 2005; McClory and Gotthardt 2008). The Alaska Department of Fish and Game is currently monitoring Atlantic Salmon populations; part of this monitoring program involves outreach and education (Carroll 2005).

**Sources:**
Carroll 2005 McClory and Gotthardt 2008

**Section Total - Scored Points:**
**Section Total - Possible Points:**
**Section Total -Data Deficient Points:**

## Literature Cited for *Salmo salar*


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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Botrylloides violaceus*

**Common Name** *chain tunicate*

| | |
|---|---|
| **Phylum** | Chordata |
| **Class** | Ascidiacea |
| **Order** | Stolidobranchia |
| **Family** | Styelidae |

**Final Rank** 56.25

**Data Deficiency:** 0.00

Species Occurrence by Ecoregion

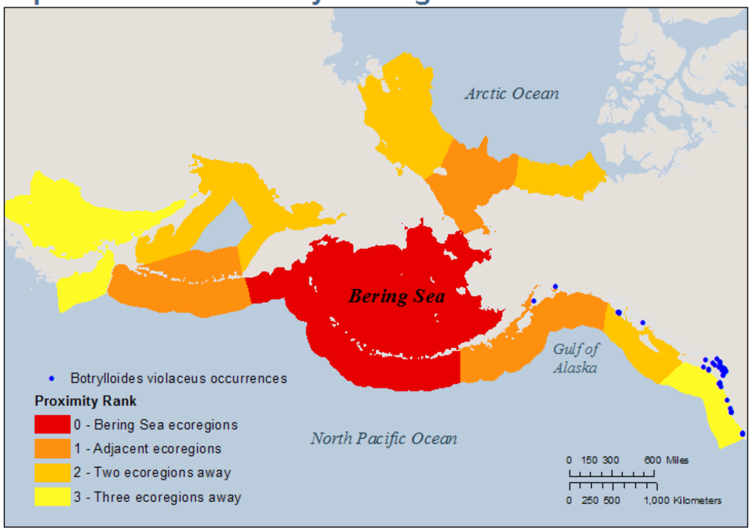


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 22 | 30 | 0 |
| Anthropogenic Influence: | 4.75 | 10 | 0 |
| Biological Characteristics: | 20.5 | 30 | 0 |
| Impacts: | 9 | 30 | 0 |
| **Totals:** | 56.25 | 100.00 | 0.00 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | -1 | Minimum Salinity (ppt) | 20 |
| Maximum Temperature (°C) | 29 | Maximum Salinity (ppt) | 38 |
| Minimum Reproductive Temperature (°C) | 15 | Minimum Reproductive Salinity (ppt) | 26 |
| Maximum Reproductive Temperature (°C) | 25 | Maximum Reproductive Salinity (ppt) | 38 |

### Additional Notes

B. violaceus is a thinly encrusting, colonial tunicate. Colonies are uniformly colored, but can vary from purple, red, yellow, orange and brown. It species is native to the Northwest Pacific, but has been introduced on both coasts of North America, and parts of Atlantic Europe. It is a common fouling organism throughout much of its introduced range, where it often displaces and competes with other native and non-native fouling organisms, including tunicates, bryozoans, barnacles, and mussels.

**Reviewed by** Linda Shaw, NOAA Fisheries Alaska Regional Office, Juneau AK

**Review Date:** 8/31/2017

# 1. Distribution and Habitat

## 1.1 Survival requirements - Water temperature

**Choice: B** Moderate overlap – A moderate area (≥25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 2.5 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**

Temperatures required for year-round survival occur in a moderate area (≥25%) of the Bering Sea. We ranked this question with "High Uncertainty" to indicate disagreements in model estimates.

**Background Information:**

Based on B. violaceus' geographic range from AK to Palau (Micronesia), Zerebecki and Sorte (2011) estimated the upper and lower temperature tolerances at -0.6 ºC and 29.3 ºC, respectively. Sorte et al. (2011) evaluated temperature tolerances in several marine invertebrate taxa in a laboratory setting, by allowing acclimation for 24 h (at ~17°C) and then raising water temperature at a rate of 1°C per 5 min until the treatment temperature was reached (21, 25, 29, and 34°C). Mortality was assessed following temperature exposure for 24 h. They report LT50 values of 27.4°C and 25.3°C for west coast and east coast populations, respectively.

**Sources:**

Zerebecki and Sorte 2011 Sorte et al. 2011

## 1.2 Survival requirements - Water salinity

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**Ranking Rationale:**

Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**

Epelbaum et al. (2009) evaluated temperature and salinity limits of two Botrylloides species, using laboratory colonies grown under five levels of salinity (14, 20, 26, 32, 38‰). B. violaceus colonies continued to grow under the most saline (38‰) conditions. Dijkstra and Harris (2007) used heart rate was used as a proxy for health to assess the condition of colonies subjected to variable salinity conditions, and found declining heart rates with decreasing salinity; specifically, that of B. violaceus remained constant between 20 psu and 30 psu, but slowed at 15 psu. B. violaceus suffered 100% mortality after 1 day at 5 psu (Dijkstra and Harris 2007).

**Sources:**

Dijkstra and Harris 2007 Epelbaum et al. 2009

## 1.3 Establishment requirements - Water temperature

**Choice: D** No overlap – Temperatures required for reproduction do not exist in the Bering Sea

**Score:** 0 of 3.75

**Ranking Rationale:**

Although temperatures in parts of the Bering Sea can support the survival of juvenile colonies, temperatures are not high enough to support growth.

**Background Information:**

Juvenile colonies grown under laboratory conditions required temperatures between 15-25ºC to grow, but tolerated temperatures as low as 5ºC (Epelbaum et al. 2009).

**Sources:**

Epelbaum et al. 2009

### *1.4 Establishment requirements - Water salinity*

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for reproduction occur over a large (>75%) area of the Bering Sea.

**Background Information:**
Botrylloides violaceus is a marine species throughout its entire life cycle. Juvenile colonies grown under laboratory conditions demonstrated positive (and optimal) growth at salinities between 26 and 38 ppt (Epelbaum et al. 2009).

**Sources:**
Epelbaum et al. 2009

### *1.5 Local ecoregional distribution*

**Choice: B** Present in an ecoregion adjacent to the Bering Sea

**Score:** 3.75 of 5

**Ranking Rationale:**
This species has been reported in Tatilek and Kachemak Bay.

**Background Information:**
This species is considered well-established in Tatitlek because of the detection of several newly-settled, healthy zooids, which suggests that mature, reproductively active colonies were nearby. B. violaceus has been reported from Kachemak Bay, AK but is not presumed to be established there.

**Sources:**
Dijkstra and Harris 2007 Epelbaum et al. 2009

### *1.6 Global ecoregional distribution*

**Choice: B** In a moderate number of ecoregions globally

**Score:** 3.25 of 5

**Ranking Rationale:**
This species is found in cold and temperate waters in the northern hemisphere.

**Background Information:**
Native to the Northwest Pacific, where it is found in Japan, China, and South Korea. It is widely distributed on the west coast of North America, where it occurs from Mexico to southern Alaska. Although it has been reported in Kachemak Bay, it is not thought to be established there. Its distribution on the East Coast extends from Newfoundland to Virginia. In Europe, it occurs along the Atlantic coast from Scotland, south to Portugal and Italy.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.7 Current distribution trends*



**Choice:** **A** Recent rapid range expansion and/or long-distance dispersal (within the last ten years)

**Score:** 5 **of** 5

**Ranking Rationale:**
This species has undergone a recent and rapid range expansion on North America's east coast.

**Background Information:**
This species was first detected in Santa Barbara, CA in 1966, and spread north to WA by 1980 and to AK by 1999 (Fofonoff et al. 2003). In eastern North America, it has spread rapidly along the coast of Prince Edward Island since its discovery in 2004 (Carver et al. 2006).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Carver et al. 2006

| | |
|---|---|
| **Section Total - Scored Points:** | 22 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 2. Anthropogenic Transportation and Establishment



### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice: B** Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 of 4

**Ranking Rationale:**
This species is known to use anthropogenic vectors for transport, but it is unlikely to undergo natural, long-distance dispersal once introduced.

**Background Information:**
Rafting on floating eelgrass and other debris can serve to transport colonies (Dijkstra 2011), but evidence from genetic analyses indicates that natural dispersal is not a major contributor to the spread B. violaceus on either coasts of North America (Bock et al. 2011). The most likely vectors for transport are hull fouling and hitchhiking on aquaculture species.

**Sources:**
Bock et al. 2011 Dijkstra 2011

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice: B** Readily establishes in areas with anthropogenic disturbance/infrastructure; occasionally establishes in undisturbed areas

**Score:** 2.75 of 4

**Ranking Rationale:**
This species is can establish on both anthropogenic substrates and natural habitats, but is more frequently found on the former.

**Background Information:**
Although this species can colonize natural habitats such as eelgrass and rocky shores, it is better able to colonize anthropogenic substrates (Simkanin et al. 2017; Wagstaff 2017).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Simkanin et al. 2012 Wagstaff 2017

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice: B** No

**Score:** 0 of 2

**Ranking Rationale:**
This species is not farmed or cultivated.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 4.75 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

# 3. Biological Characteristics



### *3.1 Dietary specialization*

**Choice: A**

Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
This species consumes foods that are readily available in the Bering Sea.

**Background Information:**
Filter feeder on phytoplankton and detritus.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice: A**

Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 of 5

**Ranking Rationale:**
This species has broad environmental tolerances.

**Background Information:**
B. violaceus can tolerate a wide range of temperatures, salinities and nutrients including high sewage and heavy metal concentrations (Carver et al. 2006; Dijkstra 2011). It is intolerant of turbid environments.

**Sources:**
Carver et al. 2006   Dijkstra 2011

### *3.3 Desiccation tolerance*

**Choice: C**

Little to no tolerance (<1 day) of desiccation during its life cycle

**High uncertainty?** ☑

**Score:** 1.75 of 5

**Ranking Rationale:**
Although exact desiccation tolerances are unknown, studies suggest that this species has a low (< 24 h) tolerance to air exposure.

**Background Information:**
Air exposure has been proposed as a method to control tunicate fouling on aquaculture equipment and bivalves. A test of the OysterGro system, which routinely exposes oysters and oyster bags to air, concluded that 24 h air exposure was efficient at controlling tunicate species including Botrylloides violaceus (Gill et al. 2008). A literature review by Carver et al. (2006) reported that colonies are very susceptible to desiccation, and are rarely observed in intertidal areas. Pleus (2008) claims that tunicates as a group have low desiccation tolerance.

**Sources:**
Carver et al. 2006   Gill et al. 2008   Pleus 2008

### 3.4 *Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice:** **A** High – Exhibits three or four of the above characteristics

**Score:** 5 of 5

**Ranking Rationale:**

This species exhibits both asexual and sexual reproduction, and has a short generation time. Fertilization is internal. Individual zooids typically produce only one egg, but the reproductive output for a single colony is likely high.

**Background Information:**

Colonial tunicates are hermaphroditic and can reproduce both sexually and asexually. Individual zooids normally produce one egg (qtd. in Carver et al. 2006). Eggs are fertilized internally and embryos are incubated in a brood pouch for 1 month (Carver et al. 2006). Eggs hatch into non-feeding, planktonic larvae that swim briefly before settling. In its native range, zooids attained sexual maturity within a week of having settled, and then began producing buds asexually (Yamaguchi 1975, qtd. in Carver et al. 2006). During this time, colonies grew exponentially. Sexual reproduction was initiated 8 weeks after metamorphosis and continued for 3 weeks. After sexual reproduction, parent colonies regress and eventually die. Many generations can be achieved in a single year.

**Sources:**

Carver et al. 2006 NEMESIS; Fofonoff et al. 2003

### 3.5 *Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice:** **C** Disperses short (< 1 km) distances

**High uncertainty?** ☑

**Score:** 0.75 of 2.5

**Ranking Rationale:**

Genetic analyses and distributional patterns suggest that this species likely has limited dispersal ability.

**Background Information:**

Adults are sessile and eggs are fertilized internally. Larvae are short-lived, and usually settle within 4 to 10 hours (Carver et al. 2006). Several lines of evidence suggest that dispersal in this species is limited. In Washington and BC, the species exhibits patchy distributions even in suitable environments (Cahill et al. 2010). In addition, high genetic differentiation, even at nearby sites (< 1 km) indicates limited capacity for natural dispersal (Bock et al. 2011).

**Sources:**

Carver et al. 2006 Bock et al. 2011 Cahill et al. 2010

### 3.6 *Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: B** Moderate – Exhibits one of the above characteristics

**Score:** 1.75 of 2.5

**Ranking Rationale:**
This species can disperse either as free-swimming larvae or as adults by rafting.

**Background Information:**
Adults are sessile, but in some instances may be dispersed by rafting on drifting vegetation or woody debris (Worcester 1994; Thiel and Gutow 2005). Eggs are fertilized internally and brooded in a pouch. Free-swimming larvae are short-lived, and usually settle within 4 to 10 hours (Carver et al. 2006), though the duration of this stage may be longer at lower temperatures (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Carver et al. 2006 Worcester 1994 Thiel and Gutow 2005

### 3.7 *Vulnerability to predators*

**Choice: D** Multiple predators present in the Bering Sea or neighboring regions

**Score:** 1.25 of 5

**Ranking Rationale:**
This species is preyed upon by a variety of taxa that occur in the Bering Sea.

**Background Information:**
This species is preyed upon by fishes, snails, crabs, urchins, and starfish. Simkanin et al. (2013) proposed that native predators may limit or slow the spread of B. violaceus in British Columbia. On the east coast of North America, B. violaceus has provided a new source of prey for some species such as the blood star Henricia sanguinolenta (qtd. in Dijkstra 2011). B. violaceus was not predated upon by the snail Mitrella lunata, and was only rarely predated upon by Anachis lafrashnayi (Osman and Whitlatch 1995, Whitlatch and Osman 2009).

**Sources:**
Dijkstra 2011 NEMESIS; Fofonoff et al. 2003 Simkanin et al. 2013 Whitlatch and Osman 2009

| | |
|---|---|
| **Section Total - Scored Points:** | 20.5 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 4. Ecological and Socioeconomic Impacts



### 4.1 *Impact on community composition*

**Choice: B** Moderate – More than one trophic level; may cause declines but not extirpation

**Score:** 1.75 **of** 2.5

**Ranking Rationale:**
This species can compete for space with other fouling organisms and can quickly become a dominant species.

**Background Information:**
By competing for space and food, B. violaceus frequently displaces other fouling organisms, including native and introduced tunicates, bryozoans, barnacles, and mussels. At two locations in California, it has formed extensive areas of 100% cover, indicating strong competitive ability (Lambert and Lambert 2003). In Portsmouth Harbor, B. violaceus was the most abundant colonial tunicate on fouling plates in 1984-1985 (Berman et al. 1992) and in 2003-2005, partially replacing B. schlosseri, the previous dominant colonial ascidian (Dijkstra et al. 2007). By 2003-2006, B. violaceus, along with Didemnum vexillum, replaced the mussel M. edulis as dominant species in fouling communities (Dijkstra and Harris 2009).

In fouling plate experiments in Humboldt Bay, Nelson (2009) found that colonial tunicates (Botryllus schlosseri and Botrylloides violaceus) quickly occupied space on fouling plates, but did not decrease recruitment or species richness. Dijkstra (2011) suggests that, while B. violaceus may become a permanent member of the community, it is unlikely to replace native species.

**Sources:**
Dijkstra 2011 NEMESIS; Fofonoff et al. 2003 Lambert and Lambert 2003 Dijkstra and Harris 2009

### 4.2 *Impact on habitat for other species*

**Choice: B** Moderate – Causes or has potential to cause changes to one or more habitats

**Score:** 1.75 **of** 2.5

**Ranking Rationale:**
By fouling eelgrass leaves and reducing their access to light, B. violaceus may negatively affect eelgrass and the species that depend on it for habitat. To our knowledge, no infestations of eelgrass beds by B. violaceus have been reported in Alaska so far (L. Shaw, pers. comm., 31 August 2017). B. violaceus may also affect habitat by reducing available habitat for some organisms, and by creating secondary settlement habitat for others.

**Background Information:**
On the east coast of North America, Botrylloides violaceus and other fouling organisms were found to adversely affect native eelgrass Zostera marina by fouling leaves and reducing light availability, which increased the mortality of Z. marina (Wong and Vercaemer 2012). The violet morph of B. violaceus had a more negative effect than lighter-colored tunicates, which allowed more light to reach the eelgrass (Wong and Vercaemer 2012). Eelgrass are highly productive habitats that serve as refuges and nurseries for several species. In Alaska, eelgrass ranging almost continuously from southeast Alaska and north into the Bering Sea up to about 67°N (qtd. in Hogrefe et al. 2014).

In fouling communities of Portsmouth Harbor, New Hampshire, tunicates including B. violaceus had competitvely displaced the mussel Mytilus edulis as the dominant species (Dijkstra and Harris 2009). A major functional habitat change occurred, because mussels provided a year-round substrate for other organisms, but B. violaceus dies off seasonally. At the same time, this seasonal die-off created large areas of bare substrate for new organisms to colonize (Dijkstra and Harris 2009).

**Sources:**
Wong and Vercaemer 2012 Dijkstra and Harris 2009 Hogrefe et al. 2014

### 4.3 Impact on ecosystem function and processes

**Choice: C** Limited – Causes or potentially causes changes to food webs and/or ecosystem functions, with limited impact and/or within a very limited region

**Score:** 0.75 of 2.5

**High uncertainty?** ☑

**Ranking Rationale:**
Through its effects on eelgrass, B. violaceus might affect ecosystem functions.

**Background Information:**
On the east coast of North America, Botrylloides violaceus and other fouling organisms were found to adversely affect native eelgrass Zostera marina by fouling leaves and reducing light availability, which increased the mortality of Z. marina (Wong and Vercaemer 2012). Eelgrass support a variety of ecosystem functions by affecting water flow, stabilizing sediments, assimilating nutrients, supporting a high diversity of plants and animals, and through their role as primary producers (qtd. in Winfree 2005; Orth et al. 2006).

**Sources:**
Wong and Vercaemer 2012   Winfree 2005   Orth et al. 2006

### 4.4 Impact on high-value, rare, or sensitive species and/or communities

**Choice: B** Moderate – Causes or has potential to cause degradation of one or more species or communities, with moderate impact

**Score:** 1.75 of 2.5

**High uncertainty?** ☑

**Ranking Rationale:**
Through fouling, can have a negative impact on the eelgrass Zostera marina, which provides valuable ecosystem services and coastal habitat for several species. To our knowledge, no infestations of eelgrass beds by B. violaceus have been reported in Alaska so far (L. Shaw, pers. comm., 31 August 2017).

**Background Information:**
A study by Wong and Vercaemer (2012) found that B. violaceus, along with other fouling organisms, reduced light availability of eelgrass, which led to reduced growth and increased mortality of eelgrass. Eelgrass is a valuable species that provides numerous ecosystem services to the marine environment, including water regulation, nutrient cycling, refuge, and food (Costanza et al. 1997).

**Sources:**
Wong and Vercaemer 2012   Costanza et al. 1997

### 4.5 Introduction of diseases, parasites, or travelers

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not known to transport diseases, parasites, or hitchhikers.

**Background Information:**
Ascidians are commensal hosts to notodelphid copepods, amphipods, and host to some specific parasitic copepods (Miller 1971, qtd. in Rudy et al. 2013).

**Sources:**
Rudy et al. 2013

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not expected to hybridize with native species in the Bering Sea.

**Background Information:**
No impacts reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.7 Infrastructure*

**Choice:** **B** Moderate – Causes or has the potential to cause degradation to infrastructure, with moderate impact and/or within only a portion of the region

**Score:** 1.5 of 3

**Ranking Rationale:**
This species is known to foul shellfish farming equipment, which is practiced in a small region of the Bering Sea. This species also fouls ship hulls and marine infrastructure.

**Background Information:**
Various surveys have listed its occurrence as a nuisance fouling organism on the hulls of ships, floating docks and nautical buoys. On Vancouver Island, B. violaceus is considered a major fouling concern for both shellfish and finfish growers who rely on nets as part of their culture technique. Finfish nets and shellfish cages may become infested with a mat of colonial tunicates that effectively eliminates the flow of oxygen and particles through the mesh. Active research on methods to control fouling by B. violaceus in eastern Canada (Gill et al. 2008; Arens et al. 2011) suggests that this species is having negative impacts on aquaculture infrastructure.

**Sources:**
Carver et al. 2006 Gill et al. 2008 Arens et al. 2011

### *4.8 Commercial fisheries and aquaculture*

**Choice:** **C** Limited – Has limited potential to cause degradation to fisheries and aquaculture, and/or is restricted to a limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
Studies suggest that Botrylloides violaceus has mild effects on mussel aquaculture.

**Background Information:**
Although B. violaceus may compete with bivalves for food and space, Arens et al. (2011) found that Botrylloides violaceus and Botryllus schlosseri had little impact on mussel productivity over the course of their study. In comparative trials in PEI where B. violaceus was actively cleaned from the surface of cultured mussels, there was no significant positive impact on growth, meat yield or survival relative to heavily fouled mussels (qtd. in Carver et al. 2006). Compared to Botryllus schlosseri, B. violaceus was only present in small amounts on mussel socks, and therefore did not substantially increase the weight of mussel socks (< 50 g; Paetzold et al. 2012). Gittenberger (2009) also asserts that B. violaceus does not add significant weight to mussel socks and only causes minimal loss during harvesting.

**Sources:**
Carver et al. 2006 Arens et al. 2011 Gittenberger 2009 Paetzold 2012

### *4.9 Subsistence*

**Choice: C** Limited – Has limited potential to cause degradation to subsistence resources, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**High uncertainty?** ✔

**Ranking Rationale:**
Botrylloides violaceus appears to be a stronger competitor on anthropogenic than natural substrates. Fouling of other organisms in natural settings seems very limited, and no negative impacts have been reported so far. However, through competition or overgrowth, this species may affect subsistence resources such as the blue mussel. By fouling eelgrass, this species may affect nursery habitats for subsistence fish species.

**Background Information:**
In PEI, B. violaceus was rarely found on the shells of rock crabs (5 of 275 crabs), and only occurred at low densities (Bernier et al. 2009). Studies on mussel farms found that B. violaceus had little to no impact on mussel productivity (Arens et al. 2011).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Arens et al. 2011   Bernier et al. 2009

### *4.101 Recreation*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to affect recreational opportunities in the Bering Sea.

**Background Information:**
No impacts reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003   Carver et al. 2006

### *4.11 Human health and water quality*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact human health or water quality in the Bering Sea.

**Background Information:**
No impacts reported.

**Sources:**
Carver et al. 2006   NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 9 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 5. Feasibility of prevention, detection and control

### *5.1 History of management, containment, and eradication*

**Choice:** **C** Attempted; control methods are currently in development/being studied

**Score:** of

**Ranking Rationale:**
Methods to control tunicates, especially on aquaculture operations, are currently being studied.

**Background Information:**
In Atlantic Canada, mussel farmers currently use pressurized seawater to remove colonial tunicates. In St. Peters Bay, PEI, high-pressure spraying was effective at reducing the biomass of the colonial tunicates Botryllus schlosseri and Botrylloides violaceus on mussel socks (Arens et al. 2011). However, results were effective only in the short term, as tunicates re-established over time. In addition, the use of pressurized seawater could increase the spread of these species through fragmentation, and can reduce mussel productivity if applied too often (Arens et al. 2011; Paetzold et al. 2012). Alternative treatments for controlling Botryllus schlosseri and Botrylloides violaceus include the use of freshwater, brine, lime, and acetic acid immersion, with exposure to ~5% acetic acid for >15 s proving the most effective (Carver et al. 2006).

**Sources:**
Carver et al. 2006 Arens et al. 2011 Paetzold 2012

### *5.2 Cost and methods of management, containment, and eradication*

**Choice:** **B** Major short-term and/or moderate long-term investment

**Score:** of

**Ranking Rationale:**
Current treatment methods need to be repeated to be successful, and require moderate, but long-term investment.

**Background Information:**
Mussel farmers currently use pressurized seawater to remove colonial tunicates. In St. Peters Bay, PEI, high-pressure spraying was effective at reducing the biomass of the colonial tunicates Botryllus schlosseri and Botrylloides violaceus on mussel socks (Arens et al. 2011). Davidson et al. (2017) estimated the cost of equipment at $156 000 for this type of treatment. The cost of labor and fuel was estimated at $54 per treatment per line (Davidson et al. 2017). Farms in their study had an average of 134 lines and applied 3 treatments per year (Davidson et al. 2017). The use of pressurized seawater as a control method is only effective only in the short term, as tunicates re-establish over time (Paetzold et al. 2012). In addition, the use of pressurized seawater could increase the spread of these species through fragmentation, and can reduce mussel productivity if applied too often (Arens et al. 2011; Paetzold et al. 2012). Alternative treatments for controlling Botryllus schlosseri and Botrylloides violaceus include the use of freshwater, brine, lime, and acetic acid immersion, with exposure to ~5% acetic acid for >15 s proving the most effective (Carver et al. 2006).

**Sources:**
Carver et al. 2006 Arens et al. 2011 Davidson et al. 2017

### 5.3 *Regulatory barriers to prevent introductions and transport*

**Choice: B** Regulatory oversight, but compliance is voluntary

**Score:** of

**Ranking Rationale:**

Botrylloides violaceus is thought to have been accidentally transported with aquaculture species (e.g., mussels and bivalves), and by hull fouling. Although regulations exist to reduce fouling organisms on ships, compliance is largely voluntary.

**Background Information:**

In the U.S., Coast Guard regulations require masters and ship owners to engage in practices that will reduce the spread of invasive species, including cleaning ballast tanks and removing fouling organisms from hulls, anchors, and other infrastructure on a "regular" basis (CFR 33 § 151.2050). However, the word "regular" is not defined, which makes the regulations hard to enforce. As a result of this technical ambiguity, compliance with ship fouling regulations remains largely voluntary (Hagan et al. 2014).

**Sources:**

CFR 2017 Hagan et al. 2014

### 5.4 *Presence and frequency of monitoring programs*

**Choice: B** Surveillance takes place, but is largely conducted by non-governmental environmental organizations (e.g., citizen science programs)

**Score:** of

**Ranking Rationale:**

Botrylloides violaceus is listed as a species of interest on the Invasive Tunicate Network website.

**Background Information:**

In Alaska, the Invasive Tunicate Network conducts monitoring for non-native tunicates and other invasive species. The network is comprised of teachers, students, outdoor enthusiasts, environmental groups and state and federal biologists.

**Sources:**

iTunicate Plate Watch 2016

### 5.5 *Current efforts for outreach and education*

**Choice: D** Programs and materials exist and are readily available in the Bering Sea or adjacent regions

**Score:** of

**Ranking Rationale:**

Outreach and education programs are in place in Alaska to educate people on invasive tunicates. Botrylloides violaceus is listed as a species of interest on the Invasive Tunicate Network website.

**Background Information:**

Alaska's Invasive Tunicate Network and the Kachemak Bay National Estuarine Research Reserve (KBNERR) provide training opportunities for identifying and detecting non-native tunicates, and public education events on coastal and marine ecosystems more generally. "Bioblitzes" were held in Southeast AK in 2010 and 2012; these events engage and educate the public on marine invasive species. Field identification guides for native and non-native tunicates, as well as common fouling organisms, are readily available.

**Sources:**

iTunicate Plate Watch 2016

**Section Total - Scored Points:**

**Section Total - Possible Points:**

**Section Total -Data Deficient Points:**

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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Botryllus schlosseri*

**Common Name** *golden star tunicate*

**Phylum** Chordata

**Class** Ascidiacea

**Order** Stolidobranchia

**Family** Styelidae

**Final Rank** 57.95

**Data Deficiency:** 2.50

## Species Occurrence by Ecoregion

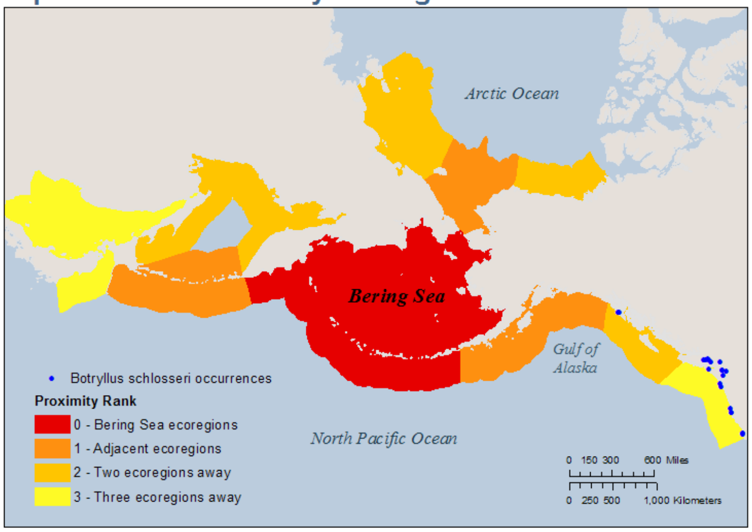


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 20.5 | 30 | 0 |
| Anthropogenic Influence: | 4.75 | 10 | 0 |
| Biological Characteristics: | 21.75 | 30 | 0 |
| Impacts: | 9.5 | 28 | 2.50 |
| **Totals:** | 56.50 | 97.50 | 2.50 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | -1 | Minimum Salinity (ppt) | 14 |
| Maximum Temperature (°C) | 30 | Maximum Salinity (ppt) | 44 |
| Minimum Reproductive Temperature (°C) | 11 | Minimum Reproductive Salinity (ppt) | 25 |
| Maximum Reproductive Temperature (°C) | NA | Maximum Reproductive Salinity (ppt) | 35* |

### Additional Notes

B. schlosseri is a colonial tunicate that grows in a flower- or star-shaped pattern. Its native range is unknown, but it is globally widespread and found in temperate waters in Europe, Asia, both coasts of North America, South America, South Africa, and Australia. In some areas of its introduced range, there is concern that B. schlosseri competes for space with native species, especially on artificial substrates where it can grow rapidly.

**Reviewed by** Linda Shaw, NOAA Fisheries Alaska Regional Office, Juneau AK

**Review Date:** 8/31/2017

# 1. Distribution and Habitat

### *1.1 Survival requirements - Water temperature*

**Choice:** **B**

Moderate overlap – A moderate area (≥25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 2.5 **of** 3.75

**Ranking Rationale:**
Temperatures required for year-round survival occur in a moderate area (≥25%) of the Bering Sea.

**Background Information:**
The temperature required for survival of B. schlosseri is -1°C to 30°C. Temperature tolerance varies with geographical location.

**Sources:**
Masterson 2007 NEMESIS; Fofonoff et al. 2003

### *1.2 Survival requirements - Water salinity*

**Choice:** **A**

Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 **of** 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
The salinity range required for survival of B. schlosseri is 14 ppt to 44 ppt.

**Sources:**
NEMESIS; Fofonoff et al. 2003 NIMPIS 2016

### *1.3 Establishment requirements - Water temperature*

**Choice:** **C**

Little overlap – A small area (<25%) of the Bering Sea has temperatures suitable for reproduction

**Score:** 1.25 **of** 3.75

**Ranking Rationale:**
Temperatures required for reproduction occur in a limited area (<25%) of the Bering Sea.

**Background Information:**
Reproduction of B. schlosseri has a lower temperature limit of 11°C (Brunetti et al. 1980).

**Sources:**
Brunetti et al. 1980 Masterson 2007 NEMESIS; Fofonoff et al. 2003

### *1.4 Establishment requirements - Water salinity*

**Choice:** **A**

Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**High uncertainty?** ☑

**Score:** 3.75 **of** 3.75

**Ranking Rationale:**
Although salinity thresholds are unknown, this species is a marine organism that does not require freshwater to reproduce. We therefore assume that this species can reproduce in saltwater (31 to 35 ppt). These salinities occur in a large (>75%) portion of the Bering Sea.

**Background Information:**
Requires a minimum salinity of 25 ppt for reproduction (NIMPIS 2016). Upper reproductive salinity requirements are unknown.

**Sources:**
NIMPIS 2016

### *1.5 Local ecoregional distribution*

**Choice: C** Present in an ecoregion two regions away from the Bering Sea (i.e. adjacent to an adjacent ecoregion)

**Score:** 2.5 **of** 5

**Ranking Rationale:**

**Background Information:**
Found in Sitka, Alaska.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.6 Global ecoregional distribution*

**Choice: A** In many ecoregions globally

**Score:** 5 **of** 5

**Ranking Rationale:**
Wide global distribution.

**Background Information:**
In Europe, established in northern Norway, south to the Mediterranean. East to the Black and Red Seas. Found on oceanic islands including the Azores and Madeira (northwest Africa). Introduced to South Africa, India's Bay of Bengal, and to Australia and New Zealand. Cryptogenic in Asia (China, Korea, Japan, southern Russia). In America, occurs on the West Coast from Sitka, AK to California, and in South America off the coasts of Chile and east to Argentina. On the east coast, found in Florida, north to Canada's maritime provinces (Nova Scotia and Newfoundland).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.7 Current distribution trends*

**Choice: C** Established outside of native range, but no evidence of rapid expansion or long-distance dispersal

**Score:** 1.75 **of** 5

**Ranking Rationale:**
Can establish easily, but have limited natural dispersal abilities.

**Background Information:**
Once established, colonial tunicate species have the potential to reach sexual maturity within a few weeks and rapidly establish broodstock populations. Capable of reproducing asexually.

Was found in Sitka, Alaska in 2000, but does not seem to have spread anywhere else in Alaska (Davis 2010). However, a survey of non-indigenous species in British Columbia documented a northern range expansion of B. schlosseri (Gartner et al. 2016).

**Sources:**
Carver et al. 2006   Davis 2010   Gartner et al. 2016

| | |
|---|---|
| **Section Total - Scored Points:** | 20.5 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 2. Anthropogenic Transportation and Establishment



### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice: B**

Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 of 4

**Ranking Rationale:**

**Background Information:**
Can be transported on ships due to hull fouling. Spread is likely due to the introduction of oyster culture. Found from California to Sitka, Alaska, and in the west from China to southern Russia.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice: B**

Readily establishes in areas with anthropogenic disturbance/infrastructure; occasionally establishes in undisturbed areas

**Score:** 2.75 of 4

**Ranking Rationale:**
Can establish on both anthropogenic and natural substrates, but is more common on the former.

**Background Information:**
B. schlosseri is more commonly found on anthropogenic structures than natural surfaces, and is especially prevalent on dock floats (Simkanin et al. 2012).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Simkanin et al. 2012

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice: B**

No

**Score:** 0 of 2

**Ranking Rationale:**

**Background Information:**
B. schlosseri is not currently farmed or intentionally cultivated.

**Sources:**
None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 4.75 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics



### *3.1 Dietary specialization*

**Choice: A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Filter feeder, phytoplankton.

**Background Information:**
B. schlosseri is a filter suspension feeder that primarily consumes phytoplankton.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice: A** Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 of 5

**Ranking Rationale:**
B. schlosseri has a wide range of temperature and salinity tolerances and has been reported in several different habitats.

**Background Information:**
B. schlosseri is a sessile organism as an adult being found on dock floats, pilings, piers, aquaculture structures, boat hulls, rocky reefs, bivalve colonies, seaweeds, and eelgrass (Glasby 2001; Carman et al. 2010; Davidson et al. 2010 qtd. in Fofonoff et al. 2003; Simkanin et al. 2012; White and Orr 2011 qtd. in Fofonoff et al. 2003; Wong and Vercaemer 2012; Carman et al. 2016).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Glasby 2001 Carman et al. 2010 Simkanin et al. 2012 Wong and Vercaemer 2012 Carman et al. 2016

### *3.3 Desiccation tolerance*

**Choice: C** Little to no tolerance (<1 day) of desiccation during its life cycle

**High uncertainty?** ☑

**Score:** 1.75 of 5

**Ranking Rationale:**
Although exact desiccation tolerances are unknown, studies suggest that this species has a low tolerance to air exposure.

**Background Information:**
Colonies are very susceptible to desiccation. They are rarely observed in intertidal areas and, when found there, only occur in damp shaded zones (Carver et al. 2016). Pleus (2008) suggests that tunicates as a group have a low tolerance to desiccation.

**Sources:**
Carver et al. 2006 Pleus 2008

### *3.4 Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice: A** High – Exhibits three or four of the above characteristics

**Score:** 5 **of** 5

**Ranking Rationale:**
Asexual, high fecundity, low parental investment.

**Background Information:**
B. schlosseri is a cyclical hermaphrodite. It reproduces asexually by budding with a sexual reproductive cycle after 5 to 10 asexual growth cycles.

In sexual reproduction, each zooid can produce up to 10 clutches of up to 5 eggs resulting in an average of 8000 eggs per colony. Eggs are internally fertilized and developed for approximately 1 week. The resulting larva is lecithotrophic and settles after 36 hours forming its first functional zooid within 3 days. Sexual maturity occurs within 49 days with an average lifespan of 12 to 18 months (Chadwick-Furman and Weissman 1995; Carver et al. 2006)

**Sources:**
Carver et al. 2006 Chadwick-Furman and Weissman 1995 NEMESIS; Fofonoff et al. 2003

### *3.5 Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice: C** Disperses short (< 1 km) distances

**Score:** 0.75 **of** 2.5

**Ranking Rationale:**
Long-distance, natural dispersal may be possible under certain conditions; however, the short longevity of sperm and free-swimming larvae, and evidence of genetically distant subpopulations within a small spatial scale, suggest that realized dispersal is low.

**Background Information:**
During sexual reproduction, it was found that sperm effect declined rapidly at only 50 cm away from the colony despite it's long effective lifespan of 28 hours (Johnson and Yund 2003 qtd. in Carver et al. 2006; Johanson and Yund 2004; Grosberg 1991).

Planktonic larval stage lasts only 24 to 36 hours and they remain withing a few meters of the parental colony settling nearby another colony or fusing together to form a new colony (Rinkevich and Weissman 1987 qtd in Carver et al. 2006; Chadwick-Furman and Weissman 2003).

Several population genetic studies suggest that larval dispersal is limited. Sabbadin and Graziani (1967 qtd. in Carver et al. 2006) found that genetically-distinct sub-populations of B. schlosseri existed under similar ecological conditions within the Lagoon of Venice. Yund and O'Neil (2000) noted that genetic differentiation may occur over very short distances (8 to 21 m), and the patterns were consistent with inbreeding and genetic drift models.

**Sources:**
Carver et al. 2006 Masterson 2007 Johnson and Yund 2004 Grosberg 1991 Chadwick-Furman and Weissman 1995 Yund and O'Neil 2000

### *3.6 Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: B** Moderate – Exhibits one of the above characteristics

**Score:** 1.75 **of** 2.5

**Ranking Rationale:**
Can disperse at more than one life stage, but larvae are short-lived and adults are sessile.

**Background Information:**
Can disperse at multiple life stages as sperm, planktonic larvae, and by drifting, but none of these stages are successful at long-distance dispersal. Sperm have a short viability in seawater (Grosberg 1987). Larvae are short-lived and tend to settle nearby the sessile parent colony (Carver et al. 2016).

**Sources:**
Carver et al. 2006 Grosberg 1987

### *3.7 Vulnerability to predators*

**Choice: C** Few predators suspected present in the Bering Sea and neighboring regions, and/or multiple predators in native range

**Score:** 2.5 **of** 5

**Ranking Rationale:**
Numerous predators, many of which exist in the Bering Sea.

**Background Information:**
Early life stages are predated upon by crabs, snails, urchins, starfish, and fish. Adult colonial tunicates generally have few predators, but certain gastropods, flatworms, and nudibranchs can eat them.

**Sources:**
Carver et al. 2006 NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 21.75 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

# 4. Ecological and Socioeconomic Impacts



## *4.1 Impact on community composition*

**Choice:** **C** Limited – Single trophic level; may cause decline but not extirpation

**Score:** 0.75 of 2.5

**Ranking Rationale:**
B. schlosseri competes with other attached benthic filter feeders for space and possibly food. Fast-growing B. schlosseri colonies may overgrow neighboring organisms, including native tunicates and seagrass.

**Background Information:**
B. schlosseri is linked to lower recruitment rates of native Spirorbis spp in Long Isand New York (Osman and Whitlatch 1995). In Humboldt Bay, California, colonial tunicates were found to not decrease recruitment or species richness (Nelson 2009). B. schlosseri was also found to adversely affect the eelgrass Zostera marina in Nova Scotia by fouling the grass leaves, limiting the available sunlight (Wong and Vercaemer 2012).

Tunicates grow more rapidly than oyster spat and can interfere with them inhibiting growth and in some cases, causing death (Arakawa 1990 qtd. in Carver et al. 2006). However, fouling by tunicates on oysters does not always have a negative or even neutral effect.

**Sources:**
Arens et al. 2011   Carver et al. 2006   NEMESIS; Fofonoff et al. 2003   Masterson 2007   Wong and Vercaemer 2012   Osman and Whitlatch 1995   Nelson 2009

## *4.2 Impact on habitat for other species*

**Choice:** **B** Moderate – Causes or has potential to cause changes to one or more habitats

**Score:** 1.75 of 2.5

**Ranking Rationale:**
By fouling eelgrass leaves and reducing their access to light, B. schlosseri may negatively affect eelgrass and the species that depend on it for habitat. To our knowledge, no infestations of eelgrass beds by B. schlosseri have been reported in Alaska so far (L. Shaw, pers. comm., 31 August 2017).

**Background Information:**
Through establishment and colonization, competes for space with other fouling organisms (Masterson 2007; Wong and Vercaemer 2012). On the east coast of North America, B. schlosseri and other fouling organisms were found to adversely affect native eelgrass Zostera marina by fouling the leaves and reducing light availability; fouling increased the mortality of Z. marina (Wong and Vercaemer 2012). Eelgrass are highly productive habitats that serve as refuges and nurseries for several species. In Alaska, eelgrass ranging almost continuously from southeast Alaska and north into the Bering Sea up to about 67°N (qtd. in Hogrefe et al. 2014).

**Sources:**
Wong and Vercaemer 2012   Masterson 2007   Hogrefe et al. 2014

### *4.3 Impact on ecosystem function and processes*

**Choice: C** — Limited – Causes or potentially causes changes to food webs and/or ecosystem functions, with limited impact and/or within a very limited region

**Score:** 0.75 of 2.5

**High uncertainty?** ✔

**Ranking Rationale:**
Through its effects on eelgrass, B. schlosseri may affect ecosystem functions. Impacts on water quality are speculative based on its biology, but have not yet been substantiated by evidence.

**Background Information:**
On the east coast of North America, B. schlosseri and other fouling organisms were found to adversely affect native eelgrass Zostera marina by fouling the leaves and reducing light availability; fouling increased the mortality of Z. marina (Wong and Vercaemer 2012). Eelgrass support a variety of ecosystem functions by affecting water flow, stabilizing sediments, assimilating nutrients, supporting a high diversity of plants and animals, and through their role as primary producers (qtd. in Winfree 2005; Orth et al. 2006). As a filter feeder, B. schlosseri may also impact water quality e.g. improve water clarity, production of waste (Carver et al. 2006).

**Sources:**
Carver et al. 2006   Winfree 2005   Orth et al. 2006   Wong and Vercaemer 2012

### *4.4 Impact on high-value, rare, or sensitive species and/or communities*

**Choice: B** — Moderate – Causes or has potential to cause degradation of one or more species or communities, with moderate impact

**Score:** 1.75 of 2.5

**High uncertainty?** ✔

**Ranking Rationale:**
Through fouling, can have a negative impact on the eelgrass Zostera marina, which provides valuable ecosystem services and coastal habitat for several species. To our knowledge, no infestations of eelgrass beds by B. schlosseri have been reported in Alaska so far (L. Shaw, pers. comm., 31 August 2017).

**Background Information:**
A study by Wong and Vercaemer (2012) found that B. violaceus, along with other fouling organisms, reduced light availability of eelgrass, which led to reduced growth and increased mortality of eelgrass. Eelgrass is a valuable species that provides numerous ecosystem services to the marine environment, including water regulation, nutrient cycling, refuge, and food (Costanza et al. 1997).

**Sources:**
Wong and Vercaemer 2012   Costanza et al. 1997

### 4.5 *Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice:** **C**

Limited – Has limited potential to spread one or more organisms, with limited impact and/or within a very limited region

**Score:** 0.75 **of** 2.5

**Ranking Rationale:**

Is host to a protist and several parasites. The effect of these parasites on other species is unknown.

**Background Information:**

Moiseeva et al. (2004) described a progressive fatal disease called 'cup cell disease' that caused mortality from 30 to 45 days in B. schlosseri colonies grown in the lab. The disease-causing protist was transferred between colonies through seawater without direct contact between infected colonies. The authors suggest that this disease may be a serious problem in stocks of inbred lines or other important Botryllus spp. genotypes raised for scientific needs (Moiseeva et al. 2004), but this disease has not been reported in nature or in other species.

B. schlosseri hosts other ectoparasites, including Lankesteria botrylii (Ormières 1965, qtd. in Moiseeva et al. 2004), Botryllophilus ruber, Mycophilus roseus, and Zygomolgus poucheti. Although M. roseus has also been recorded in Botrylloides leachii, Gotto (1954) found morphological differences between adult females inhabiting the two ascidians, and suggests that M. roseus exists in two host-specific forms. No impacts have been reported for any of these parasites.

**Sources:**

Carver et al. 2006 Gotto 1954 Moiseeva et al. 2004 Sanamyan and Monniot 2007

### 4.6 *Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice:** **U**

Unknown

**Score:** **of**

**Ranking Rationale:**

**Background Information:**

No information available in the literature.

**Sources:**

None listed

### 4.7 *Infrastructure*

**Choice:** **B**

Moderate – Causes or has the potential to cause degradation to infrastructure, with moderate impact and/or within only a portion of the region

**Score:** 1.5 **of** 3

**Ranking Rationale:**

Is an abundant fouling organism.

**Background Information:**

In Bodega Harbor, California, Botryllus schlosseri was one of the eight most abundant fouling organisms both in 1969-1971 and in 2005-2009 (Sorte and Stachowicz 2011). Because of its abundance, B. schlosseri is a nuisance species that fouls boat hulls, marine equipment, aquaculture gear, and other submerged structures.

**Sources:**

Masterson 2007 NEMESIS; Fofonoff et al. 2003 Sorte and Stachowicz 2011

### 4.8 Commercial fisheries and aquaculture

**Choice:** **C** Limited – Has limited potential to cause degradation to fisheries and aquaculture, and/or is restricted to a limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
B. schlosseri can negatively impact cultured molluscs and finfish nets by fouling aquaculture gear. However, only limited effects were observed even when B. schlosseri grew to high densities.

**Background Information:**
By fouling bivalves and aquaculture gear, B. schlosseri can compete with commercial species, and may prevent the flow of nutrients through nets and cages (Carver et al. 2006; Masterson 2007). However, several studies have found that B. schlosseri had little impact on mussels (Lesser et al. 1992; Gittenberger 2009; Arens et al. 2011; Paetzold et al. 2012). Paetzold et al. (2012) found high levels of fouling on mussel socks in 2010 (average biomass of 600-800 g per mussel sock), but still did not observe any impacts on mussel productivity.

**Sources:**
Arens et al. 2011   Carver et al. 2006   Gittenberger 2009   Masterson 2007   Paetzold et al. 2012   Lesser et al. 1992

### 4.9 Subsistence

**Choice:** **C** Limited – Has limited potential to cause degradation to subsistence resources, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
B. schlosseri may impact bivalve species by fouling shells. By fouling eelgrass, this species may affect nursery habitats for subsistence fish species.

**Background Information:**
No information found. B. schlosseri is absent or rare on natural oyster beds, presumably because of siltation (Andrews 1973).

**Sources:**
Andrews 1973   NEMESIS; Fofonoff et al. 2003

### 4.101 Recreation

**Choice:** **C** Limited – Has limited potential to cause degradation to recreation opportunities, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**High uncertainty?** ☑

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 4.11 Human health and water quality

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on human health and water quality have been reported for B. schlosseri.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 9.5 |
| **Section Total - Possible Points:** | 27.5 |
| **Section Total -Data Deficient Points:** | 2.5 |

# 5. Feasibility of prevention, detection and control

150

### *5.1 History of management, containment, and eradication*

**Choice:** **C** Attempted; control methods are currently in development/being studied

**Score:** of

**Ranking Rationale:**
Control methods were attempted and were only effective for a short while.

**Background Information:**
In Atlantic Canada, efforts to minimize the impact of tunicate invasions on mussel aquaculture operations are ongoing. Mussel farmers currently use pressurized seawater to remove colonial tunicates. In St. Peters Bay, PEI, high-pressure spraying was effective at reducing the biomass of the colonial tunicates Botryllus schlosseri and Botrylloides violaceus on mussel socks (Arens et al. 2011). However, results were effective only in the short term, as tunicates re-established over time. In addition, the use of pressurized seawater could increase the spread of these species through fragmentation, and can reduce mussel productivity if applied too often (Arens et al. 2011; Paetzold et al. 2012).

Alternative treatments for controlling Botryllus schlosseri and Botrylloides violaceus include the use of freshwater, brine, lime, and acetic acid immersion, with exposure to ~5% acetic acid for >15 s proving the most effective (Carver et al. 2006).

**Sources:**
Aquaculture Science Branch 2010   Arens et al. 2011   Carver et al. 2006   Paetzold et al. 2012

### *5.2 Cost and methods of management, containment, and eradication*

**Choice:** **B** Major short-term and/or moderate long-term investment

**Score:** of

**Ranking Rationale:**
Current methods of control are only effective in the short term and require specialized equipment.

**Background Information:**
High-pressure spraying was only effective in the short term, as tunicates re-established over time. In addition, the use of pressurized seawater could increase the spread of these species through fragmentation, and can reduce mussel productivity if applied too often (Arens et al. 2011; Paetzold et al. 2012). Davidson et al. (2017) estimated a total equipment cost of $156 000 for this type of treatment. The cost of labor and fuel was estimated at $54 per treatment (Davidson et al. 2017).

Alternative treatments for controlling Botryllus schlosseri and Botrylloides violaceus include the use of freshwater, brine, lime, and acetic acid immersion, with exposure to ~5% acetic acid for >15 s proving the most effective (Carver et al. 2006).

**Sources:**
Arens et al. 2011   Carver et al. 2006   Davidson et al. 2017   Paetzold et al. 2012

## 5.3 *Regulatory barriers to prevent introductions and transport*



**Choice: B** Regulatory oversight, but compliance is voluntary

**Score:** of

**Ranking Rationale:**

While a permit is required for shellfish transfers, hull fouling regulations are largely voluntary.

**Background Information:**

The most likely vectors for introductions of Botryllus schlosseri are via bivalve aquaculture and ship fouling. In Alaska, a Shellfish Spat Transport Permit is required for importing, exporting, and moving shellfish seed within the state. Suppliers must be approved by the Board of Fisheries.

Although regulations exist to minimize hull fouling, compliance is largely voluntary (Hagan et al. 2014). The U.S. Coast Guard requires rinsing of anchors and anchor chains, and removal of fouling from the hull, piping and tanks on a regular basis, and the EPA Vessel General Permit also requires inspection of hard-to-reach areas of vessels during drydock. At the same, the EPA recognizes that methods and technologies to manage vessel biofouling are in early stages of development.

**Sources:**

Hagan et al. 2014   EPA 2013

## 5.4 *Presence and frequency of monitoring programs*

**Choice: D** State and/or federal monitoring programs exist, and monitoring is conducted frequently

**Score:** of

**Ranking Rationale:**

There are several programs that use volunteers to monitor for invasive tunicates.

**Background Information:**

Alaska has a tunicate monitoring program that conducts education and outreach. Tammy Davis (Invasive Species Program, Alaska Department of Fish and Game) gave a presentation on marine invasive species at the Alaska Shellfish Growers Association annual meeting in 2010. Botryllus schlosseri was one of the species she discussed. Alaska's Invasive Tunicate Network provides education opportunities by training volunteers to identify and collect non-native tunicates.
Material on identifying invasive tunicates, including B. schlosseri, is available on Canada's Department of Fisheries and Oceans website.

**Sources:**

Davis 2010   DFO 2016   Sephton et al. 2011   Washington Department of Fish and Wildlife 2013

### *5.5 Current efforts for outreach and education*



**Choice:** **D** Programs and materials exist and are readily available in the Bering Sea or adjacent regions

**Score:** of

**Ranking Rationale:**

Several programs and educational materials are available in Alaska.

**Background Information:**

Alaska's Invasive Tunicate Network and the Kachemak Bay National Estuarine Research Reserve (KBNERR) provide training opportunities for identifying and detecting non-native tunicates, and public education events on coastal and marine ecosystems more generally. "Bioblitzes" were held in Southeast AK in 2010 and 2012; these events engage and educate the public on marine invasive species. Field identification guides for native and non-native tunicates, as well as common fouling organisms, are readily available. In 2010, Tammy Davis (Invasive Species Program, Alaska Department of Fish and Game) gave a presentation on marine invasive species at the Alaska Shellfish Growers Association annual meeting; Botryllus schlosseri was one of the species she discussed.

**Sources:**

Davis 2010 iTunicate Plate Watch 2016

**Section Total - Scored Points:**

**Section Total - Possible Points:**

**Section Total -Data Deficient Points:**

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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Ciona savignyi*

**Common Name** *Pacific transparent sea squirt*

| | |
|---|---|
| **Phylum** | Chordata |
| **Class** | Ascidiacea |
| **Order** | Enterogona |
| **Family** | Cionidae |

**Final Rank** 52.25

**Data Deficiency:** 0.00

## Species Occurrence by Ecoregion

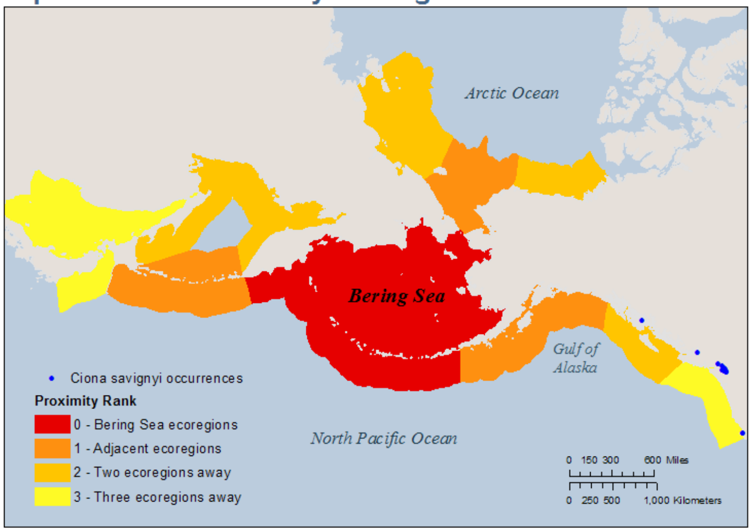


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 20.5 | 30 | 0 |
| Anthropogenic Influence: | 6 | 10 | 0 |
| Biological Characteristics: | 21.25 | 30 | 0 |
| Impacts: | 4.5 | 30 | 0 |
| **Totals:** | 52.25 | 100.00 | 0.00 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | -1.7 | Minimum Salinity (ppt) | 24 |
| Maximum Temperature (°C) | 27 | Maximum Salinity (ppt) | 37 |
| Minimum Reproductive Temperature (°C) | 12 | Minimum Reproductive Salinity (ppt) | 31* |
| Maximum Reproductive Temperature (°C) | 25 | Maximum Reproductive Salinity (ppt) | 35* |

### Additional Notes

Ciona savignyi is a solitary, tube-shaped tunicate that is white to almost clear in colour. It has two siphons of unequal length, with small yellow or orange flecks on the siphons' rim. Although C. savignyi is considered solitary, individuals are most often found in groups, and can form dense aggregations (Jiang and Smith 2005).

# 1. Distribution and Habitat



### 1.1 *Survival requirements - Water temperature*

**Choice: B** Moderate overlap – A moderate area (≥25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 2.5 of 3.75

**Ranking Rationale:**
Temperatures required for year-round survival occur in a moderate area (≥25%) of the Bering Sea.

**Background Information:**
Based on this species' geographic distribution, it is estimated to tolerate water temperatures between -1.7°C and +27°C.

**Sources:**
NEMESIS; Fofonoff et al. 2003 CABI 2017

### 1.2 *Survival requirements - Water salinity*

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
This species' salinity tolerance ranges from 24 to 37 ppt.

**Sources:**
CABI 2017

### 1.3 *Establishment requirements - Water temperature*

**Choice: C** Little overlap – A small area (<25%) of the Bering Sea has temperatures suitable for reproduction

**Score:** 1.25 of 3.75

**Ranking Rationale:**
Temperatures required for reproduction occur in a limited area (<25%) of the Bering Sea.

**Background Information:**
A study by Nomaguchi et al. (1997) found that optimal temperatures for reproduction and larval growth varied between "warm-" and "cold-water" populations. Cold water groups produced gamete between 12 and 17°C, and optimal temperatures for larval development was between 12°C and 20°C. While embryos developed normally at 11°C, larvae could not metamorphose. In contrast, the warm-water group produced gametes between 22 and 26°C, and optimal development occurred between 15 and 25°C (Nomaguchi et al. 1997).

**Sources:**
Nomaguchi et al. 1997

### *1.4 Establishment requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Although salinity thresholds are unknown, this species is a marine organism that does not require freshwater to reproduce. We therefore assume that this species can reproduce in saltwater (31 to 35 ppt). These salinities occur in a large (>75%) portion of the Bering Sea.

**Background Information:**
No information found.

**Sources:**
None listed

### *1.5 Local ecoregional distribution*

**Choice:** **C** Present in an ecoregion two regions away from the Bering Sea (i.e. adjacent to an adjacent ecoregion)

**Score:** 2.5 of 5

**Ranking Rationale:**
This species has been reported from southeastern Alaska and to the west in southern Russia.

**Background Information:**
Old records report this species in southeastern Alaska (Behm Canal, Alexander Archipelago, 1903) and northern British Columbia (Stuart Island, 1937). This species is also found in Peter the Great Bay in southern Russia.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.6 Global ecoregional distribution*

**Choice:** **C** In few ecoregions globally

**Score:** 1.75 of 5

**Ranking Rationale:**
This species has a restricted global distribution. It is native to the northwest Pacific, and has been introduced to the west coast of North America, where it has a discontinuous distribution. In 2010, it was recorded for the first time in New Zealand. With the exception of an unverified report in Argentina, this species has not been found elsewhere.

**Background Information:**
This species is native to Japan, where it has spread as far north as Peter the Great Bay in southern Russia, Sea of Japan. In the early 20th century, it was collected in northern BC and southeastern Alaska. It occurs sporadically along the West Coast: in CA, it is found from Bodega Bay to San Diego, and in Puget Sound (WA), but it has not been recorded OR. In 2010, it was found in New Zealand, which the authors claim is the first report of this species' occurrence in the Southern Hemisphere (Smith et al. 2010). There are unverified reports of its occurrence in Argentina (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 1.7 *Current distribution trends*



| Choice: | | Score: |
|---|---|---|
| A | Recent rapid range expansion and/or long-distance dispersal (within the last ten years) | 5 of 5 |

**Ranking Rationale:**

This species is currently expanding its range in Washington.

**Background Information:**

This species is currently spreading in WA (Anderson et al. 2007). It can grow rapidly and form dense aggregations (Lambert and Lambert 2003). This species likely has limited natural dispersal abilities because adults are sessile and the larval stage is short-lived.

**Sources:**

CABI 2017   Lambert and Lambert 2003   Anderson et al. 2007

| | |
|---|---|
| **Section Total - Scored Points:** | 20.5 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 2. Anthropogenic Transportation and Establishment



### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice: B** Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 of 4

**High uncertainty?** ✔

**Ranking Rationale:**
This species can be transported by fouling. Although it has limited natural dispersal abilities, it has been found in natural areas away from shipping traffic. Although further studies are needed, this information suggests that C. savignyi might be able to disperse without the assistance of anthropogenic vectors.

**Background Information:**
This species is likely dispersed by fouling ships and fishing gear. This species has limited potential for natural, long-distance dispersal, but divers in WA have found C. savignyi in areas several miles from the nearest marina (AISU 2011).

**Sources:**
AISU 2011

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice: A** Readily establishes in areas with anthropogenic disturbance/infrastructure and in natural, undisturbed areas

**Score:** 4 of 4

**Ranking Rationale:**
This species can establish on natural substrates in its introduced range.

**Background Information:**
In Washington, C. savignyi has been found growing on natural substrates such as rock, sand, and gravel. These populations were well-established and some occurred at high densities (Anderson et al. 2007). This species is an abundant fouling organism on ships and in harbors (Fofonoff et al. 2003).

**Sources:**
Anderson et al. 2007 NEMESIS; Fofonoff et al. 2003

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice: B** No

**Score:** 0 of 2

**Ranking Rationale:**
This species is not currently farmed.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 6 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics

### *3.1 Dietary specialization*

**Choice:** **A** — Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
This species is a generalist and its prey items are readily available in the Bering Sea.

**Background Information:**
C. savignyi is a filter feeder. It feeds primarily on phytoplankton, but also on zooplankton, bivalve larvae, and other suspended organic materials.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **A** — Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 of 5

**Ranking Rationale:**
This species has broad environmental tolerances at all life stages.

**Background Information:**
Adults can tolerate a wide range of temperatures and salinities. It is most commonly found at depths from 12 to 23 meters, but has been found at depths up to 100 m. This species grows on hard substrates, and prefers shaded areas in coastal, protected waters. It can tolerate polluted waters found near ports and marinas.

**Sources:**
CABI 2017 NEMESIS; Fofonoff et al. 2003

### *3.3 Desiccation tolerance*

**Choice:** **C** — Little to no tolerance (<1 day) of desiccation during its life cycle

**Score:** 1.75 of 5

**Ranking Rationale:**
Both adults and juveniles have a low tolerance to desiccation. In laboratory and field experiments, no individual survived longer than 24 hours when exposed to air.

**Background Information:**
In laboratory experiments under controlled conditions, adults exposed to air died within the first hour, and all specimens died within 24 h (Hopkins et al. 2016). In outdoor trials, mortality occurred within 6 to 24 h. Individuals facing upwards died significantly faster (range 6–12 h) than those facing downwards (range 8–24 h). Sea spray and the presence of other fouling organisms did not have significant effects. Mortality of early life stages was greatest in the first 2 h (83%), with 100% mortality achieved after 8 h for all treatments (Hopkins et al. 2016).

**Sources:**
Hopkins et al. 2016

### 3.4 *Likelihood of success for reproductive strategy*



i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice:** **A** High – Exhibits three or four of the above characteristics

**Score:** 5 **of** 5

**Ranking Rationale:**

C. savignyi is hermaphroditic, and exhibits low parental investment, external fertilization, and a short generation time.

**Background Information:**

This species is hermaphroditic and can self-fertilize, but experiments have shown that "self" sperm is greatly outcompeted by "non-self" sperm (Jiang and Smith 2005). Fertilization is external, and gametes can persist for 1-2 days in the water column. C. savignyi is typically found in groups of several individuals. Individuals in a group simultaneously release gametes in response to an environmental cue (i.e., sunrise) (Jiang and Smith 2005). Planktonic, free-swimming larvae can survive 2-10 days in the water column. When a suitable substrate is found, larvae settle, undergo metamorphosis, and become sessile. Near Tokyo, Japan, C. savignyi reproduces year-round. Its lifespan varies from 2 to 6 months, and sexual maturity occurs in 2 to 3 months. Embryo development and hatching time decreases with increasing temperatures (Nomaguchi et al. 1997).

Fecundity estimates are not available for C. savignyi. However, there are estimates for a closely related species, Ciona intestinalis. Based on length and mass of oviducts and eggs, Petersen and Svane (1995) estimated that C. intestinalis produces between 2500 to 12000 eggs per oviduct, and used a conservative estimate of 10 000 eggs/individual in their modelling exercise.

**Sources:**

Jiang and Smith 2005 Nomaguchi et al. 1997 Petersen and Svane 1995

### 3.5 *Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice:** **C** Disperses short (< 1 km) distances

**High uncertainty?** ☑

**Score:** 0.75 **of** 2.5

**Ranking Rationale:**

Adults are sessile, but eggs and larvae can be dispersed passively. Although we did not find information on the dispersal distance of C. savignyi, studies on the closely related Ciona intestinalis suggest that natural dispersal is very limited.

**Background Information:**

Adults are sessile, but may disperse naturally by rafting on floating vegetation. Eggs and larvae can be dispersed passively by water currents. Larvae are also capable of active swimming.

Information on Ciona intestinalis, a closely related species: Natural dispersal is very short (0-3 m) and occurs primarily by drifting eggs and swimming larvae. Petersen and Svane (1995) found that their study population in Scandinavia was patchily distributed and highly localized within the cove. Dispersal to the outside was very limited (Petersen and Svane 1995). Similarly, a study in Nova Scotia found that larvae settled very close to adults (Howes et al. 2007).

**Sources:**

Petersen and Svane 1995 Howes et al. 2007 NEMESIS; Fofonoff et al. 2003

### *3.6 Likelihood of dispersal or movement events during multiple life stages*



i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice:** **A** High – Exhibits two or three of the above characteristics

**Score:** 2.5 **of** 2.5

**Ranking Rationale:**

Adults are sessile, but eggs and larvae can disperse by drifting and/or swimming. Both gametes and larvae can remain viable in the water column for several days.

**Background Information:**

Fertilization is external, and gametes can persist for 1-2 days in the water column (Jiang and Smith 2005). When a suitable substrate is found, larvae settle, undergo metamorphosis, and become sessile. Larvae can exist in the water column for 2 to 10 days before settling.

**Sources:**

CABI 2017 Jiang and Smith 2005

### *3.7 Vulnerability to predators*

**Choice:** **D** Multiple predators present in the Bering Sea or neighboring regions

**Score:** 1.25 **of** 5

**Ranking Rationale:**

Based on information from a closely related species, there are several taxa in the Bering Sea that are expected to predate upon Ciona savignyi.

**Background Information:**

No information was found for C. savignyi. However, eggs and larvae of Ciona intestinalis (a closely related species) were consumed by jellyfish. Adult predators include sea stars, fishes, crabs, and small snails (Petersen and Svane 1995; CABI 2017).

**Sources:**

CABI 2017 Petersen and Svane 1995

| | |
|---|---|
| **Section Total - Scored Points:** | 21.25 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

# 4. Ecological and Socioeconomic Impacts



### 4.1 *Impact on community composition*

**Choice: C** Limited – Single trophic level; may cause decline but not extirpation

**Score:** 0.75 of 2.5

**High uncertainty?** ☑

**Ranking Rationale:**
C. savignyi is not as well-studied as its congener C. intestinalis, which has had significant impacts on the benthic community. However, the effects of C. intestinalis cannot be generalized to C. savignyi. For now, there is limited evidence that C. savignyi negatively impacts other marine organisms.

**Background Information:**
In southern California, C. savignyi may compete with C. intestinalis, another invasive tunicate. Frequent die-offs of both species make it difficult to determine the extent of competition, and environmental change seems to equalize their populations (Fofonoff et al. 2003). A study by Cordell et al. (2013) in Puget Sound found that C. savignyi, along with two other non-native tunicate species, did not have significant effects on the non-fouling community. Two species, the native solitary tunicate Corella inflata and the amphipod Monocorophium insidiosum, were more abundant at sites without C. savignyi (Cordell et al. 2013).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Cordell et al. 2013

### 4.2 *Impact on habitat for other species*

**Choice: C** Limited – Has limited potential to cause changes in one or more habitats

**Score:** 0.75 of 2.5

**Ranking Rationale:**
By fouling substrates, this species may reduce available habitat for some organisms. Conversely, it may create secondary settlement habitat for others.

**Background Information:**
C. savignyi can form dense aggregations that can provide new habitat for fouling organisms. No specific impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.3 *Impact on ecosystem function and processes*

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
Considering its limited ecological impacts in its introduced range, this species is not expected to affect ecosystem functions in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.4 Impact on high-value, rare, or sensitive species and/or communities*



**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species may establish on or near bivalve shells; however, no impacts of C. savignyi on native bivalves have been reported to date.

**Background Information:**
In Washington, large populations of C. savignyi were found in and around geoduck beds, sparking concern that C. savignyi might negatively impact the Pacific geoduck (Panopea generosa) and other bivalve species (Anderson et al. 2007). However, no impacts have been documented to date. Efforts to study interactions between C. savignyi and P. generosa were unsuccessful (AISU 2011).

**Sources:**
Anderson et al. 2007 AISU 2011

### *4.5 Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not known to transport diseases, parasites, or hitchhikers.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not expected to hybridize with native species in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.7 Infrastructure*

**Choice:** **B** Moderate – Causes or has the potential to cause degradation to infrastructure, with moderate impact and/or within only a portion of the region

**Score:** 1.5 of 3

**Ranking Rationale:**
Moderate impacts on infrastructure are expected given its abundance as a fouling organism.

**Background Information:**
Ciona savignyi is an abundant member of the fouling community in southern California and in Puget Sound.

**Sources:**
Lambert and Lambert 1998

### 4.8 *Commercial fisheries and aquaculture*

**Choice: C** Limited – Has limited potential to cause degradation to fisheries and aquaculture, and/or is restricted to a limited region

**Score:** 0.75 of 3

**High uncertainty?** ✔

**Ranking Rationale:**
No negative impacts have been reported, but there is concern that C. savignyi might affect bivalves. Shellfish aquaculture currently occurs only in a restricted area of the Bering Sea (Mathis et al. 2015).

**Background Information:**
There are concerns that Ciona savignyi might negatively affect the Pacific geoduck or other bivalves (Anderson et al. 2007). The closely related Ciona intestinalis has had negative effects on the commercial shellfish industry by fouling gear, and by overgrowing and competing with shellfish species.

**Sources:**
Mathis et al. 2015 Anderson et al. 2007 CABI 2017

### 4.9 *Subsistence*

**Choice: C** Limited – Has limited potential to cause degradation to subsistence resources, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**High uncertainty?** ✔

**Ranking Rationale:**
No negative impacts have been reported, but there is concern that C. savignyi might affect bivalves and, in so doing, affect subsistence resources.

**Background Information:**
Compared to salmon and finfish, shellfish such as oysters, clams, and mussels comprise a smaller percentage of subsistence catch in the Bering Sea (when measured by weight; Mathis et al. 2015). Although shellfish comprised almost 20% of subsistence catch in the Aleutians West, most municipalities in the Bering Sea recorded low percentages (< 5%).

**Sources:**
Mathis et al. 2015

### 4.101 *Recreation*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to affect recreational opportunities in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.11 *Human health and water quality*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact human health and water quality in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 4.5 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

# 5. Feasibility of prevention, detection and control

### *5.1 History of management, containment, and eradication*

**Choice:** **C** Attempted; control methods are currently in development/being studied

**Score:** of

**Ranking Rationale:**
Control of C. savignyi populations have been attempted. Methods to control or eradicate invasive solitary tunicates are being studied.

**Background Information:**
From 2006 to 2009, SCUBA divers in WA monitored C. savignyi populations and removed infestations by hand. In some cases, vessels were so severely infested that the divers could not feasibly remove them (AISU 2011). No removals were conducted after 2009 because the control and eradication of C. savignyi was determined to be low priority. Hand culling is expensive and time-consuming, and unlikely to eradicate the entire population, especially if it consists of small individuals.

Exposure to anoxic or very low oxygen conditions was shown to cause complete mortality in C. savignyi. Wrapping docks fouled by C. savignyi with polyethylene tarps may be an effective management option to locally-control and reduce the spread of this tunicate species from marina habitats (Pool et al. 2013).

Five allelochemicals were tested on C. savignyi to see if they prevented larval metamorphosis (i.e. prevent transition to adult stage; Cahill et al. 2012). Three chemicals (radicicol, polygodial, and ubiquinone-10) inhibited metamorphosis and increased mortality. The authors propose that these chemicals have potential for future development in antifoulant formulations targeted towards the inhibition of metamorphosis in ascidian larvae (Cahill et al. 2012).

**Sources:**
AISU 2011   Anderson et al. 2007   Cahill et al. 2012   Pool et al. 2013

### *5.2 Cost and methods of management, containment, and eradication*

**Choice:** **B** Major short-term and/or moderate long-term investment

**Score:** of

**Ranking Rationale:**
The methods currently available to control C. savignyi require major short-term investments.

**Background Information:**
Hand culling is expensive and time-consuming, and is not feasible when C. savignyi is very abundant. Wrapping docks fouled by C. savignyi with polyethylene tarps may control and reduce the spread near marinas (Pool et al. 2013). Chemicals that inhibit the establishment of C. savignyi could be used in antifouling treatments (Cahill et al. 2012), but such products have not been developed yet.

**Sources:**
Pool et al. 2013   Cahill et al. 2012   CABI 2017

### 5.3 *Regulatory barriers to prevent introductions and transport*

**Choice:** **B** Regulatory oversight, but compliance is voluntary

**Score:** of

**Ranking Rationale:**
This species is primarily transported by fouling ship. Compliance with federal fouling regulations remains voluntary.

**Background Information:**
In the U.S., Coast Guard regulations require masters and ship owners to engage in practices that will reduce the spread of invasive species, including cleaning ballast tanks and removing fouling organisms from hulls, anchors, and other infrastructure on a "regular" basis (CFR 33 § 151.2050). However, the word "regular" is not defined, which makes the regulations hard to enforce. As a result of this technical ambiguity, compliance with ship fouling regulations remains largely voluntary (Hagan et al. 2014).

**Sources:**
CFR 2017 Hagan et al. 2014

### 5.4 *Presence and frequency of monitoring programs*

**Choice:** **B** Surveillance takes place, but is largely conducted by non-governmental environmental organizations (e.g., citizen science programs)

**Score:** of

**Ranking Rationale:**
C. savignyi is listed as a species of interest on the Invasive Tunicate Network website.

**Background Information:**
In Alaska, the Invasive Tunicate Network and KBNERR conduct monitoring for non-native tunicates and other invasive or harmful species. The programs involve teachers, students, outdoor enthusiasts, environmental groups and professional biologists to detect invasive species.

**Sources:**
iTunicate Plate Watch 2016

### 5.5 *Current efforts for outreach and education*

**Choice:** **D** Programs and materials exist and are readily available in the Bering Sea or adjacent regions

**Score:** of

**Ranking Rationale:**
C. savignyi is listed as a species of interest on the Invasive Tunicate Network website.

**Background Information:**
Alaska's Invasive Tunicate Network and the Kachemak Bay National Estuarine Research Reserve (KBNERR) provide training opportunities for identifying and detecting non-native tunicates, and public education events on coastal and marine ecosystems more generally. Southeast AK hosts an annual Marine Invasive Species Bioblitz, which engages the public through education and hands-on activities. Field identification guides for native and non-native tunicates, as well as common fouling organisms, are readily available.

**Sources:**
iTunicate Plate Watch 2016

**Section Total - Scored Points:**
**Section Total - Possible Points:**
**Section Total -Data Deficient Points:**

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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Didemnum vexillum*

**Common Name** *carpet sea squirt*

| | |
|---|---|
| **Phylum** | Chordata |
| **Class** | Ascidiacea |
| **Order** | Aplousobranchia |
| **Family** | Didemnidae |

**Final Rank** 65.64

**Data Deficiency:** 2.50

## Species Occurrence by Ecoregion

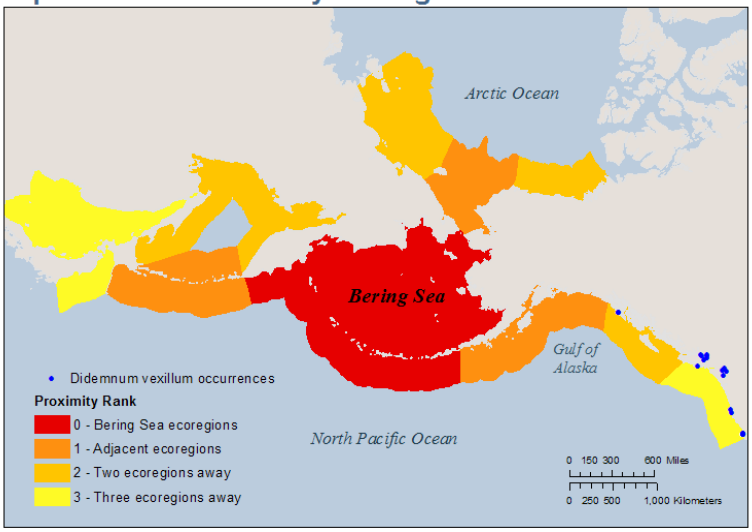


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 23.75 | 30 | 0 |
| Anthropogenic Influence: | 8 | 10 | 0 |
| Biological Characteristics: | 21.75 | 30 | 0 |
| Impacts: | 10.5 | 28 | 2.50 |
| **Totals:** | 64.00 | 97.50 | 2.50 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | -2 | Minimum Salinity (ppt) | 10 |
| Maximum Temperature (°C) | 24 | Maximum Salinity (ppt) | 35 |
| Minimum Reproductive Temperature (°C) | 14 | Minimum Reproductive Salinity (ppt) | 31* |
| Maximum Reproductive Temperature (°C) | 20 | Maximum Reproductive Salinity (ppt) | 35* |

### Additional Notes

Spreading colonial tunicate consisting of many zooids. Yellow-cream in colour. Grows on rocks, shellfish, and other marine organisms such as sponges and algae.

**Reviewed by** Linda Shaw, NOAA Fisheries Alaska Regional Office, Juneau AK

**Review Date:** 8/31/2017

# 1. Distribution and Habitat

### 1.1 *Survival requirements - Water temperature*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 3.75 **of** 3.75

**Ranking Rationale:**
Temperatures required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
Temperature range for survival is between -2°C and 24°C.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 1.2 *Survival requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 **of** 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
Salinity range required for survival is between 10 ppt and 35 ppt.

**Sources:**
NIMPIS 2016

### 1.3 *Establishment requirements - Water temperature*

**Choice:** **D** No overlap – Temperatures required for reproduction do not exist in the Bering Sea

**Score:** 0 **of** 3.75

**Ranking Rationale:**
Temperatures required for reproduction occur in a limited area (<25%) of the Bering Sea.

**Background Information:**
Requires temperatures between 14°C and 20°C for reproduction.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 1.4 *Establishment requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**High uncertainty?** ☑

**Score:** 3.75 **of** 3.75

**Ranking Rationale:**
Although salinity thresholds are unknown, this species is a marine organism that does not require freshwater to reproduce. We therefore assume that this species can reproduce in saltwater (31 to 35 ppt). These salinities occur in a large (>75%) portion of the Bering Sea.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *1.5 Local ecoregional distribution*



**Choice: C** Present in an ecoregion two regions away from the Bering Sea (i.e. adjacent to an adjacent ecoregion)

**Score:** 2.5 **of** 5

**Ranking Rationale:**

**Background Information:**
Found in Sitka, Alaska. Native to Japan.

**Sources:**
NEMESIS; Fofonoff et al. 2003 McCann et al. 2013

### *1.6 Global ecoregional distribution*

**Choice: A** In many ecoregions globally

**Score:** 5 **of** 5

**Ranking Rationale:**
Wide global distribution

**Background Information:**
Native to the northwest Pacific (Japan). Invasive to southeast AK, BC, south to CA and Mexico. On the east coast of North America, present in Nova Scotia and throughout New England. In Europe, present in Ireland, the Netherlands, France, and the Mediterranean Sea (Italy and Spain). This invasion suggests that D. vexillum has greater capacity to invade warm waters than previously thought (Ordonez et al. 2015). Discovered in New Zealand in 2001.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Ordonez et al. 2015

### *1.7 Current distribution trends*

**Choice: A** Recent rapid range expansion and/or long-distance dispersal (within the last ten years)

**Score:** 5 **of** 5

**Ranking Rationale:**
Recent documentation of range expansion.

**Background Information:**
D. vexillum has the potential for rapid colonization (Valentine et al. 2016) and is currently expanding its range in the Mediterranean Sea (Ordóñez et al. 2015). Documented instances of long-distance dispersal were likely assisted by anthropogenic vectors; however, fragments may be able to disperse naturally for up to 20 km depending on water currents (Lengyel et al. 2009). It has not spread since being discovered in 2010 in Sitka, AK (McCann et al. 2013).

**Sources:**
McCann et al. 2013 Ordonez et al. 2015 Valentine et al. 2016 Lengyel et al. 2009

| | |
|---|---|
| **Section Total - Scored Points:** | 23.75 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 2. Anthropogenic Transportation and Establishment



**2.1 *Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport***

**Choice: A** Has been observed using anthropogenic vectors for transport and transports independent of any anthropogenic vector once introduced

**Score:** 4 of 4

**Ranking Rationale:**
D. vexillum can be transported by both natural and anthropogenic vectors.

**Background Information:**
Anthropogenic vectors of dispersal include: hitchhiking on bivalves, ballast water and bilge water, and fouling of ships and gear (Dijkstra 2009). D. vexillum can also disperse naturally by larval dispersal and by fragmentation of adult colonies (Herborg et al. 2009; Lengyel et al. 2009). The impressive spread of D. vexillum on Georges Bank is likely due to such fragmentation (Valentine et al. 2007a). In a risk assessment study for British Columbia, Herborg et al. (2009) ranked natural dispersal methods as "moderately important" vectors, based on results from an expert survey.

**Sources:**
Dijkstra 2009   Lengyel et al. 2009   Herborg et al. 2009   Valentine et al. 2007a

**2.2 *Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish***

**Choice: A** Readily establishes in areas with anthropogenic disturbance/infrastructure and in natural, undisturbed areas

**Score:** 4 of 4

**Ranking Rationale:**
D. vexillum establishes on anthropogenic surfaces and can spread to natural areas once introduced.

**Background Information:**
In addition to growing on anthropogenic substrates, D. vexillum can colonize and overgrow healthy natural subtidal surfaces including rocky reefs, gravel bottoms, bivalve colonies, seaweeds, and eelgrass (Valentine et al. 2007b; Dijkstra 2009). Spread to natural substrates following introduction has been observed in several areas including Georges Bank (Valentine et al. 2007b) and in Sitka, AK (L. Shaw, pers. comm., 31 August 2017).

**Sources:**
Valentine et al. 2007b   Dijkstra 2009

**2.3 *Is this species currently or potentially farmed or otherwise intentionally cultivated?***

**Choice: B** No

**Score:** 0 of 2

**Ranking Rationale:**
D. vexillum is not currently farmed or intentionally cultivated.

**Background Information:**

**Sources:**
None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 8 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

# 3. Biological Characteristics

### *3.1 Dietary specialization*

**Choice: A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Prey taxa are readily available in the Bering Sea.

**Background Information:**
Suspension feeder. Feeds on phytoplankton, bacteria, and detritus. Larvae are non-feeding.

**Sources:**
NEMESIS; Fofonoff et al. 2003 NIMPIS 2016

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice: A** Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 of 5

**Ranking Rationale:**
Tolerant of a wide range of temperatures and salinities and found in numerous habitats.

**Background Information:**
Can tolerate a wide range of temperature, salinity, and water quality conditions (Herborg et al. 2009; Dijkstra 2009). Common in marine water, though it has also been found in estuaries. Not only common in confined, disturbed, and polluted harbors and estuaries, but is also common in the more ‘pristine’ waters of Georges Bank (Massachusetts), British Columbia and New Zealand (Fofonoff et al. 2003). Appears to have a highly plastic life-cycle that responds to thermal conditions, with winter regression in colder environments and summer regression in warmer environments such as the Mediterranean (Ordóñez et al. 2015).

A popular science article by Tammy Davis (Invasive Species Program Coordinator at ADF&G) says that D. vexillum is not known to establish on sandy or muddy seabed. However, D. vexillum is found on a variety of substrates including bivalves, algae, wood, and rocks, and its potential for establishment on unusual substrates has been noted: “In addition to the establishment of populations in more protected shallow water habitats, in 2002 we discovered that portions of deeper water (~30 m) pebble-cobble habitats in eastern Long Island Sound were heavily colonized by Didemnum [vexillum]. […] The ability of Didemnum to colonize and form mats on the pebble-cobble seafloor habitats is unlike any of the other recent ascidian invaders or native and long-term resident colonial ascidians found in Long Island Sound” (Mercer et al. 2009).

**Sources:**
Davis 2016 Dijkstra 2009 Herborg et al. 2009 Mercer et al. 2009 NEMESIS; Fofonoff et al. 2003 Ordonez et al. 2015

### *3.3 Desiccation tolerance*

**Choice: C** Little to no tolerance (<1 day) of desiccation during its life cycle

**Score:** 1.75 of 5

**High uncertainty?** ☑

**Ranking Rationale:**
Colonies died when exposed to air for 2-3 hours per days for 30 days.

**Background Information:**
Carman et al. (2009) exposed D. vexillum to 3 treatments, ranging from 1.5 to 3.5 hours of air exposure. Senescence was observed only when exposing D. vexillum to both air and freshwater. Colonies in tide pools were able to survive exposure to air for short periods of time, probably not exceeding 2 hours (Valentine et al. 2007a). Colonies died when exposed to air for extended period of time (2-3 hours per day for 30 days; Valentine et al. 2007a). In general, tunicates have low tolerance to desiccation (Daniel and Therriault 2007; Pleus 2008).

**Sources:**
Carman et al. 2009   Daniel and Therriault 2007   Valentine et al. 2007a   Pleus 2008

### *3.4 Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic   ii. High fecundity (e.g. >10,000 eggs/kg)   iii. Low parental investment and/or external fertilization   iv. Short generation time

**Choice: B** Moderate – Exhibits one or two of the above characteristics

**Score:** 3.25 of 5

**Ranking Rationale:**
Hermaphroditic, low fecundity,  low parental investment.

**Background Information:**
Hermaphroditic and internal fertilization. Sperm are released in the water column, and travel to another zooid in the colony, where fertilization occurs. A typical zooid can produce 1-20 eggs, and eggs develop in the ovary one at a time (Berrill 1950, Lambert and Lambert 2005; qtd. in Daniel and Therriault 2007). Eggs mature within several weeks and are released as non-feeding, free-swimming larvae.

Under control treatment conditions, Didemnum vexillum reached sexual maturity 62 days after recruitment (Stefaniak and Whitlatch 2014). Length of reproductive cycle is variable: In New England, recruitment in coastal sites occurred over 3.5–5 months in the range of 14–20°C and ceased at 9–11°C (Valentine et al. 2009). In New Zealand, recruitment occurred over a longer period of time (at least 9 months) (Fletcher et al. 2013b). Recruitment stopped during the winter when temperatures dipped below 12°C (Fletcher et al. 2013b).

**Sources:**
Daniel and Therriault 2007   Fletcher et al. 2013b   NIMPIS 2016   Ordonez et al. 2015   Stefaniak and Whitlatch 2014

### *3.5 Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice: B** Disperses moderate (1-10 km) distances

**Score:** 1.75 of 2.5

**Ranking Rationale:**

Primary transport is due to anthropogenic means. Can disperse naturally hundreds of meters to a few kilometers.

**Background Information:**

Limited ability for natural dispersal. Pelagic larvae only remain in the water column for a short time (≤1 day; Osman and Whitlatch 2007). Once the larva has settled and metamorphosed, individuals are sessile for the rest of their life. Unlike some other colonial tunicate invaders, there is no information about this species' ability to spread naturally by drifting on floating debris.

A field-based study consistently recorded larval dispersal on settlement plates 250 m away from source populations (Fletcher et al. 2013a). Exponential decay models suggested that dispersal greater than 250 m was theoretically possible (>1 km in some situations) (Fletcher et al. 2013a). Monitoring of settlement plates revealed dispersal distances up to 350 m from known source populations (Fletcher et al. 2013a). Small fragments can detach from D. vexillum and form new colonies by drifting within the water column. Fletcher et al. (2013a) estimated (based on rates of sinking) that fragments could spread ~100 m from their release point. Longer dispersal distances from larvae or fragmentation may be possible depending on hydrological conditions.

Human-mediated transport is the most important vector for long-distance dispersal. The most likely transport scenarios are either the direct transport of colonies fouled on aquaculture equipment, boat hulls or other mobile structures or the indirect transport of colony fragments where small parts of a colony break off during transport or disturbance (e.g. dredging, trawling) and subsequently find suitable conditions for establishment and growth.

**Sources:**

Dijkstra 2009 Fletcher et al. 2013a Herborg et al. 2009 Osman and Whitlatch 2007

### *3.6 Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: A** High – Exhibits two or three of the above characteristics

**Score:** 2.5 of 2.5

**Ranking Rationale:**

Larval viability window is < 36 hours. Can disperse as larvae (by swimming or passive dispersal) and asexually as adults via fragmentation.

**Background Information:**

The larval stage can disperse by swimming or passively by water currents. The larval stage is likely short-lived (minutes to hours, < 1 day) (Bullard et al. 2007). Under experimental conditions, most larvae (>70%) were able to undergo successful metamorphosis following an artificial delay of 2 h (Fletcher et al. 2013a). Larval viability decreased with increasing delay duration, but 10% of larvae did remain viable after a 36 h delay (Fletcher et al. 2013a). Although adults are sessile, colonies can disperse asexually by fragmentation and rafting (Thiel and Gutow 2005; Bullard et al. 2007; Lengyel et al. 2009).

**Sources:**

Bullard et al. 2007 Fletcher et al. 2013a Lengyel et al. 2009 Thiel and Gutow 2005

### 3.7 *Vulnerability to predators*



| Choice: | | Score: |
|---|---|---|
| C | Few predators suspected present in the Bering Sea and neighboring regions, and/or multiple predators in native range | 2.5 of 5 |

**High uncertainty?** ✔

**Ranking Rationale:**

It is believed that D. vexillum has few predators, but a recent study suggests that predation in its introduced range may be strong enough to limit growth and establishment.

**Background Information:**

D. vexillum is eaten by fish (perhaps accidentally), periwinkles, snails, starfish, and urchins (Fofonoff et al. 2003; Gittenberger 2007; Valentine et al. 2007a,b). Some authors believe that predation on D. vexillum is low because it is a poor source of nutrition and contains chemicals to deter predators (Daniel and Therriault 2007; Valentine et al. 2007a; Valentine et al. 2007b; Carman et al. 2009). However, a study in New Zealand by Forrest et al. (2013) found that predation on D. vexillum was strong enough to limit population growth and prevent establishment. Furthermore, the authors of this study point out that D. vexillum does not have secondary metabolites that would reduce predation (Forrest et al. 2013).

**Sources:**

Carman et al. 2009   Daniel and Therriault 2007   NEMESIS; Fofonoff et al. 2003   Forrest et al. 2013   Gittenberger 2007   Valentine et al. 2007a   Valentine et al. 2007b

| | |
|---|---|
| **Section Total - Scored Points:** | 21.75 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

# 4. Ecological and Socioeconomic Impacts



## *4.1 Impact on community composition*

**Choice:** **B** — Moderate – More than one trophic level; may cause declines but not extirpation

**Score:** 1.75 **of** 2.5

### Ranking Rationale:

May outcompete similar organisms for habitat. Affects the composition and diversity of taxa that span multiple trophic levels i.e. worms, crustaceans, and fish. To our knowledge, extirpation caused by D. vexillum has not been documented.

### Background Information:

Effects of D. vexillum are context-dependent: some sites such as Georges Bank report very large invasions, whereas at other sites, D. vexillum has not spread much from where it was initially discovered (e.g. Whiting Harbour, Sitka, AK). While D. vexillum does not seem to have negative effects on mobile species, it does overgrow several sessile marine organisms (e.g., hydroids, shellfish, anemones). Moreover, studies have found that it alters the composition of marine communities, notably by increasing the abundance and diversity of certain taxa (polychaete worms, tanaids, crabs, and fish) (Daniel and Therriault 2007; Smith et al. 2014).

### Sources:

NEMESIS; Fofonoff et al. 2003   Daniel and Therriault 2007   Smith et al. 2014

### 4.2 *Impact on habitat for other species*



**Choice:** **B** Moderate – Causes or has potential to cause changes to one or more habitats

**Score:** 1.75 **of** 2.5

**Ranking Rationale:**

Through competition and rapid expansion, has been shown to alter mussel bed habitat and pebble-gravel habitat, with potential implications for the communities that rely on those habitats.

**Background Information:**

By 2003-2006, colonial tunicates, including D. vexillum, replaced mussels (M. edulis) as the dominant species in fouling communities in Portsmouth Harbor, NH. (Dijkstra and Harris 2009). A comparison of pre- and post-invasion species richness found that species richness increased in post-invasion communities; however, the authors attribute this result to differences in life history between mussels and tunicates. While mussels provided a year-round substrate available to other organisms for settlement, tunicates, such as D. vexillum, are more resistant to secondary settlement by these other organisms because they possess a chemical defense that deters secondary settlement. However, D. vexillum dies off seasonally and creates large areas of bare substrate available for colonization by other organisms (Dijkstra and Harris 2009). Senescence of colonies or individuals from a single species eliminates them from an area and opens that area to recolonization, thereby preventing competitive exclusion of species.
The life-history cycle, e.g. senescence of invasive colonial ascidians, in this system created a community that is susceptible to colonization and can support regional increases in species richness (Dijkstra and Harris 2009).

On Georges Bank, where D. vexillum has invaded an area of 230km2, it has turned a heterogeneous pebble gravel habitat into a homogeneous tunicate mat (Lengyel et al. 2009). This may negatively effect Atlantic Cod (Gadus morhua), haddock (melanogrammus aeglefinus), and the sea scallop (Placopecten magellanicus) as pebble gravel habitat may be important to survival and success of these species (Lough et al. 1989; Thouzeau et al. 1991).

Based on results from their study, Mercer et al. (2009) suggested that mats of D. vexillum may serve as novel habitat for benthic species. Invertebrates capable of living beneath the mats may use the mats for shelter and protection from epibenthic predators. However, Mercer et al. (2009) did not explicitly test for these effects.

**Sources:**

Dijkstra and Harris 2009   NEMESIS; Fofonoff et al. 2003   Lengyel et al. 2009   Mercer et al. 2009   Lough et al. 1989   Thouzeau et al. 1991

### 4.3 *Impact on ecosystem function and processes*

**Choice: B** Moderate – Causes moderate changes to food webs or ecosystem functions in several areas, or causes severe effects in only one or a few areas (e.g., in areas where species occurs at high densities)

**Score:** 1.75 **of** 2.5

**High uncertainty?** ✔

**Ranking Rationale:**

While potential impacts have been discussed, the actual (or realized) impacts of D. vexillum on ecosystem functions and processes is unknown.

**Background Information:**

Mercer et al. (2009) suggested that Didemnum mats alter benthic-pelagic coupling and influence the biogeochemical cycling of many nutrients and elements by creating a physical barrier between the seafloor below the mats and the water column above. This physical barrier may influence dissolved oxygen exchange leading to hypoxic conditions in the sediment (Diaz and Rosenberg 1995).

Didemnum sp. could lower suspended organic particles in the water column while filter feeding (Lambert and Lambert 1998, qtd. in Daniel and Therriault 2007).

**Sources:**

Daniel and Therriault 2007 Diaz and Rosenberg 1995 Mercer et al. 2009

### 4.4 *Impact on high-value, rare, or sensitive species and/or communities*

**Choice: U** Unknown

**Score:** **of**

**Ranking Rationale:**

**Background Information:**

No information available in the literature.

**Sources:**

None listed

### 4.5 *Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice: D** No impact

**Score:** 0 **of** 2.5

**Ranking Rationale:**

To date, no diseases, parasites, or travelers have been reported for D. vexillum, and given its ecology, none would be expected.

**Background Information:**

No information available in the literature.

**Sources:**

None listed

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice: D** No impact

**Score:** 0 of 2.5

**High uncertainty?** ☑

**Ranking Rationale:**
To date, no impacts on genetic of native species have been reported for D. vexillum, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.7 Infrastructure*

**Choice: B** Moderate – Causes or has the potential to cause degradation to infrastructure, with moderate impact and/or within only a portion of the region

**Score:** 1.5 of 3

**Ranking Rationale:**
Abundant fouling species that can occur in large, thick mats.

**Background Information:**
Known to foul ships, fishing and diving gear, and infrastructure (docks, moorings). Reports of D. vexillum fouling are widespread, having been documented in New Zealand, both coasts of North America, and Europe (see Lambert 2009). Fouling by Didemnum spp. (likely D. vexillum) can be severe: in Ireland, colonies were frequently found as an overgrowing carpet that occupied up to several hundreds of square centimeters and extensive pendulous growths sometimes extended over 60 cm in length (Minchin and Sides 2006).

**Sources:**
Lambert 2009 Minchin and Sides 2006

### *4.8 Commercial fisheries and aquaculture*

**Choice: B** Moderate – Causes or has the potential to cause degradation to fisheries and aquaculture, with moderate impact in the region

**Score:** 1.5 of 3

**Ranking Rationale:**
By fouling bivalve shells and aquaculture gear, D. vexillum may have negative impacts on the shellfish industry. A recent study on Georges Bank found that D. vexillum had an overall positive effect on cod species (Smith et al. 2014).

**Background Information:**
Fouling by D. vexillum has been linked with slower mussel growth (Auker 2010; Fletcher et al. 2013c). D. vexillum mats were avoided by bay scallop larvae looking for a settlement substrate; in large numbers, D. vexillum may impact scallop recruitment (Morris et al. 2009). Colonies also foul coastal shellfish aquaculture gear, which increases maintenance costs (Morris et al. 2009). Indeed, a cost-benefit analysis in New Zealand conducted by Coutts and Spinner (2004) estimated that, if D. vexillum were to spread throughout the Marlborough Sounds area, it would foul about 10% of mussel lines within five years. They estimated that the cost to treat or replace fouled lines would reach $574 000 per year (Coutts and Spinner 2004). Managers and biologists are worried about the impacts that D. vexillum might have on gadid species (including haddock and Atlantic cod) in Georges Bank, where D. vexillum has spread extensively (Smith et al. 2014). For now, the overall effect on fish species appears positive, as fish eat organisms which are positively associated with D. vexillum mats (Smith et al.

**Sources:**
Auker 2010 Morris et al. 2009 Coutts and Sinner 2004 Fletcher et al. 2013c Smith et al. 2014

### 4.9 Subsistence

**Choice: B** Moderate – Causes or has the potential to cause degradation to subsistence resources, with moderate impact and/or within only a portion of the region

**Score:** 1.5 of 3

**Ranking Rationale:**
By fouling bivalve shells and gear, D. vexillum may have negative impacts on subsistence shellfish species.

**Background Information:**
Fouling by D. vexillum has been linked with slower mussel growth (Auker 2010; Fletcher et al. 2013c). D. vexillum mats were avoided by bay scallop larvae looking for a settlement substrate; in large numbers, D. vexillum may impact scallop recruitment (Morris et al. 2009).

**Sources:**
Morris et al. 2009 Auker 2010 Fletcher et al. 2013c

### 4.101 Recreation

**Choice: C** Limited – Has limited potential to cause degradation to recreation opportunities, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
Although this species may have a negative effect on bivalves, recreational harvesting of shellfish in the Bering Sea is limited.

**Background Information:**
Fouling by D. vexillum has been linked with slower mussel growth (Auker 2010; Fletcher et al. 2013c). D. vexillum mats were avoided by bay scallop larvae looking for a settlement substrate; in large numbers, D. vexillum may impact scallop recruitment (Morris et al. 2009). This species is also known to foul ships, fishing and diving gear, and infrastructure (docks, moorings).

**Sources:**
Auker 2010 Morris et al. 2009 Fletcher et al. 2013c

### 4.11 Human health and water quality

**Choice: D** No impact

**High uncertainty?** ☑

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on human health and water quality have been reported for D. vexillum, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 10.5 |
| **Section Total - Possible Points:** | 27.5 |
| **Section Total -Data Deficient Points:** | 2.5 |

## 5. Feasibility of prevention, detection and control

### *5.1 History of management, containment, and eradication*

**Choice:** **A** Attempted; control methods are not successful

**Score:** of

**Ranking Rationale:**

All control efforts have met with limited success.

**Background Information:**

In New Zealand, local scale eradication of D. vexillum was attempted at Shakespeare Bay without success (Coutts and Forrest 2007). However, a sustained (2006–2008) intensive surveillance and eradication program was set up afterwards and obtained a substantial reduction or eradication of populations in the Marlborough Sounds area, together with an almost complete lack of vessel infestation (and thus potential for further spread) (Forrest and Hopkins 2013).

An eradication attempt in Holyhead Marina (Wales, UK) was not successful, as D. vexillum was found a few months over a much larger proportion of the marina than had been detected earlier (Holt and Cordingley 2011).

In Sitka, AK, initial treatments have not succeeded in eradicating D. vexillum from Whiting Harbour, but it is contained to the area where it was first discovered, and the northernmost discrete population was not detected during 2016 surveys. Monitoring and treatment experiments are ongoing.

Regional eradication is unlikely, but may be possible at smaller scales.

**Sources:**

Coutts and Forrest 2007   Davis 2016   Dijkstra 2009   Forrest and Hopkins 2013   Holt and Cordingley 2011   Ordonez et al. 2015

### 5.2 *Cost and methods of management, containment, and eradication*



**Choice:** **B** Major short-term and/or moderate long-term investment

**Score:** of

**Ranking Rationale:**

Effective control methods are still in development.

**Background Information:**

Several methods of control have been tested. Chemical methods have been used to prevent infestation of D. vexillum on oyster and mussel lines. The two most effective treatments were dipping lines in a solution of bleach (0.5%) or hydrated lime (1–5%) for 2-5 minutes (Rolheiser et al. 2012; Muñoz and McDonald 2014). The latter treatment resulted in the greatest reduction of D. vexillum biomass (>90%) and maximum survival rate (>80%) of the farmed oysters.

In British Columbia, both chemical (4% hydrated lime) and physical removal methods reduced D. vexillum fouling on Pacific oysters by 85 to 96%; however, the reduction in D. vexillum fouling freed up space that allowed botryllid invasive species to establish (Switzer et al. 2011).

Structures such as pylons and floating pontoons can be treated in highly concentrated acetic acid (20%) to prevent fouling from D. vexillum. Acetic acid is inexpensive and presents a low environmental risk (highly soluble in water) compared to other chemicals. Encapsulation of structures has been proven to be the most effective method for the eradication of D. vexillum if anoxic conditions are achieved. The time required to achieve full eradication depends on the type of affected structure (e.g. size, surface characteristics). For example, for pylons and vessels, eradication can be achieved in 7 days, while for infected seabed it might take up to 14 days. However, this method, like many other control methods, is indiscriminate (non-target specific) and is likely to kill all the organisms attached to the structure (Muñoz and McDonald 2014).

In Sitka, AK, aquarium-scale immersion experiments were conducted using six different treatments: freshwater, brine (62ppt salinity), hypoxia, 10% acetic acid, and 1% bleach (McCann et al. 2013). Continuous immersion in a brine solution with at least twice the salinity of ambient seawater produced 100% mortality after 24 h and 98% die-back after four hours (McCann et al. 2013). However, achieving such treatment at larger scales still needs to be evaluated, when considering application of larger spatial scale in a complex habitat that is porous and difficult to isolate from the surrounding waters (McCann et al. 2013). Indeed, larger-scale attempts in 2015 reveal the difficulties of extrapolating aquarium experiments to the open environment of the seafloor (Davis 2015).

**Sources:**

Davis 2016   McCann et al. 2013   Muñoz and McDonald 2014   Rolheiser et al. 2012   Switzer et al. 2011

### 5.3 *Regulatory barriers to prevent introductions and transport*

**Choice:** **B** Regulatory oversight, but compliance is voluntary

**Score:** of

**Ranking Rationale:**
Alaska and New Zealand have regulations in place.

**Background Information:**
In New Zealand, a sustained (2006–2008) intensive surveillance and eradication program was set up afterwards and obtained a substantial reduction or eradication of populations in the Marlborough Sounds area (Forrest and Hopkins 2013).

Since its discovery in 2010 in Sitka, AK, monitoring and control attempts have been ongoing. As of 2016, D. vexillum remains contained within Whiting Harbour.
No regulations are currently in place to prevent the spread of invasive species via ship fouling or transport in sea chests. Given the short-lived larval phase, transport in ballast water is unlikely.

**Sources:**
Davis 2016   Forrest and Hopkins 2013   McCann et al. 2013

### 5.4 *Presence and frequency of monitoring programs*

**Choice:** **D** State and/or federal monitoring programs exist, and monitoring is conducted frequently

**Score:** of

**Ranking Rationale:**
The Alaska Department of Fish & Game has been closely monitoring and controlling D. vexillum with some success.

**Background Information:**
Since its discovery in 2010 in Sitka, AK, monitoring and control attempts have been ongoing. As of 2016, D. vexillum remains contained within Whiting Harbour (McCann et al. 2013; Davis 2016).

**Sources:**
Davis 2016   McCann et al. 2013

### 5.5 *Current efforts for outreach and education*

**Choice:** **C** Educational materials are available and outreach occurs only sporadically in the Bering Sea or adjacent regions

**Score:** of

**Ranking Rationale:**
Educational material are available for D. vexillum, but outreach only occurs sporadically.

**Background Information:**
The Invasive Tunicate Network and the Kachemak Bay National Estuarine Research Reserve (KBNERR) provide training opportunities for identifying and detecting non-native fouling organisms, and public education events on coastal and marine ecosystems more generally. "Bioblitzes" were held in Southeast AK in 2010 and 2012; these events engage and educate the public on marine invasive species. Field identification guides for native and non-native tunicates, as well as common fouling organisms, are readily available.

**Sources:**
iTunicate Plate Watch 2016

**Section Total - Scored Points:**
**Section Total - Possible Points:**
**Section Total -Data Deficient Points:**

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# Bering Sea Marine Invasive Species Assessment

## Alaska Center for Conservation Science

**Scientific Name:** *Diplosoma listerianum*

**Common Name** *compound sea squirt*

| | |
|---|---|
| **Phylum** | Chordata |
| **Class** | Ascidiacea |
| **Order** | Aplousobranchia |
| **Family** | Didemnidae |

**Final Rank** 52.75

**Data Deficiency:** 0.00

### Species Occurrence by Ecoregion

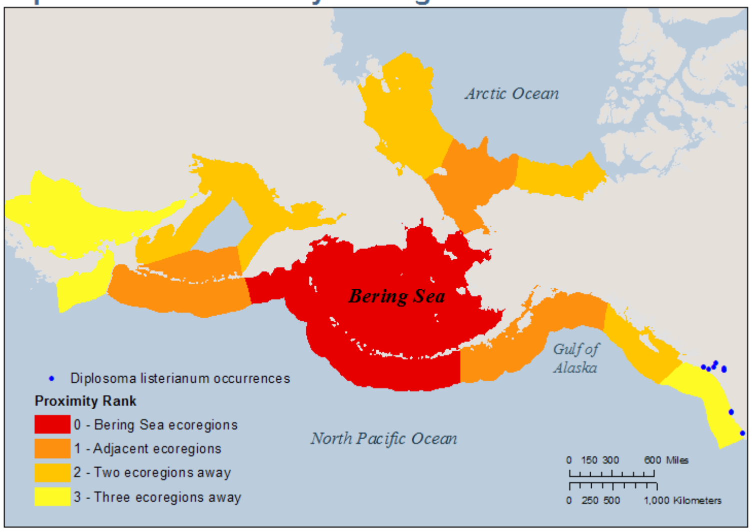


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

### Category Scores and Data Deficiencies

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 21.25 | 30 | 0 |
| Anthropogenic Influence: | 6.75 | 10 | 0 |
| Biological Characteristics: | 19.5 | 30 | 0 |
| Impacts: | 5.25 | 30 | 0 |
| **Totals:** | 52.75 | 100.00 | 0.00 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | -0.6 | Minimum Salinity (ppt) | 18 |
| Maximum Temperature (°C) | 30 | Maximum Salinity (ppt) | 40 |
| Minimum Reproductive Temperature (°C) | 15 | Minimum Reproductive Salinity (ppt) | 31* |
| Maximum Reproductive Temperature (°C) | NA | Maximum Reproductive Salinity (ppt) | 35* |

### Additional Notes

D. listerianum likely refers to a complex of colonial tunicates that grow as thin, white mats on substrates and organisms. Their native range is uncertain, but they have likely been introduced to several regions including both coasts of North America, Hawaii, New Zealand, and South Africa. D. listerianum can foul cultivated shellfish and aquaculture equipment, as well as compete with other tunicates and benthic invertebrates.

**Reviewed by** Jennifer Dijkstra, Research Assistant Professor, School of Marine Science and Ocean Engineering, University of New Hampshire, Durham, NH

**Review Date:** 9/26/2017

# 1. Distribution and Habitat

### *1.1 Survival requirements - Water temperature*

**Choice:** **B** Moderate overlap – A moderate area (≥25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 2.5 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Temperatures required for year-round survival occur in a moderate area (≥25%) of the Bering Sea. Thresholds are based on geographic distribution, which may not represent physiological tolerances; moreover, models disagree with respect to their estimates of suitable area. We therefore ranked this question with "High uncertainty".

**Background Information:**
Based on this species' geographic distribution, temperature threshold is estimated to be between -0.6°C and 30.1°C (Zerebecki and Sorte 2011; Lord et al. 2015; Lord 2017). Sorte et al. (2011) conducted experiments on two different North American populations, and reported LT50 values of 29.1°C and 27.9°C for east coast (Massachusetts) and west coast (California) populations, respectively.

**Sources:**
Zerebecki and Sorte 2011 Lord 2017 Sorte et al. 2011 Lord et al. 2015

### *1.2 Survival requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea. Thresholds are based on geographic distribution, which may not represent physiological tolerances.

**Background Information:**
The salinity threshold for survival of D. listerianum is between 18 to 40 ppt (Fofonoff et al. 2003). In Shark Bay, Australia, colonies were retrieved from fouling plates at two sites with salinities between 38 and 42 ppt (Wyatt et al. 2005). The lower salinity threshold cited by Fofonoff et al. (2003) is based on the typical salinity of the Black Sea, where D. listerianum is established (Koukouras et al. 1995, qtd. in Fofonoff et al. 2003). Studies on other populations suggest that D. listerianum may be less tolerant of low salinities. In an experiment on cultured populations from Wales, 64% and 92% of colonies died after seven days when exposed to constant salinities of 27 and 20 ppt; mortality was 100% for both treatments after 10 days (Gröner et al. 2011). In contrast, colonies exposed to 34 ppt showed positive growth and negligible mortality over 14 days (Gröner et al. 2011).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Wyatt et al. 2005 Gröner et al. 2011

### 1.3 *Establishment requirements - Water temperature*

**Choice: D** — No overlap – Temperatures required for reproduction do not exist in the Bering Sea

**Score:** 0 of 3.75

**High uncertainty?** ☑

**Ranking Rationale:**
Temperatures required for reproduction do not exist in the Bering Sea. Thresholds are not based on physiological tolerances; we therefore ranked this question with "High uncertainty".

**Background Information:**
Sexual reproduction and larval development have been successfully conducted at temperatures between 16°C and 18°C (reviewed in Ryland and Bishop 1990). Minimum reproductive temperature for D. listerianum is 15°C (based on water temperature when larvae are released; Brunetti et al. 1988 qtd. in Fofonoff et al. 2003). This species depends on annual recruitment for population establishment. Osman et al. (2010) observed nearly complete recruitment failure when mean winter sea temperatures were below 4°C. Stachowicz et al. (2002) found a strong relationship between onset of recruitment and springtime (March 1st) water temperatures in Connecticut. D. listerianum recruited earlier in years when temperatures were warmer. For example, recruitment began as early as mid-May when temperatures were ~5°C, and as late as early October when March temperatures were 2.5°C (mean onset date: July 10th; Stachowicz et al. 2002).

**Sources:**
Osman et al. 2010   NEMESIS; Fofonoff et al. 2003   Ryland and Bishop 1990   Stachowicz et al. 2002

### 1.4 *Establishment requirements - Water salinity*

**Choice: A** — Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 of 3.75

**High uncertainty?** ☑

**Ranking Rationale:**
Although exact salinity thresholds are unknown, this species is a marine organism that requires salinities > 27 ppt to survive and grow. We assume that this species can reproduce and develop in saltwater from 31 to 35 ppt; these salinities occur in a large (>75%) portion of the Bering Sea.

**Background Information:**
In an experiment on cultured populations from Wales, colonies exposed to ambient seawater (34 ppt) showed positive growth and negligible mortality over 14 days (Gröner et al. 2011). In contrast, colonies exposed to constant salinities of 27 and 20 ppt exhibited no or negative growth and high mortality rates (Gröner et al. 2011).

**Sources:**
Gröner et al. 2011

### 1.5 *Local ecoregional distribution*

**Choice: D** — Present in an ecoregion greater than two regions away from the Bering Sea

**Score:** 1.25 of 5

**Ranking Rationale:**

**Background Information:**
Found in Peter the Great Bay (Sea of Japan, southern Russia), and on Vancouver Island, B.C.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.6 Global ecoregional distribution*



**Choice:** **A** In many ecoregions globally

**Score:** 5 of 5

**Ranking Rationale:**
Wide global distribution.

**Background Information:**
Found on both the east and west coasts of North America, Central America, and South America. In Europe, occurs from Norway to the Mediterranean, and east to the Red Sea. Found in South Africa, Madagascar, and Tanzania. In Asia, occurs from Peter the Great Bay in southern Russia to Hong Kong, as well as in India. Found in Australia and New Zealand, and Pacific islands including Fiji, Tahiti, and Hawaii.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.7 Current distribution trends*

**Choice:** **A** Recent rapid range expansion and/or long-distance dispersal (within the last ten years)

**Score:** 5 of 5

**Ranking Rationale:**
Evidence of rapid range expansion in northern Europe.

**Background Information:**
Although natural long-distance dispersal is limited in this species, its reproductive characteristics and fast growth rates suggest that rapid expansion and colonization of new habitats is possible (Vance et al. 2009; Marshall et al. 2003; Pérez-Portela et al. 2013). Recent range expansions have likely occurred in the UK and the Netherlands (Gittenberger et al. 2007; Vance et al. 2009).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Marshall et al. 2003 Pérez-Portela et al. 2013 Vance et al. 2009 Gittenberger 2007

| | |
|---|---|
| **Section Total - Scored Points:** | 21.25 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 2. Anthropogenic Transportation and Establishment

### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice: A** Has been observed using anthropogenic vectors for transport and transports independent of any anthropogenic vector once introduced

**Score:** 4 of 4

**Ranking Rationale:**
Can be transported through hull fouling and by attaching to natural rafts.

**Background Information:**
Hull fouling is suspected as a form of transportation (Pérez-Portela et al. 2013). Low-survival of larvae is expected in ballast water due to their short free-swimming stage. Adults are mostly sessile, but colonies attached to natural "rafts" (e.g. sea grass, drifting wood) can be transported variable distances without the use of anthropogenic vectors.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Pérez-Portela et al. 2013

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice: B** Readily establishes in areas with anthropogenic disturbance/infrastructure; occasionally establishes in undisturbed areas

**Score:** 2.75 of 4

**Ranking Rationale:**
Introductions largely associated with anthropogenic influences.

**Background Information:**
This species is primarily found in harbors and attached to artificial structures (Pérez-Portela et al. 2013). Modelling exercises suggest that D. listerianum is resilient to local and regional disturbances (Munguia et al. 2010), and that disturbance may actually increase its spread (Altman and Whitlatch 2007). Anthropogenic development of coastal areas may promote Diplosoma-dominated communities (Osman et al. 2010).

**Sources:**
Pérez-Portela et al. 2013 Munguia et al. 2010 Altman and Whitlatch 2007 Osman et al. 2010

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice: B** No

**Score:** 0 of 2

**Ranking Rationale:**

**Background Information:**
D. listerianum is not currently farmed or cultivated.

**Sources:**
None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 6.75 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics



### 3.1 *Dietary specialization*

**Choice:** **A**

Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 **of** 5

**Ranking Rationale:**
Phytoplankton is an abundant food source in the Bering Sea.

**Background Information:**
D. listerianum is a suspension feeder that eats phytoplankton. The larval stage is non-feeding.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Pérez-Portela et al. 2013

### 3.2 *Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **A**

Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 **of** 5

**Ranking Rationale:**
Tolerant of a wide range of temperatures and salinities.

**Background Information:**
Tolerates a wide range of temperatures and salinity regimes, although its ability to tolerate brackish waters may be limited or require acclimation (Fofonoff et al. 2003; Gröner et al. 2011). A field experiment by Dijkstra et al. (2007a) found that D. listerianum grew on panels placed in both fouling and natural (benthic) habitats, and grew on all panel types (panels varied in terms of orientation and water depth).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Dijkstra et al. 2007a Gröner et al. 2011

### 3.3 *Desiccation tolerance*

**Choice:** **C**

Little to no tolerance (<1 day) of desiccation during its life cycle

**Score:** 1.75 **of** 5

**High uncertainty?** ☑

**Ranking Rationale:**

**Background Information:**
Tunicates in general have little to no desiccation tolerance (Pleus et al. 2008).

**Sources:**
Pleus et al. 2008

### 3.4 *Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice:** **A** High – Exhibits three or four of the above characteristics

**Score:** 5 **of** 5

**Ranking Rationale:**

Asexual reproduction, high fecundity, low parental investment, short generation time.

**Background Information:**

D. listerianum has both sexual and asexual reproduction. Asexual reproduction occurs through budding, and produces colonies of genetically identical zooids. Zooids are hermaphroditic. Sperm are released externally, but fertilization is internal. Populations can have between 1 to 3 generations per year, and can produce larvae in 2-4 weeks after settlement (Millar 1954, qtd. in Fofonoff et al. 2003). The complete life cycle from settlement to death ranged from 12 to 18 months (Millar 1952, qtd. in Mackenzie 2011). Fertilization can occur even with low levels of sperm concentrations (Bishop 1998).

**Sources:**

NEMESIS; Fofonoff et al. 2003 Bishop 1998 Dijkstra 2009 Mackenzie 2011

### 3.5 *Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice:** **C** Disperses short (< 1 km) distances

**Score:** 0.75 **of** 2.5

**High uncertainty?** ☑

**Ranking Rationale:**

Information is lacking, but this species probably has limited natural dispersal potential given its short-lived larval stage and sessile adult life.

**Background Information:**

Several sources agree that D. listerianum has limited dispersal potential (Munguia et al. 2010; Munguia et al. 2011; Pérez-Portela et al. 2013). Adults are sessile, but creeping movements are possible (Sommerfeldt and Bishop 1999). Rafting on macroalgae and debris may transport colonies both long and short distances (Thiel and Gutow 2005). Free-swimming larval stage lasts only a few hours (<24 h). Marshall et al. (2003) found that delaying metamorphosis by 3 to 6 h had strong negative effects on post-metamorphic growth. Similarly, short (<3 h) periods of larval swimming depleted energy reserves by almost 25%; the high cost of active swimming may limit larval dispersal (Bennett and Marshall 2005).

**Sources:**

Dijkstra 2009 Bennet and Marshall 2005 Sommerfeldt and Bishop 1999 Munguia et al. 2011 Marshall et al. 2003 Pérez-Portela et al. 2013 Munguia et al. 2010 Thiel and Gutow 2005

### *3.6 Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice:** **C** Low – Exhibits none of the above characteristics

**Score:** **0.75** **of** **2.5**

**Ranking Rationale:**

Active dispersal is only possible during short-lived larval stage. Eggs are brooded internally and adults are mostly sessile.

**Background Information:**

Sperm is viable for several hours (up to 24 hours; Bishop 1998), and sperm can be retained in oviducts for weeks (Pérez-Portela et al. 2013). Eggs are fertilized internally and brooded until ready to be released as larvae. Larvae are capable of free-swimming, but short-lived (< 24 hours). Adults are largely sessile, but natural dispersal of fragments (e.g. by rafting on kelp) is possible (Thiel and Gutow 2005).

**Sources:**

Bishop 1998 Thiel and Gutow 2005 Pérez-Portela et al. 2013

### *3.7 Vulnerability to predators*

**Choice:** **D** Multiple predators present in the Bering Sea or neighboring regions

**Score:** **1.25** **of** **5**

**Ranking Rationale:**

Numerous predators, many of which exist in the Bering Sea or nearby ecoregions.

**Background Information:**

In its introduced range, D. listerianum is preyed upon by several species, including snails (Mitrella lunata and Anachis lafrashnayi), blood stars (Henricia sanguinolenta), European green crab (Carcinus maenas), Japanese shore crab (Hemigrapsus sanguineus), portly spider crab (Libinia emarginata), Cunner (Tautogolabrus adspersus), lunar dovesnail (Astyris lunata), and well-ribbed dovesnail (Anachis lafresnayi) (Osman and Whitlatch 1995; Harris and Tyrrell 2001; Osman and Whitlatch 2004; Altman and Whitlatch 2007; Dijkstra et al. 2007a).

**Sources:**

Dijkstra 2009 Dijkstra et al. 2007a Altman and Whitlatch 2007 Harris and Tyrrell 2001 Osman and Whitlatch 1995 Osman and Whitlatch 2004 Mackenzie 2011

| | |
|---|---|
| **Section Total - Scored Points:** | 19.5 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 4. Ecological and Socioeconomic Impacts



### *4.1 Impact on community composition*

**Choice: C** Limited – Single trophic level; may cause decline but not extirpation

**Score:** 0.75 of 2.5

**Ranking Rationale:**
Can outcompete native species, especially on hard substrates.

**Background Information:**
In Long Island Sound, D. listerianum caused reduced recruitment for polychaetes (Spirorbis spp.), barnacles (Balanus spp.), and bryozoans (Bugula spp., Botryllus schlosseri, Botrylloides violaceus) (Osman and Whitlatch 1995). D. listerianum overgrows other fouling organisms on plates and panels, and few species are able to resist the overgrowth (Schmidt and Warner 1986; Agius 2007; Vance et al. 2009). When growing on algae, D. listerianum may block off light and prevent nutrient absorption (Harris and Tyrrell 2001).

**Sources:**
Agius 2007 Harris and Tyrrell 2001 Mackenzie 2011 Vance et al. 2009 NEMESIS; Fofonoff et al. 2003 Osman and Whitlatch 1995 Schmidt and Warner 1986

### *4.2 Impact on habitat for other species*

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
To date, no impacts on habitat for other species have been reported.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.3 Impact on ecosystem function and processes*

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
To date, no impacts on ecosystem function or processes have been reported, and given its ecology, none is expected.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.4 Impact on high-value, rare, or sensitive species and/or communities*

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
To date, no impacts on high-value, rare, or sensitive species have been reported.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 4.5 *Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice: C** Limited – Has limited potential to spread one or more organisms, with limited impact and/or within a very limited region

**Score:** 0.75 of 2.5

**High uncertainty?** ☑

**Ranking Rationale:**

**Background Information:**
Little is known about diseases affecting, or caused by, tunicates. There are records of copepods living parasitically inside ascidians (Ooishi 1998, qtd. in Mackenzie 2011).

**Sources:**
Mackenzie 2011

### 4.6 *Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
To date, no impacts on genetics of native species have been reported.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 4.7 *Infrastructure*

**Choice: B** Moderate – Causes or has the potential to cause degradation to infrastructure, with moderate impact and/or within only a portion of the region

**Score:** 1.5 of 3

**High uncertainty?** ☑

**Ranking Rationale:**
Moderate impacts on infrastructure are expected given its abundance as a fouling organism.

**Background Information:**
Abundant fouling organism on boats, marinas, buoys, floats, and other manmade structures (Lambert 2002). Fouling organisms on ships cause drag, reduce maneuverability, and increase fuel costs. It is estimated that hull fouling organisms cost the U.S. Navy over $50 million a year in fuel due to increased drag (Cleere 2001).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Lambert 2002   Cleere 2001

### 4.8 *Commercial fisheries and aquaculture*

**Choice:** **C** Limited – Has limited potential to cause degradation to fisheries and aquaculture, and/or is restricted to a limited region

**Score:** 0.75 of 3

**High uncertainty?** ☑

**Ranking Rationale:**
Known to foul cultivated shellfish, but its effects on shellfish are unknown.

**Background Information:**
D. listerianum has been reported fouling cultured shellfish in Brazil, United Kingdom, Croatia, Japan, and Hong Kong (Ross et al. 2004; Igic 1972; Arakawa 1990; Huang 2003 qtd. in Rocha et al. 2009). Colonies usually stop growing at the margin of the bivalve shells, and since it is very thin it is probably harmless to bivalve growth, but no studies have tested this hypothesis (Rocha et al. 2009).

The shellfish industry in Alaska is estimated at $1 million (Pacific Shellfish Institute). Aquaculture is important in the Gulf of Alaska, but only occurs in a limited portion of the Bering Sea (Mathis et al. 2015).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Rocha et al. 2009 Mathis et al. 2015 PSI Alaska 2017

### 4.9 *Subsistence*

**Choice:** **C** Limited – Has limited potential to cause degradation to subsistence resources, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**High uncertainty?** ☑

**Ranking Rationale:**
Known to foul cultivated shellfish, but its effects on shellfish and on subsistence harvesting are unknown.

**Background Information:**
The effects of D. listerianum on shellfish are unknown. In most municipalities of the Bering Sea, shellfish such as oysters, clams, and mussels comprise a small percentage of subsistence catch (< 5% when measured by weight, except for the Western Aleutians; Mathis et al. 2015).

**Sources:**
Mathis et al. 2015

### 4.101 *Recreation*

**Choice:** **C** Limited – Has limited potential to cause degradation to recreation opportunities, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**High uncertainty?** ☑

**Ranking Rationale:**
Although this species fouls shellfish species, the effects of this fouling are unknown. Recreational harvesting of shellfish in the Bering Sea is limited.

**Background Information:**
No information found.

**Sources:**
None listed

### *4.11 Human health and water quality*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on human health or water quality have been reported for D. listerianum, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 5.25 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 5. Feasibility of prevention, detection and control



### *5.1 History of management, containment, and eradication*

**Choice:** **C** Attempted; control methods are currently in development/being studied

**Score:** of

**Ranking Rationale:**
Methods to control tunicates are being studied.

**Background Information:**
Attempts to control invasive tunicates are ongoing (Carman et al. 2016). Several control methods are being tested and include high-pressure washing and cleaning with brine, freshwater or lime solutions (DFO 2010; Carman et al. 2016).

**Sources:**
DFO 2010 Carman et al. 2016

### *5.2 Cost and methods of management, containment, and eradication*

**Choice:** **B** Major short-term and/or moderate long-term investment

**Score:** of

**Ranking Rationale:**
Current methods to control tunicates require repeated treatments at moderate costs.

**Background Information:**
In PEI, chemical and water (brine and freshwater) treatments are applied to mussel socks to control fouling tunicates such as D. listerianum (Carman et al. 2016). Tunicates recolonized treated socks; repeated treatments are therefore required (Carman et al. 2016).

**Sources:**
Carman et al. 2016

### *5.3 Regulatory barriers to prevent introductions and transport*

**Choice:** **A** Little to no regulatory restrictions

**Score:** of

**Ranking Rationale:**
No species-specific regulations, but monitoring programs exist for invasive aquatic species.

**Background Information:**
Monitoring programs in New England and Canada are in place for detecting aquatic invasive species. These monitoring programs were responsible for early detection of D. listerianum in Quebec (Ma et al. 2016). In the Pacific Northwest, no regional organizations are currently tracking D. listerianum (Curran 2013). This species can be transported by hull fouling; compliance with fouling regulations is largely voluntary in the U.S. (Hagan et al. 2014).

**Sources:**
Curran 2013 Ma et al. 2016 Hagan et al. 2014

### *5.4 Presence and frequency of monitoring programs*



**Choice:** **B**

Surveillance takes place, but is largely conducted by non-governmental environmental organizations (e.g., citizen science programs)

**Score:** of

**Ranking Rationale:**

D. listerianum is monitored by volunteers from the Invasive Tunicate Network and KBNERR.

**Background Information:**

In Alaska, the Invasive Tunicate Network and KBNERR conduct monitoring for non-native tunicates and other invasive or harmful species. The programs involve teachers, students, outdoor enthusiasts, environmental groups and professional biologists to detect invasive species.

**Sources:**

iTunicate Plate Watch 2016

### *5.5 Current efforts for outreach and education*

**Choice:** **D**

Programs and materials exist and are readily available in the Bering Sea or adjacent regions

**Score:** of

**Ranking Rationale:**

Several programs in Alaska and Canada have training and educational materials for D. listerianum.

**Background Information:**

Alaska's Invasive Tunicate Network and the Kachemak Bay National Estuarine Research Reserve (KBNERR) provide training opportunities for identifying and detecting non-native tunicates, and public education events on coastal and marine ecosystems more generally. Southeast AK hosts an annual Marine Invasive Species Bioblitz, which engages the public through education and hands-on activities. Field identification guides for native and non-native tunicates, as well as common fouling organisms, are readily available. PEI Aquaculture Alliance and Salem Sound Coastwatch provide identification cards on their website. Also listed in the Aquatic Invasive Species identification booklet prepared by Fisheries and Oceans Canada.

**Sources:**

iTunicate Plate Watch 2016   FOC 2016   PEIAA 2016

**Section Total - Scored Points:**

**Section Total - Possible Points:**

**Section Total -Data Deficient Points:**

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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Molgula citrina*

**Common Name** *sea grape*

| | |
|---|---|
| **Phylum** | Chordata |
| **Class** | Ascidiacea |
| **Order** | Stolidobranchia |
| **Family** | Molgulidae |

**Final Rank** 53.15

**Data Deficiency:** 8.75

## Species Occurrence by Ecoregion

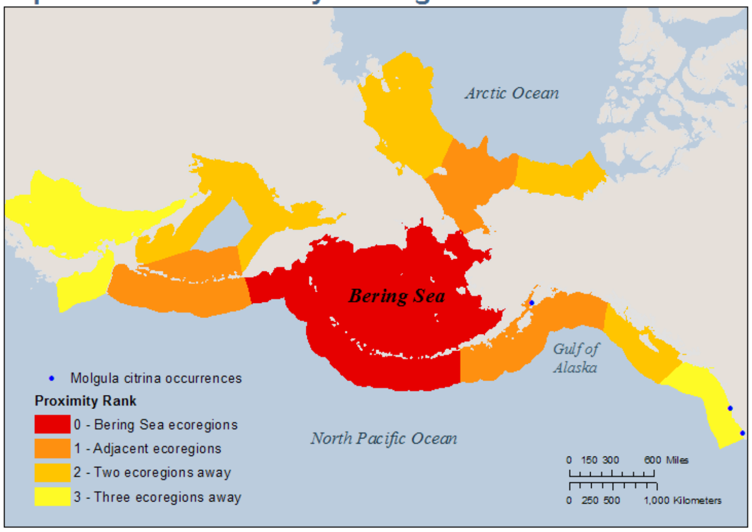


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 20.5 | 26 | 3.75 |
| Anthropogenic Influence: | 4.75 | 10 | 0 |
| Biological Characteristics: | 19.5 | 30 | 0 |
| Impacts: | 3.75 | 25 | 5.00 |
| **Totals:** | 48.50 | 91.25 | 8.75 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | -1.4 | Minimum Salinity (ppt) | 17 |
| Maximum Temperature (°C) | 12.2 | Maximum Salinity (ppt) | 35 |
| Minimum Reproductive Temperature (°C) | NA | Minimum Reproductive Salinity (ppt) | 31* |
| Maximum Reproductive Temperature (°C) | NA | Maximum Reproductive Salinity (ppt) | 35* |

### Additional Notes

M. citrina is a prominent member of the fouling community. It is widely distributed in the North Atlantic, and has been reported as far north as 78°N (Lambert et al. 2010). In North America, it has been found from eastern Canada to Massachusetts. In 2008, it was found in Kachemak Bay in Alaska, the first time it had been detected in the Pacific Ocean (Lambert et al. 2010). While it is possible that these individuals are native to AK, preliminary DNA results suggest that they are genetically identical to specimens of the NE Atlantic. It may have been transported through the Arctic Ocean as biofouling in a heated part of the ship (Fofonoff et al. 2003).

**Reviewed by** Christina Simkanin, Marine Invasions Lab, Smithsonian Environmental Research Center, Edgewater MD

**Review Date:** 9/15/2017

# 1. Distribution and Habitat

### *1.1 Survival requirements - Water temperature*

**Choice:** **B** Moderate overlap – A moderate area (≥25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 2.5 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Temperatures required for year-round survival occur in a moderate area (≥25%) of the Bering Sea. We ranked this question with "High Uncertainty" to indicate disagreements in model estimates.

**Background Information:**
Based on observations, temperature range for survival of M. citrina - 1.4°C to 12.2°C (EOL).

**Sources:**
EOL 2016 Lambert et al. 2010 Bursch and McCann 2016

### *1.2 Survival requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
Based on observations, salinity range for survival of M. citrina is 17 ppt to 35 ppt.

**Sources:**
Lambert et al. 2010 NEMESIS; Fofonoff et al. 2003

### *1.3 Establishment requirements - Water temperature*

**Choice:** **U** Unknown/Data Deficient

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *1.4 Establishment requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Although salinity thresholds are unknown, this species is a marine organism that does not require freshwater to reproduce. We therefore assume that this species can reproduce in saltwater (31 to 35 ppt). These salinities occur in a large (>75%) portion of the Bering Sea.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *1.5 Local ecoregional distribution*

**Choice: B** Present in an ecoregion adjacent to the Bering Sea

**Score:** 3.75 of 5

**Ranking Rationale:**

**Background Information:**
Found in Kachemak Bay, Alaska. On the North American Pacific coast, has also been found in Oregon and northern California.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.6 Global ecoregional distribution*

**Choice: C** In few ecoregions globally

**Score:** 1.75 of 5

**Ranking Rationale:**

**Background Information:**
Largely restricted to polar and cold temperate ecoregions, from ~ 78°N to 39°N. May be more widespread, but data is sparse.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.7 Current distribution trends*

**Choice: A** Recent rapid range expansion and/or long-distance dispersal (within the last ten years)

**Score:** 5 of 5

**Ranking Rationale:**

**Background Information:**
Potential for long-distance dispersal, but perhaps only in light of anthropogenic vectors. Since discovery in AK in 2008, has been found in OR and CA. If these are new introductions, suggests expansion towards study area.

**Sources:**
Lambert et al. 2010

| | |
|---|---|
| **Section Total - Scored Points:** | 20.5 |
| **Section Total - Possible Points:** | 26.25 |
| **Section Total -Data Deficient Points:** | 3.75 |

## 2. Anthropogenic Transportation and Establishment

### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice: B** Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 of 4

**Ranking Rationale:**

Free-swimming larval stage is very short (≤2 hours), most transportation likely occurs from attaching to anthropogenic vectors.

**Background Information:**

Transport in ship ballast water is unlikely, because the free-swimming tadpole stage is very short (minutes to maybe a few hours) (Lambert et al. 2010). A more likely vector is transport through sea chests. M. citrina probably could not survive a ship's passage through the warm waters of the Caribbean and Panama Canal, but it could survive a trip across the NW Passage – which, the authors suggest, is how M. citrina arrived in Alaska (Lambert et al. 2010). The NW Passage is expected to become an increasingly popular shipping route as conditions warm and the passage remains ice-free for longer periods of time.a

**Sources:**

Lambert et al. 2010

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice: B** Readily establishes in areas with anthropogenic disturbance/infrastructure; occasionally establishes in undisturbed areas

**Score:** 2.75 of 4

**High uncertainty?** ✔

**Ranking Rationale:**

Short dispersal potential. Lack of information about spread and spatial distribution pattern of M. citrina. Unsure if M. citrina can establish in natural areas once it has been introduced.

**Background Information:**

In its native range, M. citrina attaches on a variety of substrates, including mussels, hydroids, and red algae (Railkin and Dysina 1997). A study along the Mediterranean coast, where it is introduced, found that non-native tunicates were abundant in most of the 32 surveyed harbors (López-Legentil et al. 2015).

**Sources:**

Lopez-Legentil et al. 2015 Railkin and Dysina 1997

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice: B** No

**Score:** 0 of 2

**Ranking Rationale:**

**Background Information:**

M. citrina is not currently farmed or intentionally cultivated.

**Sources:**

None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 4.75 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics



### *3.1 Dietary specialization*

**Choice:** **A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Consumes numerous taxa.

**Background Information:**
Tunicates in general are suspension feeders and feed on diatoms, detritus, and invertebrate larvae. Short-lived larval form is non-feeding.

**Sources:**
O'Clair and O'Clair 1998

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **A** Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 of 5

**Ranking Rationale:**

**Background Information:**
Habitat is restricted to rocky, unstructured bottom, marinas and docks, which is plentiful in the Bering Sea.

**Sources:**
O'Clair and O'Clair 1998

### *3.3 Desiccation tolerance*

**Choice:** **C** Little to no tolerance (<1 day) of desiccation during its life cycle

**Score:** 1.75 of 5

**Ranking Rationale:**

**Background Information:**
Tunicates in general have little to no desiccation tolerance (Pleus 2008)

**Sources:**
Pleus 2008

### *3.4 Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice:** **A** High – Exhibits three or four of the above characteristics

**Score:** 5 of 5

**Ranking Rationale:**
Hermaphroditic with self-fertilization possible, short generation time, moderate parental investment (brood eggs before releasing tadpole juveniles)

**Background Information:**
M. citrina broods its young (Lambert et al. 2010), but there is no parental investment once the larvae are released. Solitary tunicates (such as M. citrina) do not reproduce asexually (i.e. through budding, O'Clair and O'Clair 1998).
General info: Ascidians are hermaphroditic, and self-fertilization is possible. Many species common in fouling communities grow rapidly and reach sexual maturity within just a few weeks (Lambert and Lambert 1998). The lifespan of 4 solitary tunicate species in Connecticut, including the closely related M. manhattensis, all had a lifespan between 1-2 years (Team Benthos).
Tunicates have a relatively short generation time (e.g. Thalia democratica; Heron 1972).

**Sources:**
Heron 1972 Lambert and Lambert 1998 Lambert et al. 2010 O'Clair and O'Clair 1998 Team Benthos 2016

### *3.5 Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice:** **C** Disperses short (< 1 km) distances

**Score:** 0.75 of 2.5

**Ranking Rationale:**
Larva have a short free-swimming stage that permits dispersal distances of less than 1 km. Adults are sessile and transport only if their substrate is moved (e.g. floating eel grass beds, ship hulls, etc.).

**Background Information:**
M. citrina has a free-swimming larval stage that lasts ≤ 2 hours (Lambert et al. 2010). A study on a tropical tunicate Lissoclinum patella suggests that larvae of these species have a potential dispersal distance of several hundred meters (dependent on speed of currents), but their realized dispersal is <10m (Olson and McPherson 1987).
Adults are sessile, but a study on a colonial species complex Botrylloides sp. suggested that adults can travel over 200 times farther than swimming larvae by rafting on drifting eelgrass (Worcester 1994).

**Sources:**
Lambert et al. 2010 Olson and McPherson 1987 Worcester 1994

### *3.6 Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice:** **C** — Low – Exhibits none of the above characteristics

**Score:** 0.75 of 2.5

**Ranking Rationale:**
Larvae are mobile for ~2 hours, adults are sessile.

**Background Information:**
Although free-swimming larval stage is very short (≤2 hours), post-metamorphosis juveniles could survive attached in sea chests or free-floating in ballast water (Lambert et al. 2010). Lambert et al. (2010) suggests that M. citrina could survive in these human environments for generations and sustain a viable population with which to invade new habitats. Though sessile, adults can disperse through rafting (e.g. on vegetation) or attachment to moveable substrates such as boats and fishing gear.

**Sources:**
Lambert et al. 2010

### *3.7 Vulnerability to predators*

**Choice:** **D** — Multiple predators present in the Bering Sea or neighboring regions

**Score:** 1.25 of 5

**Ranking Rationale:**
Numerous predators, many of which exist in the Bering Sea.

**Background Information:**
Tunicates predators include flatworms, mollusks, crabs, sea stars, and some fishes.
Study on a tropical tunicate Lissoclinum patella: larvae are heavily predated upon by fish and corals (Olson and McPherson 1987).

**Sources:**
Olson and McPherson 1987 O'Clair and O'Clair 1998

| | |
|---|---|
| **Section Total - Scored Points:** | 19.5 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

# 4. Ecological and Socioeconomic Impacts

### *4.1 Impact on community composition*

**Choice:** **C** Limited – Single trophic level; may cause decline but not extirpation

**Score:** 0.75 of 2.5

**Ranking Rationale:**

**Background Information:**
A study on invasive tunicates (not including M. citrina), found that, although tunicates were feeding on similar resources as commercial shellfish species and native tunicates, tunicates did not have a measurable impact on the food web (Colarusso et al. 2016). No ecological impacts have been reported for M. citrina.

**Sources:**
Colarusso et al. 2016

### *4.2 Impact on habitat for other species*

**Choice:** **D** No impact

**High uncertainty?** ☑

**Score:** 0 of 2.5

**Ranking Rationale:**

**Background Information:**
No ecological impacts have been reported for M. citrina (Foffonoff et al. 2003)

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.3 Impact on ecosystem function and processes*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No measurable impacts on ecosystem function or processes have been reported for M. citrina.

**Background Information:**
A study on invasive tunicates (not including M. citrina), found that, although tunicates were feeding on similar resources as commercial shellfish species and native tunicates, tunicates did not have a measurable impact on the food web (Colarusso et al. 2016). No ecological impacts have been reported for M. citrina.

**Sources:**
Colarusso et al. 2016   Lambert and Lambert 1998

### *4.4 Impact on high-value, rare, or sensitive species and/or communities*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No ecological impacts have been reported for M. citrina.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.5 Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.7 Infrastructure*

**Choice:** **B** Moderate – Causes or has the potential to cause degradation to infrastructure, with moderate impact and/or within only a portion of the region

**Score:** 1.5 of 3

**Ranking Rationale:**
M. citrina is a fouling organism that grows on industrial surfaces.

**Background Information:**
Ascidians in general contribute to the economic and technical problems of marine biofouling because of their growth on the surfaces of industrial objects, such as ships, buoys, and fishing nets (Feng et al. 2010). In Alaska, M. citrina was found attached to docks and ropes.

**Sources:**
Feng et al. 2010

## 4.8 *Commercial fisheries and aquaculture*



**Choice:** **B**

Moderate – Causes or has the potential to cause degradation to fisheries and aquaculture, with moderate impact in the region

**Score:** 1.5 of 3

**Ranking Rationale:**
Has been known to have a limited impact for farmed mussels outsite of Alaska. Acts as a biofouling agent which decreases the efficiency of fisheries vessels.

**Background Information:**
In PEI, tunicates in general are a nuisance to the mussel farming industry. The solitary vase tunicate Ciona intestinalis overtakes mussel socks (where mussels are grown), competing for food and increasing costs through fouling and increased sock weight. In Massachusetts, invasive tunicates (not including M. citrina) competed with farmed mussels (and scallops), leading to a reduction in shell growth and tissue weight, and a resulting negative impact on farm productivity and profitability (Carman et al. 2016). No information on the effects of M. citrina specifically.

**Sources:**
Carman et al. 2016   DFO 2010

## 4.9 *Subsistence*

**Choice:** **D**

No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on subsistence have been reported for M. citrina, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

## 4.101 *Recreation*

**Choice:** **D**

No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on recreation have been reported for M. citrina, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

## 4.11 *Human health and water quality*

**Choice:** **D**

No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on human health and/or water quality have been reported for M. citrina.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 3.75 |
| **Section Total - Possible Points:** | 25 |
| **Section Total -Data Deficient Points:** | 5 |

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# 5. Feasibility of prevention, detection and control



## *5.1 History of management, containment, and eradication*

**Choice:** **C**

Attempted; control methods are currently in development/being studied

**Score:**

of

**Ranking Rationale:**

Containment and mitigation methods have been studied, tested and proven effective for several species of non-native, fouling tunicates.

**Background Information:**

Containment and mitigation methods for tunicates have been studies and trialed in Prince Edward Island, Canada by the Department of Fisheries and Oceans and the aquaculture industry (DFO 2010). Mitigation techniques have been tested on several species including Ciona intestinalis and Styela clava. Techniques and include high-pressure nozzles to wash off or pierce hull fouling tunicates, and the delivery of a lime solution to mussel socks infested with S. clava. Lime treatment caused mortality in approximately 90% of S. clava individuals, and a one-time spray application of hydrated lime on mussels may be sufficient to reduce tunicate fouling to a manageable level (DFO 2010).

**Sources:**

DFO 2010

## *5.2 Cost and methods of management, containment, and eradication*

**Choice:** **C**

Easy and inexpensive (minor investment)

**Score:**

of

**Ranking Rationale:**

Deployment of lime solutions and/or high pressure water treatments are not time intensive and are relatively inexpensive.

**Background Information:**

Control methods for non-native, fouling tunicates are currently being researched. These tunicates have been successfully controlled in some cases using chemicals (e.g. salt or lime solutions), or high-pressure washing (DFO 2010; AISU 2011). Tunicates have also been physically removed off vessel hulls. Because mortality is not 100%, eradication is likely not a realistic option, but under certain scenarios populations may be controlled to reasonable levels (DFO 2010).

**Sources:**

AISU 2011 DFO 2010

### 5.3 Regulatory barriers to prevent introductions and transport

**Choice: B** Regulatory oversight, but compliance is voluntary

**Score:** of

**Ranking Rationale:**

In Alaska, there are regulations in place for the transport of bivalve species, via which M. citrina can be unintentionally transported. U.S. federal regulations require mandatory reporting and ballast water treatment or exchange, but compliance with hull fouling regulations - another transport vector for this species - are largely voluntary.

**Background Information:**

In Canada, Fisheries and Oceans Canada's require a license to move bivalves from tunicate infested waters. This regulation has been successful in containing and slowing the anticipated spread of several tunicate species, which can be unintentionally transported through their association with bivalves (DFO 2010). Similar regulations exist in Alaska regarding the transport and introduction of shellfish in water bodies. Under Alaska law, a permit must be obtained from the Alaska Department of Fish and Game (ADF&G) in order to collect, possess, or transport shellfish for educational, scientific, or propagative uses (AAC 2017). Ballast water management is mandatory and regulated by the U.S. Coast Guard (CFR 33 § 151.2), but compliance with ship fouling regulations are largely voluntary (Hagan et al. 2014).

**Sources:**

DFO 2010 Hagan et al. 2014 CFR 2017 AAC 2017

### 5.4 Presence and frequency of monitoring programs

**Choice: B** Surveillance takes place, but is largely conducted by non-governmental environmental organizations (e.g., citizen science programs)

**Score:** of

**Ranking Rationale:**

Invasive tunicates are monitored by volunteers from the Invasive Tunicate Network and KBNERR.

**Background Information:**

In Alaska, the Invasive Tunicate Network and KBNERR conduct monitoring for non-native tunicates and other invasive or harmful species. The programs involve teachers, students, outdoor enthusiasts, environmental groups and professional biologists to detect invasive species.

**Sources:**

iTunicate Plate Watch 2016

### 5.5 Current efforts for outreach and education

**Choice: D** Programs and materials exist and are readily available in the Bering Sea or adjacent regions

**Score:** of

**Ranking Rationale:**

Outreach and education programs are in place in Alaska to educate people on invasive tunicates.

**Background Information:**

The Invasive Tunicate Network and the Kachemak Bay National Estuarine Research Reserve (KBNERR) provide training opportunities for identifying and detecting non-native fouling organisms, and public education events on coastal and marine ecosystems more generally. "Bioblitzes" were held in Southeast AK in 2010 and 2012; these events engage and educate the public on marine invasive species. Field identification guides for native and non-native tunicates, as well as common fouling organisms, are readily available.

**Sources:**

iTunicate Plate Watch 2016

| | |
|---|---|
| **Section Total - Scored Points:** | 221 |
| **Section Total - Possible Points:** | |
| **Section Total -Data Deficient Points:** | |

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# Bering Sea Marine Invasive Species Assessment

## Alaska Center for Conservation Science

**Scientific Name:** *Molgula manhattensis*

**Common Name** *sea grapes*

| | |
|---|---|
| **Phylum** | Chordata |
| **Class** | Ascidiacea |
| **Order** | Stolidobranchia |
| **Family** | Molgulidae |

**Final Rank** 45.00

**Data Deficiency:** 0.00

### Species Occurrence by Ecoregion

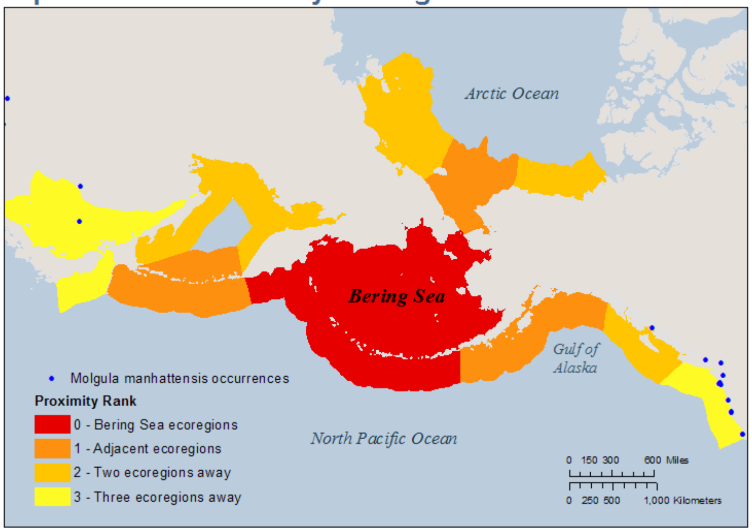


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 14.5 | 30 | 0 |
| Anthropogenic Influence: | 4.75 | 10 | 0 |
| Biological Characteristics: | 20.5 | 30 | 0 |
| Impacts: | 5.25 | 30 | 0 |
| **Totals:** | 45.00 | 100.00 | 0.00 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | 5 | Minimum Salinity (ppt) | 10 |
| Maximum Temperature (°C) | NA | Maximum Salinity (ppt) | 35 |
| Minimum Reproductive Temperature (°C) | 10 | Minimum Reproductive Salinity (ppt) | 31* |
| Maximum Reproductive Temperature (°C) | NA | Maximum Reproductive Salinity (ppt) | 35* |

### Additional Notes

This species is a solitary tunicate with a round, globular body. It is greenish-grey in color and 20-30 mm in length. M. manhattensis is native to the East and Gulf Coasts of the United States and has been introduced to Europe, Japan, Australia, Argentina, and the West Coast of North America. It is a common fouling species that was likely transported on ship hulls or with Eastern oyster (Crassostrea virginica) aquaculture. It can negatively affect oysters and related industries through fouling, and has also been observed competing with other fouling species. It is tolerant of a wide range of temperatures, salinities and pollution levels.

Confused taxonomy: Several species had, until recently, been included in Molgula manhattensis: Molgula simplex Alder & Hancock, 1870, Molgula siphonata Alder 1850, Molgula socialis Alder 1848, and Molgula tubifera Orstedt 1844. Currently, M. tubifera is considered synonymous with M. manhattensis, while M. socialis has been found to be genetically distinct and is presumably native to the northeast Atlantic.

**Reviewed by** Christina Simkanin, Marine Invasions Lab, Smithsonian Environmental Research Center, Edgewater MD

**Review Date:** 9/15/2017

# 1. Distribution and Habitat

### *1.1 Survival requirements - Water temperature*

**Choice:** **D** No overlap – Temperatures required for survival do not exist in the Bering Sea

**Score:** 0 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Although year-round temperature requirements do not exist in the Bering Sea, thresholds are based on geographic distribution, which may not represent physiological tolerances. We therefore ranked this question with "High uncertainty".

**Background Information:**
This species has been reported as far north as Bergen, Norway (61.3°N), where water temperatures average 5°C to 18°C (Fofonoff et al. 2003; IMR 2017). It is native to the east coast of North America, from New Hampshire to the Gulf of Mexico.

**Sources:**
NEMESIS; Fofonoff et al. 2003 IMR 2017

### *1.2 Survival requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea. Thresholds are based on geographic distribution, which may not represent physiological tolerances; we therefore ranked this question with "High uncertainty".

**Background Information:**
Based on its geographic distribution, this species can tolerate salinities from 10 to 35 ppt, if not higher (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.3 Establishment requirements - Water temperature*

**Choice:** **D** No overlap – Temperatures required for reproduction do not exist in the Bering Sea

**Score:** 0 of 3.75

**Ranking Rationale:**
This species cannot survive year-round in the Bering Sea. Year-round survival is required to establish a self-sustaining population.

**Background Information:**
In Denmark, reproduction started when water temperatures reached 10°C (Lützen 1967, qtd. in Jensen 2010). In southern Russia, settlement of juveniles was observed between 13 and 22°C (Zvyagintsev et al. 2003).

**Sources:**
NOBANIS 2016 Zvyagintsev et al. 2003

### *1.4 Establishment requirements - Water salinity*

**Choice:** **D** No overlap – Salinities required for reproduction do not exist in the Bering Sea

**Score:** 0 of 3.75

**Ranking Rationale:**
This species cannot survive year-round in the Bering Sea. Year-round survival is required to establish a self-sustaining population.

**Background Information:**
No information found.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 1.5 *Local ecoregional distribution*

**Choice: C** Present in an ecoregion two regions away from the Bering Sea (i.e. adjacent to an adjacent ecoregion)

**Score:** 2.5 **of** 5

**Ranking Rationale:**
This species is found on Vancouver Island, BC and in the Sea of Japan.

**Background Information:**
This species has been introduced to the west coast of North America, where it occurs from CA to BC. It is also found on the Pacific west coast, from the Sea of Japan to China.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 1.6 *Global ecoregional distribution*

**Choice: A** In many ecoregions globally

**Score:** 5 **of** 5

**Ranking Rationale:**
M. manhattensis is native to eastern North America. It has been introduced to the northwest Pacific, the western coast of North America, Europe, Argentina, and Australia.

**Background Information:**
Native to eastern North America, from Maine down the coast to Florida and west to Texas. Introduced on the West Coast from California to Vancouver Island, BC. In southern hemisphere, it has been found in temperate waters in Argentina and Australia. In Asia, it is found in southern Russia to southern China. It is relatively widespread in northwestern Europe, occurring in Norway, the Netherlands, Germany, Belgium, and France. It is also found along the Mediterranean Sea (Italy, Greece, and Bulgaria).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 1.7 *Current distribution trends*

**Choice: B** History of rapid expansion or long-distance dispersal (prior to the last ten years)

**Score:** 3.25 **of** 5

**Ranking Rationale:**
This species has historically been known to undergo rapid range expansions.

**Background Information:**
This species has spread rapidly and has been introduced worldwide (Zvyagintsev et al. 2003).

**Sources:**
Zvyagintsev and Korn 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 14.5 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 2. Anthropogenic Transportation and Establishment



### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice:** **B**

Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 **of** 4

**Ranking Rationale:**
This species uses anthropogenic vectors for transport and has low dispersal abilities.

**Background Information:**
This species is likely transported by fouling or hitchhiking. It has limited potential for long-distance dispersal (Haydar et al. 2011).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Haydar et al. 2011

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice:** **B**

Readily establishes in areas with anthropogenic disturbance/infrastructure; occasionally establishes in undisturbed areas

**Score:** 2.75 **of** 4

**Ranking Rationale:**
This species is more commonly reported from anthropogenic substrates.

**Background Information:**
Although it occurs on both artificial and natural substrates, it is most often found on anthropogenic substrates in ports and harbors.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Hiscock 2016

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice:** **B**

No

**Score:** 0 **of** 2

**Ranking Rationale:**
This species is not currently farmed.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 4.75 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics



### 3.1 Dietary specialization

**Choice:** **A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Food items are readily available in the Bering Sea.

**Background Information:**
This species is a filter feeder that feeds on phytoplankton and detritus.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 3.2 Habitat specialization and water tolerances

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **A** Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 of 5

**Ranking Rationale:**
This species has broad environmental tolerances with respect to temperature, salinity, substrate type, water quality and water depth.

**Background Information:**
This species can tolerate a wide range of temperatures and salinities. It can also tolerate polluted waters, high turbidity, and high levels of organic content (Fofonoff et al. 2003, Haydar et al. 2011). It is found on both natural and artificial substrates, and usually occurs on hard substrates such as bivalves, rocks, and ship hulls. It is found in a range of habitats and water depths, from wave-exposed to sheltered sites, and up to 90 m in depth (Hiscock 2016).

**Sources:**
Hiscock 2016 NEMESIS; Fofonoff et al. 2003 Haydar et al. 2011

### 3.3 Desiccation tolerance

**Choice:** **C** Little to no tolerance (<1 day) of desiccation during its life cycle

**High uncertainty?** ✔

**Score:** 1.75 of 5

**Ranking Rationale:**
The desiccation tolerance of this species is unknown; however, in general, tunicates have a low tolerance to desiccation.

**Background Information:**
Tunicates have a low tolerance to desiccation (Pleus 2008).

**Sources:**
Pleus 2008

### *3.4 Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice: A** High – Exhibits three or four of the above characteristics

**Score:** 5 of 5

**Ranking Rationale:**

This species is hermaphroditic, and exhibits a short generation time and low parental investment. Fertilization is internal.

**Background Information:**

This species is hermaphroditic. Self-fertilization has been documented in the laboratory (Morgan 1942, qtd. in Haydar et al. 2011), but the frequency of self-fertilization in the field is unknown. Fertilization is internal. Eggs hatch within 24 h (Grave 1933, qtd. in Jensen 2010), but have been observed to hatch within 10 h at temperatures of 18°C (Berill 1931, qtd. in Hiscock 2016). The larval stage is free-swimming and lasts a few days at most, at which point they settle and metamorphose (Saffo & Davis 1982, qtd. in Jensen 2010). Berill (1931, qtd. in Hiscock 2016) observed larval settlement within 1 to 10 h. The larval stage may also be bypassed and metamorphosis may be completed in situ (Morgan 1942, qtd. in Jensen 2010). Individuals typically live less than 1 year, and reach sexual maturity in 3 weeks, though fertility increases after one month (Grave 1933, qtd. in Jensen 2010).

**Sources:**

Haydar et al. 2011 NOBANIS 2016 Hiscock 2016

### *3.5 Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice: C** Disperses short (< 1 km) distances

**Score:** 0.75 of 2.5

**High uncertainty?** ☑

**Ranking Rationale:**

This species has low potential for long-distance dispersal.

**Background Information:**

Haydar et al. (2011) suggests that M. manhattensis has low dispersal potential, because although larval stage is free-swimming, it is also short-lived, ranging from minutes to several hours. Rafting of eggs, juveniles or adults has not been reported (Thiel and Gutow 2005, qtd. in Haydar et al. 2011). Adults are sessile. Shanks (2009) estimated that Molgula pacifica, a related species, can disperse < 1 m under natural conditions. Gregarious settlement has been reported in this species, meaning that larvae are more likely to settle near conspecifics. In an experimental community, this settlement behavior was so extreme that it caused the entire Molgula aggregation to fall off the substrate (Stachowicz et al. 1999).

**Sources:**

Haydar et al. 2011 Shanks 2009 Stachowicz et al. 1999

### 3.6 *Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: B** Moderate – Exhibits one of the above characteristics

**Score:** 1.75 of 2.5

**Ranking Rationale:**
This species can only disperse during its larval stage. Larvae can be free-swimming from several hours to days.

**Background Information:**
This species' larval stage may last up to a few days (qtd. in Jensen 2010). Adults are sessile. Rafting of eggs, juveniles or adults has not been reported in this species (Thiel and Gutow 2005, qtd. in Haydar et al. 2011).

**Sources:**
Haydar et al. 2011 NOBANIS 2016

### 3.7 *Vulnerability to predators*

**Choice: D** Multiple predators present in the Bering Sea or neighboring regions

**Score:** 1.25 of 5

**Ranking Rationale:**
Ascidians are eaten by several taxa commonly found in the Bering Sea.

**Background Information:**
Predators of ascidians include flatworms, mollusks, crabs, sea stars, and some fishes.

**Sources:**
O'Clair and O'Clair 1998

| | |
|---|---|
| **Section Total - Scored Points:** | 20.5 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

# 4. Ecological and Socioeconomic Impacts



## 4.1 *Impact on community composition*

**Choice: C** Limited – Single trophic level; may cause decline but not extirpation

**Score:** 0.75 of 2.5

**Ranking Rationale:**
At high densities, M. manhattensis may compete for space with other fouling organisms.

**Background Information:**
In Chesapeake Bay, where it is native, M. manhattensis can rapidly settle on and overgrow other fouling organisms. Molgula species are often found on hydroids and erect bryozoans (qtd. in Dijkstra et al. 2007). Complete cover of M. manhattensis was occasionally observed in Newport and Alamitos Bays, California; however, it was absent from most sites, and, where present, usually occurred at much lower densities (0.1 to 1 individuals/m2) (Lambert and Lambert 2003). The 13 other invasive species that were surveyed were either far more common and/or abundant across the study area (Lambert and Lambert 2003). Settlement panel experiments by Osman and Whitlatch (1995) found that the recruitment of other sessile invertebrates was not affected by the presence of M. manhattensis.

**Sources:**
Lambert and Lambert 2003   Dijkstra et al. 2007   Osman and Whitlatch 1995

## 4.2 *Impact on habitat for other species*

**Choice: C** Limited – Has limited potential to cause changes in one or more habitats

**Score:** 0.75 of 2.5

**Ranking Rationale:**
By fouling substrates, this species may reduce available habitat for some organisms. Conversely, it may create secondary settlement habitat for others.

**Background Information:**
M. manhattensis can cover substrates with layers of tunicates ~10 to 20 mm deep. Osman and Whitlatch (1995) found low levels of recruitment on panels fouled by M. manhattensis, suggesting that M. manhattensis did not create secondary habitat for fouling species. However, Otsuka and Dauer (1982) observed hydroids, bryozoans, and polychaetes settling on M. manhattensis.

**Sources:**
Osman and Whitlatch 1995   Otsuka and Dauer 1982

## 4.3 *Impact on ecosystem function and processes*

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not expected to impact ecosystem function in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.4 *Impact on high-value, rare, or sensitive species and/or communities*



**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not expected to impact high-value species or communities in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.5 *Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not expected to transport diseases, parasites, or hitchhikers that will impact the Bering Sea.

**Background Information:**
M. manhattensis has a symbiotic relationship with a fungus-like protist, Nephromyces sp. (Saffo 1988). Nephromyces is found in the renal sac of M. manhattensis and is likely associated with urate metabolism. This organism is found in six other molgulid tunicates (Saffo 1988). No impacts have been reported.

**Sources:**
Saffo 1988

### 4.6 *Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not expected to hybridize with native species in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.7 *Infrastructure*

**Choice:** **B**

Moderate – Causes or has the potential to cause degradation to infrastructure, with moderate impact and/or within only a portion of the region

**Score:** 1.5 of 3

**Ranking Rationale:**
This species is an abundant fouler of ships. Fouling organisms on ships cause drag and reduce maneuverability, and impose high economic costs on vessel owners.

**Background Information:**
M. manhattensis is a major fouling organism on ships (Fofonoff et al. 2003). Fouling organisms on ships cause drag and reduce maneuverability. They are estimated to cost the U.S. Navy over $50 million a year in fuel costs due to increased drag (Cleere 2001).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Cleere 2001

### 4.8 *Commercial fisheries and aquaculture*

**Choice:** **C**

Limited – Has limited potential to cause degradation to fisheries and aquaculture, and/or is restricted to a limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
This species may affect the growth and development of bivalves by fouling their shells. However, no impacts have been reported. Shellfish aquaculture currently occurs only in a restricted area of the Bering Sea.

**Background Information:**
In its native range, M. manhattensis is a major fouling organism on oyster shells and trays used in aquaculture (Andrews 1973, qtd. in Fofonoff et al. 2003). Through fouling, it may double or triple the weight of oyster trays in one month (Andrews 1973, qtd. in Fofonoff et al. 2003). No other impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.9 *Subsistence*

**Choice:** **C**

Limited – Has limited potential to cause degradation to subsistence resources, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**High uncertainty?** ☑

**Ranking Rationale:**
This species may affect the growth and development of bivalves by fouling their shells, but no impacts have been reported. Shellfish is an important subsistence resource for certain communities in the Bering Sea (Mathis et al. 2015).

**Background Information:**
In its native range, M. manhattensis is a major fouling organism on oyster shells (Andrews 1973). No further impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Mathis et al. 2015

### 4.101 Recreation

**Choice: C** Limited – Has limited potential to cause degradation to recreation opportunities, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**High uncertainty?** ✔

**Ranking Rationale:**
This species may affect the growth and development of bivalves by fouling their shells, but no impacts have been reported. Recreational harvesting of shellfish occurs in a limited area of the Bering Sea.

**Background Information:**
In its native range, M. manhattensis is a major fouling organism on oysters (Andrews 1973, qtd. in Fofonoff et al. 2003), but no further impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.11 Human health and water quality

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact human health and water quality in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 5.25 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

# 5. Feasibility of prevention, detection and control



### 5.1 *History of management, containment, and eradication*

**Choice:** **C**

Attempted; control methods are currently in development/being studied

**Score:** of

**Ranking Rationale:**

No species-specific plans are in place to control or eradicate this species. This species is transported by fouling and hitchhiking. Controlling the spread of fouling organisms is an active area of research.

**Background Information:**

**Sources:**

NEMESIS; Fofonoff et al. 2003

### 5.2 *Cost and methods of management, containment, and eradication*

**Choice:** **A**

Major long-term investment, or is not feasible at this time

**Score:** of

**Ranking Rationale:**

At this time, there are no known control methods for solitary tunicates.

**Background Information:**

Preliminary results suggest that exposure to freshwater may be effective against solitary tunicates, but further work is needed (Carman et al. 2016). Hand removal may be feasible for small areas with low densities.

**Sources:**

AISU 2011   Carman et al. 2016

### 5.3 *Regulatory barriers to prevent introductions and transport*

**Choice:** **B**

Regulatory oversight, but compliance is voluntary

**Score:** of

**Ranking Rationale:**

In Alaska, there are regulations in place for the transport of bivalve species, via which M. manhattensis can be unintentionally transported. Compliance with U.S. hull fouling regulations - another transport vector for this species - are largely voluntary.

**Background Information:**

In Canada, Fisheries and Oceans Canada's require a license to move bivalves from tunicate infested waters. This regulation has been successful in containing and slowing the anticipated spread of several tunicate species, which can be unintentionally transported through their association with bivalves (DFO 2010). Similar regulations exist in Alaska regarding the transport and introduction of shellfish in water bodies. Under Alaska law, a permit must be obtained from the Alaska Department of Fish and Game (ADF&G) in order to collect, possess, or transport shellfish for educational, scientific, or propagative uses (AAC 2017). Compliance with ship fouling regulations are largely voluntary (Hagan et al. 2014).

**Sources:**

CFR 2017   DFO 2010   AAC 2017

### *5.4 Presence and frequency of monitoring programs*

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**Choice: B** Surveillance takes place, but is largely conducted by non-governmental environmental organizations (e.g., citizen science programs)

**Score:** of

**Ranking Rationale:**
Surveillance for invasive tunicates in Alaska is conducted by scientists and volunteers.

**Background Information:**
In Alaska, the Invasive Tunicate Network and KBNERR conduct monitoring for non-native tunicates and other invasive or harmful species. The programs involve teachers, students, outdoor enthusiasts, environmental groups and professional biologists to detect invasive species.

**Sources:**
iTunicate Plate Watch 2016

### *5.5 Current efforts for outreach and education*

**Choice: D** Programs and materials exist and are readily available in the Bering Sea or adjacent regions

**Score:** of

**Ranking Rationale:**
Outreach and education programs are in place in Alaska to educate people on invasive tunicates.

**Background Information:**
The Invasive Tunicate Network and the Kachemak Bay National Estuarine Research Reserve (KBNERR) provide training opportunities for identifying and detecting non-native fouling organisms, and public education events on coastal and marine ecosystems more generally. "Bioblitzes" were held in Southeast AK in 2010 and 2012; these events engage and educate the public on marine invasive species. Field identification guides for native and non-native tunicates, as well as common fouling organisms, are readily available.

**Sources:**
iTunicate Plate Watch 2016

**Section Total - Scored Points:**

**Section Total - Possible Points:**

**Section Total -Data Deficient Points:**

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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Styela clava*

**Common Name** *club sea squirt*

**Phylum** Chordata

**Class** Ascidiacea

**Order** Stolidobranchia

**Family** Styelidae

**Final Rank** 55.25

**Data Deficiency:** 0.00

### Species Occurrence by Ecoregion

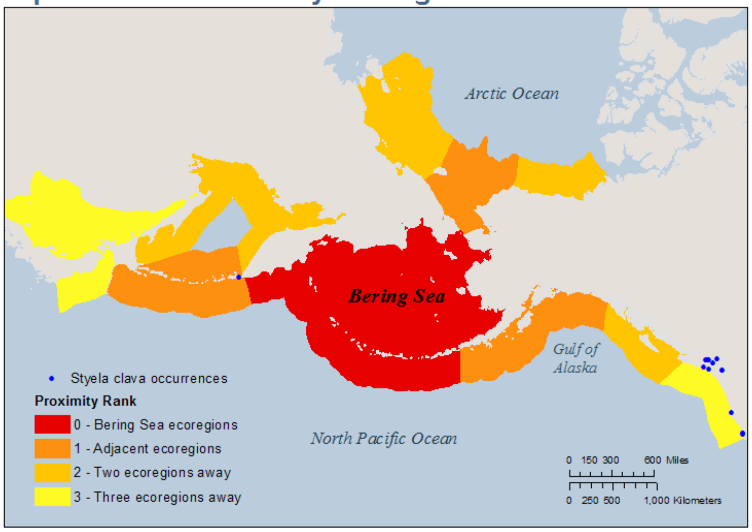


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 21.75 | 30 | 0 |
| Anthropogenic Influence: | 6.75 | 10 | 0 |
| Biological Characteristics: | 23 | 30 | 0 |
| Impacts: | 3.75 | 30 | 0 |
| **Totals:** | 55.25 | 100.00 | 0.00 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | -2 | Minimum Salinity (ppt) | 18 |
| Maximum Temperature (°C) | 27 | Maximum Salinity (ppt) | 35 |
| Minimum Reproductive Temperature (°C) | 15 | Minimum Reproductive Salinity (ppt) | 20 |
| Maximum Reproductive Temperature (°C) | NA | Maximum Reproductive Salinity (ppt) | 35* |

### Additional Notes

Styela clava is a small, solitary tunicate whose colors range from yellow to red to brown. It can attain a maximum length of 90 mm. It is native to the Northwest Pacific, from China to the southern Russia. It has become widely distributed in coastal waters through ship fouling, sea chests, and accidental transport with oysters.

**Reviewed by** Christina Simkanin, Marine Invasions Lab, Smithsonian Environmental Research Center, Edgewater MD

**Review Date:** 9/15/2017

# 1. Distribution and Habitat

## *1.1 Survival requirements - Water temperature*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 3.75 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Temperatures required for year-round survival occur over a large (>75%) area of the Bering Sea. Thresholds are based on geographic distribution, which may not represent physiological tolerances; we therefore ranked this question with "High uncertainty".

**Background Information:**
Temperature range for this species is between -2°C and 26.6°C (based on geographic distribution).

**Sources:**
NEMESIS; Fofonoff et al. 2003

## *1.2 Survival requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
The salinity range for this species is from 18 to 35 ppt (based on experimental data).

**Sources:**
NEMESIS; Fofonoff et al. 2003

## *1.3 Establishment requirements - Water temperature*

**Choice:** **D** No overlap – Temperatures required for reproduction do not exist in the Bering Sea

**Score:** 0 of 3.75

**Ranking Rationale:**
Temperatures required for reproduction do not exist in the Bering Sea.

**Background Information:**
In a survey of 260 European harbours, no specimens were found in sites where water temperatures do not exceed 16°C during the summer months, which is the temperature at which development of the gonad is thought to occur (Holmes 1968, qtd. in Davis and Davis 2007). Similarly, in PEI, Canada, S. clava began spawning when water temperatures reached 15°C. Larvae can tolerate colder temperatures as some were found in water samples with temperatures as low as ~11°C (Bourque et al. 2007).

**Sources:**
Bourque et al. 2007 Davis and Davis 2007

### *1.4 Establishment requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 **of** 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
We assume that this species can tolerate sea water up to 35 ppt. These salinities are found in a large (>75%) area of the Bering Sea.

**Background Information:**
In a survey of 260 European harbours, no specimens were found in water with salinity <20 PSU or >35 PSU (Davis and Davis 2007). A previous study suggested that larvae metamorphose at salinities between 20 and 32 (Kashenko 1996, qtd. in Davis and Davis 2007).

**Sources:**
Davis and Davis 2007

### *1.5 Local ecoregional distribution*

**Choice:** **B** Present in an ecoregion adjacent to the Bering Sea

**Score:** 3.75 **of** 5

**Ranking Rationale:**
This species is found in the Sea of Okhotsk (to the west) and on Vancouver Island.

**Background Information:**
This species is found on the west coast of North America from Baja California to Vancouver Island. Its native range is in Asia, from southern Russia (Kurile Island) to the East China Sea.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.6 Global ecoregional distribution*

**Choice:** **A** In many ecoregions globally

**Score:** 5 **of** 5

**Ranking Rationale:**
This species is currently found in several cold- and warm-temperate regions of the southern and northern hemisphere.

**Background Information:**
Native to the Sea of Okhotsk, potentially as far north as 51°N. Along the western North American coast, it is found from Mexico north to Vancouver Island. Its distribution on the east coast extends from Prince Edward Island to Virginia. Introduced to southern temperate regions of Patagonia, Australia and New Zealand. In Europe, it was first introduced to England, and it now extends as far south as Spain and Portugal. It has made its way along the North Sea as far north as Limfjord and Kattegat in Denmark (57°N).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 1.7 *Current distribution trends*



**Choice:** **C**

Established outside of native range, but no evidence of rapid expansion or long-distance dispersal

**Score:** **1.75 of 5**

**Ranking Rationale:**

In PEI, where it reached high densities in just a few years, S. clava expanded its range by 12 km in 3 years. Its spread is thought to be facilitated by anthropogenic vectors, as natural dispersal is limited in this species.

**Background Information:**

In PEI, this species expanded its range rapidly since it was first reported in 2002. By 2006, it was found 12 km from the area where it was first detected. Its population increased to such a level that it became a nuisance species for the mussel industry within three years of detection.

**Sources:**

Arsenault et al. 2009

| | |
|---|---|
| **Section Total - Scored Points:** | 21.75 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 2. Anthropogenic Transportation and Establishment



### 2.1 *Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice: B** Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 of 4

**Ranking Rationale:**
Once introduced, S. clava can be transported passively by water currents, or by rafting on vegetation. However, its patchy distribution in areas where it has been introduced suggests that this species has limited potential for natural dispersal.

**Background Information:**
The patchy distribution observed in Britain, in the eastern US, and in PEI suggests that natural larval dispersal is sporadic and does not necessarily lead to the colonization of neighbouring sites (Clarke and Therriault 2007; Darbyson et al. 2009). However, colonization of natural areas was observed recently in Argentina, where individuals of S. clava were found on mollusk beds several kilometers away from the presumed point of introduction (Pereyra et al. 2015).

**Sources:**
Clarke and Therriault 2007   Darbyson et al. 2009   Pereyra et al. 2015

### 2.2 *Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice: B** Readily establishes in areas with anthropogenic disturbance/infrastructure; occasionally establishes in undisturbed areas

**Score:** 2.75 of 4

**Ranking Rationale:**
This species can establish on natural substrates, but is found most often on anthropogenic infrastructure.

**Background Information:**
In both its native and introduced range, S. clava is more frequently reported from anthropogenic structures than from natural surfaces (Simkanin et al. 2012). For example, the successful establishment of S. clava in Malpeque Bay, PEI was largely dependent on the availability of hard substrate associated with anthropogenic infrastructure (Bourque et al. 2007). However, S. clava can also establish on rocks, and can grow epiphytically on bivalves and seaweed. In Argentina, where S. clava has been recently introduced, populations were found growing on bivalve beds, and high-density populations have established on rocky shorelines away from anthropogenic structures (Pereyra et al. 2015; Pereyra et al. 2017).

**Sources:**
Bourque et al. 2007   Simkanin et al. 2012   Pereyra et al. 2015   Pereyra et al. 2017

### 2.3 *Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice: A** Yes

**Score:** 2 of 2

**Ranking Rationale:**
This species is farmed for food in Asia.

**Background Information:**
S. clava is a popular food item in Korea and is extensively cultured on long lines in Korea and Japan.

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 6.75 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

# 3. Biological Characteristics

## *3.1 Dietary specialization*

**Choice: A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Food items are readily available in the Bering Sea.

**Background Information:**
Larval stage is non-feeding. Adults are sessile and filter feed on phytoplankton and oyster larvae.

**Sources:**
NEMESIS; Fofonoff et al. 2003

## *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice: A** Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 of 5

**Ranking Rationale:**
This species does not require specialized habitat for survival or reproduction. It can tolerate a broad range of temperatures and salinities, and has been found on a variety of substrates.

**Background Information:**
S. clava is most common in sheltered habitats with low wave action, such as inlets, bays, harbours and marinas (Lutzen 1999). In a survey of 260 European harbours, no specimens of S. clava were found in shallow exposed sites, supporting the observation that S. clava is intolerant of wave exposure (Davis and Davis 2007). Adults establish on a variety of anthropogenic and hard substrates, including docks, pilings, boat hulls, rocks, bivalves, and seaweed, but are more frequently reported from anthropogenic structures than from natural surfaces (Simkanin et al. 2012). It is often a secondary settler, settling on substrates already fouled by other species. S. clava was abundant in harbors with poor, fair, or good water quality (Carman et al. 2007). It can tolerate a wide range of temperatures and salinities (Clarke and Therriault 2007), although minimum temperatures and marine waters are required for reproduction and larval development.

**Sources:**
Lutzen 1999 Davis and Davis 2007 Carman et al. 2016 Simkanin et al. 2012 Clarke and Therriault 2007

### 3.3 *Desiccation tolerance*



**Choice:** **B** Moderately tolerant (1-7 days) during one or more stages during its life cycle

**Score:** 3.25 **of** 5

**Ranking Rationale:**

Depending on air temperature and sun exposure, S. clava can survive outside of water from < 24 hours to > 48 hours.

**Background Information:**

Aluminum and fiberglass hull material that had one-year-old [adult] tunicates growing on them were exposed to open air for 48 h during September (mean daytime high temperature 29.7˚C, night-time low 8.5˚C) (Darbyson et al. 2009). Nearly all tunicates were alive after 8 hours, and only 10 to 11 % mortality was observed after 48 h. High desiccation tolerance suggests that S. clava could survive overland transport (e.g. on a trailered boat), facilitating spread and increasing dispersal potential (Darbyson et al. 2009).

An experiment by Hillock and Costello (2013) considered three different treatments to test for desiccation tolerance in S. clava adults: 1) constant 10°C, 2) sun (25-27°C), and 3) shade (range: 15-27°C). Only the group held at 10 °C had any individuals surviving after 48 h. There was > 50% mortality amongst S. clava exposed to shade after 24 h, with 100% mortality after 48 h. In the group that was exposed to sun, no individuals survived after 24 h. A modelling exercise found that it would take 11 days for 99% of an S. clava population to die at 10°C. The authors suggest air exposure for at least two weeks to ensure complete mortality (Hillock and Costello 2013).

**Sources:**

Darbyson et al. 2009   Hillock et al. 2013

### 3.4 *Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic   ii. High fecundity (e.g. >10,000 eggs/kg)   iii. Low parental investment and/or external fertilization   iv. Short generation time

**Choice:** **A** High – Exhibits three or four of the above characteristics

**Score:** 5 **of** 5

**Ranking Rationale:**

This species is hermaphroditic and highly fecund. Eggs are fertilized externally. S. clava has a short generation time.

**Background Information:**

Solitary tunicates cannot reproduce asexually (i.e. through budding; O'Clair and O'Clair 1998). This species is hermaphroditic, but not self-fertile. It exhibits external fertilization and low parental investment (Clarke and Therriault 2007). In PEI, S. clava exhibited seasonal reproduction brought about by warming water temperatures in early summer (Bourque et al. 2007). Davis (1997) estimated a production of ~ 5000 eggs per individual, which hatched after 12 to 15 h (qtd. in Davis and Davis 2007). S. clava reaches maturity around 10 months and can live 2 to 3 years (JNCC 1997, NIMPIS, 2002, Parker et al. 1999; qtd. in Global Species Invasive Data 2006). Upon maturity, this species has the ability to spawn every 24 hours (Biosecurity New Zealand 2005, qtd. in Clarke and Therriault 2007).

**Sources:**

O'Clair and O'Clair 1998   Davis and Davis 2007   Clarke and Therriault 2007   GISD 2016

### 3.5 *Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice:** **B** Disperses moderate (1-10 km) distances

**Score:** 1.75 of 2.5

**High uncertainty?** ☑

**Ranking Rationale:**

The dispersal distance of S. clava is unknown, but its distributional pattern suggests that natural dispersal is limited. In PEI, this species spread at a rate of 4 km/year, but anthropogenic vectors likely facilitated this expansion. In Argentina, S. clava has been found growing on bivalve beds several kilometers away from its presumed point of introduction.

**Background Information:**

S. clava is not able to spread long distances by most natural vectors because it has a relatively short planktonic larval phase of 12 to 36 hours (Stachowicz et al. 2002, qtd. in Darbyson et al. 2009). Pre-settlement metamorphosed juveniles do not actively swim, but may be passively dispersed short distances by water currents or rafting (Darbyson et al. 2009). Adults are sessile, but may be able to naturally disperse by rafting on floating vegetation. The patchy distribution observed in Britain, in the eastern US, and in PEI suggests that natural larval dispersal is sporadic and does not necessarily lead to the colonization of neighbouring sites (Clarke and Therriault 2007; Darbyson et al. 2009). A study by Darbyson et al. (2009) found that S. clava spread 12 km within 3 years, but the authors hesitate to attribute this spread entirely to natural dispersal. In Argentina, where this species likely established after 2012, S. clava was found growing on bivalve beds several kilometers away from its presumed point of introduction (Pereyra et al. 2015).

**Sources:**

Darbyson et al. 2009   Clarke and Therriault 2007   Pereyra et al. 2015

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### 3.6 *Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile  ii. Larval viability window is long (days v. hours)  iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice:** **B** Moderate – Exhibits one of the above characteristics

**Score:** 1.75 of 2.5

**Ranking Rationale:**

Both adults and larvae may be capable of passive dispersal. The larval stage is relatively short-lived, and usually lasts less than 1 day before undergoing metamorphosis.

**Background Information:**

The larval stage lasts between ~12 to 36 hours (Clarke and Therriault 2007; Darbyson et al. 2009). Natural dispersal is limited at all life stages. Larvae can disperse passively by water currents. Adults are sessile but may disperse by rafting on floating vegetation or debris.

**Sources:**

Clarke and Therriault 2007   Darbyson et al. 2009

### *3.7 Vulnerability to predators*

**Choice:** **D** Multiple predators present in the Bering Sea or neighboring regions

**Score:** 1.25 **of** 5

**Ranking Rationale:**

This species is predated upon by several taxa which occur in the Bering Sea, including urchins, crabs, snails, and fishes.

**Background Information:**

An experimental study exposing S. clava to predators in BC found that S. clava experienced 100% mortality in treatments with the green sea urchin Strongylocentrotus droebachiensis, the red sea urchin Strongylocentrotus franciscanus, the red rock crab Cancer productus, and the European green crab Carcinus maenas (Epelbaum et al. 2009). It experienced 30% mortality with the sea star Evasterias troschelii. Two other species of sea stars were unable to kill S. clava (Epelbaum et al. 2009). The authors suggest that predation alone will not be sufficient to limit the establishment and spread of S. clava and other invasive tunicates in BC. Other predators include snails and fishes (Fofonoff et al. 2003).

**Sources:**

Epelbaum et al. 2009 NEMESIS; Fofonoff et al. 2003

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|---|---|
| **Section Total - Scored Points:** | 23 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 4. Ecological and Socioeconomic Impacts



### 4.1 Impact on community composition

**Choice: C** Limited – Single trophic level; may cause decline but not extirpation

**Score:** 0.75 of 2.5

**Ranking Rationale:**
Through competition and overgrowth, this species may lead to the decline of other fouling organisms. It may also have a negative impact on oyster populations by predating upon oyster larvae. Field studies have reported moderate to mild community effects.

**Background Information:**
In southern California harbors, it often forms dense patches with 100% cover, where it and other introduced ascidians have replaced native species (Lambert and Lambert 1998; Lambert and Lambert 2003). In English waters, the population growth of S. clava was paralleled by a decrease in Ciona intestinalis (Lutzen 1999). An experimental study showed that predation on oyster larvae by S. clava can greatly reduce settlement rate of oysters (Osman et al. 1989 qtd. in Clarke and Therriault 2007). In Argentina, it is believed to have facilitated the invasion of the seaweed Undaria pinnatifida by providing attachment sites for spores (Pereyra et al. 2015).

A field-based experiment by Ross et al. (2007) found a significant negative relationship between Styela density and the abundance of lumbrinerids, tanaids, crustaceans, and the bivalve Laternula rostrata. Nonetheless, these taxa only represent a small proportion of those present, and the effects emerged at Styela densities greater than what was typically recorded in the wild (>1 to 2 ind./m2). As a result, Ross et al. (2007) concluded that the effects of Styela on soft sediment assemblages in Port Phillip Bay were likely to be negligible (Ross et al. 2007).

**Sources:**
Ross et al. 2007   Clarke and Therriault 2007   Pereyra et al. 2015   Lutzen 1999   Lambert 2003   Lambert and Lambert 1998

### 4.2 Impact on habitat for other species

**Choice: C** Limited – Has limited potential to cause changes in one or more habitats

**Score:** 0.75 of 2.5

**Ranking Rationale:**
This species may simultaneously reduce habitat and create secondary habitat for fouling organisms. No specific impacts on habitat have been reported.

**Background Information:**
Dense aggregations provide secondary settlement substrates for other fouling organisms. At the same time, S. clava may compete for habitat (Clarke and Therriault 2007).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Clarke and Therriault 2007

### 4.3 Impact on ecosystem function and processes

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not expected to affect ecosystem function in the Bering Sea.

**Background Information:**
No species-specific information found. Ascidians can play a positive role in some areas by filtering and sequestering heavy metals and other pollutants from the water (Lambert and Lambert 1998).

**Sources:**
Lambert and Lambert 1998

### *4.4 Impact on high-value, rare, or sensitive species and/or communities*

**Choice:** **D** No impact

**Score:** **0** of **2.5**

**Ranking Rationale:**
This species is not expected to affect high-value species or communities in the Bering Sea.

**Background Information:**
No impacts reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Clarke and Therriault 2007

### *4.5 Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice:** **D** No impact

**Score:** **0** of **2.5**

**Ranking Rationale:**
This species is not known to transport diseases, parasites, or hitchhikers.

**Background Information:**
No impacts reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Clarke and Therriault 2007

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice:** **D** No impact

**Score:** **0** of **2.5**

**Ranking Rationale:**
This species is not expected to hybridize with native species in the Bering Sea.

**Background Information:**
No impacts reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Clarke and Therriault 2007

### 4.7 *Infrastructure*



**Choice: B** Moderate – Causes or has the potential to cause degradation to infrastructure, with moderate impact and/or within only a portion of the region

**Score:** 1.5 of 3

**Ranking Rationale:**
This species can severely foul and impact aquaculture and marine infrastructure.

**Background Information:**
Styela clava can grow in very dense populations, fouling boat hulls, docks, fishing gear, and aquaculture equipment. Densities as high as 500-1000/m2 have been recorded, especially on artificial substrates (Lützen 1999). In Denmark, S. clava is a major gear fouling problem for the cod, flounder and eel fisheries. In Prince Edward Island, mussel lines and floating docks have been weighed down by heavy growth of S. clava.

**Sources:**
Lutzen 1999   Clarke and Therriault 2007   NEMESIS; Fofonoff et al. 2003

### 4.8 *Commercial fisheries and aquaculture*

**Choice: C** Limited – Has limited potential to cause degradation to fisheries and aquaculture, and/or is restricted to a limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
The shellfish industry in Alaska is estimated at $1 million (PSI Alaska 2017), but only occurs in a limited area in the Bering Sea. Revenues from shellfish are most important in the Gulf of Alaska and in southwest Alaska (Aleutians East through Lake and Peninsula; Mathis et al. 2015).

**Background Information:**
The largest economic impacts of Styela clava have been seen in Prince Edward Island, Canada. Dense populations foul cages ropes, and other gear used in fish aquaculture and mussel culture (Locke et al. 2007; Arsenault et al. 2009). S. clava also competes with cultured mussels, reducing mussel harvests by ~50%. This species is considered a serious threat to the long-term economic viability of the shellfish industry in PEI (Clarke and Therriault 2007). The estimated economic impact is CAN $34-88 million per year (Coulatti et al. 2006).

**Sources:**
Clarke and Therriault 2007   Mathis et al. 2015   PSI Alaska 2017

### 4.9 *Subsistence*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact subsistence resources in the Bering Sea.

**Background Information:**
The impacts of Styela clava on shellfish result from S. clava fouling aquaculture infrastructure such as cages and mussel socks. No impacts on wild populations have been reported.

**Sources:**
Clarke and Therriault 2007

### 4.101 *Recreation*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to affect recreational opportunities in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.11 *Human health and water quality*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
S. clava is not expected to have any impacts on human health or water quality in the Bering Sea.

**Background Information:**
In Japan, where this species is cultivated, it is responsible for an asthmatic-like condition in workers exposed to their fluids when detaching them from oysters (NIMPIS 2009; Cohen 2005 qtd. in Clarke and Therriault 2007). This effect is more likely to happen in poorly-ventilated work environments (Minchin 2008).

**Sources:**
Clarke and Therriault 2007 Minchin 2008 NIMPIS 2009

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|---|---|
| **Section Total - Scored Points:** | 3.75 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

# 5. Feasibility of prevention, detection and control

## *5.1 History of management, containment, and eradication*

**Choice:** **C** Attempted; control methods are currently in development/being studied

**Score:** of

**Ranking Rationale:**
Efforts to control S. clava are ongoing.

**Background Information:**
Control and eradication have been attempted in several regions, including Australia, PEI, and Washington. The success of management methods is context-dependent. Lowering water levels in power plants has been successful in controlling S. clava in Australia. In aquaculture settings, various combinations of salinity, temperature and exposure to air have proved successful in killing S. clava on oyster farms, without harming the oysters (NIMPIS 2009). Dipping of oysters or mussels in a brine solution is extremely effective at killing ascidians without harming oysters, but some treatments cause high mortality rates when applied to mussels (Carman et al. 2016). In PEI growers are using an acetic acid solution to treat mussel lines, but this method has limited success (Clarke and Therriault 2007).

**Sources:**
Carman et al. 2016   Darbyson et al. 2009   Clarke and Therriault 2007   NIMPIS 2009

## *5.2 Cost and methods of management, containment, and eradication*

**Choice:** **B** Major short-term and/or moderate long-term investment

**Score:** of

**Ranking Rationale:**
The methods that are currently used need to be repeated for sustained population control to be achieved. With respect to aquaculture fouling, these methods may also cause mussel mortality.

**Background Information:**
Control methods include: exposing S. clava to air, or to brine or acid solutions, applying antifouling paints on ships and marine infrastructure, hand removal, and biocides. These methods have had various degrees of efficacy depending on the context of the study. Dipping of oysters or mussels in a brine solution is extremely effective at killing ascidians without harming oysters, but some treatments cause high mortality rates when applied to mussels (Carman et al. 2016). In PEI growers are using an acetic acid solution to treat mussel lines, but this method has limited success (Clarke and Therriault 2007).

**Sources:**
Clarke and Therriault 2007   Carman et al. 2016   Darbyson et al. 2009

### 5.3 *Regulatory barriers to prevent introductions and transport*



**Choice:** **B** Regulatory oversight, but compliance is voluntary

**Score:** of

**Ranking Rationale:**

This species is likely transported by fouling ship hulls and sea chests. Regulations to prevent the spread of species by fouling do exist, but compliance is voluntary.

**Background Information:**

According to Davis and Davis (2007), this species is more likely to have been transported to new areas by fouling protected areas in ships such as sea chests and bow thruster tubes. Transport of larvae by ballast water is unlikely, given that this species has a short-lived larval stage. In the U.S., Coast Guard regulations require masters and ship owners to clean vessels and related infrastructure on a regular basis (CFR 33 § 151.2050). However, because the word "regular" is not defined, regulations are hard to enforce and compliance remains largely voluntary (Hagan et al. 2014).

**Sources:**

Davis and Davis 2007 Hagan et al. 2014 CFR 2017

### 5.4 *Presence and frequency of monitoring programs*

**Choice:** **B** Surveillance takes place, but is largely conducted by non-governmental environmental organizations (e.g., citizen science programs)

**Score:** of

**Ranking Rationale:**

Styela clava is listed as a species of interest on the Invasive Tunicate Network website.

**Background Information:**

In Alaska, the Invasive Tunicate Network and KBNERR conduct monitoring for non-native tunicates and other invasive or harmful species. The programs involve teachers, students, outdoor enthusiasts, environmental groups and professional biologists to detect invasive species.

**Sources:**

iTunicate Plate Watch 2016

### 5.5 *Current efforts for outreach and education*

**Choice:** **D** Programs and materials exist and are readily available in the Bering Sea or adjacent regions

**Score:** of

**Ranking Rationale:**

Outreach and education programs are in place in Alaska to educate people on invasive tunicates. Styela clava is listed as a species of interest on the Invasive Tunicate Network website.

**Background Information:**

The Invasive Tunicate Network and the Kachemak Bay National Estuarine Research Reserve (KBNERR) provide training opportunities for identifying and detecting non-native fouling organisms, and public education events on coastal and marine ecosystems more generally. "Bioblitzes" were held in Southeast AK in 2010 and 2012; these events engage and educate the public on marine invasive species. Field identification guides for native and non-native tunicates, as well as common fouling organisms, are readily available.

**Sources:**

iTunicate Plate Watch 2016

**Section Total - Scored Points:**

**Section Total - Possible Points:**

**Section Total -Data Deficient Points:**

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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Diadumene lineata*

**Common Name** *orange-striped anemone*

| | |
|---|---|
| **Phylum** | Cnidaria |
| **Class** | Anthozoa |
| **Order** | Actiniaria |
| **Family** | Diadumenidae |

**Final Rank** 50.13

**Data Deficiency:** 3.75

Species Occurrence by Ecoregion

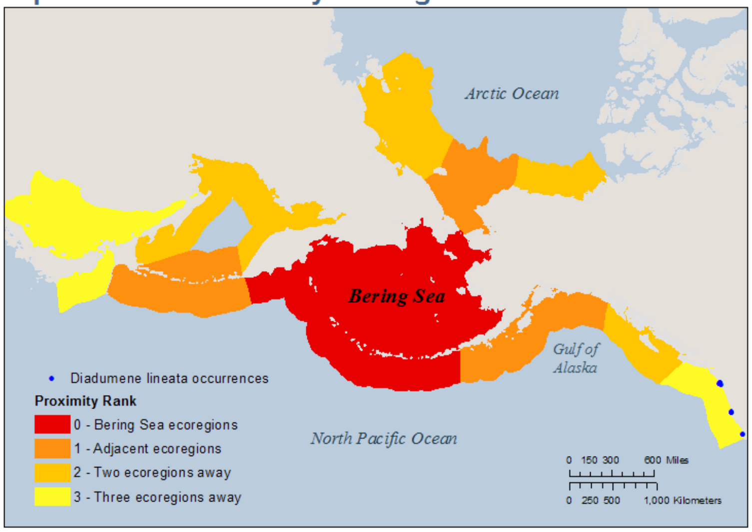


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 19.5 | 26 | 3.75 |
| Anthropogenic Influence: | 6 | 10 | 0 |
| Biological Characteristics: | 22 | 30 | 0 |
| Impacts: | 0.75 | 30 | 0 |
| **Totals:** | 48.25 | 96.25 | 3.75 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | 0 | Minimum Salinity (ppt) | 7 |
| Maximum Temperature (°C) | 27.5 | Maximum Salinity (ppt) | 74 |
| Minimum Reproductive Temperature (°C) | NA | Minimum Reproductive Salinity (ppt) | 8 |
| Maximum Reproductive Temperature (°C) | NA | Maximum Reproductive Salinity (ppt) | 35* |

### Additional Notes

Diadumene lineata is a sea anemone with 50-100 long, thin tentacles. Tentacles are usually colourless, but may be gray or light green. The column can be brown to green, or gray, and can be plain or with white or orange-red stripes. Individuals are small-bodied: the largest specimen found was 31 mm in height and 22 mm wide.

# 1. Distribution and Habitat



### *1.1 Survival requirements - Water temperature*

**Choice: B** Moderate overlap – A moderate area (≥25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 2.5 of 3.75

**High uncertainty?** ☑

**Ranking Rationale:**
Temperatures required for year-round survival occur in a moderate area (≥25%) of the Bering Sea. This species may have adaptations that allow it to tolerate temperature extremes; moreover, models disagree with respect to their estimates of suitable area. We therefore ranked this question with "High uncertainty".

**Background Information:**
This species can tolerate temperatures from 0 to 27.5°C (Shick 1976, qtd. in Fofonoff et al. 2003). At least in the short-term, it can survive drastic temperatures e.g., being under ice (Shick and Lamb 1977) and temperatures as high as 40°C (Shick 1976, qtd. in Fofonoff et al. 2003). This species can secrete a thick layer of mucous or a hard coating, which can protect it against environmental extremes (qtd. in Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Shick and Lamb 1977

### *1.2 Survival requirements - Water salinity*

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
This species can tolerate salinities between 8 and 74 PSU (based on experimental data). Although it can survive at lower salinities (<8 PSU), it exhibits stress responses and is unable to reproduce asexually (Podbielski et al. 2016). Salinities below 8 PSU are likely a physiological limit for this species (Podbielski et al. 2016).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Podbielski et al. 2016

### *1.3 Establishment requirements - Water temperature*

**Choice: U** Unknown/Data Deficient

**Score:** of

**Ranking Rationale:**
In its introduced range, only asexual reproduction has been reported. Temperature requirements for asexual reproduction are unknown.

**Background Information:**
In Japan, spawning occurred when water temperatures reached 25°C (Fukui 1989). However, in its introduced range, D. lineata is only known to reproduce asexually (Fofonoff et al. 2003). The temperature requirements for asexual reproduction are unknown.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Fukui 1989

## 1.4 *Establishment requirements - Water salinity*



**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Although upper salinity thresholds are unknown, D. lineata is a marine species that does not require freshwater to reproduce. We therefore assume that this species can reproduce in saltwater up to 35 ppt. These salinities occur in a large (>75%) portion of the Bering Sea.

**Background Information:**
Podbielski et al. (2016) observed that asexual reproduction stopped at salinities below 7 PSU.

**Sources:**
Podbielski et al. 2016

## 1.5 *Local ecoregional distribution*

**Choice: D** Present in an ecoregion greater than two regions away from the Bering Sea

**Score:** 1.25 of 5

**Ranking Rationale:**
D. lineata has been reported as far north as Vancouver Island.

**Background Information:**
D. lineata has been reported as far north as Vancouver Island.

**Sources:**
NEMESIS; Fofonoff et al. 2003

## 1.6 *Global ecoregional distribution*

**Choice: A** In many ecoregions globally

**Score:** 5 of 5

**Ranking Rationale:**
This species has a global distribution, and has been introduced to both coasts of North America, temperate South America, western Europe, and some Pacific islands.

**Background Information:**
D. lineata is native to the Northwest Pacific, from Japan to Hong Kong (Fofonoff et al. 2003). It has been introduced on both coasts of North America, from AK to CA in the west and from Halifax to Texas in the east. In South America, it has recently been reported in South America (Chile, Argentina). In Europe, it occurs from Ireland and England, south to Spain, and east to the Mediterranean, Black, and Aegean Seas. It is also considered introduced on Pacific islands (New Zealand, Hawaii) (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.7 Current distribution trends*

**Choice:** **B** History of rapid expansion or long-distance dispersal (prior to the last ten years)

**Score:** 3.25 **of** 5

**Ranking Rationale:**
This species has been reported from new areas, but rapid spread has not been documented recently.

**Background Information:**
This species sometimes undergoes boom and bust cycles, spreading rapidly and then dying back (Stephenson 1935, qtd. in Häussermann et al. 2015). It has recently been reported in Argentina (Molina et al. 2009), in Chile (Häussermann et al. 2015), and in the Baltic Sea (Podbielski et al. 2016).

**Sources:**
Podbielski et al. 2016   Häussermann et al. 2015   Molina et al. 2009

| | |
|---|---|
| **Section Total - Scored Points:** | 19.5 |
| **Section Total - Possible Points:** | 26.25 |
| **Section Total -Data Deficient Points:** | 3.75 |

## 2. Anthropogenic Transportation and Establishment



***2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport***

**Choice:** **B** Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 of 4

**Ranking Rationale:**
This species is known to use anthropogenic vectors for transport, but independent spread following its introduction has not been reported.

**Background Information:**
This species is sesille, but can be spread via hull fouling or with introductions of other species such as oysters. This species is not known to reproduce sexually in its introduced range, which may limit its potential for independent transport.

**Sources:**
NEMESIS; Fofonoff et al. 2003

***2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish***

**Choice:** **A** Readily establishes in areas with anthropogenic disturbance/infrastructure and in natural, undisturbed areas

**Score:** 4 of 4

**Ranking Rationale:**
In its introduced range, this species can establish on natural and anthropogenic substrates.

**Background Information:**
This species has been observed growing on the roots and stems of the marsh grass Spartina alterniflora (Molina et al. 2009). In the Baltic Sea, it was reported on both natural and anthropogenic hard substrates (Podbielski et al. 2016).

**Sources:**
Molina et al. 2009   Podbielski et al. 2016

***2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?***

**Choice:** **B** No

**Score:** 0 of 2

**Ranking Rationale:**
This species is not currently farmed or cultivated.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 6 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

# 3. Biological Characteristics



### *3.1 Dietary specialization*

**Choice:** **A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 **of** 5

**Ranking Rationale:**
D. lineate has a generalist diet and prey items are readily available in the Bering Sea.

**Background Information:**
This species eats zooplankton and other small organisms.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **A** Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 **of** 5

**Ranking Rationale:**
This species can tolerate a wide range of temperatures and salinities, and can settle on a range of substrates.

**Background Information:**
This species is usually found in protected coastal areas. It can grow on a range of substrates including aquatic vegetation, mussels, and marine infrastructure (Shick and Lamb 1977; Fofonoff et al. 2003). It can tolerate a wide range of salinities and temperatures, and has established populations in the brackish Baltic Sea (Podbielski et al. 2016).

**Sources:**
Podbielski et al. 2016 NEMESIS; Fofonoff et al. 2003 Shick and Lamb 1977

### *3.3 Desiccation tolerance*

**Choice:** **B** Moderately tolerant (1-7 days) during one or more stages during its life cycle

**High uncertainty?** ☑

**Score:** 3.25 **of** 5

**Ranking Rationale:**
This species is able to tolerate environmental extremes. Although information on its dessication tolerance is scarce, we suspect that it can survive for at least 24 hours.

**Background Information:**
D. lineata can survive exposure to high heat in the intertidal zone (Shick and Lamb 1997). Larger individuals may be able to tolerate being exposed to air for ~24 hours (Clodius 2013, access to abstract only). Individuals exposed to air for ~20 hours were still viable after returning to saltwater (Gollasch and Riemann-Zürneck 1996).

**Sources:**
Shick and Lamb 1977 Clodius 2013 Gollasch and Riemann-Zürneck 1996

### 3.4 *Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice: A** High – Exhibits three or four of the above characteristics

**Score:** 5 of 5

**Ranking Rationale:**
In its introduced range, this species is known to reproduce exclusively by asexual means. Fertilization is likely external, and asexual reproduction requires low parental investment. Fecundity estimates are unknown, but its ability to reach high densities through asexual reproduction suggests high output and survival of clones. Several authors have highlighted the success of this species' reproductive strategy.

**Background Information:**
This species can reproduce both sexually and asexually. Sexual reproduction has not been reported in any introduced population (Fofonoff et al. 2003). In Maine, this species was able to reach extremely high densities (4000 individuals/m2) solely through asexual reproduction. Asexual reproduction in this species may contribute to its invasion success (Shick and Lamb 1977; Ting and Geller 2000; Molina et al. 2009; Podbielski et al. 2016). Most species in this genus exhibit external fertilization (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Shick and Lamb 1977 Podbielski et al. 2016 Molina et al. 2009 Ting and Geller 2000

### 3.5 *Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice: B** Disperses moderate (1-10 km) distances

**High uncertainty?** ☑

**Score:** 1.75 of 2.5

**Ranking Rationale:**
Estimates for this species' dispersal distance is unknown. The dispersal potential for this species is likely limited in its introduced range, where only asexual reproduction has been documented. Long-distance (>10 km) dispersals are possible, but genetic analyses suggest that these events are rare. Given this information, it is likely that this species typically disperses moderate or low distances.

**Background Information:**
This species exhibits external fertilization, and larvae can remain in the water column for up to 26 days if no suitable substrate is found (Fukui 1989). However, sexual reproduction has not been observed in non-native populations (Fofonoff et al. 2003). Asexual fragments may disperse via rafting on floating material to which it is attached (Ting and Geller 2000). Genetic analyses by Ting and Geller (2000) revealed that the majority of the genotypes they identified (52 of 56) were only present in one population. Populations with the same genotype were separated by a maximum distance of 43 km (Ting and Geller 2000).

**Sources:**
Fukui 1989 NEMESIS; Fofonoff et al. 2003 Ting and Geller 2000

### 3.6 *Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: C** Low – Exhibits none of the above characteristics

**Score:** 0.75 of 2.5

**Ranking Rationale:**
This species can disperse at different life stages and has a long-lived larval stage. However, because it is only known to reproduce asexually in its introduced range, we have downgraded its ranking to "Low" to reflect the limited dispersal potential when the gametic and larval stage are discounted.

**Background Information:**
This species has a long-lived larval stage (Fukui 1989). Adults are sessile, but polyps can disperse by rafting on floating vegetation or wood (Ting and Geller 2000). This species exhibits external fertilization (Fukui 1989), which allows gametes to be dispersed passively.

**Sources:**
Fukui 1989 Ting and Geller 2000

### *3.7 Vulnerability to predators*

**Choice:** **D** — Multiple predators present in the Bering Sea or neighboring regions

**Score:** 1.25 **of** 5

**Ranking Rationale:**
Predators of this species are present in the Bering Sea.

**Background Information:**
This species is eaten by nudibranchs and gastropods (Molina et al. 2009).

**Sources:**
Molina et al. 2009

| | |
|---|---|
| **Section Total - Scored Points:** | 22 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 4. Ecological and Socioeconomic Impacts



### 4.1 *Impact on community composition*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No impacts have been reported so far.

**Background Information:**
No impacts have been reported to date (Fofonoff et al. 2003), however the ecological impacts of this species are unknown (Molina et al. 2009; Häussermann et al. 2015). As a predator, D. lineata has the potential to affect invertebrate communities (Molina et al. 2009). Competition with native species are estimated to be minimal (Masterson 2007).

**Sources:**
Molina et al. 2009   Häussermann et al. 2015   Masterson 2007

### 4.2 *Impact on habitat for other species*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No impacts have been reported. Based on its biology, we do not expect D. lineata to affect habitat in the Bering Sea.

**Background Information:**
No ecological impacts have been reported for this species (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.3 *Impact on ecosystem function and processes*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No impacts have been reported. Based on its biology, we do not expect D. lineata to affect ecosystem function in the Bering Sea.

**Background Information:**
No impacts have been reported for this species (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.4 *Impact on high-value, rare, or sensitive species and/or communities*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No impacts have been reported for this species, and we do not expect D. lineata to impact high-value species in the Bering Sea.

**Background Information:**
No impacts have been reported (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.5 Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not known to transport diseases, parasites, or hitchhikers.

**Background Information:**
No impacts have been reported (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No impacts have been reported for this species. In its introduced range, D. lineata is only known to reproduce asexually; thus, we do not expect this species to hybridize with native anemones.

**Background Information:**
No impacts have been reported (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.7 Infrastructure*

**Choice: C** Limited – Has limited potential to cause degradation to infrastructure, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
This species fouls anthropogenic substrates, but is not known to have a significant impact.

**Background Information:**
Although this species fouls anthropogenic substrates, but no economic impacts have been reported (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.8 Commercial fisheries and aquaculture*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact commercial fisheries in the Bering Sea.

**Background Information:**
No impacts have been reported for this species.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Molnar et al. 2008

### *4.9 Subsistence*

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact subsistence resources in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Molnar et al. 2008

### *4.101 Recreation*

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact recreational opportunities in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Molnar et al. 2008

### *4.11 Human health and water quality*

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact human health or water quality in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Molnar et al. 2008

| | |
|---|---|
| **Section Total - Scored Points:** | 0.75 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 5. Feasibility of prevention, detection and control



### *5.1 History of management, containment, and eradication*

**Choice:** **B** Not attempted

**Score:** of

**Ranking Rationale:**
Control or eradication has not been attempted for this species.

**Background Information:**
No information found.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *5.2 Cost and methods of management, containment, and eradication*

**Choice:** **A** Major long-term investment, or is not feasible at this time

**Score:** of

**Ranking Rationale:**
This species can be transported via fouling and hitchhiking. Methods to control the spread of invasive species via these vectors are being developed, and currently necessitate major long-term investments.

**Background Information:**

**Sources:**
CFR 2017 Hagan et al. 2014

### *5.3 Regulatory barriers to prevent introductions and transport*

**Choice:** **B** Regulatory oversight, but compliance is voluntary

**Score:** of

**Ranking Rationale:**
This species is transported by numerous vectors and no species-specific regulations are currently in place. Although there are federal regulations for hull fouling, compliance with these regulations is largely voluntary.

**Background Information:**

**Sources:**
Hagan et al. 2014 CFR 2017

### *5.4 Presence and frequency of monitoring programs*

**Choice:** **A** No surveillance takes place

**Score:** of

**Ranking Rationale:**
No surveillance programs are in place for this species.

**Background Information:**

**Sources:**
None listed

### *5.5 Current efforts for outreach and education*

**Choice:** **A** No education or outreach takes place

**Score:** of

**Ranking Rationale:**
No education or outreach programs are in place for this species.

**Background Information:**

**Sources:**
None listed

**Section Total - Scored Points:**
**Section Total - Possible Points:**
**Section Total -Data Deficient Points:**

## Literature Cited for *Diadumene lineata*


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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Nematostella vectensis*

**Common Name** *starlet sea anemone*

**Phylum** Cnidaria

**Class** Anthozoa

**Order** Actiniaria

**Family** Edwardsiidae

**Final Rank** 43.47

**Data Deficiency:** 17.75

## Species Occurrence by Ecoregion

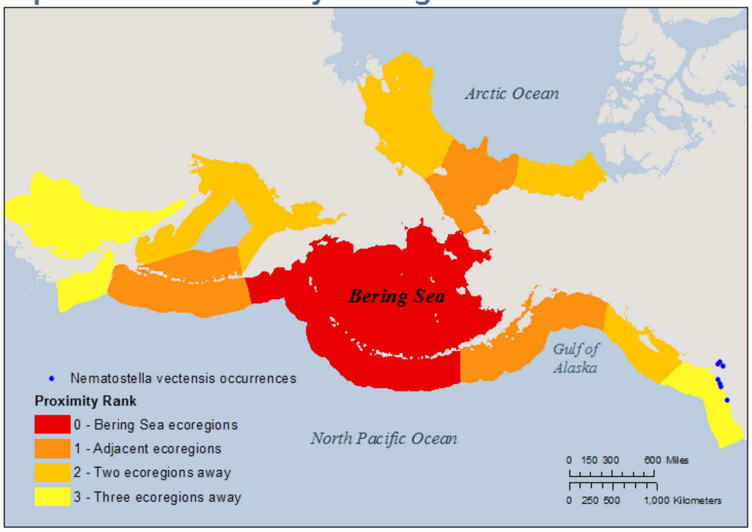


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 14.75 | 26 | 3.75 |
| Anthropogenic Influence: | 2 | 6 | 4.00 |
| Biological Characteristics: | 17.5 | 25 | 5.00 |
| Impacts: | 1.5 | 25 | 5.00 |
| **Totals:** | 35.75 | 82.25 | 17.75 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | -1.5 | Minimum Salinity (ppt) | 7 |
| Maximum Temperature (°C) | 32.5 | Maximum Salinity (ppt) | 52 |
| Minimum Reproductive Temperature (°C) | NA | Minimum Reproductive Salinity (ppt) | 12 |
| Maximum Reproductive Temperature (°C) | NA | Maximum Reproductive Salinity (ppt) | 34 |

### Additional Notes

Nematostella vectensis is a small (typically <1 cm) burrowing anemone. It has an elongate, wormlike body, which is usually buried with only the oral disk and mouth protruding. It typically has 16 tentacles, but may range from 12 to 18. The body is translucent and nematosomes (small ciliated spheres, unique to this genus) may be seen circulating in the gut. The typical size is 10-19 mm, but it may grow larger in culture. The crown of tentacles may reach 8 mm in diameter when extended. The anemone uses adhesive rugae on its column to anchor and move in the sediment (Sheader et al. 1997). Although common in North America, is listed as vulnerable by the IUCN Red List because of its restricted distribution in England.

# 1. Distribution and Habitat

### *1.1 Survival requirements - Water temperature*

**Choice: B** Moderate overlap – A moderate area (≥25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 2.5 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Temperatures required for year-round survival occur in a moderate area (≥25%) of the Bering Sea. Thresholds are based on geographic distribution, which may not represent physiological tolerances; we therefore ranked this question with "High uncertainty".

**Background Information:**
Found in waters that with temperatures ranging from -1.5 to 32.5 C (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.2 Survival requirements - Water salinity*

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
Salinity range for the survival is between 7 and 52 ppt (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.3 Establishment requirements - Water temperature*

**Choice: U** Unknown/Data Deficient

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *1.4 Establishment requirements - Water salinity*

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for reproduction occur over a large (>75%) area of the Bering Sea.

**Background Information:**
Sexual reproduction in the laboratory occurred at 12-34 PSU (Hand and Uhlinger 1992).

**Sources:**
Hand and Uhlinger 1992

### *1.5 Local ecoregional distribution*

**Choice: D** Present in an ecoregion greater than two regions away from the Bering Sea

**Score:** 1.25 of 5

**Ranking Rationale:**
Present in an ecoregion three regions away from the Bering Sea.

**Background Information:**
Occurrence records in the NEMESIS database indicate presence in California, Oregon and Washington (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.6 Global ecoregional distribution*

**Choice: C** In few ecoregions globally

**Score:** 1.75 of 5

**Ranking Rationale:**
Mainly restricted to its native range on the east coast of North America and the Gulf of Mexico. Introductions include the west coast of North America, England and Brazil.

**Background Information:**
Native to the east coast of North America, from Nova Scotia (Canada) to Georgia on the Atlantic coast, and from Florida to Louisiana in the Gulf of Mexico. N. vectensis has been introduced to the west coast of North America (from WA to CA) and England, and in 2004, seven specimens were reported from Brazil's Port of Recife.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.7 Current distribution trends*

**Choice: C** Established outside of native range, but no evidence of rapid expansion or long-distance dispersal

**Score:** 1.75 of 5

**Ranking Rationale:**
Low natural capacity for dispersal.

**Background Information:**
Genetic and experimental studies suggest that N. vectensis have very low dispersal capacity (Stocks and Grassle 2001; Darling et al. 2004).

**Sources:**
Stocks and Grassle 2001 Darling et al. 2004

| | |
|---|---|
| **Section Total - Scored Points:** | 14.75 |
| **Section Total - Possible Points:** | 26.25 |
| **Section Total -Data Deficient Points:** | 3.75 |

## 2. Anthropogenic Transportation and Establishment



### 2.1 *Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice:** **B** Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 **of** 4

**Ranking Rationale:**
This species uses ballast water and ship fouling for long distance transport.

**Background Information:**
Possibly introduced to England with Eastern oysters (Crassostrea virginica) (Sheader et al. 1997). Larval stage may also have been transported in ballast water. Darling et al. (2009) refutes the proposal of ballast water as a possible means of dispersal, and suggests that individuals are transported via ship fouling instead: Adult anemones are generally infaunal, and are typically found in habitats where their entrainment in ballast water tanks would be improbable. Dispersal propagules are much more likely to travel as components of fouling communities, on recreational watercraft or other equipment (e.g. waders, fishing gear). N. vectensis polyps have an impressive adhesive quality (J. Darling & A. Reitzel, pers. obs.) and are capable of passively attaching to most surfaces.

**Sources:**
Sheader et al. 1997   Darling et al. 2009

### 2.2 *Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 2.3 *Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice:** **B** No

**Score:** 0 **of** 2

**Ranking Rationale:**

**Background Information:**
This species is not currently farmed or intentionally cultivated.

**Sources:**
None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 2 |
| **Section Total - Possible Points:** | 6 |
| **Section Total -Data Deficient Points:** | 4 |

# 3. Biological Characteristics



### 3.1 *Dietary specialization*

**Choice: A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Preys on numerous taxa readily available in the Bering Sea.

**Background Information:**
Feeds on a wide range of small invertebrates, including hydrobiid snails, copepods, ostracods, polychaetes, insect larvae, and bivalve larvae (Posey and Hines 1991; Hand and Uhlinger 1994).

**Sources:**
Posey and Hines 1991 Hand and Uhlinger 1994 NEMESIS; Fofonoff et al. 2003

### 3.2 *Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice: C** Specialist; dependent on a narrow range of habitats for all life stages

**Score:** 1.75 of 5

**Ranking Rationale:**
Broad range of temperature and salinity, but limited to slow-moving or still water and requires sheltered conditions.

**Background Information:**
Broad temperature and salinity ranges. Associated with slow-moving or still water; sheltered conditions are required as it allows a layer of fine mud to build up, in which the animal can burrow (Williams 1983 as qtd. In Marshall and Jackson 2007). In the UK, Nematostella vectensis was absent from areas where water flow exceeded 0.18 cm/s (Sheader et al., 1997).

Sensitive to hypoxic or anoxic conditions, although it can crawl up on algal mats to avoid unfavorable conditions.

**Sources:**
Marshall and Jackson 2007 Sheader et al. 1997 NEMESIS; Fofonoff et al. 2003 Mossman 2000

### 3.3 *Desiccation tolerance*

**Choice: B** Moderately tolerant (1-7 days) during one or more stages during its life cycle

**Score:** 3.25 of 5

**Ranking Rationale:**
Adults are moderately tolerant of dessication. No information for larvae.

**Background Information:**
Adults can survive up to 4 days without water in an experimental setting (Williams 1976). This is likely shorter in a natural environment where sunlight and wind can enhance dessication.

**Sources:**
Williams 1976

### *3.4 Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice: A** High – Exhibits three or four of the above characteristics

**Score:** 5 of 5

**Ranking Rationale:**

Capable of asexual reproduction with low parental investment, external fertilization and a short generation time.

**Background Information:**

Appears to primarily reproduce through asexual reproduction, as some populations consist of primarily one sex. Fission can be achieved in as little as 3 days when an organism is as young as 7 weeks. Sexual reproduction does occur but requires specialized conditions that only occur during the warmer parts of the year (Hand and Uhlinger 1994; Sheader et al. 1997).

**Sources:**

Hand and Uhlinger 1994 Sheader et al. 1997 Marshall and Jackson 2007 NEMESIS; Fofonoff et al. 2003

### *3.5 Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice: C** Disperses short (< 1 km) distances

**Score:** 0.75 of 2.5

**Ranking Rationale:**

Only capable of short distance dispersal at only one life stage.

**Background Information:**

Larval stage is the only stage that is planktonic and free-swimming, and can last up to 14 days under laboratory conditions. Adults are effectively sessile, asexual propagules are incapable of dispersal, and egg mass has the tendency to sink rather than float (Darling et al. 2004; Reitzel et al. 2008). Genetic and experimental studies suggest that N. vectensis has a very low dispersal capacity (Stocks and Grassle 2001; Darling et al. 2004).

In at least certain parts of its range, N. vectensis undergoes dramatic seasonal fluctuations in population density. Demographic studies in England populations have revealed that densities can vary over three orders of magnitude, from under 100/m2 to over 2500/m2 and back again in the course of a single calendar year (Sheader et al. 1997)

**Sources:**

Darling et al. 2004 Reitzel et al. 2008 Stocks and Grassle 2001 Sheader et al. 1997 Darling et al. 2009

### 3.6 *Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: B** Moderate – Exhibits one of the above characteristics

**Score:** 1.75 of 2.5

**Ranking Rationale:**

Dispersal is limited ot the larval stage only, however, the larval viability window is relatively long (up to 14 days).

**Background Information:**

Larval stage is the only stage that is planktonic and free-swimming, and can last up to 14 days under laboratory conditions. Adults are effectively sessile, asexual propagules that are incapable of dispersal, and egg mass has the tendency to sink rather than float (Darling et al. 2004; Reitzel et al. 2008).

In at least certain parts of its range, N. vectensis undergoes dramatic seasonal fluctuations in population density. Demographic studies in England populations have revealed that densities can vary over three orders of magnitude, from under 100/m2 to over 2500/m2 and back again in the course of a single calendar year (Sheader et al. 1997).

**Sources:**

Darling et al. 2004 Reitzel et al. 2008 Sheader et al. 1997

### 3.7 *Vulnerability to predators*

**Choice: U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**

Posey and Hines (1991) suggest that in the Rhode River, MD, distribution outside lagoons may be limited through predation by shrimps. No other predators have been listed.

**Sources:**

Posey and Hines 1991

| | |
|---|---|
| **Section Total - Scored Points:** | 17.5 |
| **Section Total - Possible Points:** | 25 |
| **Section Total -Data Deficient Points:** | 5 |

# 4. Ecological and Socioeconomic Impacts

## *4.1 Impact on community composition*

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
N. vectensis' small size and the fact that it is also predated upon result in a negligible impact on community composition.

**Background Information:**
As a benthic predator, N. vectensis can have direct effects on survival and recruitment of prey species. In experiments, N. vectensis decreased survivorship of Macoma mitchelli larvae, and decreased recruitment of Streblospio benedicti, relative to controls. However, in its natural range, the population of N. vectensis is itself subject to important predation by the grass shrimp Palaemonetes pugio. Given these balancing forces, net community effects will vary with seasonally fluctuating predator abundance and prey recruitment (Posey and Hines 1991).

N. vectensis can achieve high densities throughout the year, but it is individually very small with a dry weight of 0.5 mg. Even the highest reported density of 2,500 individuals/m2 would result in 1.25 g/m2 of biomass. Due to this, N. vectensis' impact is likely to be negligible (Reitzel et al. 2008).

**Sources:**
Posey and Hines 1991 Reitzel et al. 2008

## *4.2 Impact on habitat for other species*

**Choice: U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

## *4.3 Impact on ecosystem function and processes*

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**

**Background Information:**
No ecological or economic impacts have been reported (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.4 *Impact on high-value, rare, or sensitive species and/or communities*

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**

**Background Information:**
No ecological or economic impacts have been reported (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.5 *Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice: U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 4.6 *Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice: D** No impact

**High uncertainty?** ☑

**Score:** 0 of 2.5

**Ranking Rationale:**
To date, hybridization of N. vectensis with similar species has not been reported.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 4.7 *Infrastructure*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on infrastructure have been reported for N. vectensis, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.8 Commercial fisheries and aquaculture*

**Choice: C** Limited – Has limited potential to cause degradation to fisheries and aquaculture, and/or is restricted to a limited region

**Score:** 0.75 of 3

**High uncertainty?** ☑

**Ranking Rationale:**
May be a predator for oyster larvae.

**Background Information:**
Hand and Uhlinger (1994) suggested that it could be a significant predator of oyster larvae in estuaries such as Chesapeake Bay, because of its dense populations in marshes and mudflats. However, its apparent scarcity and sporadic appearance (Posey and Hines 1991) argues against a role in recruitment of oysters and other commercially important shellfish in the upper Chesapeake Bay. Its importance as a predator has not yet been studied in other estuaries.

**Sources:**
Hand and Uhlinger 1994   Posey and Hines 1991   NEMESIS; Fofonoff et al. 2003

### *4.9 Subsistence*

**Choice: C** Limited – Has limited potential to cause degradation to subsistence resources, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**High uncertainty?** ☑

**Ranking Rationale:**
May be a predator for oyster larvae.

**Background Information:**
No information found. Impact on oyster larvae (if any) would affect subsistence harvesting as well.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.101 Recreation*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on recreation have been reported for N. vectensis, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.11 Human health and water quality*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on human health or water quality have been reported for N. vectensis, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 1.5 |
| **Section Total - Possible Points:** | 25 |
| **Section Total -Data Deficient Points:** | 5 |

# 5. Feasibility of prevention, detection and control



### *5.1 History of management, containment, and eradication*

**Choice: B** Not attempted

**Score:** of

**Ranking Rationale:**

**Background Information:**
No species-specific management, containtment or eradication exists for N. vectensis.

**Sources:**
None listed

### *5.2 Cost and methods of management, containment, and eradication*

**Choice: B** Major short-term and/or moderate long-term investment

**Score:** of

**Ranking Rationale:**

**Background Information:**
No species-specific management, containment or eradication methods exist. Current hull fouling technologies that address invasive species require purchasing of specialized equipment and regular cleaning.

**Sources:**
Hagan et al. 2014

### *5.3 Regulatory barriers to prevent introductions and transport*

**Choice: B** Regulatory oversight, but compliance is voluntary

**Score:** of

**Ranking Rationale:**
Compliance with fouling regulations are voluntary.

**Background Information:**
In Brazil, where this species was recorded in 2004, introduced species such as N. vectensis may easily be overlooked (Silva et al. 2010). The scarcity of studies on cnidarians in soft sediments may explain the absence of earlier reports of the species. Most of the sampling that does take place is done by ecologists studying community dynamics, after which specimens are sent to taxonomists for identification (this is what led to the discovery of N. vectensis in Brazil). The authors recommend establishing a monitoring program for this species in the Port of Recife, where the anemone was found (Silva et al. 2010).
In the U.S., Coast Guard regulations require masters and ship owners to clean vessels and related infrastructure on a "regular" basis (CFR 33 § 151.2050). Failure to remove fouling organisms is punishable with a fine (up to $27 500). However, because the word "regular" is not defined, regulations are hard to enforce and compliance remains largely voluntary (Hagan et al. 2014). Cleaning of recreational vessels is also voluntary, although state and federal programs are in place to encourage owners to clean their boats. Boat inspection is mandatory on some lakes (e.g. Lake Tahoe in CA/NV, Lake George in NY). In summer 2016, state and federal agencies conducted voluntary inspections for aquatic invasive species on trailered boats entering the state of Alaska (Davis 2016).

**Sources:**
Silva et al. 2010 CFR 2017 Hagan et al. 2014 Davis 2016

### *5.4 Presence and frequency of monitoring programs*

**Choice:** **A** No surveillance takes place

**Score:** of

**Ranking Rationale:**

**Background Information:**
No species-specific monitoring for N. vectensis occurs, and no regular monitoring effort currently exists for hull fouling.

**Sources:**
None listed

### *5.5 Current efforts for outreach and education*

**Choice:** **A** No education or outreach takes place

**Score:** of

**Ranking Rationale:**
Education and outreach occurs in its native region, but no information or outreach exists for N. vectensis as a non-native species.

**Background Information:**
Interestingly, in England, where its distribution is restricted, N. vectensis is listed as rare and is protected under the Wildlife and Countryside Act since 1988. Factsheets exist to inform the public on actions being taken to increase its habitat and population size. No educational or outreach material informing the public about the status of N. vectensis as an introduced (or invasive) species was found in the literature. The conservation of introduced N. vectensis populations in England appears to be motivated by its misidentification as a native species and a desire to protect vulnerable coastal habitats (Reitzel et al. 2008).

**Sources:**
Bamber 2013   Reitzel et al. 2008

**Section Total - Scored Points:**

**Section Total - Possible Points:**

**Section Total -Data Deficient Points:**

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- Hand, C., and K. R. Uhlinger. 1994. The unique, widely distributed, estuarine sea anemone, Nematostella vectensis Stephenson: A review, new facts and questions. Estuaries 17(2):501-508.

# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Cordylophora caspia*

**Common Name** *freshwater hydroid*

**Phylum** Cnidaria

**Class** Hydrozoa

**Order** Anthomedusae

**Family** Cordylophoridae

**Final Rank** 46.84

**Data Deficiency:** 5.00

## Species Occurrence by Ecoregion

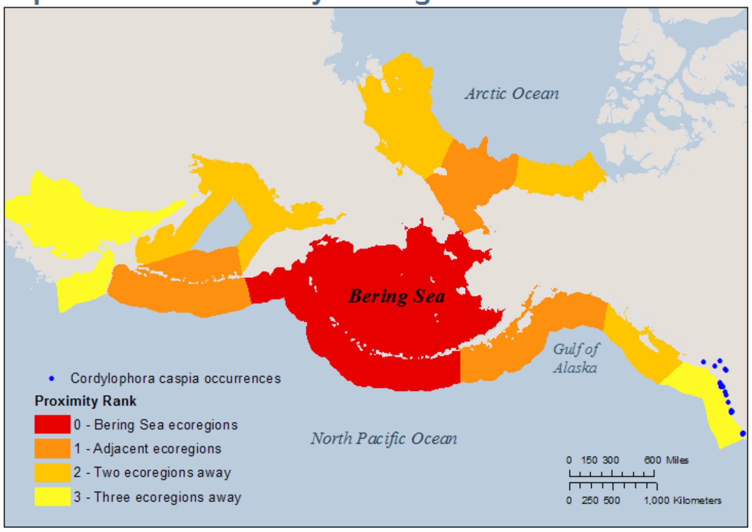


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

### Category Scores and Data Deficiencies

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 17 | 30 | 0 |
| Anthropogenic Influence: | 6 | 10 | 0 |
| Biological Characteristics: | 17.75 | 25 | 5.00 |
| Impacts: | 3.75 | 30 | 0 |
| **Totals:** | 44.50 | 95.00 | 5.00 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | -10 | Minimum Salinity (ppt) | 0 |
| Maximum Temperature (°C) | 30 | Maximum Salinity (ppt) | 35 |
| Minimum Reproductive Temperature (°C) | 10 | Minimum Reproductive Salinity (ppt) | 0.2 |
| Maximum Reproductive Temperature (°C) | 28 | Maximum Reproductive Salinity (ppt) | 30 |

### Additional Notes

Cordylophora caspia is a freshwater or brackish hydroid that grows in erect, branching colonies growing from a single stem. A colony may have over a dozen tentacles and 40 or more hydranths. Hydranths are white or pale pink, and the stems are yellowish-brown. Specimens are small (usually a few centimeters tall), but some may measure 15 cm or more. C. caspia is considered native to the Black Sea and Caspian Sea, but has been introduced to tropical and temperate regions worldwide. This species has broad environmental tolerances and can have ecological and economic impacts where it occurs at high densities.

# 1. Distribution and Habitat



### *1.1 Survival requirements - Water temperature*

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Because this species has a highly tolerant dormant state, we consider that temperatures required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
This species' temperature tolerance varies across populations. Cold water populations in German had an upper temperature threshold of $24^{0}$C, whereas individuals from Massachusetts could tolerate temperatures above $30^{0}$C (qtd. in Fofonoff et al. 2003). Tyler-Walters and Pizzolla (2007) state an upper temperature limit of $35^{0}$C. A lower temperature threshold of $0^{0}$C is estimated based on this species' geographic distribution (Fofonoff et al. 2003). However, this species has a dormant state (called menont) that can tolerate temperatures as low as -$10^{0}$C (Tyler-Walters and Pizzolla 2007).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Tyler-Walters and Pizzolla 2007

### *1.2 Survival requirements - Water salinity*

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
C. caspia is usually considered a brackish or freshwater species, but can tolerate salinities up to 35 ppt (based on experimental studies).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.3 Establishment requirements - Water temperature*

**Choice: D** No overlap – Temperatures required for reproduction do not exist in the Bering Sea

**Score:** 0 of 3.75

**Ranking Rationale:**
Temperatures required for reproduction occur in a limited area (<25%) of the Bering Sea. However, required salinities that do not occur in the Bering Sea. We therefore ranked this question as "No overlap".

**Background Information:**
This species reproduces at temperatures between 10 and 28°C (Arndt 1989; Tyler-Walters and Pizzolla 2007).

**Sources:**
Tyler-Walters and Pizzolla 2007   Arndt 1989

### *1.4 Establishment requirements - Water salinity*

**Choice:** **D** No overlap – Salinities required for reproduction do not exist in the Bering Sea

**Score:** 0 of 3.75

**Ranking Rationale:**
Salinities required for reproduction do not occur in the Bering Sea.

**Background Information:**
This species can reproduce in nearly freshwater conditions (0.2 ppt; Arndt 1989), but reproduces optimally at ≥ 5 ppt (Ringelband 2001). The upper limit for sexual reproduction was cited as 27 ppt by Kinne (1958, qtd. in Fofonoff et al. 2003), and as low as 20 ppt by Arndt (1989). The upper tolerance for asexual (vegetative) reproduction is 30 ppt (Arndt 1989).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Ringelband 2001 Arndt 1989

### *1.5 Local ecoregional distribution*

**Choice:** **D** Present in an ecoregion greater than two regions away from the Bering Sea

**Score:** 1.25 of 5

**Ranking Rationale:**
This species is found in northern Washington and southern BC.

**Background Information:**
On the west coast of North America, this species occurs from CA to northern WA. It has also been found in Victoria, British Columbia.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.6 Global ecoregional distribution*

**Choice:** **A** In many ecoregions globally

**Score:** 5 of 5

**Ranking Rationale:**
This species has a worldwide distribution including both coasts of North America, Central and South America, western and Mediterranean Europe. In the Pacific, it has been reported in Australia, New Zealand, Hawaii, and Shanghai.

**Background Information:**
This species is native to the Black and Caspian Seas. In North America, it has been introduced on the west coast from CA to BC. On the east coast, it occurs from QC to TX and Panama, and has invaded the Great Lakes region. It has been reported in various countries in South America including Brazil, Uruguay, Argentina, and Chile. It is widespread in Europe, where it is found in Finland and Norway, south to Spain and Italy. It is introduced in New Zealand, Hawaii, Australia, Iraq, and Shanghai.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.7 Current distribution trends*



**Choice:** **B** History of rapid expansion or long-distance dispersal (prior to the last ten years)

**Score:** **3.25** **of** **5**

**Ranking Rationale:**

This species has spread rapidly throughout Europe and the Great Lakes. Natural long-distance dispersal in this species is unlikely.

**Background Information:**

This species was first introduced to western Europe in the 17th century, where it spread rapidly (Fofonoff et al. 2003). It has also proliferated in the Great Lakes region, where it was first discovered in 1957 (Folino 1999; Darling and Folino-Rorem 2009). This species is sessile and has a short-lived larval stage, which makes long-distance dispersal unlikely (Gili and Hughes 1995).

**Sources:**

NEMESIS; Fofonoff et al. 2003   Darling and Folino-Rorem 2009   Gili and Hughes 1995   Folino 1999

| | |
|---|---|
| **Section Total - Scored Points:** | 17 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 2. Anthropogenic Transportation and Establishment



### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice:** **B** Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 **of** 4

**Ranking Rationale:**
This species has a limited natural dispersal potential, which only allows for local expansion (on the scale of a few kilometers). The regional and global expansion in its distribution is likely the result of transport via anthropogenic vectors (e.g., ballast water and hull fouling).

**Background Information:**
Most life stages in this species can only disperse short distances; however, dormant stages may be capable of long-distance dispersal (Gili and Hughes 1995). Genetic analyses on populations in the Great Lakes revealed that natural dispersal was highly localized (< 20 km) (Darling and Folino-Rorem 2009). Patterns of regional spread were attributed to anthropogenic vectors (Darling and Folino-Rorem 2009).

**Sources:**
Gili and Hughes 1995 Darling and Folino-Rorem 2009

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice:** **A** Readily establishes in areas with anthropogenic disturbance/infrastructure and in natural, undisturbed areas

**Score:** 4 **of** 4

**Ranking Rationale:**
This species can establish in both disturbed and undisturbed areas.

**Background Information:**
This species has been found on a variety of substrates including vegetation, bivalve shells, rocks, wood, and anthropogenic substrates.

**Sources:**
Tyler-Walters and Pizzolla 2007 NEMESIS; Fofonoff et al. 2003

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice:** **B** No

**Score:** 0 **of** 2

**Ranking Rationale:**
This species is not farmed or cultivated.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 6 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics



### *3.1 Dietary specialization*

**Choice:** **A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
This species has a generalized diet and food items are readily available in the Bering Sea.

**Background Information:**
This species is a sit-and-wait carnivore that eats prey that swim into it. Its diet includes zooplankton, larvae, detritus, crustaceans, and other small aquatic invertebrates (Gili and Hughes 1995).

**Sources:**
Gili and Hughes 1995

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **B** Requires specialized habitat for some life stages (e.g., reproduction)

**Score:** 3.25 of 5

**Ranking Rationale:**
This species can tolerate a wide range of environmental conditions, but both sexual and asexual reproduction require salinities < 30 ppt, which are not found in the Bering Sea.

**Background Information:**
This species, and especially its dormant state, can tolerate a wide range of environmental conditions, including temperature, salinity, and substrate type (Tyler-Walters and Pizzolla 2007). Folino (1999) attributes the expansion of Cordylophora spp. in the US not only to increased shipping traffic, but also to changes in salt concentrations (as a result of human activity), which favour its establishment. Salinity tolerances for sexual reproduction have been listed as high as 27 ppt (Kinne 1958, qtd. in Fofonoff et al. 2003), but Arndt (1989) suggests a limit of 20 ppt.

**Sources:**
Folino 1999 Tyler-Walters and Pizzolla 2007 NEMESIS; Fofonoff et al. 2003 Arndt 1989

### *3.3 Desiccation tolerance*

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**
The desiccation tolerance of this species unknown.

**Background Information:**
This species produces a dormant state that is capable of tolerating extreme temperatures and perhaps other environmental stressors such as desiccation.

**Sources:**
Tyler-Walters and Pizzolla 2007

### *3.4 Likelihood of success for reproductive strategy*



i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice:** **A** High – Exhibits three or four of the above characteristics

**Score:** 5 of 5

**Ranking Rationale:**

This species exhibits asexual reproduction and high fecundity. This species can live for several years, but we consider it to have a short generation time because of its short-lived larval stage and rapid growth rate. These r-selected traits are underscored in colder parts of its range, where this species undergoes seasonal die-offs in the winter.

**Background Information:**

This species is dioecious. Sperm is released in the water column, and eggs are brooded internally by the female. Because this species is colonial, fecundity depends on the size of the colony (Tyler-Walters and Pizzolla 2007). Large colonies may contain upwards of 2000 individuals, and each individual can have several female gonophores. Each female gonophore produces several eggs (~7-16; Fofonoff et al. 2003). Although hydroids can be extremely long-lived, this species has a short larval stage (<24 hours) and an exponential growth rate, with the number of polyps in a colony doubling every 2-4 days (Fulton 1962, qtd. in Tyler-Walters and Pizzolla 2007; Gili and Hughes 1995). In colder parts of its range, it undergoes seasonal die-offs during the winter, returning to an active state as temperatures become warmer (Fofonoff et al. 2003). C. caspia is also capable of asexual reproduction by budding or fragmentation (Gili and Hughes 1995).

**Sources:**

Tyler-Walters and Pizzolla 2007 NEMESIS; Fofonoff et al. 2003 Gili and Hughes 1995

### *3.5 Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice:** **C** Disperses short (< 1 km) distances

**Score:** 0.75 of 2.5

**Ranking Rationale:**

While long-distance dispersal is possible under some conditions, the importance of these dispersal mechanisms is uncertain. In general, this species is considered to have highly limited dispersal abilities.

**Background Information:**

This species has a short-lived (<24 hours), free-swimming larval stage (Folino 1999; Darling and Folino-Rorem 2009). Long-distance dispersal may be achieved by rafting or by the dormant states; however, in general, this species is considered to have very limited dispersal potential (Gili and Hughes 1995). Populations separated by < 21 km were found to have significant genetic differences between each other (Darling and Folino-Rorem 2009). Tyler-Walters and Pizzolla (2007) categorize this species' dispersal potential as <10 m.

**Sources:**

Darling and Folino-Rorem 2009 Gili and Hughes 1995 Folino 1999 Tyler-Walters and Pizzolla 2007

### 3.6 *Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: A** High – Exhibits two or three of the above characteristics

**Score:** 2.5 **of** 2.5

**Ranking Rationale:**
Although adults are sessile, this species can disperse in several ways and at more than one life stage.

**Background Information:**
This species has a short-lived (< 1 day), but free-swimming larval stage (Folino 1999; Darling and Folino-Rorem 2009). It can disperse naturally in several ways, including by rafting (e.g., on wood or vegetation), by fragmentation, and by dispersal of its highly tolerant dormant stage (Gili and Hughes 1995; Darling and Folino-Rorem 2009).

**Sources:**
Gili and Hughes 1995   Darling and Folino-Rorem 2009

### 3.7 *Vulnerability to predators*

**Choice: D** Multiple predators present in the Bering Sea or neighboring regions

**Score:** 1.25 **of** 5

**Ranking Rationale:**
This species is preyed upon by several taxa that occur in the Bering Sea.

**Background Information:**
This species is preyed upon by nudibranchs, amphipods, and fish (Matern and Brown 2005).

**Sources:**
Tyler-Walters and Pizzolla 2007   Matern and Brown 2005

| | |
|---:|---:|
| **Section Total - Scored Points:** | 17.75 |
| **Section Total - Possible Points:** | 25 |
| **Section Total -Data Deficient Points:** | 5 |

# 4. Ecological and Socioeconomic Impacts

### 4.1 *Impact on community composition*

**Choice:** **C**

Limited – Single trophic level; may cause decline but not extirpation

**Score:** 0.75 of 2.5

**Ranking Rationale:**
Studies on this species' impacts are scarce. C. caspia may compete for space with other fouling organism.

**Background Information:**
Because this species is a rapid colonizer and can reach high densities, it may compete with other fouling organisms for space. In field experiments, establishment of C. caspia led to reduced abundances of several species (qtd. in Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.2 *Impact on habitat for other species*

**Choice:** **C**

Limited – Has limited potential to cause changes in one or more habitats

**Score:** 0.75 of 2.5

**Ranking Rationale:**
This species' physical structure may create secondary settlement habitat for other aquatic organisms. The impacts from this species are largely restricted to brackish systems, where this species has greater competitive abilities. No impacts have been reported for marine ecosystems.

**Background Information:**
The branching structure of C. caspia has been shown to increase abundance of barnacles, amphipods, and annelids in field experiments (Von Holle and Ruiz 1997, qtd. in Fofonoff et al. 2003). It can also provide habitat for settlement of zebra mussels , but the beneficial impacts may be dampened by C. caspia predation on mussel larvae (Folino-Rorem and Stoeckel 2006).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Folino-Rorem and Stoeckel 2006

### 4.3 *Impact on ecosystem function and processes*

**Choice:** **C**

Limited – Causes or potentially causes changes to food webs and/or ecosystem functions, with limited impact and/or within a very limited region

**Score:** 0.75 of 2.5

**Ranking Rationale:**
This species may impact ecosystem functions and food web dynamics through predation, biodeposition, and particle trapping. However, the realized impacts of C. caspia on ecosystems are still unknown.

**Background Information:**
The ecological impacts of C. caspia are still unknown (Darling and Folino-Rorem 2009). In the Baltic Sea, where C. caspia occurs at high densities, it may alter ecosystem processes by contributing to biodeposition and by trapping particles on its branches and stolons. Both of these effects may increase eutrophication (Olenin and Leppäkoski 1999), This species may also impact food web dynamics by preying upon bivalve larvae and other aquatic invertebrates (USGS 2017).

**Sources:**
U.S. Geological Survey; Fuller and Benson 2017   Darling and Folino-Rorem 2009   Olenin and Leppäkoski 1999

### *4.4 Impact on high-value, rare, or sensitive species and/or communities*

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No impacts have been reported.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003 U.S. Geological Survey; Fuller and Benson 2017

### *4.5 Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No impacts have been reported.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003 U.S. Geological Survey; Fuller and Benson 2017

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No impacts have been reported.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003 U.S. Geological Survey; Fuller and Benson 2017

### *4.7 Infrastructure*

**Choice: B** Moderate – Causes or has the potential to cause degradation to infrastructure, with moderate impact and/or within only a portion of the region

**Score:** 1.5 of 3

**Ranking Rationale:**
This species fouls power plants in freshwater and brackish ecosystems. Severe economic impacts have been reported in some cases. Significant impacts have not been reported from marine systems.

**Background Information:**
This species is known to foul power plants in freshwater and brackish systems in Europe, the U.S., and Brazil (Folino 1999, Grohmann 2008). Fouling by C. caspia has led to decreased efficiency, increased maintenance costs, and even plant closure (Grohmann 2008). Its impacts on ships, buoys, and associated infrastructures are minimal (Fofonoff et al. 2003).

**Sources:**
Folino 1999 Grohmann 2008

### *4.8 Commercial fisheries and aquaculture*



**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
No impacts have been reported.

**Background Information:**
This species can prey upon bivalve larvae, and can grow on mussel shells, but no negative impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.9 Subsistence*

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact subsistence resources in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.101 Recreation*

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact recreational opportunities in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.11 Human health and water quality*

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact human health and water quality in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 3.75 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 5. Feasibility of prevention, detection and control



### *5.1 History of management, containment, and eradication*

**Choice:** **C** Attempted; control methods are currently in development/being studied

**Score:** of

**Ranking Rationale:**
Control has been attempted, but unsuccessful. Methods are currently being investigated.

**Background Information:**
Methods of control have focused on eradicating C. caspia from equipment and infrastructure. Chlorine or temperature treatments were not successful, as colonies regenerated within 2 weeks (Folino-Rorem and Indelicato 2005).

**Sources:**
Folino-Rorem and Indelicato 2005

### *5.2 Cost and methods of management, containment, and eradication*

**Choice:** **B** Major short-term and/or moderate long-term investment

**Score:** of

**Ranking Rationale:**
While treatments using chlorine or extreme temperatures ae successful at reducing fouling, colonies regenerate rapidly and treatments must be repeated periodically. For the time being, control of C. caspia requires long-term investment.

**Background Information:**
Chlorine and thermal treatments are the most common control methods used to prevent or reduce biofouling by C. caspia. Of the different treatments that were applied, thermal treatments (> 40˚C) were most effective, and had lower environmental impacts than chlorine (Folino-Rorem and Indelicato 2005). However, colony regeneration occurred in all cases (Folino-Rorem and Indelicato 2005). In Brazil, fouling by C. caspia required maintenance to be performed every four months, instead of every 18 months, which increased overall costs (although no estimates were provided; Grohmann 2008).

**Sources:**
Folino-Rorem and Indelicato 2005   Grohmann 2008

### *5.3 Regulatory barriers to prevent introductions and transport*

**Choice:** **B** Regulatory oversight, but compliance is voluntary

**Score:** of

**Ranking Rationale:**
This species is transported by ballast water and ship fouling. No species-specific regulations are currently in place. Although there are federal regulations for both ballast water and hull fouling, compliance with federal fouling regulations remains voluntary.

**Background Information:**

**Sources:**
Hagan et al. 2014   CFR 2017

### 5.4 *Presence and frequency of monitoring programs*

**Choice:** **A** No surveillance takes place

**Score:** of

**Ranking Rationale:**
There is no surveillance currently taking place for this species.

**Background Information:**

**Sources:**
None listed

### 5.5 *Current efforts for outreach and education*

**Choice:** **A** No education or outreach takes place

**Score:** of

**Ranking Rationale:**
No education or outreach is taking place for this species.

**Background Information:**

**Sources:**
None listed

**Section Total - Scored Points:**

**Section Total - Possible Points:**

**Section Total -Data Deficient Points:**

## Literature Cited for *Cordylophora caspia*


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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Ectopleura crocea*

**Common Name** *pink mouthed hydroid*

| | |
|---|---|
| Phylum | Cnidaria |
| Class | Hydrozoa |
| Order | Anthomedusae |
| Family | Tubulariidae |

**Final Rank** 54.47

**Data Deficiency:** 5.00

## Species Occurrence by Ecoregion

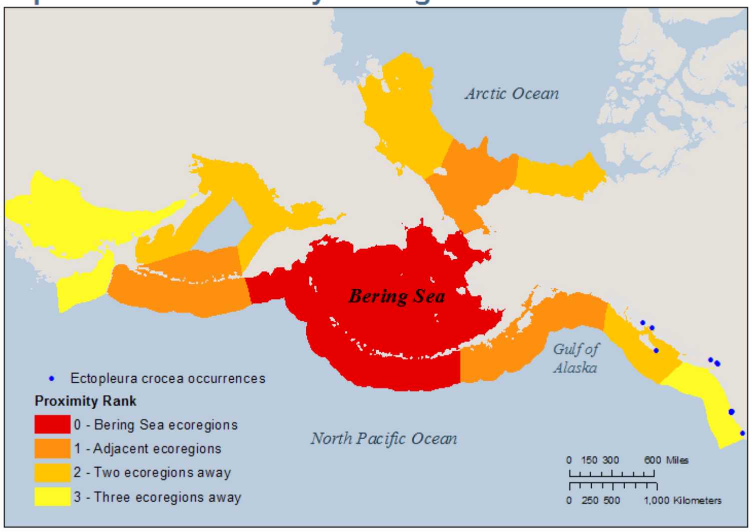


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

### Category Scores and Data Deficiencies

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 20.5 | 30 | 0 |
| Anthropogenic Influence: | 4.75 | 10 | 0 |
| Biological Characteristics: | 19.5 | 25 | 5.00 |
| Impacts: | 7 | 30 | 0 |
| **Totals:** | 51.75 | 95.00 | 5.00 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | 0 | Minimum Salinity (ppt) | 23 |
| Maximum Temperature (°C) | 30 | Maximum Salinity (ppt) | 34 |
| Minimum Reproductive Temperature (°C) | 12 | Minimum Reproductive Salinity (ppt) | 31* |
| Maximum Reproductive Temperature (°C) | 26 | Maximum Reproductive Salinity (ppt) | 34* |

### Additional Notes

Ectopleura crocea is a colonial hydroid that can grow up to 100-120 mm in height. Colonies are pink and composed of hundreds of unbranched stems with one hydranth per stalk and two whorls of 20 to 24 tentacles. This species lacks a medusa stage. Taxonomy is debated, and there exists many synonyms including Tubularia crocea and Pinauay crocea (see NEMESIS for a complete list). This species is native to the east coast of North America, but has spread to the West Coast, as well as to Europe, Africa, Australia, New Zealand, and the South China Sea. In the Mediterranean Sea, the species has been declining in abundance since ~1980, likely due to warming temperatures (Di Camillo et al. 2013).

# 1. Distribution and Habitat

### 1.1 *Survival requirements - Water temperature*

**Choice: B** Moderate overlap – A moderate area (≥25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 2.5 **of** 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Temperatures required for year-round survival occur in a moderate area (≥25%) of the Bering Sea. Thresholds are based on geographic distribution, which may not represent physiological tolerances; moreover, models disagree with respect to their estimates of suitable area. We therefore ranked this question with "High uncertainty".

**Background Information:**
This species can tolerate temperatures from 0 to 30°C (based on geographic range; Fofonoff et al. 2003). In some regions, this species becomes dormant during the summer (when temperatures exceed ~19-21°C) and regenerates when conditions become suitable again (Di Camillo et al. 2013).

**Sources:**
Di Camillo et al. 2013 NEMESIS; Fofonoff et al. 2003

### 1.2 *Survival requirements - Water salinity*

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 **of** 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea. Thresholds are based on geographic distribution, which may not represent physiological tolerances; moreover, models disagree with respect to their estimates of suitable area. We therefore ranked this question with "High uncertainty".

**Background Information:**
Based on geographic distribution, E. crocea's salinity range is estimated to range from 23 to 34 ppt (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 1.3 *Establishment requirements - Water temperature*

**Choice: C** Little overlap – A small area (<25%) of the Bering Sea has temperatures suitable for reproduction

**Score:** 1.25 **of** 3.75

**Ranking Rationale:**
Temperatures required for reproduction occur in a limited area (<25%) of the Bering Sea.

**Background Information:**
Asexual and sexual reproduction have been observed from 12 to 26°C (surface water temperature) (Yamashita et al. 2003).

**Sources:**
Yamashita et al. 2003

### 1.4 *Establishment requirements - Water salinity*

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 of 3.75

**High uncertainty?** ☑

**Ranking Rationale:**
Although salinity thresholds are unknown, this species is a marine organism that does not require freshwater to reproduce. We therefore assume that this species can reproduce in saltwater up to 34 ppt. These salinities occur in a large (>75%) portion of the Bering Sea.

**Background Information:**
We were unable to find specific information on this species' reproductive salinity requirements. Based on its geographic distribution, this species tolerates salinities from 23 to 34 ppt (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 1.5 *Local ecoregional distribution*

**Choice: C** Present in an ecoregion two regions away from the Bering Sea (i.e. adjacent to an adjacent ecoregion)

**Score:** 2.5 of 5

**Ranking Rationale:**
This species has been reported along the west coast of North America, from CA to Ketchikan, AK.

**Background Information:**
In 2003, one individual was collected in Ketchikan. It is unknown whether this hydroid is established in Alaska (Ruiz et al. 2006). This species has also been reported in BC and WA, and is established in OR and CA.

**Sources:**
Ruiz et al. 2006 NEMESIS; Fofonoff et al. 2003

### 1.6 *Global ecoregional distribution*

**Choice: A** In many ecoregions globally

**Score:** 5 of 5

**Ranking Rationale:**
This species has a broad geographic distribution and has been recorded on both coasts of North America, as well as in Europe, Asia, South Africa, Australia, and New Zealand.

**Background Information:**
Established in cold temperate, warm temperate, and tropical waters. E. crocea is native to the Atlantic coast of North America, from New Brunswick to FL and TX. It is considered cryptogenic in the Caribbean and South America. On the West Coast, established populations have been recorded in CA and OR. Individuals have been detected in WA, BC, and southern AK, but it is unknown whether populations are established there. It has been introduced in Europe and the Middle East, including in France, the Mediterranean Sea (Italy, Turkey, Egypt), and the Red Sea near Israel. It has been recorded in Japan, the China Sea, South Africa, Australia, and New Zealand.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.7 Current distribution trends*



**Choice:** **C** Established outside of native range, but no evidence of rapid expansion or long-distance dispersal

**Score:** 1.75 **of** 5

**Ranking Rationale:**
This species has established itself in many regions outside of its native range. However, there have not been reports of rapid spread, and natural dispersal is limited.

**Background Information:**
One individual was discovered in Ketchikan, AK in 2003, but it has not spread since then. No rapid range expansions have been documented. This species does not have the potential for natural, long-distance dispersal.

**Sources:**
Ruiz et al. 2006 NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 20.5 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 2. Anthropogenic Transportation and Establishment



### 2.1 *Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice: B** Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 of 4

**High uncertainty?** ☑

**Ranking Rationale:**
This species can be transported on ships, but its potential for natural dispersal is likely limited.

**Background Information:**
E. crocea is a fouling organism that has been found on ships and other anthropogenic structures such as fishing gear. A survey in New Zealand found E. crocea in sheltered areas on ships (e.g., sea chests, propellers) (Cawthron Institute 2010).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Cawthron Institute 2010

### 2.2 *Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice: B** Readily establishes in areas with anthropogenic disturbance/infrastructure; occasionally establishes in undisturbed areas

**Score:** 2.75 of 4

**High uncertainty?** ☑

**Ranking Rationale:**
Surveys of E. crocea suggest that this species may be more prevalent on anthropogenic structures than in natural habitats.

**Background Information:**
A survey near a shipwreck in Italy did not find E. crocea on natural substrates, though the reasons for this are unknown (Di Camillo et al. 2013). If this is a general trend, it suggests that the potential for establishment is limited to anthropogenic substrates, at least in soft-bottom habitats.

**Sources:**
Di Camillo et al. 2013

### 2.3 *Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice: B** No

**Score:** 0 of 2

**Ranking Rationale:**
This species is not currently farmed or cultivated.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 4.75 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

# 3. Biological Characteristics

## *3.1 Dietary specialization*

**Choice: A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
E. crocea feeds on a range of taxa that are readily available in the Bering Sea.

**Background Information:**
E. crocea feeds on both planktonic and benthic prey, including diatoms, bivalve larvae, and crustaceans (Di Camillo et al. 2013; Fitridge and Keough 2013). Stomach contents of E. crocea in the Adriatic Sea were found to contain mostly crustaceans (Di Camillo et al. 2013). Di Camillo et al. (2013) suggest that E. crocea is a generalist predator, but Fitridge and Keough (2013) assert that this species preferentially preys upon mussel larvae.

**Sources:**
Fitridge and Keough   Di Camillo et al. 2013

## *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice: A** Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 of 5

**Ranking Rationale:**
This species can tolerate a broad range of temperatures and salinities. It is most commonly associated with hard substrates, including bivalves and anthropogenic structures.

**Background Information:**
Thrives in cold water with good movement, and is typically found in estuaries and eutrophic areas (Di Camillo et al. 2013; Piazzola 2015). It lives in low intertidal and subtidal zones, down to 40 m depths (qtd. in Piazzola 2015). This species is readily found on anthropogenic substrates including boats, ship hulls, pilings, and industrial cooling systems (Di Camillo et al. 2013). It does not settle on mud or sand, but is often associated with mussel beds. It can tolerate polluted waters (Schuchert 2010, qtd. in Fofonoff et al. 2003).

**Sources:**
Di Camillo et al. 2013   Piazzola 2015   NEMESIS; Fofonoff et al. 2003

## *3.3 Desiccation tolerance*

**Choice: U** Unknown

**Score:** of

**Ranking Rationale:**
This species' desiccation tolerance is unknown.

**Background Information:**
No information found.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 3.4 *Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice:** **A** High – Exhibits three or four of the above characteristics

**Score:** 5 of 5

**Ranking Rationale:**

This species exhibits asexual reproduction, external fertilization, and short generation time. Because this is a colonial species, the number of eggs produced depend on colony size, but can be very high.

**Background Information:**

Colonies are dioecious, and can reproduce both sexually and asexually. Male gonophores release sperm in the water column, which are attracted to female gonophores and result in internal fertilization. Larvae are short-lived, and usually settle on a substrate within ~ 24 hours.

Yamashita et al. (2003) found that the maximum number of released larvae per polyp was 300, meaning that a colony of 300 polyps may release up to 90 000 larvae. Colonies can occur at densities of 10 colonies/m2, with a potential release of 900 000 larvae/m2 (Di Camillo et al. 2003). This species can reproduce year-round in some areas (Fitridge and Keough 2013).

Larvae are released into the water column within 6 to 8 days of egg production (Mackie 1966, qtd. in Piazzola 2015). Juveniles reach sexual maturity within two weeks (Piazzola 2015).

**Sources:**

Di Camillo et al. 2013 Fitridge and Keough NEMESIS; Fofonoff et al. 2003 Yamashita et al. 2003 Piazzola 2015

### 3.5 *Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice:** **C** Disperses short (< 1 km) distances

**Score:** 0.75 of 2.5

**High uncertainty?** ☑

**Ranking Rationale:**

No specific dispersal distances were found, but several sources claim that this species has limited dispersal potential. Larval stage is short-lived, and larvae usually settle close to the parent colony. Adults are sessile. The longevity of adult fragments and their potential for dispersal under natural conditions is unknown.

**Background Information:**

Larvae are short-lived (~ 24 hours) and usually disperse only a short distance away from the parent colony (Gili and Hughes 1995; Piazzola 2015), though further distances may be possible if larvae are passively dispersed by water currents (Di Camillo et al. 2013). Adults are sessile, but autotomized hydranths (pieces of the colony which have detached) may have high dispersal potential. Under laboratory conditions, these fragments can survive for 30 days and continue to feed and spawn (Rungger 1969, qtd. in Di Camillo et al. 2013). Similarly, in the absence of a suitable substrate, larvae under laboratory conditions were found to stay in the water column for up two weeks (Yamashita et al. 2003).

**Sources:**

Di Camillo et al. 2013 Piazzola 2015 Gili and Hughes 1995 Yamashita et al. 2003

### *3.6 Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: A** High – Exhibits two or three of the above characteristics

**Score:** 2.5 of 2.5

**Ranking Rationale:**
This species can disperse during more than one life stage. Modes of dispersal include active swimming (larvae), passive dispersal by water currents (hydranth and larvae), and rafting on floating substrates (adults).

**Background Information:**
Adults are sessile unless a hydranth is detached. Free-swimming larval phase is short-lived (~24 hours).

**Sources:**
Di Camillo et al. 2013 NEMESIS; Fofonoff et al. 2003

### *3.7 Vulnerability to predators*

**Choice: D** Multiple predators present in the Bering Sea or neighboring regions

**Score:** 1.25 of 5

**Ranking Rationale:**
E. crocea is eaten by several taxa that are found in the Bering Sea.

**Background Information:**
Predators include sea spiders, nudibranchs, polychaete worms, fishes, and insects (Gili and Hughes 1995; Piazzola 2015).

**Sources:**
Gili and Hughes 1995 Piazzola 2015

| | |
|---|---|
| **Section Total - Scored Points:** | 19.5 |
| **Section Total - Possible Points:** | 25 |
| **Section Total -Data Deficient Points:** | 5 |

# 4. Ecological and Socioeconomic Impacts



### 4.1 *Impact on community composition*

**Choice:** **C** Limited – Single trophic level; may cause decline but not extirpation

**Score:** 0.75 of 2.5

**High uncertainty?** ✔

**Ranking Rationale:**
This species may affect the growth and recruitment of bivalves through fouling and predation. E. crocea can be a dominant member of the fouling communities, but few impacts have been reported.

**Background Information:**
E. crocea have been observed feeding on mussel larvae in both natural and laboratory conditions, which may lead to reduced recruitment rates (Fitridge and Keough 2013). Fouling of shells by E. crocea has also been linked to decreased growth (length and weight) in juvenile mussels (Fitridge and Keough 2013). In several parts of its range, E. crocea colonies are known to regress (Okamura 1986; Di Camillo et al. 2013), which may limit its long-term implications on communities.

**Sources:**
NEMESIS; Fofonoff et al. 2003   Fitridge and Keough   Okamura 1986   Di Camillo et al. 2013

### 4.2 *Impact on habitat for other species*

**Choice:** **B** Moderate – Causes or has potential to cause changes to one or more habitats

**Score:** 1.75 of 2.5

**Ranking Rationale:**
By fouling anthropogenic substrates, E. crocea creates secondary settlement habitat for other species.

**Background Information:**
E. crocea is often a dominant member of the fouling community. By establishing on toxic substrates (e.g. hulls with anti-fouling paints), it facilitates secondary settlement by other species. On shipwrecks, it can provide a suitable substrate for other species (Di Camillo et al. 2013). E. crocea colonies host a rich assemblage of mobile and sessile species, including amphipods and bacteria (Di Camillo et al. 2012; Di Camillo et al. 2013).

**Sources:**
Di Camillo et al. 2013   Di Camillo et al. 2012

### 4.3 *Impact on ecosystem function and processes*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not expected to impact ecosystem function in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.4 *Impact on high-value, rare, or sensitive species and/or communities*

**Choice:** **D** No impact

**Score:** **0** **of** **2.5**

**Ranking Rationale:**
This species is not expected to impact high-value species or communities in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.5 *Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice:** **D** No impact

**Score:** **0** **of** **2.5**

**Ranking Rationale:**
E. crocea forms species-specific associations with bacteria, but these ecological relationships are not expected to impact the Bering Sea ecoregion.

**Background Information:**
E. crocea is host to other invertebrates and bacteria (Di Camillo et al. 2012); however, these associations are species-specific symbioses and are not thought to affect the larger community or ecosystem.

**Sources:**
Di Camillo et al. 2012

### 4.6 *Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice:** **D** No impact

**Score:** **0** **of** **2.5**

**Ranking Rationale:**
This species is not expected to hybridize with native species in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.7 *Infrastructure*



**Choice:** **B**

Moderate – Causes or has the potential to cause degradation to infrastructure, with moderate impact and/or within only a portion of the region

**Score:** 1.5 of 3

**Ranking Rationale:**
This species is known to damage infrastructure when it occurs at high densities.

**Background Information:**
Through fouling, this species can damage water cooling systems or aquaculture infrastructure, especially if it occurs at high densities. Heavy fouling may lead to increased drag on mussel lines and result in lost stock, as the weight pulls mussels off long lines. In field experiments in San Francisco Bay, E. crocea was a dominant species on fouling plates during certain parts of the year, occupying up to 60% of the plates' surface (Okamura 1986).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Di Camillo et al. 2013 Okamura 1986

### 4.8 *Commercial fisheries and aquaculture*

**Choice:** **C**

Limited – Has limited potential to cause degradation to fisheries and aquaculture, and/or is restricted to a limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
The shellfish industry in Alaska is estimated at $1 million (PSI Alaska 2017), but only occurs in a limited area in the Bering Sea. Revenues from shellfish are most important in the Gulf of Alaska and in southwest Alaska (Aleutians East through Lake and Peninsula; Mathis et al. 2015).

**Background Information:**
E. crocea is a nuisance species on shellfish farms. By fouling juvenile mussels, it competes for food and impedes their filter feeding ability, thereby restricting their growth. E. crocea also selectively preys upon mussel larvae, which can decrease settlement and recruitment rates (Fitridge and Keough 2013; Mondon 2015). In Tasmania, black mussels fouled with E. crocea exhibited a 23% reduction in flesh weight (Mondon 2015). At the same time, hydroid stalks can provide a settlement surface for mussel larvae (Fitridge and Keough 2013).

**Sources:**
Mathis et al. 2015 Fitridge and Keough Mondon 2015 PSI Alaska 2017

### 4.9 *Subsistence*

**Choice:** **B**

Moderate – Causes or has the potential to cause degradation to subsistence resources, with moderate impact and/or within only a portion of the region

**Score:** 1.5 of 3

**High uncertainty?** ☑

**Ranking Rationale:**
This species can negatively affect the growth and recruitment of bivalves through fouling and predation. Given its effects and the importance of subsistence shellfish harvesting in the Bering Sea, it is expected to have a moderate impact on subsistence resources in this region.

**Background Information:**
By selectively feeding on mussel larvae, this species may affect mussel settlement and recruitment rates (Fitridge and Keough 2013; Mondon 2015). Compared to salmon and finfish, shellfish comprise a smaller percentage of subsistence catch in the Bering Sea (when measured by weight; Mathis et al. 2015). Although shellfish comprised almost 20% of subsistence catch in the Aleutians West, most municipalities in the Bering Sea recorded low percentages (< 5%).

**Sources:**
Mathis et al. 2015 Fitridge and Keough Mondon 2015

### *4.101 Recreation*

**Choice: C** Limited – Has limited potential to cause degradation to recreation opportunities, with limited impact and/or within a very limited region

**Score:** 0.75 **of** 3

**High uncertainty?** ☑

**Ranking Rationale:**
This species may affect recruitment and development of bivalves, but is expected to have limited impacts on recreational harvesting of shellfish in the Bering Sea.

**Background Information:**
By selectively feeding on mussel larvae, this species may affect mussel settlement and recruitment rates (Fitridge and Keough 2013; Mondon 2015). In Alaska, recreational harvesting of shellfish is discouraged on untested beaches because of the potential for paralytic shellfish poisoning (PSP).

**Sources:**
Fitridge and Keough   Mondon 2015

### *4.11 Human health and water quality*

**Choice: D** No impact

**Score:** 0 **of** 3

**Ranking Rationale:**
This species is not expected to impact human health or water quality in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 7 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 5. Feasibility of prevention, detection and control



### *5.1 History of management, containment, and eradication*

**Choice:** **C** Attempted; control methods are currently in development/being studied

**Score:** of

**High uncertainty?** ☑

**Ranking Rationale:**
No attempts have been made to control E. crocea. This species fouls sheltered areas on vessels such as sea chests and propellers; methods and best practices are currently being developed to control the spread of species by these and other vectors.

**Background Information:**
We did not find any management plans that were specific to this species. E. crocea is tolerant to copper (found in anti-fouling paints) (Crooks et al. 2011), which suggest that traditional methods for controlling fouling organisms may not be successful in controlling E. crocea. A survey on a New Zealand vessel collected E. crocea from sheltered parts of the ship (e.g., sea chests) (Cawthron Institute 2010). Sea chests are known vectors for transporting non-indigenous species and methods to control the spread of species by sea chests are being investigated (Frey et al. 2014).

**Sources:**
Crooks et al. 2011 Cawthron Institute 2010 Frey et al. 2014

### *5.2 Cost and methods of management, containment, and eradication*

**Choice:** **B** Major short-term and/or moderate long-term investment

**Score:** of

**Ranking Rationale:**
To our knowledge, control of E. crocea has not been attempted. Methods for successfully controlling the spread of antifouling organisms are being studied. Current technologies that clean ships of fouling species require purchasing of specialized equipment and regular cleaning.

**Background Information:**
According to Franmarine Underwater Services (2013), the cost of dry docking (including cleaning and "loss of business" costs) varies from AUD $62 200 to more than $1.3 million, depending on vessel size. In-water cleaning costs range from AUD $18 800 to $255 000+ (for offshore cleaning of large vessels), with cleaning times estimated between 16 to 48 hours. The Franmarine cleaning system, which collects, treats, and disposes of biological waste (e.g., organisms) has a purchasing cost between AUD ~ $500 000 to $750 000, depending on vessel size. Hagan et al. (2014) proposed similar estimates for the cost and time of in-water cleaning.

**Sources:**
Franmarine 2013 Hagan et al. 2014

### 5.3 *Regulatory barriers to prevent introductions and transport*

**Choice:** **B** Regulatory oversight, but compliance is voluntary

**Score:** of

**Ranking Rationale:**
Although there are regulations to control the spread of ship fouling species, compliance is largely voluntary.

**Background Information:**
In the U.S., Coast Guard regulations require masters and ship owners to engage in practices that will reduce the spread of invasive species, including cleaning ballast tanks and removing fouling organisms from hulls, anchors, and other infrastructure on a "regular" basis (CFR 33 § 151.2050). Failure to remove fouling organisms is punishable with a fine (up to $27 500). However, the word "regular" is not defined, which makes the regulations hard to enforce. As a result of this technical ambiguity, compliance with ship fouling regulations remains largely voluntary (Hagan et al. 2014).

Cleaning of recreational vessels is also voluntary, although state and federal programs are in place to encourage owners to clean their boats. Boat inspection is mandatory on some lakes (e.g. Lake Tahoe in CA/NV, Lake George in NY). In summer 2016, state and federal agencies conducted voluntary inspections for aquatic invasive species on trailered boats entering the state of Alaska (Davis 2016).

**Sources:**
CFR 2017 Hagan et al. 2014 Davis 2016

### 5.4 *Presence and frequency of monitoring programs*

**Choice:** **A** No surveillance takes place

**Score:** of

**Ranking Rationale:**
No surveillance takes place for this species.

**Background Information:**
No information found.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 5.5 *Current efforts for outreach and education*

**Choice:** **A** No education or outreach takes place

**Score:** of

**Ranking Rationale:**
Little information is available on E. crocea in general, and no information is targeted towards the general public.

**Background Information:**
We did not find any information on outreach or education programs for this species.

**Sources:**
None listed

**Section Total - Scored Points:**
**Section Total - Possible Points:**
**Section Total -Data Deficient Points:**

## Literature Cited for *Ectopleura crocea*


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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Caprella mutica*

**Common Name** *Japanese skeleton shrimp*

| | |
|---|---|
| Phylum | Arthropoda |
| Class | Malacostraca |
| Order | Amphipoda |
| Family | Caprellidae |

**Final Rank** 64.95

**Data Deficiency:** 8.00

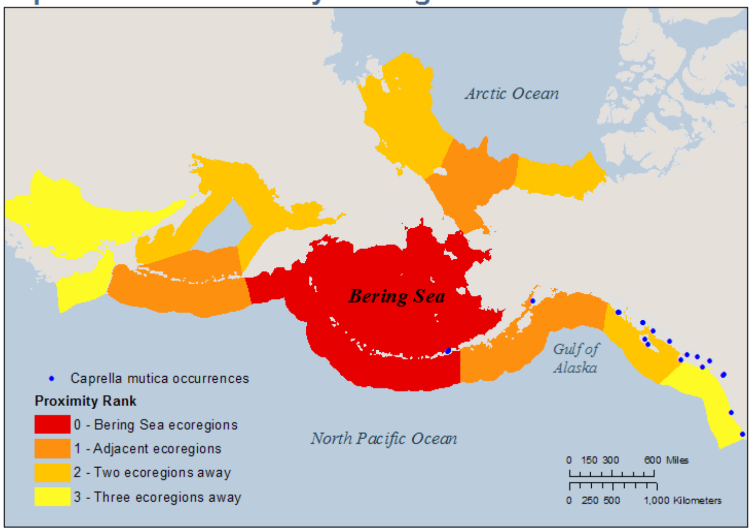


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 28.25 | 30 | 0 |
| Anthropogenic Influence: | 8 | 10 | 0 |
| Biological Characteristics: | 18.75 | 30 | 0 |
| Impacts: | 4.75 | 22 | 8.00 |
| **Totals:** | 59.75 | 92.00 | 8.00 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | -2 | Minimum Salinity (ppt) | 11 |
| Maximum Temperature (°C) | 28 | Maximum Salinity (ppt) | 40 |
| Minimum Reproductive Temperature (°C) | 4 | Minimum Reproductive Salinity (ppt) | 31* |
| Maximum Reproductive Temperature (°C) | 20 | Maximum Reproductive Salinity (ppt) | 35* |

### Additional Notes

First described from sub-boreal areas of north-east Asia in 1935 and has since spread to both northern and southern hemispheres. C. mutica is frequently associated with man-made structures and is found in abundance on boat hulls, navigation/offshore buoys, floating pontoons and aquaculture infrastructure. Likely dispersed via hull fouling, presence in ballast water and sea chests, or accidental introduction linked to aquaculture (e.g. import of Pacific oyster spat).

# 1. Distribution and Habitat



### 1.1 *Survival requirements - Water temperature*

**Choice:** **A**

Considerable overlap – A large area (>75%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 3.75 **of** 3.75

**Ranking Rationale:**
Temperatures required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
Caprella mutica tolerates water temperatures from -1.8 to 28°C as determine by both field distribution and experimental laboratory experiments. Although lethargic at low temperatures (2°C), no mortality was observed, and the species is known to survive at temperatures as low as −1.8°C (Ashton et al. 2007)

**Sources:**
Ashton 2006   Boos et al. 2011   NEMESIS; Fofonoff et al. 2003   Ashton et al. 2007

### 1.2 *Survival requirements - Water salinity*

**Choice:** **A**

Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 **of** 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
Caprella mutica is a polyhaline-euhaline species that tolerates water salinity from 14.6 to >40 ppt, based on experimental laboratory experiments. In addition, it has been documented to tolerate salinities as low as 11 psu in the field in the northern Sea of Japan (Schevchenko et al. 2004, cited by Turcotte and Sainte Marie 2009). C. mutica is tolerant to a wide range of temperatures and salinities. 100% mortality was observed at 30°C (48 h exposure), and at salinities lower than 15 (48 h exposure). The upper salinity threshold was greater than the highest salinity tested (40 ppt), thus it is unlikely that salinity will limit the distribution of C. mutica in open coastal waters, though it might exclude this species from brackish water environments such as estuaries (Ashton et al 2007).

**Sources:**
Ashton 2006   NEMESIS; Fofonoff et al. 2003   Turcotte and Sainte-Marie 2009   Ashton et al. 2007

### 1.3 *Establishment requirements - Water temperature*

**Choice:** **A**

Considerable overlap – A large area (>75%) of the Bering Sea has temperatures suitable for reproduction

**Score:** 3.75 **of** 3.75

**Ranking Rationale:**
Temperatures required for reproduction occur over a large (>75%) area of the Bering Sea.

**Background Information:**
The reproductive temperature range of Caprella mutica is 4°C to20°C. In a lab setting, hatchlings maintained at 4°C died after 4 months (Boos et al. 2011).

**Sources:**
Boos et al. 2011

### 1.4 Establishment requirements - Water salinity

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Although salinity thresholds are unknown, this species is a marine organism that does not require freshwater to reproduce. We therefore assume that this species can reproduce in saltwater (31 to 35 ppt). These salinities occur in a large (>75%) portion of the Bering Sea.

**Background Information:**
No information found.

**Sources:**
None listed

### 1.5 Local ecoregional distribution

**Choice: A** Present in the Bering Sea

**Score:** 5 of 5

**Ranking Rationale:**
There is one documented case of Caprella mutica in the Bering Sea (NEMESIS).

**Background Information:**
Present in Dutch Harbor, Unalaska Island. Also found in Kachemak Bay. See Ashton et al. (2008) for a summary of sampled sites and occurrences in Alaska.

**Sources:**
Ashton et al. 2008   NEMESIS; Fofonoff et al. 2003

### 1.6 Global ecoregional distribution

**Choice: A** In many ecoregions globally

**Score:** 5 of 5

**Ranking Rationale:**

**Background Information:**
Caprella mutica is indigenous to sub-boreal waters of north-east Asia (Peter the Great Bay, Russia and northern Japan), and has been found in 14 ecoregions outside of the three ecoregions in which it is considered a native species. C. mutica has been introduced along the entire western coast of North America, from California to Alaska. It is also found along the Atlantic, in northeastern North America (Maine north to PEI and Nova Scotia). In Europe, C. mutica is found from Spain to Norway, and during 2004, it was discovered in New Zealand.

C. mutica is unlikely to survive in the central and eastern Baltic Sea due to low salinities (below 19ppt, FIMR 2006), and based on current knowledge it is not expected to become established in the Mediterranean Sea on account of the high summer seawater temperatures (Cook et al. 2006).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Cook et al. 2007   Boos et al. 2011

## *1.7 Current distribution trends*



**Choice:** **B** History of rapid expansion or long-distance dispersal (prior to the last ten years)

**Score:** 3.25 **of** 5

**Ranking Rationale:**
History of rapid expansion and disperal throughout Europe.

**Background Information:**
C. mutica is one of the most rapidly invading species in Europe. It has extended its range along both the North and Celtic Sea coasts, and the English Channel in less than 14 years. European dispersal from its original location in the Netherlands includes a 1200km range expansion to the west coast of Norway, and a 1000km expansion to the west coast of Ireland (Boos el a. 2011).

**Sources:**
Boos et al. 2011   Cook et al. 2007

| | |
|---|---|
| **Section Total - Scored Points:** | 28.25 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 2. Anthropogenic Transportation and Establishment



### 2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport

**Choice: A** — Has been observed using anthropogenic vectors for transport and transports independent of any anthropogenic vector once introduced

**Score:** 4 of 4

**Ranking Rationale:**

C. mutica has been observed using numerous anthropogenic vectors, and short-range natural dispersal has been observed in natural habitats near populations established on artifical structures.

**Background Information:**

Transport in ballast water and sea chests, or via ship fouling, have been proposed as possible means of introduction. C. mutica (Fofonoff et al. 2003) also has the tendency to cling to clothes and working gear when removed from the substrate (Coolen et al. 2016). In addition, it often attaches to brown alga Sargassum muticum, which has been used as packing material when exporting Pacific Oysters (Crassostrea gigas) (Turcotte and Saint-Marie 2009).

Within its native environment, C. mutica may be found attached to the macroalgae (Ulva spp. and Cladophora spp.) which are regularly found attached to ships hulls (Mineur et al. 2007). It has also been observed with other algae present at high densities on recreational boat hulls (Fofonoff et al. 2003).

A modelling exercise by Coolen et al. (2016) found a strong association between C. mutica and nearshore waters, as well as shallow water objects giving C. mutica a high potential for encounters with microalgae rafts. It is suggested that this association may have contributed to its dispersal in European waters.

Individuals have been found swimming short distances and small numbers of individuals have been observed up to 1km from a source population (M. Janke, pers. comm. 2007, qtd. in Boos et al. 2011).

**Sources:**

NEMESIS; Fofonoff et al. 2003 Turcotte and Saint-Marie 2009 Boos et al. 2011 Coolen et al. 2016

### 2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish

**Choice: B** — Readily establishes in areas with anthropogenic disturbance/infrastructure; occasionally establishes in undisturbed areas

**Score:** 2 of 4

**Ranking Rationale:**

In its introduced range, this species is more commonly associated with anthropogenic substrates and disturbed areas than with natural habitats.

**Background Information:**

Frequently fouls organisms that grow on anthropogenic substrates (reviewed in Boos et al. 2011). In its introduced range, this species is abundant on anthropogenic structures, but tends to be rare in natural habitats (reviewed in Boos et al. 2011).

**Sources:**

Boos et al. 2011

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*



**Choice: B** No

**Score:** 2 of 2

**Ranking Rationale:**

**Background Information:**

**Sources:**

None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 8 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics

### *3.1 Dietary specialization*

**Choice:** **A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 **of** 5

**Ranking Rationale:**
Has the ability to feed on a variety of things that are readily available in the study area.

**Background Information:**
C. mutica is primarily a detritivore, but can also filter feed, and has been observed feeding on a variety of different sessile and mobile benthic organisms including hydroids, bryozoans, gammarid amphipods and even conspecifics (Boos et al. 2011). Can be highly opportunistic in its feeding strategy in non-native habitats (Boos et al. 2011).

Caprellids can feed in a variety of ways, including filtering small particles from the water, browsing on small filamentous algae, scraping tissue from large algae, scavenging, and predation (Turcotte and Sainte Marie 2009). Caprella mutica appears to be capable of using all these modes of feeding, which may contribute to its success as an invader (Cook et al. 2007, Turcotte and Sainte-Marie 2009; Cook et al. 2010; Best et al. 2013).

Under laboratory conditions, can survive for up to 20 days without additional food.

**Sources:**
Boos et al. 2011   Cook et al. 2007   NEMESIS; Fofonoff et al. 2003

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **A** Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 **of** 5

**Ranking Rationale:**
Tolerates a wide range of temperatures and salinities and has been recorded in a variety of environments.

**Background Information:**
Non-native populations of C. mutica have been recorded from environments with a variety of flow regimes, including those experiencing strong tidal and wind currents (e.g., exposed fish farms) and those that are more sheltered (e.g., enclosed bays and harbours) (Ashton 2006; Shucksmith 2007 – qtd. in Boos et al. 2011).

Found in artificial environments that have been enriched with nutrients by fish feed (Boos et al. 2011). An experiment by Ashton et al. (2010, qtd. in Boos et al. 2011) found that, compared to populations in nutrient enriched environments, populations at the other two sites which experienced no artificial nutrient enrichment were significantly less abundant and had a shorter period of summer population growth.

C. mutica is tolerant to a wide range of temperatures and salinities.

**Sources:**
Ashton et al. 2007   Boos et al. 2011   Cook et al. 2007   Coolen et al. 2016

### 3.3 *Desiccation tolerance*



**Choice: C** Little to no tolerance (<1 day) of desiccation during its life cycle

**Score:** 1.75 of 5

**Ranking Rationale:**
Can survive slight desiccation, however is intolerant to most aerial exposure.

**Background Information:**
C. mutica is intolerant to aerial exposure during summer months and will die within an hour of emergence from water (Cook, pers. obs.). However, cool and damp conditions typically found in anchor lockers or bundles of mooring lines and fish farm netting are likely to prolong their survival out of water for up to 7 h (Boos and Cook, pers. obs.).

**Sources:**
Boos et al. 2011

### 3.4 *Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice: B** Moderate – Exhibits one or two of the above characteristics

**Score:** 3.25 of 5

**Ranking Rationale:**
Sexual reproduction, high fecundity, moderate parental investment, short generation time.

**Background Information:**
On average, females reach sexual maturity 53 days after birth (at 14°C), and 1 month at 16°C (Boos et al. 2011). The average lifespan was 90-180 days, with most females producing two broods before death (Cook et al. 2007; Boos et al. 2011). However, estimated brooding time and lifespan varies greatly in the field, with varying temperature and food conditions (Turcotte and Sainte Marie 2009). Boos (2009, qtd. in Boos et al. 2011) recorded a maximum number of seven successful broods at 16°C.

Field studies in both native (Fedotov 1991) and European introduced ranges (Ashton 2006), have both confirmed a positive relationship between brood size and body size in female C. mutica. Both authors reported maximum numbers of more than 300 eggs per single clutch in individual females, reflecting much higher fecundities under natural than laboratory conditions, where average clutch sizes of 40 eggs have been recorded (qtd. in Boos et al. 2011).

**Sources:**
Boos et al. 2011 Cook et al. 2007 NEMESIS; Fofonoff et al. 2003

### 3.5 *Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice:** **B** Disperses moderate (1-10 km) distances

**Score:** **1.75** **of** **2.5**

**Ranking Rationale:**

Naturally disperses 500m - 5km using free-swimming and drifting on large algal mats.

**Background Information:**

C. mutica spends its entire life cycle attached to a substrate but can move short distance from one substrate to another (Buschbaum and Gutow 2005). C. mutica does not have a free-swimming, planktonic larval stage (young hatch onto the substrate in the form of small adults), however, short-range dispersal may be achieved through free-swimming of adults, and long-range dispersal may be achieved by attachment to floating artificial structures.

Short-range dispersal may be achieved through short-distance swimming or current-driven dispersal following disturbance from the substrate (Ashton 2006, qtd. in Cook 2007; Boos et al. 2011). C. mutica has been observed swimming short distances in the laboratory and field (E Cook, Scottish Association of Marine Science, UK, personal observation, 2008), however, the maximum distance of dispersal for this method is unknown (Cook 2007). Individuals have been found swimming short distances and small numbers of individuals have been observed up to 1km from a source population (M. Janke, pers. comm. 2007, qtd. in Boos et al. 2011). Turcotte and Saint-Marie (2009) argue that the swimming capacities of C. mutica are very limited, and would only allow for dispersal of < 100 m. C. mutica have been observed in natural habitats adjacent to source populations that are located on artificial structures, and these populations are likely established due to free-swimming dispersal (Boos et al. 2011).

Long-range dispersal may be achieved by attachment to floating artificial structures (e.g. boats) or floating marine algae. Buschbaum and Gutow (2005) propose that C. mutica may have colonised Helgoland using algal rafts, and Ashton (2006, qtd. in Coolen et al. 2006) showed this species' ability to use drifting algae for dispersal over distances > 5 km. On the west coast of Scotland, Ashton (2006) found C. mutica on 27% of the drifting mats of macroalgae that were collected (qtd. in Cook 2007). The maximum number of individuals on one algal mat was 71, including ovigerous females and males (Ashton 2006, qtd. in Cook 2007). This dispersal mechanism is most likely used in the spring and summer months, when large quantities of algae are produced along the continental shelf (Thiel and Haye, 2006).

**Sources:**

Cook et al. 2007 Buschbaum and Gutow 2005 Cook 2007 Coolen et al. 2016 Turcotte and Sainte-Marie 2009

### *3.6 Likelihood of dispersal or movement events during multiple life stages*



i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: C** Low – Exhibits none of the above characteristics

**Score:** 0.75 of 2.5

**Ranking Rationale:**
Females brood young which restricts dispersal to adults only.

**Background Information:**
Because C. mutica does not have a planktonic larval stage, modes of dispersal are the same throughout its life (swimming or current drifting if disturbed from substrate attachment, or rafting on algae). According to Turcotte and Sainte-Marie (2009), swimming ability is limited, and medium-scale dispersal is likely only achievable via rafting or passive dispersal.

**Sources:**
Turcotte and Sainte-Marie 2009

### *3.7 Vulnerability to predators*

**Choice: D** Multiple predators present in the Bering Sea or neighboring regions

**Score:** 1.25 of 5

**Ranking Rationale:**
Numerous predators, many of which exist in the the Bering Sea.

**Background Information:**
In general, natural predators of caprellids are primarily fish species. Additional predators include invertebrates such as crabs, nudibranchs, starfish and hydrozoans (reviewed in Turcotte and Saint-Marie 2009). Specific predators identified include European green crab (Carciunus maenas) and goldsinny wrasse (Ctenolabrus rupestris) and painted greenling (Oxylebius pictus) (Page et al. 2007, Boos et al. 2011).

**Sources:**
Boos et al. 2011 Turcotte and Sainte-Marie 2009 Page et al. 2007

| | |
|---|---|
| **Section Total - Scored Points:** | 18.75 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

# 4. Ecological and Socioeconomic Impacts

## *4.1 Impact on community composition*

**Choice:** **B** Moderate – More than one trophic level; may cause declines but not extirpation

**Score:** 1.75 **of** 2.5

**High uncertainty?** ☑

**Ranking Rationale:**

Predation on tunicates and competition with native caprellids have been observed, however the impact on native tunicates in the Bering sea in uncertain.

**Background Information:**

C. mutica has been observed preying on invsaive tunicates and competing with native caprellids. In the northern Atlantic (NA-S3, Gulf of St Lawrence), high densities of C. mutica have been documented to inhibit settlement of the invasive tunicate Ciona intestinalis on fouling plates; because Ciona intestinalis is an invasive tunicate in that region, C. mutica has been proposed as a biocontrol agent. In Bodega Harbor (NEP-V), caging experiments and feeding trials showed that Caprella mutica was a significant predator on recruits of Ciona intestinalis (Rius et al. 2014).
Similarly, fouling plate studies detected a negative correlation between newly settled tunicates (Ciona intestinalis) and caprellids (Caprella mutica and C. linearis), suggesting possible predation by caprellids on tunicate larvae (Collin and Johnson 2014).

In laboratory-based competition experiments between Caprella mutica and two ecologically similar native caprellids, Caprella linearis and Pseudoprotella phasma, C. mutica successfully displaced both species from homogeneous artificial habitat patches after 48 hours (Shucksmith et al. 2009). Patches that contained a refuge reduced the number of C. linearis being displaced, but only when C. mutica was at a low density. Based on their findings, Shucksmith et al. (2009) suggested that the non-native C. mutica can displace ecologically similar native species when the resource space is limited, and even when the density of C. mutica was significantly (10 times) lower than the density of C. linearis. However, a modelling exercise by Coolen et al. (2016) found that the habitat preference of C. linearis does not fully overlap with that of C. mutica in the North Sea, and that the two species are likely to be able to co-exist in this region.

**Sources:**

Boos et al. 2011 Cook et al. 2007 Coolen et al. 2016 NEMESIS; Fofonoff et al. 2003 Page et al. 2007 Shucksmith et al. 2009

## *4.2 Impact on habitat for other species*

**Choice:** **C** Limited – Has limited potential to cause changes in one or more habitats

**Score:** 0.75 **of** 2.5

**High uncertainty?** ☑

**Ranking Rationale:**

May displace native caprellids however very little information is available.

**Background Information:**

Studies on ecological impacts are limited and no ecological impacts have been reported in the literature (Fofonoff et al. 2003), however, C. mutica can establish very dense populations that can displace native caprellids (Shucksmith et al. 2009).

**Sources:**

NEMESIS; Fofonoff et al. 2003 Shucksmith et al. 2009

### 4.3 *Impact on ecosystem function and processes*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**High uncertainty?** ✔

**Ranking Rationale:**
No impacts have been reported, however the literature is lacking.

**Background Information:**
Studies on ecological impacts are limited and no impacts on ecosystem function or processes have been reported in the literature (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.4 *Impact on high-value, rare, or sensitive species and/or communities*

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**
Lacking information.

**Background Information:**
No impacts to high-value, rare or sensitive species and/or communities have been reported in the literature (Fofonoff et al. 2003). C. mutica is known to occur in marine protected areas in the UK (e.g. Firth of Lorne, west coast of Scotland), but the impact of this species on the habitats within these areas is unknown (Cook 2007).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Cook 2007

### 4.5 *Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice:** **D** No impact

**Score:** 0 of 2.5

**High uncertainty?** ✔

**Ranking Rationale:**
No disease, parasites or travelers are expected to be associated with C. mutica but the literature is lacking.

**Background Information:**
There are no reports of disease, parasites or travelers associated with C. mutica.

**Sources:**
None listed

### 4.6 *Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information is available in the literature.

**Sources:**
None listed

### 4.7 *Infrastructure*

**Choice:** **B** Moderate – Causes or has the potential to cause degradation to infrastructure, with moderate impact and/or within only a portion of the region

**Score:** 1.5 of 3

**Ranking Rationale:**
Has the potential to foul gear and infrastructure.

**Background Information:**
To date, no studies have assessed the economic impacts of C. mutica (Boos et al. 2011), and no economic impacts have been reported for the Chesapeak Bay region (Fofonoff et al. 2003). In Europe and Atlantic Canada, high densities of C. mutica can foul gear such as ropes, nets, water intake pumps and ship hulls, and may interfere with the settlement of mussel spate (Boos et al. 2011; Turcotte and Sainte-Marie 2009; Fofonoff et al. 2003).

**Sources:**
Boos et al. 2011   Turcotte and Sainte-Marie 2009   NEMESIS; Fofonoff et al. 2003

### 4.8 *Commercial fisheries and aquaculture*

**Choice:** **C** Limited – Has limited potential to cause degradation to fisheries and aquaculture, and/or is restricted to a limited region

**Score:** 0.75 of 3

**High uncertainty?** ☑

**Ranking Rationale:**
Fouling may effect efficiency of fisheries and aquaculture. There may also be an impact on mussel farm production, however research is limited and results are uncertain.

**Background Information:**
High densities of C. mutica can foul gear such as ropes, nets, water intake pumps and ship hulls, and may interfere with the settlement of mussel spate (Boos et al. 2011; Turcotte and Sainte-Marie 2009; Fofonoff et al. 2003).

Mussel farmers observed reduced settlement of spat during periods where C. mutica was most abundant; however a causal connection could not be confirmed (Ashton 2006). Field and laboratory work (unpublished) indicates that high densities of C. mutica interfere with settlement of mussel spat (Turcotte and Sainte Marie 2009).

On the west coast of Scotland and Canada, C. mutica have been observed settling on mussel lines where juvenile mussels (Mytilus edulis), which are typically abundant, have declined. However, no studies have been performed to determine the relationship between the abundance of caprellids and the lack of juvenile mussels. In addition, preliminary studies suggest that other factors such as strong freshwater influence or natural predators may be responsible for the lack of juvenile mussels, and that the presence of C. mutica was a consequence of free settlement space (Boos et al. 2011).

**Sources:**
Ashton 2006   Boos et al. 2011   Turcotte and Sainte-Marie 2009   NEMESIS; Fofonoff et al. 2003

### 4.9 *Subsistence*

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information is available in the literature regarding the impact of C. mutica on subsistence activities.

**Sources:**
None listed

### *4.101 Recreation*

**Choice:** **D** No impact

**Score:** **0** of **3**

**High uncertainty?** ☑

**Ranking Rationale:**
No reports in literature, however lack of impact is uncertain.

**Background Information:**
There are no reports in the literature of C. mutica having an impact on recreational activities, and given the biology, none would be expected.

**Sources:**
None listed

### *4.11 Human health and water quality*

**Choice:** **D** No impact

**Score:** **0** of **3**

**High uncertainty?** ☑

**Ranking Rationale:**
No reports in literature, however lack of impact is uncertain.

**Background Information:**
There are no reports in the literature of C. mutica having an impact on health or water quality, and given the biology, none would be expected.

**Sources:**
None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 4.75 |
| **Section Total - Possible Points:** | 22 |
| **Section Total -Data Deficient Points:** | 8 |

# 5. Feasibility of prevention, detection and control

## 5.1 *History of management, containment, and eradication*

**Choice:** **B** Not attempted

**Score:** of

**Ranking Rationale:**
Management plans, containment and/or eradication have not been developed or attempted for C. mutica.

**Background Information:**
No species-specific plans are in place to control or eradicate this species. This species is transported by numerous vectors. Controlling the spread of invasive species that use these vectors for transport is an active area of research (Hagan et al 2014; Ruiz and Reid 2007).

**Sources:**
Hagan et al. 2014 Ruiz and Reid 2007

## 5.2 *Cost and methods of management, containment, and eradication*

**Choice:** **A** Major long-term investment, or is not feasible at this time

**Score:** of

**Ranking Rationale:**
No control methods currently exist, therefore controlling is not feasible at this time.

**Background Information:**
No control methods currently exist. Control methods, using freshwater, aerial exposure, traps and/or pheromones have not been tested as yet. However, it is likely that the former two methods would be the most promising for this and other nonnative marine invertebrates. Prevention methods including cleaning ship hulls and sterilizing ballast water (Molnar et al. 2008).

**Sources:**
Boos et al. 2011 Cook 2007 Molnar et al. 2008

## 5.3 *Regulatory barriers to prevent introductions and transport*

**Choice:** **B** Regulatory oversight, but compliance is voluntary

**Score:** of

**Ranking Rationale:**
This species is transported by numerous vectors and no species-specific regulations are currently in place. Although there are federal regulations for both ballast water and hull fouling, compliance with federal fouling regulations remains voluntary.

**Background Information:**
In the U.S., Coast Guard regulations require masters and ship owners to engage in practices that will reduce the spread of invasive species, including cleaning ballast tanks and removing fouling organisms from hulls, anchors, and other infrastructure on a “regular” basis (CFR 33 § 151.2050). However, the word “regular” is not defined, which makes the regulations hard to enforce. As a result of this technical ambiguity, compliance with ship fouling regulations remains largely voluntary (Hagan et al. 2014).
Source: CFR, Hagan

**Sources:**
CFR 2017

### *5.4 Presence and frequency of monitoring programs*

**Choice:** **B**

Surveillance takes place, but is largely conducted by non-governmental environmental organizations (e.g., citizen science programs)

**Score:** of

**Ranking Rationale:**

Limited in North America to non species-specific monitoring by non-governmental organizations.

**Background Information:**

Monitoring for C. mutica is well established in Europe, however, there is no information to suggest that active education or outreach is taking place in North America. In New England, Salem Sound Coastwatch provides an ID card for C. mutica and engages volunteers to conduct invasive species monitoring in coastal habitats; however, these events are not specific to C. mutica.

**Sources:**

Salem Sound Coast Watch

### *5.5 Current efforts for outreach and education*

**Choice:** **B**

Some educational materials are available and passive outreach is used (e.g. signs, information cards), or programs exist outside Bering Sea and adjacent regions

**Score:** of

**Ranking Rationale:**

Outreach in North America is limited to information cards produced for New England.

**Background Information:**

Monitoring for C. mutica is well established in Europe, however, there is no information to suggest that active education or outreach is taking place in North America. In New England, Salem Sound Coastwatch provides an ID card for C. mutica and engages volunteers to conduct invasive species monitoring in coastal habitats; however, these events are not specific to C. mutica.

Monitoring for C. mutica is conducted on a regular basis in the UK, Belgium and the Netherlands. A monthly monitoring programme for C. mutica at a fish farm and marina in the Lynne of Lorne, west coast of Scotland has been conducted since 2004. In the UK, public awareness has been largely funded by a charitable trust, the Esmée Fairbairn Foundation, with support from the UK government environment agencies, which has enabled the establishment of a marine non-native species website including C. mutica, production of leaflets, posters, splash-proof ID guides and popular articles and public lectures throughout the UK.

**Sources:**

Salem Sound Coast Watch   Cook 2007

**Section Total - Scored Points:**

**Section Total - Possible Points:**

**Section Total -Data Deficient Points:**

## Literature Cited for *Caprella mutica*


- Ashton, G. V., E. I. Riedlecker, and G. M. Ruiz. 2008. First non-native crustacean established in coastal waters of Alaska. Aquatic Biology 3:133-137
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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Jassa marmorata*

**Common Name** *a tube-building amphipod*

| | |
|---|---|
| Phylum | Arthropoda |
| Class | Malacostraca |
| Order | Amphipoda |
| Family | Ischyroceridae |

**Final Rank** 57.18

**Data Deficiency:** 11.25

Species Occurrence by Ecoregion

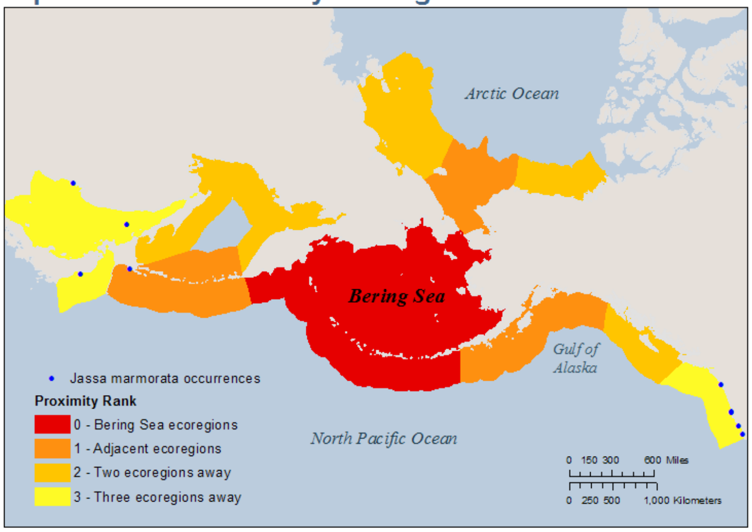


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 25 | 26 | 3.75 |
| Anthropogenic Influence: | 6.75 | 10 | 0 |
| Biological Characteristics: | 16 | 25 | 5.00 |
| Impacts: | 3 | 28 | 2.50 |
| **Totals:** | 50.75 | 88.75 | 11.25 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | -2 | Minimum Salinity (ppt) | 12 |
| Maximum Temperature (°C) | 27 | Maximum Salinity (ppt) | 38 |
| Minimum Reproductive Temperature (°C) | NA | Minimum Reproductive Salinity (ppt) | 31* |
| Maximum Reproductive Temperature (°C) | NA | Maximum Reproductive Salinity (ppt) | 35* |

### Additional Notes

J. marmot is a tube-building amphipod, greyish in color with red-brown markings. Its maximum length is 10 mm and there are two distinct morphs of males with two different mating strategies. The 'major' morphs are fighter males, while the 'minor' morphs are sneaker males. This species is difficult to identify in the field, and easily confused with other Jassa species.

There is some uncertainty around its native distribution due to the difficulty of distinguishing between J. marmorata and similar species, but it is likely native to the northwest Atlantic. It was introduced to Western North America, South America, South Africa, Australia, New Zealand, China, Japan, and Russia. It is generally found in ballast water, fouling communities and intertidal areas, attached to ship hulls, rocks, algae, and buoys. It builds tubes of detritus and algae fragments and can occur in very high densities (up to 1 million individuals/m2)

# 1. Distribution and Habitat



### *1.1 Survival requirements - Water temperature*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 3.75 **of** 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Temperatures required for year-round survival occur over a large (>75%) area of the Bering Sea. Thresholds are based on geographic distribution, which may not represent physiological tolerances; we therefore ranked this question with "High uncertainty".

**Background Information:**
Found in the Gulf of Alaska, Primorsky Krai in Russia, Hirtshals, Denmark (57.6°N) and Tjärnö, Sweden (58.9°N), which are similar in latitude to the Bering Sea (Conlan 1990). Based on geographic range, can tolerate temperatures ranging from -2°C to 27°C.

**Sources:**
Conlan 1990 NEMESIS; Fofonoff et al. 2003

### *1.2 Survival requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 **of** 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
The salinity range for survival of J. marmorata is 12ppt to 38ppt (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.3 Establishment requirements - Water temperature*

**Choice:** **U** Unknown/Data Deficient

**Score:** **of**

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *1.4 Establishment requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 **of** 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Although salinity thresholds are unknown, this species is a marine organism that does not require freshwater to reproduce. We therefore assume that this species can reproduce in saltwater (31 to 35 ppt). These salinities occur in a large (>75%) portion of the Bering Sea.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *1.5 Local ecoregional distribution*

**Choice: B** Present in an ecoregion adjacent to the Bering Sea

**Score:** 3.75 of 5

**Ranking Rationale:**
There is one documented occurrence for J. marmorata in an ecoregion adjacent to the Bering Sea, and numerous occurrences documented in areas two and three ecoregions away (Nemesis database).

**Background Information:**
J. marmota has been observed in the Gulf of Alaska and the Sea of Okhotsk (Conlan 1990).

**Sources:**
Conlan 1990 NEMESIS; Fofonoff et al. 2003

### *1.6 Global ecoregional distribution*

**Choice: A** In many ecoregions globally

**Score:** 5 of 5

**Ranking Rationale:**
Wide global distribution.

**Background Information:**
J. marmorata has a global distribution including cold temperate waters of the north Atlantic, where it is native, and the north Pacific Ocean (California, British Columbia, Russia, Japan) where it is considered non-native. In Europe, J. marmorata is found from Denmark to Spain. In subtropical areas in South America (Brazil, Chile), Africa (South Africa, Tanazania). Found in Australia and New Zealand (Conlan 1990; Fofonoff et al. 2003).

**Sources:**
Conlan 1990 NEMESIS; Fofonoff et al. 2003

### *1.7 Current distribution trends*

**Choice: A** Recent rapid range expansion and/or long-distance dispersal (within the last ten years)

**Score:** 5 of 5

**Ranking Rationale:**
Continual expansion observed since arrival along the west coast of North America.

**Background Information:**
Can rapidly colonize artificial and natural habitats (Fofonoff et al. 2003; Franz and Mohamed 1989). Invasion history includes arrival on the west coast around the 1950's and continued expansion associated with anthropogenic structures and transportation all along the coast extending from Mexico to Alaska (reviewed in Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Franz and Mohamed 1989

| | |
|---|---|
| **Section Total - Scored Points:** | 25 |
| **Section Total - Possible Points:** | 26.25 |
| **Section Total -Data Deficient Points:** | 3.75 |

## 2. Anthropogenic Transportation and Establishment



### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice: A** Has been observed using anthropogenic vectors for transport and transports independent of any anthropogenic vector once introduced

**Score:** 4 of 4

**Ranking Rationale:**
Has been observed using ballast water and ship fouling to transport, and has the capability to disperse naturally once in a new environment.

**Background Information:**
Observed transporting in ballast water and on ship hulls. Once it is transported to a new area, individuals can disperse away from original substrate by drifting or floating (Havermans et al. 2007). Although dispersal capability is limited, strong water currents may increase dispersal distance (Molnar et al. 2008).

**Sources:**
Molnar et al. 2008   Havermans et al. 2007

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice: B** Readily establishes in areas with anthropogenic disturbance/infrastructure; occasionally establishes in undisturbed areas

**Score:** 2.75 of 4

**High uncertainty?** ✔

**Ranking Rationale:**
Readily observed in association with anthropogenic infrastructure, as well as in undisturbed areas.

**Background Information:**
Can establish on natural substrates such as macroalgae, rocks, and oyster reefs (Conlan 1990; Carr et al. 2011; Beermann and Franke 2012). Studies suggest a preference for hard, anthropogenic substrates, including pilings, fishing traps, and ships, although this emphasis on anthropogenic substrates may be due to sampling bias.

**Sources:**
NEMESIS; Fofonoff et al. 2003   Beermann and Franke 2012   Carr et al. 2011   Conlan 1990

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice: B** No

**Score:** 0 of 2

**Ranking Rationale:**
Not currently farmed or intentionally cultivated.

**Background Information:**

**Sources:**
None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 6.75 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics



### *3.1 Dietary specialization*

**Choice:** **A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 **of** 5

**Ranking Rationale:**
Preys on numerous taxa readily available in the Bering Sea.

**Background Information:**
Primarily a suspension feeder on phytoplankton and detritus, but also preys on ostracods and other small crustaceans (Dixon and Moore 1997; reviewed in Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Dixon and Moore 1997

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **A** Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 **of** 5

**Ranking Rationale:**
Tolerates wide range of water temperatures and salinities, and uses numerous habitat types.

**Background Information:**
J. marmorata is widely distributed in both temperate and subtropical regions, and can tolerature a wide range of temperatures and salinities (Franz 1989;  Fofonoff et al. 2003). It prefers hard substrates including rocks, woody detritus, docks, ships and other organisms such as oysters (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Franz 1989

### *3.3 Desiccation tolerance*

**Choice:** **U** Unknown

**Score:** **of**

**Ranking Rationale:**
The tolerance of amphipods to desiccation is suspected to be quite low, however, no information regarding desiccation tolerance of J. marmorata was available in the literature.

**Background Information:**
J. marmorata is an intertidal species. A study in Sicily reported that J. marmorata were dominant in the surf zone, +0.5m above water (Krapp-Schickel 1993). A report from Denmark found J. marmorata most commonly associated with the “mid-zone” 1 to 5m below water, but occurring throughout the water depths they sampled (0 to >7m) (Leonhard and Pedersen 2006). Bousfield (1973) suggests the tolerance of amphipods to desiccation is generally quite low (qtd. in Hill 2000).

**Sources:**
Hill 2000   Krapp-Schickel 1993   Bousfield 1973   Leonhard and Pedersen 2006

### 3.4 *Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice:** **B**

Moderate – Exhibits one or two of the above characteristics

**Score:** 3.25 of 5

**Ranking Rationale:**

Short generation time but not asexual or hermaphroditic, moderate fecundity, and high parental investment.

**Background Information:**

Females brood their eggs and care for their young. Brood size is dependent on adult female body size, and large females can produce 125-175 embryos (Beerman and Purz 2013). Fecundity period is short and occurs for females immediately after they moult, however, individuals can mate multiple times and reproduction can occur throughout the year (Clark and Caudill 2001). Gravid females have been observed year-round in some locations, but are most abundant in May-August (e.g. Jamaica Bay, New York; Franz 1980). A closely related species, Jassa falcata, is reported to have a generation time of <1 year, and age at maturity of 2 to 6 months (Hill 2000).

**Sources:**

Hill 2000 Clark and Caudill 2001 NEMESIS; Fofonoff et al. 2003 Beermann and Purz 2013

### 3.5 *Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice:** **C**

Disperses short (< 1 km) distances

**Score:** 0.75 of 2.5

**Ranking Rationale:**

No larval dispersal stage. Poor swimmers, short-distance dispersal (centimeters) of juveniles searching for habitat or mates; adults live inside their self-built tubes and move around by crawling or swimming, but rarely leave the home they have built. There is potential for dispersal by currents.

**Background Information:**

Amphipod crustaceans lack a larval dispersal stage. Tube-building amphipods are generally poor swimmers, but short-distance dispersal (on the scale of centimeters) occur in juveniles in search of a substrate or mates (Franz and Mohamed 1989). Adults live inside their self-built tube and move around by crawling and swimming, but rarely leave the home they have built for themselves (Fact Sheet 14). There is also potential for dispersal by currents (Franz and Mohamed 1989), however, once introduced in an area, it tends to remain at the point of introduction (Fact Sheet 14).

**Sources:**

Franz and Mohamed 1989 Fact Sheet 14

### 3.6 *Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice:** **C** Low – Exhibits none of the above characteristics

**Score:** **0.75** **of** **2.5**

**Ranking Rationale:**
Dispersal is limited at all lifestages.

**Background Information:**
Embryos are kept inside a maternal pouch and young are cared for by the mother. Once they are old enough, juveniles may engage in short-distance dispersal (on the scale of centimeters), but tend to stay close to their parents (Fact Sheet 14; Franz and Mohamed 1989). Adults live inside their self-built tube. They move around by crawling and swimming, but rarely leave the home they have built for themselves (Fact Sheet 14).

**Sources:**
Franz and Mohamed 1989 Fact Sheet 14

### 3.7 *Vulnerability to predators*

**Choice:** **D** Multiple predators present in the Bering Sea or neighboring regions

**Score:** **1.25** **of** **5**

**Ranking Rationale:**
Consumed by numerous taxa.

**Background Information:**
Preyed upon by fish, crabs and shrimps (Leonhard and Pedersen 2006; Fofonoff et al. 2003)

**Sources:**
NEMESIS; Fofonoff et al. 2003 Leonhard and Pedersen 2006

| | |
|---|---|
| **Section Total - Scored Points:** | 16 |
| **Section Total - Possible Points:** | 25 |
| **Section Total -Data Deficient Points:** | 5 |

# 4. Ecological and Socioeconomic Impacts

## 4.1 *Impact on community composition*

**Choice:** **C** Limited – Single trophic level; may cause decline but not extirpation

**Score:** 0.75 **of** 2.5

**Ranking Rationale:**
Limited/short-term impact on communities.

**Background Information:**
J. marmorata is capable of rapid colonization, and often the dominant amphipod species in an community. It may compete with native marine organisms for food and space (Molnar et al. 2008), however, over time it is typically displaced by slower-growing organisms such as sponges (Conlan 1994). More general studies have shown that amphipods may play important roles in determining the type and distribution of algal communities, particularly where predation pressure is low (Molnar et al. 2008)

**Sources:**
Molnar et al. 2008 Leonhard and Pedersen 2006 Conlan 1994

## 4.2 *Impact on habitat for other species*

**Choice:** **C** Limited – Has limited potential to cause changes in one or more habitats

**Score:** 0.75 **of** 2.5

**Ranking Rationale:**
High abundance may reduce habitat for some species.

**Background Information:**
Dense masses of amphipod tubes may inhibit the settlement of boring organisms and other foulers such as tunicates (e.g. Ciona spp.; Barnard 1958). These dense masses can also provide habitat for other organisms, such as polychaetes (Barnard 1958; Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Barnard 1958

## 4.3 *Impact on ecosystem function and processes*

**Choice:** **D** No impact

**High uncertainty?** ☑

**Score:** 0 **of** 2.5

**Ranking Rationale:**

**Background Information:**
No ecosystem impacts have been reported in the literature (Fofonoff et al. 2003)

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.4 Impact on high-value, rare, or sensitive species and/or communities*



**Choice:** **D** No impact

**Score:** 0 of 2.5

**High uncertainty?** ☑

**Ranking Rationale:**

**Background Information:**
No impacts to high-value, rare or sensitive species have been reported in the literature (Fofonoff et al. 2003)

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.5 Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice:** **D** No impact

**Score:** 0 of 2.5

**High uncertainty?** ☑

**Ranking Rationale:**

**Background Information:**
No disease or parasite interactions have been reported in the literature (Fofonoff et al. 2003)

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
The ability of J. marmorata to hybridize with native species in the Bering Sea is unknown, however, there have been no reports of hybridization with local species outside of the Bering Sea.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.7 Infrastructure*

**Choice:** **B** Moderate – Causes or has the potential to cause degradation to infrastructure, with moderate impact and/or within only a portion of the region

**Score:** 1.5 of 3

**Ranking Rationale:**
Fouling of infrastructure may cause damage.

**Background Information:**
Tubes can form dense mats, which may foul infrastructure (e.g. pilings) and obstruct water flow through pipes (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.8 Commercial fisheries and aquaculture

**Choice: D** No impact

**Score:** 0 of 3

**High uncertainty?** ☑

**Ranking Rationale:**
None reported.

**Background Information:**
No economic impacts have been reported in the literature (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.9 Subsistence

**Choice: D** No impact

**Score:** 0 of 3

**High uncertainty?** ☑

**Ranking Rationale:**
None reported.

**Background Information:**
No economic impacts have been reported in the literature (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.101 Recreation

**Choice: D** No impact

**Score:** 0 of 3

**High uncertainty?** ☑

**Ranking Rationale:**
None reported.

**Background Information:**
No impacts to recreation have been reported in the literature (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.11 Human health and water quality

**Choice: D** No impact

**Score:** 0 of 3

**High uncertainty?** ☑

**Ranking Rationale:**
None reported.

**Background Information:**
No impacts to human health or water quality have been reported in the literature (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 3 |
| **Section Total - Possible Points:** | 27.5 |
| **Section Total -Data Deficient Points:** | 2.5 |

# 5. Feasibility of prevention, detection and control



## 5.1 *History of management, containment, and eradication*

**Choice:** **C** Attempted; control methods are currently in development/being studied

**Score:** of

**Ranking Rationale:**

No species-specific management, conatinment or eradication efforts have been made for Jassa marmorata; however certain measures have been taken to address the issue of invasive species in ballast water. While BWE can be highly effective at reducing the abundance of coastal organisms, efficacy varies across taxonomic groups, and residual organisms still remain in ballast tanks following exchange (Ruiz and Reid 2007). As a result, ballast water exchange is commonly viewed as a short-term or "stop-gap" option that is immediately available for use on most ships, but that will gradually be phased out as more effective, technology-based methods become available (Ruiz and Reid 2007).

BWTS are replacing BWE as a method for reducing the risk of introductions. However, a review of current BWMS concluded that no system achieves complete sterilization or removal of all living organisms (Science Advisory Board 2011). Additionally, performance standards still allow for a certain number of organisms to exist in treated ballast water, such that vessels carrying large volumes of ballast water (e.g. $\geq$ 100,000 tons) may still discharge a high number of organisms, with potential risk of introductions (Gollasch et al. 2007)

**Background Information:**

Ballast water exchange (BWE) can be highly effective at replacing coastal ballast water with mid-ocean water (88-99% replacement of original water) and reducing coastal planktonic organisms (80-95% reduction in concentration) across ship types, when conducted according to guidelines and regulations (Ruiz and Reid 2007). However, presently, there is no way to verify the extent to which BWE occurred, and whether exchange approached the 100% empty-refill or 300% flow-through as required (Ruiz and Reid 2007). Moreover, because efficacies are < 100%, coastal organisms still remain in ballast tanks following exchange. Several studies have found coastal organisms in ships that had reportedly undertaken BWE (qtd. in Ruiz and Reid 2007). Oceanic species added to tanks during exchange can pose additional invasion risk if recipient ports are saltwater (Cordell et al., 2009; Roy et al., 2012, qtd. in Bailey 2015).

Treatment of ballast water is replacing ballast water exchange as a method for preventing the spread of aquatic invasive species. In the U.S., treatment systems must be approved by the U.S. Coast Guard. As of Dec. 23rd 2016, USCG has approved 3 ballast water management system (BWMS) and 56 alternate management systems (to be replaced by a BWMS within 5 years of compliance date). These systems must meet certain water performance standards

**Sources:**

Ruiz and Reid 2007

## 5.2 *Cost and methods of management, containment, and eradication*

**Choice:** **B** Major short-term and/or moderate long-term investment

**Score:** of

**Ranking Rationale:**

To comply with ballast water regulations, vessels will have to equip themselves with an onboard ballast water treatment system. These systems represent a major short-term cost for vessel owners (up to $3 million), with additional costs over time to maintain and replace equipment (e.g. chemicals, filters, UV light bulbs).

**Background Information:**

The costs associated with purchasing a ballast water treatment system depend on the volume of water that needs to be treated. Systems with a pump capacity of 200-250 $m^3$/h can cost from $175,000 to $490,000. The estimated price for larger systems with a pump capacity of around 2000 $m^3$/h range from $650,000 to nearly $3 million.

**Sources:**

Zagdan 2010

### 5.3 *Regulatory barriers to prevent introductions and transport*



**Choice:** **C** Regulatory oversight and/or trade restrictions

**Score:** of

**Ranking Rationale:**

No species-specific regulatory oversight or trade restrictions are currently in place for Jassa marmorata. Alaska does not have state regulations on ballast water management, but two federal regulations (USCG and EPA) require mandatory reporting and ballast water treatment or exchange.

**Background Information:**

State regulations: Alaska does not have a state regulations related to the management of aquatic invasive species in discharged ballast water. It relies on the U.S. Coast Guard (USCG) to enforce national standards. In Alaska, data from 2009-2012 show moderate to high compliance with USCG reporting requirements (Verna et al. 2016).

Federal regulations: In the U.S., ballast water management (treatment or exchange) and record-keeping is mandatory and regulated by the USCG, with additional permitting by the Environmental Protection Agency (EPA). Certain vessels (e.g. small vessels or those traveling within 1 Captain of the Port Zone) are exempt from USCG and EPA regulations.

**Sources:**

EPA 2013 Verna et al. 2016

### 5.4 *Presence and frequency of monitoring programs*

**Choice:** **A** No surveillance takes place

**Score:** of

**Ranking Rationale:**

**Background Information:**

No information regarding monitoring programs for J. marmorata exist online or in the literature.

**Sources:**

None listed

### 5.5 *Current efforts for outreach and education*

**Choice:** **A** No education or outreach takes place

**Score:** of

**Ranking Rationale:**

**Background Information:**

No education or outreach materials were available online or in the literature for J. marmorata.

**Sources:**

None listed

**Section Total - Scored Points:**

**Section Total - Possible Points:**

**Section Total -Data Deficient Points:**

## Literature Cited for *Jassa marmorata*


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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Melita nitida*

**Common Name** *an amphipod*

| | |
|---|---|
| **Phylum** | Arthropoda |
| **Class** | Malacostraca |
| **Order** | Amphipoda |
| **Family** | Melitidae |

**Final Rank** 47.30

**Data Deficiency:** 21.25

Species Occurrence by Ecoregion

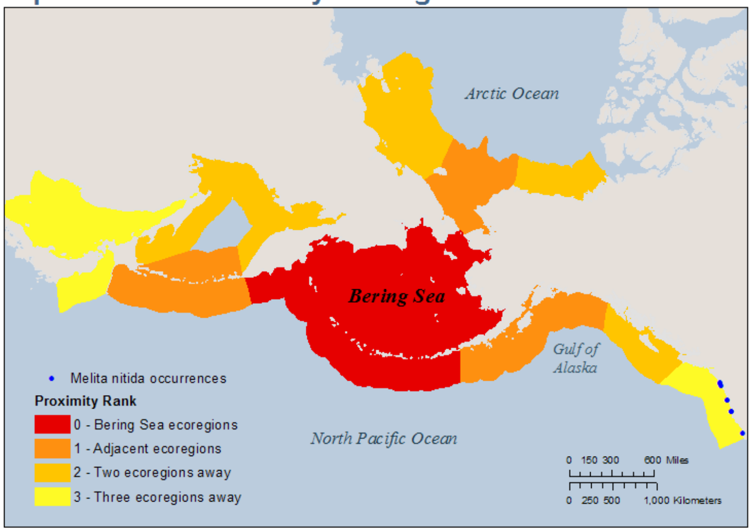


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 16.25 | 26 | 3.75 |
| Anthropogenic Influence: | 4.75 | 10 | 0 |
| Biological Characteristics: | 14.75 | 23 | 7.50 |
| Impacts: | 1.5 | 20 | 10.00 |
| **Totals:** | 37.25 | 78.75 | 21.25 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | 0 | Minimum Salinity (ppt) | 0 |
| Maximum Temperature (°C) | 32 | Maximum Salinity (ppt) | 35 |
| Minimum Reproductive Temperature (°C) | NA | Minimum Reproductive Salinity (ppt) | 31* |
| Maximum Reproductive Temperature (°C) | NA | Maximum Reproductive Salinity (ppt) | 35* |

### Additional Notes

Melita nitida is a slender amphipod with a grayish body and a red spot on the head. Males can reach 12 mm and females 9 mm in length. It is Native to east coast of North America and introduced to the West Coast and Europe (Fofonoff et al. 2003). Is very similar to three other Melita species found in the Gulf of Mexico (Sheridan 1979). West Coast populations may not be M. nitida, but another similar or undescribed species (Chapman, in Carlton 2007; Graening et al. 2012).

# 1. Distribution and Habitat

### *1.1 Survival requirements - Water temperature*

**Choice: B** Moderate overlap – A moderate area (≥25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 2.5 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Temperatures required for year-round survival occur in a moderate area (≥25%) of the Bering Sea. Thresholds are based on geographic distribution, which may not represent physiological tolerances; moreover, models disagree with respect to their estimates of suitable area. We therefore ranked this question with "High uncertainty".

**Background Information:**
The survival temperature threshold for M. nitida is 0 to 32°C (based on geographic distribution; Fofonoff 2003)

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.2 Survival requirements - Water salinity*

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
The salinity range for survival of M. nitida is 0 to 35 ppt (Fofonoff et al. 2003)

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.3 Establishment requirements - Water temperature*

**Choice: U** Unknown/Data Deficient

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information on optimal temperature thresholds for reproduction of M. nitida were available in the literature. A lab study found that an increase in temperature from 17 to 21°C led to quicker embryonic development (10 days vs. 5 days; Borowsky 1980).

**Sources:**
Borowsky 1980

### 1.4 *Establishment requirements - Water salinity*

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Although salinity thresholds are unknown, this species is a marine organism that does not require freshwater to reproduce. We therefore assume that this species can reproduce in saltwater (31 to 35 ppt). These salinities occur in a large (>75%) portion of the Bering Sea.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 1.5 *Local ecoregional distribution*

**Choice: D** Present in an ecoregion greater than two regions away from the Bering Sea

**Score:** 1.25 of 5

**Ranking Rationale:**
Closest occurrence is British Columbia.

**Background Information:**
Current occurrence records in the NEMESIS data base include British Columbia and California (Fofonoff et al 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 1.6 *Global ecoregional distribution*

**Choice: B** In a moderate number of ecoregions globally

**Score:** 3.25 of 5

**Ranking Rationale:**
Found along East and West coasts of North America and in Europe.

**Background Information:**
Wide native distribution in eastern North America, from Nova Scotia/PEI to Florida, and from the Gulf of Mexico to Colombia (Caribbean Sea). Introduced to the west coast of North America from California to British Columbia, Canada. In Europe, M. nitida is recorded in France, Germany and the Netherlands.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.7 Current distribution trends*

**Choice:** **C**

Established outside of native range, but no evidence of rapid expansion or long-distance dispersal

**Score:** 1.75 **of** 5

**Ranking Rationale:**

Can rapidly colonize and increase in abundance, but evidence exists for declines in introduced ranges.

**Background Information:**

In 2010, twenty-seven specimens were collected in the Kiel Canal, Germany, near the Baltic Sea entrance in Kiel (Reichert and Beermann 2011). Future establishment and spread of this amphipod in the North Sea and Baltic seems likely (Fofonoff et al. 2003). Although M. nitida can rapidly colonize new habitats and increase local abundance rapidly, colonization experiments found that population growth on clam shells decreased over time and became negative after several months (Munguia et al. 2007). In the Western Scheldt in the Netherlands, M. nitida had a very limited range four years after it was first discovered (Faasse and van Moorsel 2003).

**Sources:**

Reichert and Beerman 2011 NEMESIS; Fofonoff et al. 2003 Munguia et al. 2007 Faasse and Moorsel 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 16.25 |
| **Section Total - Possible Points:** | 26.25 |
| **Section Total -Data Deficient Points:** | 3.75 |

## 2. Anthropogenic Transportation and Establishment

### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice: B** Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 of 4

**High uncertainty?** ☑

**Ranking Rationale:**
Has been observed using anthropogenic vectors; limited information regarding movements after introduction.

**Background Information:**
Presumed to have been introduced through anthropogenic vectors, including ballast water and hull fouling, in bait packed in seaweed, or with oyster transplants. Found on the western coast of North America (Fofonoff 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice: B** Readily establishes in areas with anthropogenic disturbance/infrastructure; occasionally establishes in undisturbed areas

**Score:** 2.75 of 4

**High uncertainty?** ☑

**Ranking Rationale:**
Known to use anthropogenic or disturbed sites for establishment; no information on the use of natural sites after introduction.

**Background Information:**
Introductions in Europe are currently associated with anthropogenic sites (oyster farms, canals), and no follow-up studies have been published on its subsequent spread into natural areas (Faasse and van Moorsel 2003; Reichert and Beermann 2011; Gouillieux et al. 2016). In California, was found in greater densities on non-native tubeworms than on native oysters (Heiman et al. 2008). Has been recorded at many sites throughout the west coast of North America, where it occurs from California to British Columbia, but no genetic analysis has been conducted to determine whether these records are the result of natural dispersal or anthropogenic spread (e.g. primary followed by secondary dispersal).

**Sources:**
Faasse and Moorsel 2003   Reichert and Beerman 2011   Gouillieux et al. 2016   Heiman et al. 2008

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice: B** No

**Score:** 0 of 2

**Ranking Rationale:**

**Background Information:**
This species is not currently farmed or intentionally cultivated.

**Sources:**
None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 4.75 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

# 3. Biological Characteristics



### 3.1 Dietary specialization

**Choice:** **A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Preys on taxa that are readily available in the Bering Sea.

**Background Information:**
M. nitida is a surface deposit feeder, interface feeder and faculative suspension feeder (Lowrey and Costello 2010; Wildish and Peer 1981). It feeds primarily on epiphytic algae and seagrass debris (Fofonoff 2003).

**Sources:**
Lowrey and Costello 2010   Wildish and Peer 1981   NEMESIS; Fofonoff et al. 2003

### 3.2 Habitat specialization and water tolerances

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **A** Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 of 5

**Ranking Rationale:**
Tolerates wide range of water temperatures and salinities, and uses numerous habitat types.

**Background Information:**
M. nitida tolerates temperatures of 0°C to 32°C and salinities of 0 PSU to 35 PSU (Bousfield 1973; Sheridan 1979, as qtd. In Fofonoff et al. 2003; Chapman 1988). Habitats include intertidal mudflats, rocks, and debris, clumps of hydroids and bryozoans, floats and pilings, buoys, and crevices created by oysters and bivalves (Bousfield 1973; Sheridan 1979, as qtd. in Fofonoff et al. 2003; Chapman 1988; Munguia et al. 2007). Associated with low-tide to subtidal areas, and with the seafloor, where it burrows and feeds (Borowsky et al. 1997).

**Sources:**
Bousfield 1973   Chapman 1988   Munguia et al. 2007   Borowsky et al. 1997   NEMESIS; Fofonoff et al. 2003

### 3.3 Desiccation tolerance

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 3.4 *Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice:** **C** Low – Exhibits none of the above characteristics

**Score:** 1.75 **of** 5

**Ranking Rationale:**
Sexual reproduction, moderate fecundity, high parental investment, internal fertilization.

**Background Information:**
Sexual reproduction with internal fertilization. Direct development (no larval stage) and long parental investment. Brood sizes range from 5 - 51 embryos with an average of 30 (Fofonoff et al. 2003). Under controlled conditions, embryos took 10 days to develop at 17°C, and 5 days at 21°C (Borowsky 1980). M. nitida has two generations a year, one in the spring and one in the fall (that overwinters) (Borowsky et al. 1997).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Borowsky 1980 Borowsky et al. 1997

### 3.5 *Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice:** **U** Unknown

**Score:** **of**

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
Munguia et al. 2007

### 3.6 *Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice:** **B** Moderate – Exhibits one of the above characteristics

**Score:** 1.75 **of** 2.5

**Ranking Rationale:**
Disperses only as an adult.

**Background Information:**
Eggs are brooded internally with no external larval stage; individuals hatch as juveniles, which resemble adults. Munguia et al. (2007) found that 97% of M. nitida dispersers were adults, which suggests that the juvenile life stage is not an important dispersal stage.

**Sources:**
Munguia et al. 2007

### *3.7 Vulnerability to predators*



| Choice: D | Multiple predators present in the Bering Sea or neighboring regions | Score: 1.25 of 5 |
|---|---|---|

**Ranking Rationale:**
Numerous predators, many of which exist in the Bering Sea.

**Background Information:**
Likely predators include crabs, shrimps, fishes, and shorebirds (Fofonoff 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 14.75 |
| **Section Total - Possible Points:** | 22.5 |
| **Section Total -Data Deficient Points:** | 7.5 |

# 4. Ecological and Socioeconomic Impacts



### 4.1 *Impact on community composition*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
Little to no information in literature suggesting a strong impact of M. nitida on community composition.

**Background Information:**
In the Netherlands, M. nitida frequently occurs together with M. palmata. A study in 2003 found that the two species exploited different niches: M. palmata occurs mainly higher in the intertidal zone and, unlike M. nitida, was not restricted to the mesohaline part of the estuary (Faasse and van Moorsel 2003). However, as the range of M. nitida was still very limited, it was not possible to predict whether significant competition with M. palmata could occur (Faasse and van Moorsel 2003).

**Sources:**
Faasse and Moorsel 2003

### 4.2 *Impact on habitat for other species*

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.3 *Impact on ecosystem function and processes*

**Choice:** **U** Unknown

**High uncertainty?** ☑

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.4 *Impact on high-value, rare, or sensitive species and/or communities*

**Choice:** **D** No impact

**High uncertainty?** ☑

**Score:** 0 of 2.5

**Ranking Rationale:**
To date, nor impacts on high-value, rare, or sensitive species have been reported for M. nitida, and given its ecology, none would be expected.

**Background Information:**
No impacts have been reported in the literature (Fofonoff 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.5 *Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 4.6 *Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 4.7 *Infrastructure*

**Choice:** **C** Limited – Has limited potential to cause degradation to infrastructure, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
Is a fouling species found on ships, dock floats, and pilings.

**Background Information:**
M. nitida has been found fouling ships, dock floats and pilings (Faase and Moorsel 2003; Reichert and Beermann 2011; Gouillieux et al. 2016), but no economic impacts have been recorded.

**Sources:**
Faasse and Moorsel 2003   Reichert and Beerman 2011   Gouillieux et al. 2016

### 4.8 *Commercial fisheries and aquaculture*

**Choice:** **C** Limited – Has limited potential to cause degradation to fisheries and aquaculture, and/or is restricted to a limited region

**Score:** 0.75 of 3

**Ranking Rationale:**

**Background Information:**
In its native range, M. nitida is commonly associated with the Eastern oyster, but no economic impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.9 Subsistence



**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on subsistence have been reported for M. nitida, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 4.101 Recreation

**Choice:** **D** No impact

**High uncertainty?** ☑

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on recreation have been reported for M. nitida, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.11 Human health and water quality

**Choice:** **D** No impact

**High uncertainty?** ☑

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on human health or water quality have been reported for M. nitida, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 1.5 |
| **Section Total - Possible Points:** | 20 |
| **Section Total -Data Deficient Points:** | 10 |

## 5. Feasibility of prevention, detection and control



### 5.1 *History of management, containment, and eradication*

**Choice:** **C**

Attempted; control methods are currently in development/being studied

**Score:**

of

**Ranking Rationale:**

Effective methods of managing ballast water and hull fouling are currently being developed.

**Background Information:**

Although regulations for ballast water and hull fouling exist in Alaska, this species is transported by numerous vectors and no species-specific regulations are currently in place. Management of both ballast water and hull fouling is currently being developed (Hagan et al. 2014; Ruiz and Reid 2007).

**Sources:**

Hagan et al. 2014   Ruiz and Reid 2007

### 5.2 *Cost and methods of management, containment, and eradication*

**Choice:** **B**

Major short-term and/or moderate long-term investment

**Score:**

of

**Ranking Rationale:**

Current hull fouling technologies that address invasive species require purchasing of specialized equipment and regular cleaning.

**Background Information:**

Current hull fouling technologies that address invasive species require purchasing of specialized equipment and regular cleaning. To comply with ballast water regulations, vessels will have to equip themselves with an onboard ballast water treatment system. These systems represent a major short-term cost for vessel owners (up to $3 million), with additional costs over time to maintain and replace equipment (e.g. chemicals, filters, UV light bulbs).

**Sources:**

Zagdan 2010   Hagan et al. 2014

## 5.3 *Regulatory barriers to prevent introductions and transport*



**Choice:** **B** Regulatory oversight, but compliance is voluntary

**Score:** of

**Ranking Rationale:**

Compliance with fouling regulations are voluntary. Alaska does not have state regulations on ballast water management, but two federal regulations (USCG and EPA) require mandatory reporting and either exchange or treatment of ballast water.

**Background Information:**

Hull fouling: In the U.S., Coast Guard regulations require masters and ship owners to clean vessels and related infrastructure on a “regular” basis (CFR 33 § 151.2050). Failure to remove fouling organisms is punishable with a fine (up to $27 500). However, because the word “regular” is not defined, regulations are hard to enforce and compliance remains largely voluntary (Hagan et al. 2014). Cleaning of recreational vessels is also voluntary, although state and federal programs are in place to encourage owners to clean their boats. Boat inspection is mandatory on some lakes (e.g. Lake Tahoe in CA/NV, Lake George in NY). In summer 2016, state and federal agencies conducted voluntary inspections for aquatic invasive species on trailered boats entering the state of Alaska (Davis 2016).

Ballast Water: State regulations: Alaska does not have a state regulations related to the management of aquatic invasive species in discharged ballast water. It relies on the U.S. Coast Guard (USCG) to enforce national standards. In Alaska, data from 2009-2012 show moderate to high compliance with USCG reporting requirements (Verna et al. 2016).

Federal regulations: In the U.S., ballast water management (treatment or exchange) and record-keeping is mandatory and regulated by the USCG, with additional permitting by the Environmental Protection Agency (EPA). Certain vessels (e.g. small vessels or those traveling within 1 Captain of the Port Zone) are exempt from USCG and EPA regulations.

**Sources:**

CFR 2017 Hagan et al. 2014 Davis 2016 Verna et al. 2016 EPA 2013

## 5.4 *Presence and frequency of monitoring programs*

**Choice:** **A** No surveillance takes place

**Score:** of

**Ranking Rationale:**

**Background Information:**

No information available in the literature to suggest that there are monitoring programs in place for M. nitida.

**Sources:**

None listed

### *5.5 Current efforts for outreach and education*

**Choice:** **A** No education or outreach takes place

**Score:** of

**Ranking Rationale:**
Information on M. nitida is scarce, and no evidence of outreach taking place was present in the literature.

**Background Information:**
M. nitida was mentioned in an educational brochure on aquatic invasive species (100th Meridian Initiative 2009). Listed on a few invasive/nonnative species "checklists" (e.g. in CA and OR), but with little information provided beyond that.

**Sources:**
Behrens Yamada 1982

**Section Total - Scored Points:**
**Section Total - Possible Points:**
**Section Total -Data Deficient Points:**

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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Paracorophium spp.*

**Common Name** *an amphipod*

| | |
|---|---|
| Phylum | Arthropoda |
| Class | Malacostraca |
| Order | Amphipoda |
| Family | Corophiidae |

**Final Rank** 29.15

**Data Deficiency:** 26.25

## Species Occurrence by Ecoregion

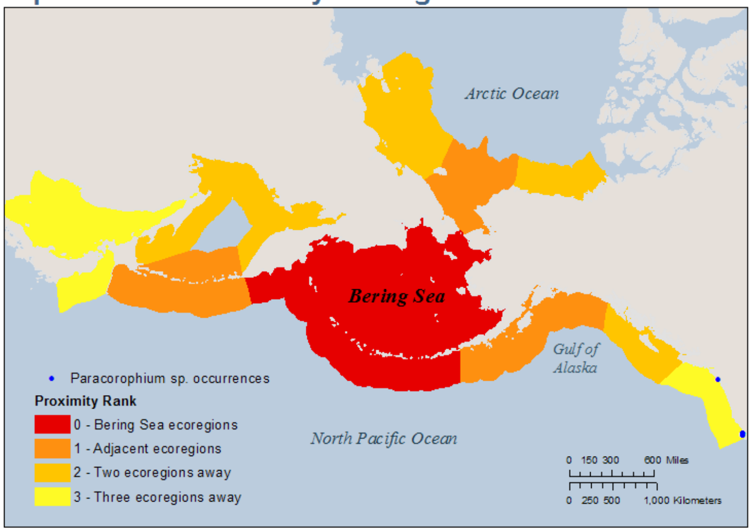


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 6.75 | 14 | 16.25 |
| Anthropogenic Influence: | 2 | 10 | 0 |
| Biological Characteristics: | 12 | 23 | 7.50 |
| Impacts: | 0.75 | 28 | 2.50 |
| **Totals:** | 21.50 | 73.75 | 26.25 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | NA | Minimum Salinity (ppt) | 0 |
| Maximum Temperature (°C) | NA | Maximum Salinity (ppt) | 31 |
| Minimum Reproductive Temperature (°C) | NA | Minimum Reproductive Salinity (ppt) | NA |
| Maximum Reproductive Temperature (°C) | NA | Maximum Reproductive Salinity (ppt) | NA |

### Additional Notes

Paracorophium sp. is a tube-building amphipod endemic to warm and temperate waters in the Southern Hemisphere. In North America, it has been introduced to California. The taxonomic identity of this introduced population is unknown.

# 1. Distribution and Habitat



### 1.1 Survival requirements - Water temperature

**Choice:** **U** Unknown/Data Deficient

**Score:** of

**High uncertainty?** ✔

**Ranking Rationale:**
Temperatures requirements for survival are unknown.

**Background Information:**
Paracorophium spp. occur in warm temperate to cold temperate environments (Fofonoff et al. 2003). Occurrence records are available for Paracorophium species in Eureka (NAS database) which has an average water temperature that ranges from 10 to 11.1 C (Trinidad CA; NOAA 2017).

**Sources:**
NEMESIS; Fofonoff et al. 2003   NAS database, USGS 2017   NOAA 2017

### 1.2 Survival requirements - Water salinity

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Surival has been observed in a variety of salinities from 0 ppt to full salinity.

**Background Information:**
Tolerant of a wide range of salinities. Has been observed in water ranging from 0 ppt to full salinity (Boyd et al. 2002; Chapman et al. 2002; Stevens et al. 2002; Chapman 2007 as qtd. In Fofonoff et al. 2003; Southern California Association of Marine Invertebrate Taxonomists 2008).

**Sources:**
Boyd et al. 2002   Chapman et al. 2002   Stevens et al. 2002   NEMESIS; Fofonoff et al. 2003   Southern California Association of Marine Invertebrate Taxonomists 2008

### 1.3 Establishment requirements - Water temperature

**Choice:** **U** Unknown/Data Deficient

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 1.4 Establishment requirements - Water salinity

**Choice:** **U** Unknown/Data Deficient

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 1.5 *Local ecoregional distribution*

**Choice: D** Present in an ecoregion greater than two regions away from the Bering Sea

**Score:** 1.25 of 5

**Ranking Rationale:**
Present in an ecoregion three regions away from the Bering Sea.

**Background Information:**
Occurrences for Paracorophium spp. have been reported in Humboldt Bay, Tomales Bay, Morro Bay, and Elkhorn Slough CA (Boyd et al. 2002; Southern California Association of Marine Invertebrate Taxonomists 2008; Graening et al. 2012; California Department of Fish and Wildlife 2014).

**Sources:**
Boyd et al. 2002 Southern California Association of Marine Invertebrate Taxonomists 2008 Graening et al. 2012 California Department of Fish and Wildlife 2014 NEMESIS; Fofonoff et al. 2003

### 1.6 *Global ecoregional distribution*

**Choice: C** In few ecoregions globally

**High uncertainty?** ☑

**Score:** 1.75 of 5

**Ranking Rationale:**
Paracorophium spp. are present to numerous locations in the Southern Hemisphere, however, these results are for three species; the species located in California may be more limited in its distribution.

**Background Information:**
Paracorophium spp. is known from its introduced range: Humboldt Bay, Tomales Bay, Elkhorn Slough, and Morro Bay, CA (Chapman 2007 as qtd. In Fofonoff et al. 2003; Southern California Association of Marine Invertebrate Taxonomists 2008; Graening et al. 2012; California Department of Fish and Wildlife 2014). It is an unknown amphipod that may actually be one or more species. Other paracorophium species are mainly known in the Southern Hemisphere with specific species occurring in New Zealand, Australia, Chile, Palau, and Thailand (Gonzalez 1986, as qtd. in Fofonoff et al. 2003; Barnard and Karaman 1991; Fenwick 2001; Myers 2009; Wongkamhaeng et al. 2015).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Southern California Association of Marine Invertebrate Taxonomists 2008 Graening et al. 2012 California Department of Fish and Wildlife 2014 Barnard and Karaman 1991 Fenwick 2001 Myers 2009 Wongkamhaeng et al. 2015

### 1.7 *Current distribution trends*

**Choice: U** Unknown/Data Deficient

**High uncertainty?** ☑

**Score:** of

**Ranking Rationale:**
Data deficient. The only non-native records for Paracorophium spp. are in California (2011; NAS, USGS 2017). No information available regarding recent spread in non-native range.

**Background Information:**
No information available in the literature.

**Sources:**
NAS database, USGS 2017

| | |
|---|---|
| **Section Total - Scored Points:** | 6.75 |
| **Section Total - Possible Points:** | 13.75 |
| **Section Total -Data Deficient Points:** | 16.25 |

## 2. Anthropogenic Transportation and Establishment



### 2.1 *Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice:** **B**

Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 **of** 4

**Ranking Rationale:**

Reported as using ballast water and hull fouling as a transportation vector. Has not been observed moving naturally outside of areas of introduction.

**Background Information:**

Paracorophium spp. is considered native to New Zealand and South America. The lumber trade with New Zealand and Brazil could have introduced this species to California through hull fouling, dry ballast, and ballast water (Boyd et al. 2002; NAS database, USGS 2017). Ballast water and hull fouling are listed as potential transportation vectors for Paracorophium sp. in the NAS database (NAS database, USGS 2017).

**Sources:**

Boyd et al. 2002   NAS database, USGS 2017   NEMESIS; Fofonoff et al. 2003

### 2.2 *Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice:** **D**

Does not use anthropogenic disturbance/infrastructure to establish

**Score:** 0 **of** 4

**Ranking Rationale:**

Establishes in natural habitat; has not been observed establishing on marine infrastructure.

**Background Information:**

Paracorophium spp. in CA is found in muddy intertidal areas and salt marshes. Does not require marine infrastructure to establish.

**Sources:**

NEMESIS; Fofonoff et al. 2003

### 2.3 *Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice:** **B**

No

**Score:** 0 **of** 2

**Ranking Rationale:**

**Background Information:**

This species is not currently farmed or intentionally cultivated.

**Sources:**

NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 2 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics

### *3.1 Dietary specialization*

**Choice: A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Preys on numerous taxa readily available in the Bering Sea.

**Background Information:**
If Paracorophium spp. are like other corophiid amphipods, it probably consumes phytoplankton, detritus, benthic microalgae, and filamentous epiphytic algae (Bousfield 1973).

**Sources:**
Bousfield 1973 NEMESIS; Fofonoff et al. 2003

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice: B** Requires specialized habitat for some life stages (e.g., reproduction)

**Score:** 3.25 of 5

**Ranking Rationale:**

**Background Information:**
Near shore species, restricted to muddy intertidal habitats, salt marshes, and shallow channels, often with freshwater input. Tolerant of a variety of habitats (intertidal and freshwater), temperatures and salinity regimes.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *3.3 Desiccation tolerance*

**Choice: U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *3.4 Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice: C** Low – Exhibits none of the above characteristics

**Score:** 1.75 of 5

**Ranking Rationale:**
Sexual reproduction, low fecundity, high parental investment, internal fertilization.

**Background Information:**
Paracorophium spp. are not asexual or hermaphroditic. Females brood small broods of eggs and sexual maturity is achieved at approximately 6 months of age.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 3.5 *Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
Dispersal is limited to crawling, swimming or rafting (Fofonoff 2003). Distances are not mentioned in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 3.6 *Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice:** **C** Low – Exhibits none of the above characteristics

**Score:** 0.75 of 2.5

**Ranking Rationale:**

**Background Information:**
There is no larval stage for Paracorophium spp. and adults have low mobility with dispersal being limited to crawling, swimming and rafting (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 3.7 *Vulnerability to predators*

**Choice:** **D** Multiple predators present in the Bering Sea or neighboring regions

**High uncertainty?** ☑

**Score:** 1.25 of 5

**Ranking Rationale:**
Numerous predators, many of which exist in the Bering Sea.

**Background Information:**
Likely predators include fish and shrimp.

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 12 |
| **Section Total - Possible Points:** | 22.5 |
| **Section Total -Data Deficient Points:** | 7.5 |

## 4. Ecological and Socioeconomic Impacts



### 4.1 *Impact on community composition*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**High uncertainty?** ✔

**Ranking Rationale:**
To date, no impacts on community composition have been reported for Paracorophium spp., and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 4.2 *Impact on habitat for other species*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**High uncertainty?** ✔

**Ranking Rationale:**
To date, no impacts on habitat for other species have been reported for Paracorophium spp., and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.3 *Impact on ecosystem function and processes*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**High uncertainty?** ✔

**Ranking Rationale:**
To date, no impacts on ecosystems functions and processes have been reported for Paracorophium spp., and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.4 *Impact on high-value, rare, or sensitive species and/or communities*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**High uncertainty?** ✔

**Ranking Rationale:**
To date, no impacts on high-value, rare, or sensitive species have been reported for Paracorophium spp., and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.5 Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice: C** Limited – Has limited potential to spread one or more organisms, with limited impact and/or within a very limited region

**Score:** 0.75 of 2.5

**High uncertainty?** ☑

**Ranking Rationale:**
A closely related species was found to be a host to a nematode species.

**Background Information:**
Paracorophium excavatum, a closely related species found in New Zealand, was found to be a host for a previously undescribed fourth-stage larvae of anisakid nematodes. The impacts of this parasite are unknown and it has not been studied in introduced populations (Luque et al. 2007).

**Sources:**
Luque et al. 2007   NEMESIS; Fofonoff et al. 2003

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice: U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.7 Infrastructure*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**

**Background Information:**
Paracorophium spp. have not been observed interacting with marine infrastructure and no impacts on infrastructure are predicted.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.8 Commercial fisheries and aquaculture*

**Choice: D** No impact

**Score:** 0 of 3

**High uncertainty?** ☑

**Ranking Rationale:**
To date, no impacts on commercial fisheries an aquaculture have been reported for Paracorophium spp., and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.9 Subsistence*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on subsistence have been reported for Paracorophium spp., and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.101 Recreation*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on recreation have been reported for Paracorophium spp., and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.11 Human health and water quality*

**Choice: D** No impact

**High uncertainty?** ☑

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on human health or water quality have been reported for Paracorophium spp., and given its ecology, noe would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 0.75 |
| **Section Total - Possible Points:** | 27.5 |
| **Section Total -Data Deficient Points:** | 2.5 |

## 5. Feasibility of prevention, detection and control



### *5.1 History of management, containment, and eradication*

**Choice:** **C**

Attempted; control methods are currently in development/being studied

**Score:**

of

**Ranking Rationale:**

No species-specific management, containment or eradication exists for Paracorophium spp. Management and control methods do exist for ballast water and hull fouling in general.

**Background Information:**

Ballast water exchange is the method currently used by most ships to reduce the spread of species by ballast water. However, it is considered a short-term or "stop-gap" option until more effective, technology-based methods become available e.g., ballast water treatment systems (Ruiz and Reid 2007). The treatment of ballast water is an active area of research as vessels are forced to comply with new regulations. Hull fouling technologies that treat and/or safely dispose of marine organisms, without being toxic to the environment, are currently being studied.

**Sources:**

Hagan et al. 2014   Ruiz and Reid 2007

### *5.2 Cost and methods of management, containment, and eradication*

**Choice:** **B**

Major short-term and/or moderate long-term investment

**Score:**

of

**Ranking Rationale:**

To comply with ballast water regulations, vessels will have to equip themselves with an onboard ballast water treatment system. These systems represent a major short-term cost for vessel owners (up to $3 million), with additional costs over time to maintain and replace equipment (e.g. chemicals, filters, UV light bulbs). Current hull fouling technologies that address invasive species require purchasing of specialized equipment and regular cleaning.

**Background Information:**

No species specific methods have been reported in the literature. However, methods to deal with ballast water and hull fouling have been tested.

The costs associated with purchasing a ballast water treatment system depend on the volume of the water that needs to be treated. Systems with a pump capacity of 200-250 m3/h can cost form $175,000 to $490,000. The estimated price for larger systems with a pump capacity of around 2000 m3/h range from $650,000 to nearly $3 million.

Current hull fouling technologies that address invasive species require purchasing of specialized equipment and regular cleaning.

**Sources:**

FUSP 2013   Zagdan 2010

### 5.3 *Regulatory barriers to prevent introductions and transport*



**Choice:** **B** Regulatory oversight, but compliance is voluntary

**Score:** of

**Ranking Rationale:**

Regulatory barriers and preventative measures for general biofouling and ballast water discharge apply to this species but nothing specific could be found in the literature. Compliance with general fouling regulations are voluntary.

**Background Information:**

In the U.S., Coast Guard regulations require masters and ship owners to clean vessels and related infrastructure on a "regular" basis (CFR 33 § 151.2050). Failure to remove fouling organisms is punishable with a fine (up to $27 500). However, because the word "regular" is not defined, regulations are hard to enforce and compliance remains largely voluntary (Hagan et al. 2014). Cleaning of recreational vessels is also voluntary, although state and federal programs are in place to encourage owners to clean their boats. Boat inspection is mandatory on some lakes (e.g. Lake Tahoe in CA/NV, Lake George in NY). In summer 2016, state and federal agencies conducted voluntary inspections for aquatic invasive species on trailered boats entering the state of Alaska (Davis 2016).

**Sources:**

CFR 2017 Hagan et al. 2014 Davis 2016

### 5.4 *Presence and frequency of monitoring programs*

**Choice:** **A** No surveillance takes place

**Score:** of

**Ranking Rationale:**

**Background Information:**

No monitoring programs currently exist for Paracorophium spp.

**Sources:**

None listed

### 5.5 *Current efforts for outreach and education*

**Choice:** **A** No education or outreach takes place

**Score:** of

**Ranking Rationale:**

**Background Information:**

Education and outreach efforts are limited to more general invasive awareness and prevention methods such as ballast water discharge reduction.

**Sources:**

None listed

**Section Total - Scored Points:**

**Section Total - Possible Points:**

**Section Total -Data Deficient Points:**

## Literature Cited for *Paracorophium spp.*


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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Amphibalanus amphitrite*

**Common Name** *striped barnacle*

| | |
|---|---|
| **Phylum** | Arthropoda |
| **Class** | Maxillopoda |
| **Order** | Sessilia |
| **Family** | Balanidae |

**Final Rank** 57.50

**Data Deficiency:** 0.00

Species Occurrence by Ecoregion

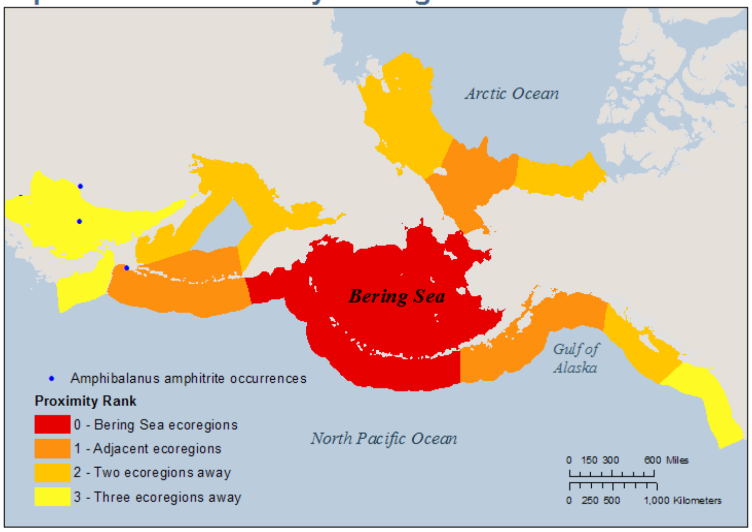


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 21.75 | 30 | 0 |
| Anthropogenic Influence: | 4.75 | 10 | 0 |
| Biological Characteristics: | 22 | 30 | 0 |
| Impacts: | 9 | 30 | 0 |
| **Totals:** | 57.50 | 100.00 | 0.00 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | 0 | Minimum Salinity (ppt) | 10 |
| Maximum Temperature (°C) | 40 | Maximum Salinity (ppt) | 52 |
| Minimum Reproductive Temperature (°C) | 12 | Minimum Reproductive Salinity (ppt) | 20 |
| Maximum Reproductive Temperature (°C) | 23 | Maximum Reproductive Salinity (ppt) | 35 |

### Additional Notes

Amphibalanus amphitrite is a barnacle species with a conical, toothed shell. The shell is white with vertical purple stripes. Shells can grow up to 30.2 mm in diameter, but diameters of 5.5 to 15 mm are more common. This species is easily transported through fouling of hulls and other marine infrastructure. Its native range is difficult to determine because it is part of a species complex that has been introduced worldwide.

# 1. Distribution and Habitat



### 1.1 *Survival requirements - Water temperature*

**Choice: B** Moderate overlap – A moderate area (≥25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 2.5 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Temperatures required for year-round survival occur in a moderate area (≥25%) of the Bering Sea. Thresholds are based on geographic distribution, which may not represent physiological tolerances; moreover, models disagree with respect to their estimates of suitable area. We therefore ranked this question with "High uncertainty".

**Background Information:**
Maximum temperature threshold (40°C) is based on an experimental study (qtd. in Fofonoff et al. 2003). According to observations at a field site in Argentina, this species can survive under freezing water (Calcagno et al. 1998).

**Sources:**
Calcagno et al. 1998   NEMESIS; Fofonoff et al. 2003

### 1.2 *Survival requirements - Water salinity*

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
Minimum salinity: 10 ppt (from lab experiments)
Maximum salinity: 52 ppt (based on field observations in San Francisco Bay; qtd. in Fofonoff et al. 2003).

**Sources:**
Anil et al. 1995   Qiu and Qian 1999   NEMESIS; Fofonoff et al. 2003

### 1.3 *Establishment requirements - Water temperature*

**Choice: C** Little overlap – A small area (<25%) of the Bering Sea has temperatures suitable for reproduction

**Score:** 1.25 of 3.75

**Ranking Rationale:**
Temperatures required for reproduction occur in a limited area (<25%) of the Bering Sea.

**Background Information:**
In Hong Kong, low water temperatures (<15°C) in the winter had negative effects on recruitment and survivorship (Qiu and Qian 1999). Similarly, Anil et al. (1995) found that larval mortality rates were highest at 15°C and lowest at 23°C. In Russia's Peter the Great Bay, larvae were observed in water temperatures between 12 and 22.5°C (Zvyagintsev and Korn 2003). No reproduction was observed at temperatures below 12°C (Zvyagintsev and Korn 2003).

**Sources:**
Anil et al. 1995   Qiu and Qian 1999   Zvyagintsev and Korn 2003

### *1.4 Establishment requirements - Water salinity*

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 of 3.75

**High uncertainty?** ☑

**Ranking Rationale:**
Although upper salinity thresholds are unknown, we assume that it can reproduce in saltwater up to 35 ppt. Salinities required for reproduction occur over a large (>75%) area of the Bering Sea.

**Background Information:**
Of the three salinity treatments that were tested, Anil et al. (1995) observed 99% and 58% mortality of larvae at 10 ppt and 20 ppt in 15°C. Lowest larval mortality rates occurred at 30 ppt (Anil et al. 1995).

**Sources:**
Anil et al. 1995 NEMESIS; Fofonoff et al. 2003

### *1.5 Local ecoregional distribution*

**Choice: B** Present in an ecoregion adjacent to the Bering Sea

**Score:** 3.75 of 5

**Ranking Rationale:**
Occurs in southern Russia and the Sea of Okhotsk.

**Background Information:**
Present in the Northwestern Pacific (Korea, Japan, Russia). Recently detected in the Nanaimo, British Columbia, but is not thought to be established there (Brown et al. 2016).

**Sources:**
Brown et al. 2016

### *1.6 Global ecoregional distribution*

**Choice: A** In many ecoregions globally

**Score:** 5 of 5

**Ranking Rationale:**
This species has a wide global distribution, and is found in temperate and tropical waters in Europe, North America, Africa, Asia, and New Zealand. Its native range is difficult to determine because it is part of a species complex that has been introduced worldwide.

**Background Information:**
Occurs from southeastern Africa to southern China, and in the northwestern Pacific (Korea, Japan, Russia). Also found in New Zealand (and possibly in Australia), as well as in Hawaii. In North America, it occurs from Panama to California, and from the Caribbean to New York. In Europe, it occurs in the northern Atlantic (Germany, England, France), but its distribution in this region is largely confined to warmer waters.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.7 Current distribution trends*

**Choice: C** Established outside of native range, but no evidence of rapid expansion or long-distance dispersal

**Score:** 1.75 of 5

**High uncertainty?** ☑

**Ranking Rationale:**
Colonization of new sites is likely due to transport by anthropogenic vectors, rather than long-distance dispersal.

**Background Information:**

**Sources:**
Masterson 2007

378

| | |
|---|---|
| **Section Total - Scored Points:** | 21.75 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 2. Anthropogenic Transportation and Establishment

### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice: B**

Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 **of** 4

**Ranking Rationale:**

This species can be transported as a fouling organism on ship hulls and other infrastructure, but colonization of new sites is likely due to anthropogenic transport rather than long-distance dispersal.

**Background Information:**

**Sources:**

Masterson 2007   Cohen 2011

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice: B**

Readily establishes in areas with anthropogenic disturbance/infrastructure; occasionally establishes in undisturbed areas

**Score:** 2.75 **of** 4

**Ranking Rationale:**

Increase in hard, anthropogenic substrates may have facilitated the invasion of A. amphitrite on the east coast of North America.

**Background Information:**

Common fouling species that readily attaches itself to hard substrates including rocks, oysters, and docks. The proliferation of anthropogenic structures in marine environments may have increased the abundance of this species on the east coast of North America (Boudreaux et al. 2009).

**Sources:**

NEMESIS; Fofonoff et al. 2003   Boudreaux et al. 2009

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice: B**

No

**Score:** 0 **of** 2

**Ranking Rationale:**

This species is not currently cultivated.

**Background Information:**

**Sources:**

NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 4.75 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

# 3. Biological Characteristics



### 3.1 *Dietary specialization*

**Choice:** **A**

Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 **of** 5

**Ranking Rationale:**
Food is readily available in study area.

**Background Information:**
Nauplii larvae feed on plankton and eventually molt into a non-feeding cyprid stage. Juvenile and adult barnacles are filter feeders, and feed on phytoplankton, zooplankton, and detritus.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 3.2 *Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **A**

Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 **of** 5

**Ranking Rationale:**
Generalist at all life stages with respect to habitat, food, temperature and salinity requirements.

**Background Information:**

**Sources:**
Masterson 2007   Boudreaux et al. 2009   Calcagno et al. 1998

### 3.3 *Desiccation tolerance*

**Choice:** **B**

Moderately tolerant (1-7 days) during one or more stages during its life cycle

**High uncertainty?** ✔

**Score:** 3.25 **of** 5

**Ranking Rationale:**
Did not find information on desiccation tolerance specific to this species. However, a study on a related species, as well as A. amphitrite's occurrence in intertidal and spray zones, suggests that this species is at least moderately tolerant to desiccation.

**Background Information:**
A study by Ware and Hartnoli (1996) considered the desiccation tolerance of a related species, Semibalanus balanoides, across individiuals of different shell sizes and different shore levels. Median lethal time varied from 6 to 48 hours. Desiccation tolerance increased with shell size. Individuals in high tide zones exhibited the greatest tolerance to desiccation. Amphibalanus amphitrite inhabits a wide range of tidal zones, from supralittoral (“spray zone”) to subtidal, and have physiological mechanisms that allow them to survive exposure to air (Desai and Prakash 2009; Anil et al. 2010).

**Sources:**
Desai and Prakash 2009   Anil et al. 2010   Ware and Hartnoli

### 3.4 *Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice:** **B** Moderate – Exhibits one or two of the above characteristics

**Score:** 3.25 **of** 5

**Ranking Rationale:**
This species exhibits moderate fecundity, with the ability to produce several broods per year. Eggs are brooded in the mantle cavity, and parental investment is relatively high. This species is hermaphroditic and has a short generation time.

**Background Information:**
Hermaphroditic, but typically requires cross-fertilization. Experiments with B. amphitrite indicate high egg production: this species breeds several times a year, at intervals of 5–8 days (Crisp and Davis 1955; El-Komi and Kajihara 1991, qtd. in Anil et al. 2010). Individuals produce 1,000 to 10,000 eggs, depending on body size (qtd. in Fofonoff et al. 2003). Fertilized eggs are brooded in the mantle cavity, sometimes for several months, and are released as larvae (qtd. in Fofonoff et al. 2003).

**Sources:**
Anil et al. 2010 El-Komi and Kajihara NEMESIS; Fofonoff et al. 2003

### 3.5 *Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice:** **A** Disperses long (>10 km) distances

**Score:** 2.5 **of** 2.5

**High uncertainty?** ☑

**Ranking Rationale:**
Favourable water currents can likely disperse long-lived planktonic larvae over long distances.

**Background Information:**
Barnacles have a long-lived planktonic larval stage that can remain in the water column for up to two months (qtd. in Anil et al. 1995).

**Sources:**
Anil et al. 1995

### 3.6 *Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice:** **B** Moderate – Exhibits one of the above characteristics

**Score:** 1.75 **of** 2.5

**Ranking Rationale:**
Larval stage is long-lived, but adults are sessile. Eggs are brooded.

**Background Information:**
Planktonic larval stage can remain in the water column for up to two months before settling (Anil et al. 1995). Adults are sessile and eggs are brooded (Fofonoff et al. 2003).

**Sources:**
Anil et al. 1995 NEMESIS; Fofonoff et al. 2003

### 3.7 *Vulnerability to predators*

**Choice: D** — Multiple predators present in the Bering Sea or neighboring regions

**Score:** 1.25 of 5

**Ranking Rationale:**
Barnacles are predated upon by several taxa that occur in the Bering Sea.

**Background Information:**
Barnacles are eaten by worms, whelks, sea stars, fish, and shorebirds.

**Sources:**
MESA 2015

| | |
|---|---|
| **Section Total - Scored Points:** | 22 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 4. Ecological and Socioeconomic Impacts

### *4.1 Impact on community composition*

**Choice:** **C** Limited – Single trophic level; may cause decline but not extirpation

**Score:** 0.75 of 2.5

**Ranking Rationale:**
Can compete for space with other species in the same trophic level, such as native barnacles, other fouling organisms, bivalves, and corals. These taxa are also found in the Bering Sea.

**Background Information:**
Competition may occur among A. amphitrite and other barnacle species, and other hard fouling taxa, though vertical zonation may moderate competition. Boudreaux and Walters (2005) report coexistence between A. amphitrite and the native Balanus eburneus (qtd. in Masterson 2007). In the Indian River Lagoon, FL, it competes with Eastern Oyster (Crassostrea virginica) for settlement sites, and reduces their growth and survival by settling on their shells (Boudreaux et al. 2009). By settling on substrates, A. amphitrite may compete for space and prevent recruitment of corals in marginal environments (Chui and Ang 2010).

**Sources:**
Masterson 2007   Boudreaux et al. 2009   Chui and Ang 2010

### *4.2 Impact on habitat for other species*

**Choice:** **C** Limited – Has limited potential to cause changes in one or more habitats

**Score:** 0.75 of 2.5

**Ranking Rationale:**
This species may change habitats by settling on natural and anthropogenic substrates.

**Background Information:**
Barnacle shells provide habitat and refugia for many invertebrate and epibiotic species. An experiment by Bros (1987) showed that the addition of barnacle shells increased the abundance and diversity of mobile fouling species. By heavily fouling substrates, it decreases habitat availability for other species and can prevent other species such as coral from settling (Chui and Ang 2010).

**Sources:**
Bros 1987   Chui and Ang 2010

### *4.3 Impact on ecosystem function and processes*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No impacts on ecosystem functions or processes have been reported.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003   Molnar et al. 2008

### *4.4 Impact on high-value, rare, or sensitive species and/or communities*

**Choice: C** Limited – Has limited potential to cause degradation of one more species or communities, with limited impact and/or within a very limited region

**Score:** 0.75 of 2.5

**Ranking Rationale:**
Along with other barnacle species, Amphibalanus amphitrite may negatively impact Eastern oysters.

**Background Information:**
Barnacles affect the settlement, growth, and survival of Eastern oysters (Crassostrea virginica), a species currently experiencing population declines. Negative impacts did not seem to be caused by A. amphitrite in particular, but rather by an overall increase in barnacle numbers (Boudreaux et al. 2009). Other factors such as an increase in boating activity may also be contributing to the decline of Eastern oysters (Boudreaux et al. 2009).

**Sources:**
Boudreaux et al. 2009

### *4.5 Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No impacts have been reported.

**Background Information:**
Boschmaella japonica is a parasite that is known to infect the striped barnacle (Deichmann and Hoeg 1990). This parasite also affects at least one other barnacle species that is found in Japan.

**Sources:**
Deichmann and Hoeg 1990

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No impacts reported.

**Background Information:**

**Sources:**
Molnar et al. 2008 NEMESIS; Fofonoff et al. 2003

### 4.7 *Infrastructure*

**Choice: A** High – Is known to cause degradation to infrastructure and/or is expected to have severe impacts and/or will impact the entire region

**Score:** 3 of 3

**Ranking Rationale:**
High impacts on infrastructure are predicted given its abundance as a fouling organism.

**Background Information:**
A. amphitrite is one of the most abundant fouling barnacles on ships and harbours in warmer parts of the U.S. and worldwide (qtd. in Fofonoff et al. 2003). Fouling organisms cost the U.S. Navy over $50 million a year in fuel costs due to drag (Cleere 2001).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Cleere 2001

### 4.8 *Commercial fisheries and aquaculture*

**Choice: B** Moderate – Causes or has the potential to cause degradation to fisheries and aquaculture, with moderate impact in the region

**Score:** 1.5 of 3

**Ranking Rationale:**
Pacific oysters and other bivalves are commercially harvested in the Bering Sea. Shellfish aquaculture is a small industry in Alaska and is limited in the Bering Sea by cold water temperatures.

**Background Information:**
Frequently fouls cultured Pacific oysters (Crassostrea gigas) and Eastern oysters (Crassostrea virginica) (qtd. in Boudreaux et al. 2009). By settling on the shells of bivalves, A. amphitrite may affect their growth and survival (Boudreaux et al. 2009). Barnacles were not listed as one of the main threats to Eastern oyster populations (Eastern Oyster Biological Review Team 2007).

**Sources:**
Boudreaux et al. 2009 Eastern Oyster Biological Review Team 2007

### 4.9 *Subsistence*

**Choice: B** Moderate – Causes or has the potential to cause degradation to subsistence resources, with moderate impact and/or within only a portion of the region

**Score:** 1.5 of 3

**Ranking Rationale:**
Settlement on oyster and mussel shells by Amphibalnus amphitrite may reduce the growth and survival of bivalves. Several bivalve species are harvested for subsistence in the Bering Sea. In the Aleutians West, shellfish harvesting comprised nearly 20% of subsistence catch when measured by weight. However, most municipalities in the Bering Sea recorded much lower percentages (<5%) (Mathis et al. 2015).

**Background Information:**
Compared to salmon and finfish, shellfish such as oysters, clams, and mussels comprise a smaller percentage of subsistence catch in the Bering Sea (when measured by weight; Mathis et al. 2015). Values ranged from < 1% in Bethel and Wade Hampton, to almost 20% in Aleutians West; however, most municipalities in the Bering Sea recorded low percentages (< 5%) of subsistence shellfish.

**Sources:**
Mathis et al. 2015

### 4.101 Recreation

**Choice: C** Limited – Has limited potential to cause degradation to recreation opportunities, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
This species is predicted to have limited impacts on recreational harvesting of bivalves, and on the aesthetic value of beaches in the Bering Sea.

**Background Information:**
Sharp shells may be dangerous for beachgoers. Settlement of Amphibalanus amphitrite on bivalve shells may affect these species' growth and survival. Bivalves are recreationally harvested in Alaska, but is discouraged on most beaches because of the potential for paralytic shellfish poisoning (PSP).

**Sources:**
ADEC 2013

### 4.11 Human health and water quality

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
No negative impacts have been reported. This species has been used as a bioindicator of water quality.

**Background Information:**
Barnacles, particularly a widespread cosmopolitan species such as Amphibalanus amphitrite, have been used worldwide as indicators of water quality in coastal waters (Reis et al. 2011). Barnacles are sensitive to heavy metal contamination, but an increase in barnacle settlement may also point to poor water quality (e.g. urban run-off increases phytoplankton via eutrophication, which provides food for barnacles) (Courtenay et al. 2009).

**Sources:**
Reis et al. 2011 Courtenay et al. 2011

| | |
|---|---|
| **Section Total - Scored Points:** | 9 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

# 5. Feasibility of prevention, detection and control



### *5.1 History of management, containment, and eradication*

**Choice:** **C** Attempted; control methods are currently in development/being studied

**Score:** 0 **of**

**Ranking Rationale:**

Hull fouling technologies that treat and/or safely dispose of marine organisms are currently being studied.

**Background Information:**

No species-specific control methods are being developed for A. amphibalanus, but there are some control methods for fouling species in general. Current methods such as hull cleaning during dry-docking or in-water cleaning do not address all the areas in which fouling organisms may establish (e.g. sea chests, pipes) and do not properly dispose of the biological debris (Hagan et al. 2014). Technologies that address these issues are currently being studied (Hagan et al. 2014).

**Sources:**

Hagan et al. 2014

### *5.2 Cost and methods of management, containment, and eradication*

**Choice:** **B** Major short-term and/or moderate long-term investment

**Score:** **of**

**Ranking Rationale:**

Current hull fouling technologies that address invasive species require purchasing of specialized equipment and regular cleaning.

**Background Information:**

According to Franmarine Underwater Services (2013), a company that supplies an in-water hull cleaning system, the cost of dry docking (including cleaning and "loss of business" costs) varies from AUD $62 200 to more than $1.3 million, depending on vessel size. The Franmarine cleaning system, which collects, treats, and disposes of biological waste (e.g., organisms) has a purchasing cost between AUD ~ $500 000 to $750 000, depending on vessel size. In-water cleaning costs range from AUD $18 800 to $255 000+ (for offshore cleaning of large vessels), with cleaning times estimated between 16 to 48 hours. Hagan et al. (2014) proposed similar estimates for the cost and time of in-water cleaning.

**Sources:**

Hagan et al. 2014   Franmarine 2013

### 5.3 *Regulatory barriers to prevent introductions and transport*



**Choice:** **B** Regulatory oversight, but compliance is voluntary

**Score:** of

**Ranking Rationale:**
Compliance with fouling regulations are voluntary.

**Background Information:**
In the U.S., Coast Guard regulations require masters and ship owners to engage in practices that will reduce the spread of invasive species, including cleaning ballast tanks and removing fouling organisms from hulls, anchors, and other infrastructure on a "regular" basis (CFR 33 § 151.2050). Failure to remove fouling organisms is punishable with a fine (up to $27 500). However, the word "regular" is not defined, which makes the regulations hard to enforce. As a result of this technical ambiguity, compliance with ship fouling regulations is largely voluntary (Hagan et al. 2014). Cleaning of recreational vessels is also voluntary on most lakes, although state and federal programs are in place to encourage owners to clean their boats (Davis et al. 2016).

Cleaning of recreational vessels is also voluntary, although state and federal programs are in place to encourage owners to clean their boats. Boat inspection is mandatory on some lakes (e.g. Lake Tahoe in CA/NV, Lake George in NY). In summer 2016, state and federal agencies conducted voluntary inspections for aquatic invasive species on trailered boats entering the state of Alaska (Davis 2016).

**Sources:**
Hagan et al. 2014   CFR 2017   Davis 2016

### 5.4 *Presence and frequency of monitoring programs*

**Choice:** **A** No surveillance takes place

**Score:** of

**Ranking Rationale:**
This species is not currently monitored.

**Background Information:**
No information found to suggest this species is being monitored.

**Sources:**
None listed

### 5.5 *Current efforts for outreach and education*

**Choice:** **B** Some educational materials are available and passive outreach is used (e.g. signs, information cards), or programs exist outside Bering Sea and adjacent regions

**Score:** of

**Ranking Rationale:**
Because of its abundance as a fouling organism, A. amphitrite is mentioned in a few educational materials about invasive species and hull foulers.

**Background Information:**
Amphibalanus amphitrite is occasionally mentioned in fact sheets about invasive species and hull foulers (Cleere 2001; Johnson et al. 2006).

**Sources:**
Johnson et al. 2006   Cleere 2001

| | |
|---|---|
| **Section Total - Scored Points:** | 0 |
| **Section Total - Possible Points:** | |
| **Section Total -Data Deficient Points:** | |

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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Amphibalanus improvisus*

**Common Name** *bay barnacle*

| | |
|---|---|
| **Phylum** | Arthropoda |
| **Class** | Maxillopoda |
| **Order** | Sessilia |
| **Family** | Balanidae |

**Final Rank** 65.21

**Data Deficiency:** 3.00

### Species Occurrence by Ecoregion

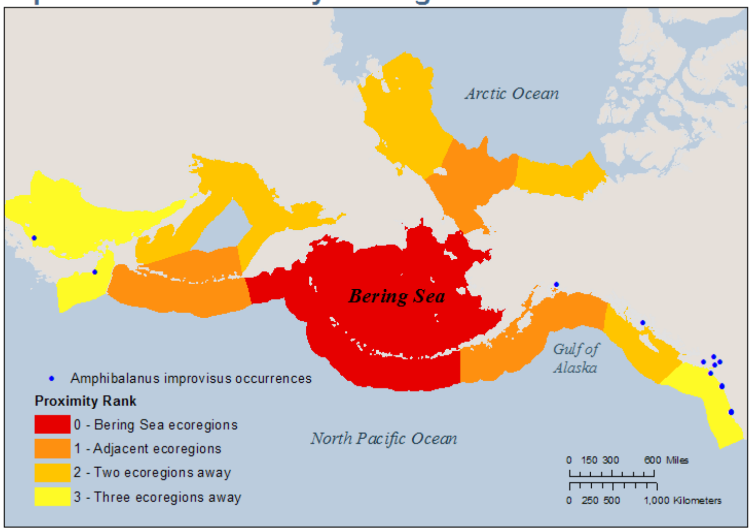


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 26.25 | 30 | 0 |
| Anthropogenic Influence: | 4.75 | 10 | 0 |
| Biological Characteristics: | 23.75 | 30 | 0 |
| Impacts: | 8.5 | 27 | 3.00 |
| **Totals:** | 63.25 | 97.00 | 3.00 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | -2 | Minimum Salinity (ppt) | 0 |
| Maximum Temperature (°C) | 38 | Maximum Salinity (ppt) | 40 |
| Minimum Reproductive Temperature (°C) | 10 | Minimum Reproductive Salinity (ppt) | 2 |
| Maximum Reproductive Temperature (°C) | 30 | Maximum Reproductive Salinity (ppt) | 40 |

### Additional Notes

A barnacle that attaches itself to natural and anthropogenic substrates on the sea floor and inhabits estuaries and coastal areas. Native to the Atlantic and Gulf coasts of North America, with a northward expansion predicted towards Alaska (de Rivera et al. 2007). In Europe, fouling of shipping gear, infrastructure and other species (e.g. oysters) have imposed a major economic cost.

# 1. Distribution and Habitat



### *1.1 Survival requirements - Water temperature*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 3.75 **of** 3.75

**Ranking Rationale:**
Temperatures required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
Inhabits numerous waters from cold temperate to tropical. Can tolerate temperatures from -2ºC to 38ºC with an optimal range of 10ºC to 20ºC (Fofonoff et al. 2003; Shalaeva 2011).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Shalaeva 2011

### *1.2 Survival requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 **of** 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
Tolerant of a large range of salinities. Inhabits water ranging from 0 to 40 PSU with an optimal range of 10 to 20 parts per thousand (Fofonoff et al. 2003; Shalaeva 2011).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Shalaeva 2011

### *1.3 Establishment requirements - Water temperature*

**Choice:** **C** Little overlap – A small area (<25%) of the Bering Sea has temperatures suitable for reproduction

**Score:** 1.25 **of** 3.75

**Ranking Rationale:**
Temperatures required for reproduction occur in a limited area (<25%) of the Bering Sea.

**Background Information:**
The temperature range for reproduction is 10ºC to 30ºC (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.4 Establishment requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 **of** 3.75

**Ranking Rationale:**
Salinities required for reproduction occur over a large (>75%) area of the Bering Sea.

**Background Information:**
The salinity range required for reproduction is 2 to 40ppt as determined by experimental results (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.5 Local ecoregional distribution*



**Choice: B** Present in an ecoregion adjacent to the Bering Sea

**Score:** 3.75 **of** 5

**Ranking Rationale:**
Ocurrence records exist for coastal southeast Alaska.

**Background Information:**
A. improvisus has been observed in coastal southeast Alaska and British Columbia (Chan 2010; Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Chan 2010

### *1.6 Global ecoregional distribution*

**Choice: A** In many ecoregions globally

**Score:** 5 **of** 5

**Ranking Rationale:**
Wide global distribution.

**Background Information:**
Native to the Atlantic and Gulf coasts of North America, ranging south to South America. The bay barnacle has a long history of invasions. Found in Europe (England, Scotland), West Coast of North America (California, Washington), the Northwest Pacific (Japan, Russia, South Korea). Has been recorded in Australia, but is not established there.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Chan 2010

### *1.7 Current distribution trends*

**Choice: A** Recent rapid range expansion and/or long-distance dispersal (within the last ten years)

**Score:** 5 **of** 5

**Ranking Rationale:**
Recent documentation of long-distance dispersal and range expansion.

**Background Information:**
Rapid colonization and long-distance dispersal (through anthropogenic vectors) have both been documented (Chan 2010; Fofonoff et al. 2003). The ability for A. improvises to establish in the Bering Sea is not known – NEMESIS lists colonization of Alaska as "failed" (Fofonoff et al. 2003).

**Sources:**
Chan 2010 NEMESIS; Fofonoff et al. 2003 Shalaeva 2011

| | |
|---|---|
| **Section Total - Scored Points:** | 26.25 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 2. Anthropogenic Transportation and Establishment



### 2.1 *Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice:** **B**

Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 of 4

**Ranking Rationale:**

Readily transported via hull fouling and ballast water, however it is a sessile species with little ability to transport independent of a vector.

**Background Information:**

Long-distance dispersal is associated with anthropogenic vectors such as ship fouling, ballast water and hitchhiking on other organisms transported for mariculture (e.g. oysters) (Carlton et al. 2011; Gruet et al. 1976 cited in Shalaeva 2011). Natural dispersal is restricted to water currents and range in annual distance of 13.9 to 30km/year (Iwasaki and Kinoshita 2004; Leppakoski and Olenin 2000).

**Sources:**

Shalaeva 2011 Carlton et al. 2011 Gruet et al. 1976 Iwasaki and Kinoshita 2004 Leppakoski and Olenin 2000

### 2.2 *Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice:** **B**

Readily establishes in areas with anthropogenic disturbance/infrastructure; occasionally establishes in undisturbed areas

**Score:** 2.75 of 4

**Ranking Rationale:**

Readily establishes on hard surfaces such as marine infrastructure, in addition to natural substrates.

**Background Information:**

A hard substrate is required for establishment. This may include anthropogenic structures such as docks and ships, or natural substrates such as woody debris, rocks and shelled organisms (e.g. crabs and molluscs) (Fofonoff et al. 2003; Shalaeva 2011).

**Sources:**

NEMESIS; Fofonoff et al. 2003 Shalaeva 2011

### 2.3 *Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice:** **B**

No

**Score:** 0 of 2

**Ranking Rationale:**

**Background Information:**

This species is not currently farmed or intentionally cultivated.

**Sources:**

None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 4.75 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics

### *3.1 Dietary specialization*

**Choice:** **A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Feed on foods that are redily available in the study area.

**Background Information:**
Adults and juveniles are filter feeders and consume microplankton and deitritus (Fofonoff et al. 2003; Olenin 2006; Shalaeva 2011).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Olenin 2006 Shalaeva 2011

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **A** Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 of 5

**Ranking Rationale:**
Tolerant of a wide range of habitats and water quality.

**Background Information:**
Tolerant of a wide range of water temperatures and salinities and has a wide tolerance for oxygen concentration in the water; found in the polluted and eutrophical parts of the Baltic, Black, Caspian and other Seas (described in Shalaeva 2011). Inhabitas sheltered estuaries along the coast as well as lagoons and intertidal zones of depths up to 10 m (Fofonoff et al. 2003; Shalaeva 2011).

**Sources:**
Shalaeva 2011 NEMESIS; Fofonoff et al. 2003

### *3.3 Desiccation tolerance*

**Choice:** **B** Moderately tolerant (1-7 days) during one or more stages during its life cycle

**Score:** 3.25 of 5

**Ranking Rationale:**
Desiccation tolerance is inferred from other barnacle studies.

**Background Information:**
Based on dessication studies for Semibalanus balanoides (Ware and Hartnoli 1996), a barnacle from the low tidal zone, the size of A. improvisus should be able to survive dessication for more than 24 hours.

**Sources:**
Ware and Hartnoli

### *3.4 Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice: A** High – Exhibits three or four of the above characteristics

**Score:** 5 of 5

**Ranking Rationale:**
Hermaphroditic, high fecundity, capable of self-fertilization and short generation time.

**Background Information:**
A hermaphroditic species, capable of self-fertilization but mainly relies on cross-fertilization. Reaches maximum size in 2 to 3 weeks (Elfimov et al. 1995), can produce 1000 to 10,000 eggs per season (Costlow and Bookhout, 1957) and can generate 7 to 10 generations a month (Brayko 1982).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Shalaeva 2011 Costlow and Bookhout 1957 Brayko 1982 Elfimov et al. 1995

### *3.5 Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice: A** Disperses long (>10 km) distances

**Score:** 2.5 of 2.5

**Ranking Rationale:**
Natural dispersal via water currents range from 13.9 to 30km/year.

**Background Information:**
Larvae are mobile while adults remain sessile and are limited to transportation via movement of the substrate they area attached to. Transporation via water currents range in annual distance of 13.9 to 30km/year (Iwasaki and Kinoshita 2004; Leppakoski and Olenin 2000). Long-distance dispersal is associated with anthropogenic vectors such as ship fouling, ballast water and hitchhiking on other organisms transported for mariculture (e.g. oysters) (Carlton et al. 2011; Gruet et al. 1976 cited in Shalaeva 2011).

**Sources:**
Iwasaki and Kinoshita 2004 Leppakoski and Olenin 2000 Carlton et al. 2011 Gruet et al. 1976 Shalaeva 2011 NEMESIS; Fofonoff et al. 2003

### *3.6 Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: B** Moderate – Exhibits one of the above characteristics

**Score:** 1.75 of 2.5

**Ranking Rationale:**
Can actively dispersal in larval form, adult dispersal is limited to the movement of habitat substrate.

**Background Information:**
Adult form is sessile. Range expansion and establishment of populations in the central and northern Baltic has most likely been due to the dispersal of planktonic larvae on ocean currents (Leppäkoski and Olenin 2000; Shalaeva 2011).

**Sources:**
Leppakoski and Olenin 2000 Shalaeva 2011

### 3.7 *Vulnerability to predators*



| Choice: D | Multiple predators present in the Bering Sea or neighboring regions | Score: 1.25 of 5 |
|---|---|---|

**Ranking Rationale:**

Barnacles are predated upon by several taxa that occur in the Bering Sea.

**Background Information:**

Barnacles are eaten by worms, whelks, sea stars, fish, and shorebirds (MESA 2015; Shalaeva 2011).

**Sources:**

MESA 2015 Shalaeva 2011

| | |
|---|---|
| **Section Total - Scored Points:** | 23.75 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 4. Ecological and Socioeconomic Impacts



### 4.1 *Impact on community composition*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
Studies have shown no significant effect on community structure.

**Background Information:**
Barnacles in general have been found to have no significant effect on community structure (Durr and Wahl 2004). Potential positive effect include increased abundance of other invertebrates due to facilitating the settlement of other organisms and providing new microhabitats for other species such as small annelids, crustaceans and chironomids by providing empty shells for occupancy (Leppäkoski and Olenin 2000; Leppäkoski 1999; Fofonoff et al. 2003; Shalaeva 2011).

**Sources:**
Durr and Wahl 2004   Leppakoski and Olenin 2000   Leppakoski 1999   NEMESIS; Fofonoff et al. 2003   Shalaeva 2011

### 4.2 *Impact on habitat for other species*

**Choice:** **B** Moderate – Causes or has potential to cause changes to one or more habitats

**Score:** 1.75 of 2.5

**Ranking Rationale:**
Large densities can alter habitat structure and availability for other species.

**Background Information:**
Has the ability to change habitat structure and availability, especially in areas where it occurs in high densities, by settling on natural substrates (rocks, trees) and anthropogenic structures (Shalaeva 2011). Barnacle shells provide habitat and refugia for many invertebrate and epibiotic species. An experiment by Bros (1987) showed that the addition of barnacle shells increased the abundance and diversity of motile species.

**Sources:**
Shalaeva 2011   Bros 1987

### 4.3 *Impact on ecosystem function and processes*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
Limited impact predicted with little to no impact expected in Alaska where other barnacles and fouling organisms already occur.

**Background Information:**
Remineralizes nutrients and increases water clarity, which may promote the growth of green algae (Kotta et al. 2006). In high densities, populations may inhibit water flow by forming dense layers on natural and artificial structures (Shalaeva 2011). However, an experimental study by Durr and Wahl (2004) suggested that A. improvises does not have a significant impact on ecosystem function. In addition, in Alaska, where there already are barnacles and other fouling organisms, the ecosystem changes caused by A. improvisus (if any) are likely to be redundant. Alaska has at least four native Balanus spp. (Balanus nubilus, B. glandula, B. rostratus, and B. crenatus), as well as other barnacle species and a diverse fouling community.

**Sources:**
Durr and Wahl 2004   Shalaeva 2011   Kotta et al. 2006

### *4.4 Impact on high-value, rare, or sensitive species and/or communities*

**Choice: D** No impact

**Score:** 0 of 2.5

**High uncertainty?** ☑

**Ranking Rationale:**

**Background Information:**
No known impacts listed in the literature.

**Sources:**
Shalaeva 2011

### *4.5 Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice: C** Limited – Has limited potential to spread one or more organisms, with limited impact and/or within a very limited region

**Score:** 0.75 of 2.5

**High uncertainty?** ☑

**Ranking Rationale:**
A. improvisus can carry viruses, however, the threat, if any, of these viruses has not been documented.

**Background Information:**
Boschmaella balani and Hemioniscus balani are listed as parasites present on adult bay barnacles, but no information on the threat of these viruses to other species was found in the literature (Shalavaeva 2011).

**Sources:**
Shalaeva 2011

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**

**Background Information:**
No sources were found in the literature to indicate hybridization or genetic impact with native barnacles.

**Sources:**
Shalaeva 2011

### 4.7 Infrastructure

**Choice: A** High – Is known to cause degradation to infrastructure and/or is expected to have severe impacts and/or will impact the entire region

**Score:** 3 of 3

**Ranking Rationale:**
Causes expensive destruction to marine infrastructure.

**Background Information:**
Well documented fouling by A. improvisus to shipping equipment and infrastructure, as well as power plant pipes (Shalaeva 2011; Fofonoff et al. 2003). In Sweden, the estimated cost of hull fouling by A. improvisus are 23-56 million dollars per year and estimated costs of power plant fouling are 1.5-5.5 million per year (Gren et al. 2009). Economic impacts have also been reported in the Baltic (Leppakoski and Olenin 2000; Leppakoski 1999).

**Sources:**
Gren et al. 2009   Shalaeva 2011   Leppakoski 1999   Leppakoski and Olenin 2000   NEMESIS; Fofonoff et al. 2003

### 4.8 Commercial fisheries and aquaculture

**Choice: B** Moderate – Causes or has the potential to cause degradation to fisheries and aquaculture, with moderate impact in the region

**Score:** 1.5 of 3

**Ranking Rationale:**
Causes reductions in aquaculture productivity and increased transit time and fuel consumption for fishing vessels.

**Background Information:**
Gear fouling of cages and mollusk shells (e.g. blue mussels, oysters) has been recorded as reducing aquaculture productivity (Leppakoski 1999). Hull fouling of fishing vessels can slow boat speed and increase transit time and fuel use due to drag (Gordon and Mawatari 1992; Shalaeva 2011).

**Sources:**
Gordon and Mawatari 1992   Shalaeva 2011

### 4.9 Subsistence

**Choice: C** Limited – Has limited potential to cause degradation to subsistence resources, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
Limited potential for impact on shellfish harvesting activities.

**Background Information:**
A. improvisus can attach themselves onto oysters and mussels and can negatively impact these subsistence activities (Shalaeva 2011; Fofonoff et al. 2003). However, shellfish harvesting is not a popular activity in southeast Alaska because of paralytic shellfish poisoning (PSP).

**Sources:**
Shalaeva 2011   NEMESIS; Fofonoff et al. 2003

### *4.101 Recreation*

**Choice: C** Limited – Has limited potential to cause degradation to recreation opportunities, with limited impact and/or within a very limited region

**Score:** 0.75 **of** 3

**Ranking Rationale:**
Limited potential for beach fouling.

**Background Information:**
Can affect the recreational quality of shorelines by leaving an abundance of sharp shells along the beach and fouling rocks along the shore (Shalaeva 2011). Alternatively, it is a large filter-feeding speceis that in high densities may increase the clarity of the water (Olenin and Leppakoski 2000), providing a nicer experience for recreation.

**Sources:**
Shalaeva 2011 Olenin and Leppäkoski 1999

### *4.11 Human health and water quality*

**Choice: U** Unknown

**Score:** **of**

**Ranking Rationale:**
Barnacles, as filter feeders, can affect water quality. The impact of these behaviors on human health or water quality is not mentioned in the literature.

**Background Information:**
Impacts to human health and water quality are not mentioned in the literature.

**Sources:**
Shalaeva 2011 NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 8.5 |
| **Section Total - Possible Points:** | 27 |
| **Section Total -Data Deficient Points:** | 3 |

# 5. Feasibility of prevention, detection and control



## *5.1 History of management, containment, and eradication*

**Choice:** **C** Attempted; control methods are currently in development/being studied

**Score:** 0 of

**Ranking Rationale:**
Hull fouling technologies that treat and/or safely dispose of marine fouling organisms, such as A. improvisus, are currently being studied.

**Background Information:**
No species-specific control methods are being developed for A. improvisus, but there are some control methods for fouling species in general. Current methods such as hull cleaning during dry-docking or in-water cleaning do not address all the areas in which fouling organisms may establish (e.g. sea chests, pipes) and do not properly dispose of the biological debris (Hagan et al. 2014). Technologies that address these issues are currently being studied (Hagan et al. 2014).

**Sources:**
Hagan et al. 2014

## *5.2 Cost and methods of management, containment, and eradication*

**Choice:** **B** Major short-term and/or moderate long-term investment

**Score:** of

**Ranking Rationale:**
Current hull fouling technologies that address invasive species require purchasing of specialized equipment and regular cleaning.

**Background Information:**
According to Franmarine Underwater Services (2013), a company that supplies an in-water hull cleaning system, the cost of dry docking (including cleaning and "loss of business" costs) varies from AUD $62 200 to more than $1.3 million, depending on vessel size. The Franmarine cleaning system, which collects, treats, and disposes of biological waste (e.g., organisms) has a purchasing cost between AUD ~ $500 000 to $750 000, depending on vessel size. In-water cleaning costs range from AUD $18 800 to $255 000+ (for offshore cleaning of large vessels), with cleaning times estimated between 16 to 48 hours. Hagan et al. (2014) proposed similar estimates for the cost and time of in-water cleaning.

**Sources:**
Franmarine 2013 Hagan et al. 2014

### 5.3 *Regulatory barriers to prevent introductions and transport*



**Choice:** **B** Regulatory oversight, but compliance is voluntary

**Score:** of

**Ranking Rationale:**

Compliance with fouling regulations are voluntary.

**Background Information:**

In the U.S., Coast Guard regulations require masters and ship owners to engage in practices that will reduce the spread of invasive species, including cleaning ballast tanks and removing fouling organisms from hulls, anchors, and other infrastructure on a "regular" basis (CFR 33 § 151.2050). Failure to remove fouling organisms is punishable with a fine (up to $27 500). However, the word "regular" is not defined, which makes the regulations hard to enforce. As a result of this technical ambiguity, compliance with ship fouling regulations remains largely voluntary (Hagan et al. 2014).

Cleaning of recreational vessels is also voluntary, although state and federal programs are in place to encourage owners to clean their boats. Boat inspection is mandatory on some lakes (e.g. Lake Tahoe in CA/NV, Lake George in NY). In summer 2016, state and federal agencies conducted voluntary inspections for aquatic invasive species on trailered boats entering the state of Alaska (Davis 2016).

**Sources:**

CFR 2017 Hagan et al. 2014 Davis 2016

### 5.4 *Presence and frequency of monitoring programs*

**Choice:** **A** No surveillance takes place

**Score:** of

**Ranking Rationale:**

No species-specific monitoring for A. improvisus occurs, and no regular monitoring effort currently exists for hull fouling.

**Background Information:**

The U.S. legal regime to control hull fouling and the transport of invasive species via ships' hulls is extremely sparse. Hull fouling is mentioned in the Coast Guard's new mandatory ballast water program and several states have adopted laws to address the problem, but there is little focused management to control fouling organisms (Johnson et al. 2006)

**Sources:**

Johnson et al. 2006

### 5.5 *Current efforts for outreach and education*

**Choice:** **B** Some educational materials are available and passive outreach is used (e.g. signs, information cards), or programs exist outside Bering Sea and adjacent regions

**Score:** of

**Ranking Rationale:**

No species-specific educaitonal material or outreach exists for A. improvisus. General educational material exists regarding hull fouling.

**Background Information:**

General educational material on aquatic invasive species, and their spread via hull fouling and/or ballast water, is available (e.g. Rhode Island Marine & Estuarine Invasive Species, Office of Naval Research, Sea Grant).

**Sources:**

"Needs Reference"

| | |
|---|---|
| **Section Total - Scored Points:** | 0 404 |
| **Section Total - Possible Points:** | |
| **Section Total -Data Deficient Points:** | |

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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Limnoithona tetraspina*

**Common Name** *a copepod*

| | |
|---|---|
| **Phylum** | Arthropoda |
| **Class** | Maxillopoda |
| **Order** | Cyclopoida |
| **Family** | Cyclopettidae |

**Final Rank** 34.26

**Data Deficiency:** 10.25

Species Occurrence by Ecoregion

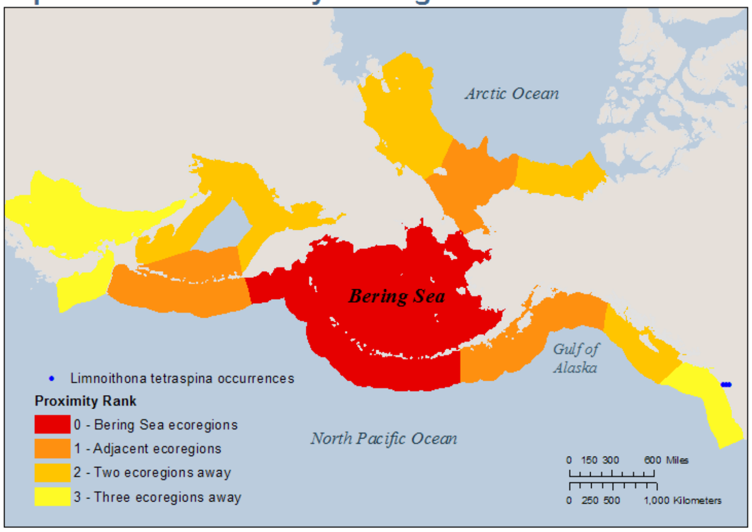


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 7.5 | 26 | 3.75 |
| Anthropogenic Influence: | 2 | 6 | 4.00 |
| Biological Characteristics: | 18 | 28 | 2.50 |
| Impacts: | 3.25 | 30 | 0 |
| **Totals:** | 30.75 | 89.75 | 10.25 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | 4 | Minimum Salinity (ppt) | 1 |
| Maximum Temperature (°C) | NA | Maximum Salinity (ppt) | 30 |
| Minimum Reproductive Temperature (°C) | NA | Minimum Reproductive Salinity (ppt) | NA |
| Maximum Reproductive Temperature (°C) | NA | Maximum Reproductive Salinity (ppt) | NA |

### Additional Notes

Limnoithona tetraspina is a copepod native to the Yangtze River Delta, China. Introduced populations are found in Iraq and the North American Pacific coast. In San Francisco Bay, California; it quickly replaced another non native copepod, L. sinensis. It prefers estuarine waters and can tolerate a wider range of salinities than L. sinensis. It may adversely affect larval fish who rely on copepods for food by replacing the larger native copepods.

# 1. Distribution and Habitat

### *1.1 Survival requirements - Water temperature*

**Choice:** **C** Little overlap – A small area (<25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 1.25 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Temperatures required for year-round survival occur in a limited area (<25%) of the Bering Sea. We ranked this question with "High Uncertainty" to indicate disagreements in model estimates.

**Background Information:**
L. tetraspina is a warm-temperate-subtropical species and has a minimum temperature threshold of 4°C (Bollens et al. 2012).

**Sources:**
Bollens et al. 2012   NEMESIS; Fofonoff et al. 2003

### *1.2 Survival requirements - Water salinity*

**Choice:** **D** No overlap – Salinities required for survival do not exist in the Bering Sea

**Score:** 0 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Year-round salinity requirements do not exist in the Bering Sea. Because thresholds are based on geographic distribution rather than physiological tolerances, we ranked this question with "High uncertainty".

**Background Information:**
Based on field observations, the salinity range for this species is from 1 ppt to 30 ppt (Orsi and Ohtsuka 1999; Bouley and Kimmerer 2006; Bollens et al. 2011)

**Sources:**
NEMESIS; Fofonoff et al. 2003   Orsi and Ohtsuka 1999   Bollens et al. 2002   Bouley and Kimmerer 2006

### *1.3 Establishment requirements - Water temperature*

**Choice:** **U** Unknown/Data Deficient

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *1.4 Establishment requirements - Water salinity*

**Choice:** **D** No overlap – Salinities required for reproduction do not exist in the Bering Sea

**Score:** 0 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Reproductive salinity requirements for this species are unknown. However, this species has been collected from waters with salinities between 1 and 30 ppt; these salinities do not exist in the Bering Sea. Because thresholds are based on geographic distribution rather than physiological tolerances, we ranked this question with "High uncertainty".

**Background Information:**
This species has been found in salinities from 1 ppt to 30 ppt (Orsi and Ohtsuka 1999; Bouley and Kimmerer 2006; Bollens et al. 2011)

**Sources:**
Orsi and Ohtsuka 1999   Bouley and Kimmerer 2006   Bollens et al. 2011   NEMESIS; Fofonoff et al. 2003

### *1.5 Local ecoregional distribution*

**Choice: D** Present in an ecoregion greater than two regions away from the Bering Sea

**Score:** 1.25 of 5

**Ranking Rationale:**
Present in Washington, Oregon, and California.

**Background Information:**
Limoithona tetraspina has been observed in San Francisco Bay, California; Grays River, Washington; and Columbia River, Oregon (Bollens et al. 2011; Sytsma et al. 2004).

**Sources:**
Bollens et al. 2011 Sytsma et al. 2004 NEMESIS; Fofonoff et al. 2003

### *1.6 Global ecoregional distribution*

**Choice: C** In few ecoregions globally

**Score:** 1.75 of 5

**Ranking Rationale:**
Occurrence records exist for China, Iraq, California and Washington only.

**Background Information:**
Limnoithona tetraspina was first described in the Yangtze River Delta, China (Orsi and Ohtuska 1999). It's full native range is not known, but it appears to not exist in interior freshwaters. It has been introduced to Shat al Arab estuary, Iraq; San Francisco Bay, California; Grays River, Washington; and Columbia River Oregon (Bollens et al. 2011; Sytsma et al. 2004; Fofonoff et al. 2003).

**Sources:**
Orsi and Ohtsuka 1999 Bollens et al. 2011 Sytsma et al. 2004 NEMESIS; Fofonoff et al. 2003

### *1.7 Current distribution trends*

**Choice: B** History of rapid expansion or long-distance dispersal (prior to the last ten years)

**Score:** 3.25 of 5

**Ranking Rationale:**
Dispersal distances appear to be limited, however, population expansion where it is introduced is relatively great.

**Background Information:**
In 1993 L. tetraspina was collected in Suisan Bay at Chipps Island, CA. By 1999 it could be found throughout the San Francisco Bay area ranging from San Pablo Bay to the South Bay (Bollens et al. 2011). In 2003 it was discovered in the Grays River, Washington and the Columbia River, Oregon (Sytsma et al. 2004).

**Sources:**
Bollens et al. 2011 Sytsma et al. 2004 NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 7.5 |
| **Section Total - Possible Points:** | 26.25 |
| **Section Total -Data Deficient Points:** | 3.75 |

## 2. Anthropogenic Transportation and Establishment



### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice: B** Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 of 4

**Ranking Rationale:**
Observed in ballast water; little observation of species expanding its range naturally after introduction.

**Background Information:**
Long distance dispersal is achieved through ballast water. L. tetraspina has been observed in the ballast water of ships arriving in Puget Sound (Cordell et al. 2008; Lawrence and Cordell 2010).

**Sources:**
Cordell et al. 2008 Lawrence and Cordell 2010

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice: U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
In its introduced range, this species has been reported from San Francisco Bay, the Sacramento-San Joaquin River, the Columbia River and Grays River. Habitat preferences and establishment patterns with respect to anthropogenic disturbances are unknown.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice: B** No

**Score:** 0 of 2

**Ranking Rationale:**

**Background Information:**
This species is not currently farmed or intentionally cultivated.

**Sources:**
None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 2 |
| **Section Total - Possible Points:** | 6 |
| **Section Total -Data Deficient Points:** | 4 |

# 3. Biological Characteristics



### 3.1 *Dietary specialization*

**Choice:** **A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Preys on numerous taxa readily available in the Bering Sea.

**Background Information:**
L. tetraspina is a raptorial feeder that consumes algae, ciliates, rotifers, and copepod nauplii (Barnes 1983 as qtd. in Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 3.2 *Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **B** Requires specialized habitat for some life stages (e.g., reproduction)

**Score:** 3.25 of 5

**Ranking Rationale:**
Restricted to subtidal habitats.

**Background Information:**
Lives in subtidal habitats but can tolerate a wide range of salinities. The lower limit of temperatures was 4˚C in North America. Dissolved oxygen, calcium, pollution tolerances, etc. are unknown.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 3.3 *Desiccation tolerance*

**Choice:** **A** Highly tolerant (>7 days) of desiccation at one or more stages during its life cycle

**High uncertainty?** ✔

**Score:** 5 of 5

**Ranking Rationale:**
No species-specific research has been published on the desiccation tolerance for L. tetraspina; tolerance is being inferred from studies of other copepod species.

**Background Information:**
Desiccation tolerance has been investigated in the lab for numerous copepods including the Cyclopoida family. These studies suggest that both coepodids and adult copepod populations exhibit resistance to desiccation for at least 1 month (Zhen et al. 1994).

**Sources:**
NEMESIS; et al. 2003 Zhen et al. 1994

### *3.4 Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice: C** Low – Exhibits none of the above characteristics

**Score:** 1.75 of 5

**High uncertainty?** ☑

**Ranking Rationale:**
Sexual reproduction, moderate parental investment (brood eggs), generation time unknown, fecundity unknown.

**Background Information:**
Sexual reproduction. Females brood eggs on abdomen (Barnes 1983 as qtd. In Fofonoff et al. 2003). In lab experiments, development took ~21 days but was suspected to be longer in natural conditions (Gould and Kimmerer 2010).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Gould and Kimmerer 2010

### *3.5 Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice: U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *3.6 Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: B** Moderate – Exhibits one of the above characteristics

**Score:** 1.75 of 2.5

**Ranking Rationale:**
Can disperse at more than one life stage but uses the same modes of dispersal at each stage (swimming).

**Background Information:**
L. tetraspina mates in the water column. Females will then brood eggs (Barnes 1983 as qtd. in Fofonoff et al. 2003) until they hatch as a free-swiming nauplii. The nauplii then undergoes 6 stages of growth where it progressively gains appendages and higher differentiation of its body segments. (Uchima 1979 as qtd. in Fofonoff et al. 2003). Under experimental conditions, develoment took 21 days but was suspected to be longer in natural conditions (Gould and Kimmerer 2010).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Gould and Kimmerer 2010

### *3.7 Vulnerability to predators*



| Choice: | | Score: |
|---|---|---|
| D | Multiple predators present in the Bering Sea or neighboring regions | 1.25 of 5 |

**Ranking Rationale:**
Numerous predators, several of which exist in the Bering Sea.

**Background Information:**
L. tetraspina is a planktonic species, which are important for larval fish as a food source. Its small size may deter visual predators and it also may be nutritionally poor as it lacks high quality lipids found in the larger copepods (Winder and Jassby 2011).

**Sources:**
Winder and Jassby 2011 NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 18 |
| **Section Total - Possible Points:** | 27.5 |
| **Section Total -Data Deficient Points:** | 2.5 |

# 4. Ecological and Socioeconomic Impacts



### 4.1 *Impact on community composition*

**Choice: B** Moderate – More than one trophic level; may cause declines but not extirpation

**Score:** 1.75 of 2.5

**Ranking Rationale:**
May cause changes in planktonic community; has the potential to affect fish populations by interferring with large copepod prey abundance.

**Background Information:**
In low-salinity regions of estuaries, L. tetraspina replaces local copepods (Orsi and Ohtsuka 1999). By replacing the local copepods L. tetraspina may also effect copepod predators, such as fish larvae, due to its small size and lower nutritional composition (Fofonoff et al. 2003).

**Sources:**
Orsi and Ohtsuka 1999 NEMESIS; Fofonoff et al. 2003

### 4.2 *Impact on habitat for other species*

**Choice: D** No impact

**High uncertainty?** ☑

**Score:** 0 of 2.5

**Ranking Rationale:**
To date, no impacts on habitat for other species have been reported for L. tetraspina, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.3 *Impact on ecosystem function and processes*

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
Alterations to planktonic communities is not expected to affect ecosystem function and processes.

**Background Information:**
In low-salinity regions of estuaries, L. tetraspina replaces local copepods (Orsi and Ohtsuka 1999). By replacing the local copepods L. tetraspina may also effect copepod predators, such as fish larvae, due to its small size and lower nutritional composition (Fofonoff et al. 2003).

**Sources:**
Orsi and Ohtsuka 1999 NEMESIS; Fofonoff et al. 2003

### 4.4 *Impact on high-value, rare, or sensitive species and/or communities*

**Choice: C** Limited – Has limited potential to cause degradation of one more species or communities, with limited impact and/or within a very limited region

**Score:** 0.75 of 2.5

**Ranking Rationale:**
Has an impact on critically endangered species in California, however, susceptible species are unknown for the Bering Sea.

**Background Information:**
L. tetraspina is a smaller copepod that will hinder visual predators such as the critically endangered Delta Smelt (Sullivan et al. 2016). It is also has a lower nutritional composition as its prey lack high-quality lipids found in the prey of the larger copepods (Winder and Jassby 2011). Because L. tetraspina can replace local copepods, these effects may be exacerbated.

**Sources:**
Sullivan et al. 2016 Winder and Jassby 2011 NEMESIS; Fofonoff et al. 2003

### 4.5 *Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice: D** No impact

**High uncertainty?** ☑

**Score:** 0 of 2.5

**Ranking Rationale:**
To date, no known diseases, parasites, or travelers have been reported for L. tetraspina.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 4.6 *Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice: D** No impact

**High uncertainty?** ☑

**Score:** 0 of 2.5

**Ranking Rationale:**
To date, hybridization has not been reported for L. tetraspina, and given its biology, hybridization would not be expected.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 4.7 *Infrastructure*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on infrastructure have been reported for L. tetraspina, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.8 Commercial fisheries and aquaculture*



**Choice: C** Limited – Has limited potential to cause degradation to fisheries and aquaculture, and/or is restricted to a limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
L. tetraspina is a smaller, less nutritous species that replaces local copepods.

**Background Information:**
The replacement of larger copepods by the smaller L. tetraspina may adversely affect larval fishes that selectively prefer larger copepods such as the Delta Smelt (Hypomesus transpacificus) (Sullivan et al. 2016). L. tetraspina may also have a lower nutritional composition as the prey it consumes does not have high quality lipids found in the prey of larger copepods (Winder and Jassby 2011).

**Sources:**
Sullivan et al. 2016 Winder and Jassby 2011 NEMESIS; Fofonoff et al. 2003

### *4.9 Subsistence*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on subsistence have been reported for L. tetraspina, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.101 Recreation*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on recreation have been reported for L. tetraspina, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.11 Human health and water quality*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on human health and water quality have been reported for L. tetraspina, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 3.25 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

417

## 5. Feasibility of prevention, detection and control



### 5.1 *History of management, containment, and eradication*

**Choice:** **C** Attempted; control methods are currently in development/being studied

**Score:** of

**Ranking Rationale:**
No history of management, containment, or eradication found. Efforts to limit or restrict ballast water discharge is the primary preventative method known.

**Background Information:**
Ballast water exchange is the method currently used by most ships to reduce the spread of species by ballast water. However, it is considered a short-term or "stop-gap" option until more effective, technology-based methods become available e.g., ballast water treatment systems (Ruiz and Reid 2007). The treatment of ballast water is an active area of research as vessels are forced to comply with new regulations.

**Sources:**
Ruiz and Reid 2007

### 5.2 *Cost and methods of management, containment, and eradication*

**Choice:** **B** Major short-term and/or moderate long-term investment

**Score:** of

**Ranking Rationale:**
To comply with ballast water regulations, vessels will have to equip themselves with an onboard ballast water treatment system. These systems represent a major short-term cost for vessel owners (up to $3 million), with additional costs over time to maintain and replace equipment (e.g. chemicals, filters, UV light bulbs).

**Background Information:**
The costs associated with purchasing a ballast water treatment system depend on the volume of water that needs to be treated. Systems with a pump capacity of 200-250 $m^3/h$ can cost from $175,000 to $490,000. The estimated price for larger systems with a pump capacity of around 2000 $m^3/h$ range from $650,000 to nearly $3 million.

**Sources:**
Zagdan 2010

### 5.3 *Regulatory barriers to prevent introductions and transport*

**Choice:** **C** Regulatory oversight and/or trade restrictions

**Score:** of

**Ranking Rationale:**
Alaska does not have state regulations on ballast water management, but two federal regulations (USCG and EPA) require mandatory reporting and either exchange or treatment of ballast water. No species-specific regulations exist for L. tetraspina.

**Background Information:**
State regulations: Alaska does not have a state regulations related to the management of aquatic invasive species in discharged ballast water. It relies on the U.S. Coast Guard (USCG) to enforce national standards. In Alaska, data from 2009-2012 show moderate to high compliance with USCG reporting requirements (Verna et al. 2016).

Federal regulations: In the U.S., ballast water management (treatment or exchange) and record-keeping is mandatory and regulated by the USCG, with additional permitting by the Environmental Protection Agency (EPA). Certain vessels (e.g. small vessels or those traveling within 1 Captain of the Port Zone) are exempt from USCG and EPA regulations.

**Sources:**
Verna et al. 2016 EPA 2013

### *5.4 Presence and frequency of monitoring programs*

**Choice:** **A** No surveillance takes place

**Score:** of

**Ranking Rationale:**

**Background Information:**
No species-specific monitoring exists for L. tetraspina.

**Sources:**
None listed

### *5.5 Current efforts for outreach and education*

**Choice:** **A** No education or outreach takes place

**Score:** of

**Ranking Rationale:**

**Background Information:**
No species-specific outreach or education exists for L. tetraspina.

**Sources:**
None listed

**Section Total - Scored Points:**
**Section Total - Possible Points:**
**Section Total -Data Deficient Points:**

## Literature Cited for *Limnoithona tetraspina*


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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Mytilicola orientalis*

**Common Name** *a bivalve-parasitic copepod*

| | |
|---|---|
| **Phylum** | Arthropoda |
| **Class** | Maxillopoda |
| **Order** | Cyclopoida |
| **Family** | Mytilicolidae |

**Final Rank** 36.12

**Data Deficiency:** 16.25

### Species Occurrence by Ecoregion

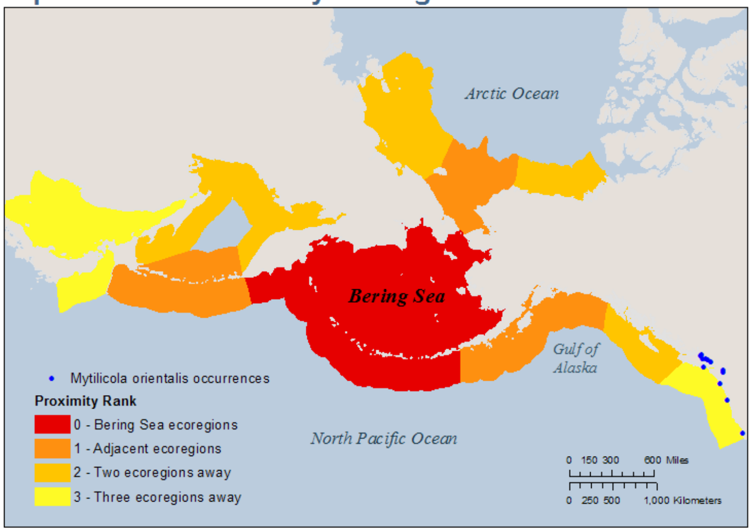


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 10 | 19 | 11.25 |
| Anthropogenic Influence: | 3.25 | 10 | 0 |
| Biological Characteristics: | 13.25 | 25 | 5.00 |
| Impacts: | 3.75 | 30 | 0 |
| **Totals:** | 30.25 | 83.75 | 16.25 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | NA | Minimum Salinity (ppt) | 31* |
| Maximum Temperature (°C) | NA | Maximum Salinity (ppt) | 35* |
| Minimum Reproductive Temperature (°C) | NA | Minimum Reproductive Salinity (ppt) | NA |
| Maximum Reproductive Temperature (°C) | NA | Maximum Reproductive Salinity (ppt) | NA |

### Additional Notes

A parasitic copepod that infects the Pacific oyster, Crassostrea gigas, the blue mussel Mytilus edulis, the Mediterranean mussel M. galloprovincialis, and other bivalves (Torchin et al. 2002; Bower 2010). Infestations rate as high as 73.6% have been recorded (Bower 2010). Can also be transported on ships' hulls through infected bivalves.

# 1. Distribution and Habitat

### *1.1 Survival requirements - Water temperature*

**Choice:** **U** Unknown/Data Deficient

**Score:** of

**Ranking Rationale:**
Temperatures required for survival are unknown.

**Background Information:**
Current distribution is largely restricted to cold temperate and warm temperate waters. Crassostrea gigas, one of its native hosts, has recently been found as far north as 60°N, likely as a result of recent warming events, but it is still unknown whether C. gigas can establish populations in Alaska. The blue mussel Mytilus edulis has recently expanded its northern distribution in the Arctic, and is now found north up to 77°N, in water temperatures as cold as -1°C (Thyrring et al. 2015). Not known whether Mytilicola orientalis can survive in these more northern populations.

**Sources:**
Thyrring et al. 2015 NEMESIS; Fofonoff et al. 2003

### *1.2 Survival requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Although salinity thresholds are unknown, this species is a marine organism. We therefore assume that it can survive in saltwater (31 to 35 ppt); these salinities occur in a large (>75%) portion of the Bering Sea.

**Background Information:**
No species-specific thresholds listed in literature. Fofonoff et al. (2003) lists M. orientalis as a polyhaline-euhaline species with a salinity range somewhere between 18 PSU and 40 PSU.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.3 Establishment requirements - Water temperature*

**Choice:** **U** Unknown/Data Deficient

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *1.4 Establishment requirements - Water salinity*

**Choice: U** Unknown/Data Deficient

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *1.5 Local ecoregional distribution*

**Choice: D** Present in an ecoregion greater than two regions away from the Bering Sea

**Score:** 1.25 of 5

**Ranking Rationale:**
Present in British Columbia.

**Background Information:**
Found along the North American West Coast from California to Vancouver Island, British Columbia (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

**Choice: B** In a moderate number of ecoregions globally

**Score:** 3.25 of 5

**Ranking Rationale:**
Found in Japan, Korea, the West Coast of North America, and Europe.

**Background Information:**
Distribution is largely restricted to cold temperate and warm temperate waters. Native to Japan and Korea. Has been accidentally introduced to the Pacific Coast of North America, from California to British Columbia. In Europe, introduced to France, Ireland, the Netherlands, and the French Mediterranean Coast. Northernmost European record is the Island of Sylt in Germany's North Sea (55°N). In NA, north to ~50°N.
Many bivalves cannot establish self-sustaining populations in areas where they are cultivated, and the aquaculture industry relies on spat supplied from elsewhere (Steele and Mulcahy 2001). Distribution of M. orientalis is limited to the immediate vicinity where infested oysters have been introduced (Bernard 1969). Nearby areas are free of Mytilicola, even where the oyster population is contiguous due to natural spawning (Bernard 1969)

**Sources:**
Steele and Mulcahy 2001 Bernard 1969 Bower 2010 NEMESIS; Fofonoff et al. 2003 Torchin et al. 2002

### 1.7 *Current distribution trends*



**Choice:** **C** Established outside of native range, but no evidence of rapid expansion or long-distance dispersal

**Score:** 1.75 **of** 5

**Ranking Rationale:**
Limited to wherever infected bivalves have been introduced.

**Background Information:**
Larvae are limited to short distance dispersals, and distribution is limited to areas where infected bivalves have been introduced. Distribution of M. orientalis is limited to the immediate vicinity where infested oysters have been introduced (Bernard 1969). Nearby areas are free of Mytilicola, even where the oyster population is contiguous due to natural spawning (Bernard 1969).

**Sources:**
Bernard 1969

| | |
|---|---|
| **Section Total - Scored Points:** | 10 |
| **Section Total - Possible Points:** | 18.75 |
| **Section Total -Data Deficient Points:** | 11.25 |

## 2. Anthropogenic Transportation and Establishment

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice:** **C**

Uses anthropogenic disturbance/infrastructure to establish; never observed establishing in undisturbed areas

**Score:** 1.25 of 4

**Ranking Rationale:**
Has only been observed establishing in areas of anthropogenic disturbance, usually areas associated with the Pacific Oyster culture.

**Background Information:**
Distribution is sporadic and limited to the immediate vicinity where infected oysters have been introduced. Nearby areas are free of Mytilicola, even where the oyster population is contiguous due to natural spawning (Bernard 1969).

**Sources:**
Bernard 1969 NEMESIS; Fofonoff et al. 2003

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice:** **B**

No

**Score:** 0 of 2

**Ranking Rationale:**
This species is not currently farmed or intentionally cultivated.

**Background Information:**
While this species is not farmed, it is associated with the Pacific Oyster that is intentionally farmed.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice:** **B**

Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 of 4

**Ranking Rationale:**
Readily transported by hull fouling and the stocking of infected oysters. However, M. orientalis has a limited natural dispersal ability.

**Background Information:**
Can be transported in oysters on ships' hulls; however, the main introduction pathway is the stocking of infected oysters for the aquaculture industry.

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 3.25 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

### 3.2 *Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice: C** Specialist; dependent on a narrow range of habitats for all life stages

**Score:** 1.75 of 5

**Ranking Rationale:**

Has a short free-swimming stage as a nauplii, followed by a parasitic relationship within a bivalve.

**Background Information:**

Restricted regional distribution of this copepod in Barkley Sound (and throughout the Pacific Northwest) may be limited by factors that confine transmission to sheltered, muddy estuaries (Goater and Weber 1996). Within such sites, copepod abundance is highest in large mussels collected near the low-tide mark. Factors such as wave action, tidal currents, salinity and/or substratum may restrict colonization by free-swimming larvae.

Natural distribution of M. orientalis is limited by the bivalve species it parasitizes. Many bivalves in which it occurs, including the Mediterranean mussel and the Pacific oyster, cannot live in cold waters. There are several bivalve species that occur in Alaska and that are potential hosts of M. orientalis: Mytilus californianus, Mytilus edulis, Protothaca staminea, and Saxidomus giganteus (Foster 1991; Fofonoff et al. 2003). Enclosed inlets with poor to moderate tidal flushing are more likely to develop local populations (Holmes and Minchin 1995, qtd. in Bower 2010). Obligate parasitic life stage severely limits distribution.

**Sources:**

Goater and Weber 1996   Foster 1991   NEMESIS; Fofonoff et al. 2003

### 3.3 *Desiccation tolerance*

**Choice: U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**

No information available in the literature.

**Sources:**

None listed

### *3.1 Dietary specialization*

**Choice: C** Specialist; dependent on a narrow range of foods for all life stages and/or foods are not commonly available in the study area

**Score:** 1.75 of 5

**Ranking Rationale:**
Relies on bivalves for food.

**Background Information:**
Larval stages are non-feeding. Adults are parasitic, and found inside the gut of bivalves. Flexible in its host choices (Pogoda et al. 2012).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Pogoda et al. 2012

**Choice: B** Moderate – Exhibits one or two of the above characteristics

**Score:** 3.25 of 5

**Ranking Rationale:**
Sexual reproduction, high fecundity, low parental investment, generation time unknown.

**Background Information:**
Sexual reproduction. In California, M. orientalis showed continuous reproductive activity (Bradley and Siebert 1978). In British Columbia, there was a single reproductive period from June to late August (Bernard 1969). The wormlike adult female and male mate inside the host's intestine. The female produces paired egg sacs containing approximately 200 eggs.

**Sources:**
Bradley and Siebert 1978 Bernard 1969 Bower 2010 NEMESIS; Fofonoff et al. 2003

### *3.5 Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice: C** Disperses short (< 1 km) distances

**Score:** 0.75 of 2.5

**Ranking Rationale:**

**Background Information:**
Experiments in Ladysmith Harbour, British Columbia, indicate that larval stages are short and do not travel far (Bernard 1969). Adult is parasitic on sessile bivalves.

**Sources:**
Bernard 1969

### *3.6 Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: C** Low – Exhibits none of the above characteristics

**Score:** 0.75 of 2.5

**Ranking Rationale:**
Not highly mobile, larval viability window is short, adults are restricted to parasitic host.

**Background Information:**
Larval stages are free-swimming but short-lived, and do not disperse great distances. Adults are parasites within the intestine of a bivalve.

**Sources:**
Bernard 1969 NEMESIS; Fofonoff et al. 2003

### *3.7 Vulnerability to predators*



**Choice: A** Lacks natural predators

**Score:** 5 **of** 5

**Ranking Rationale:**

**Background Information:**
No known natural predators.

**Sources:**
None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 13.25 |
| **Section Total - Possible Points:** | 25 |
| **Section Total -Data Deficient Points:** | 5 |

# 4. Ecological and Socioeconomic Impacts

### *4.101 Recreation*

**Choice: C** Limited – Has limited potential to cause degradation to recreation opportunities, with limited impact and/or within a very limited region

**Score:** 0.75 **of** 3

**Ranking Rationale:**
Has an adverse effect on bivalves harvested for recreation.

**Background Information:**
M. orientalis is a parasite that resides in the intestinal tract of bivalves. This can alter the epithelial lining in the gut. Otherwise, effects appear to be minor beyond minimal tissue damage and decreased condition factors (Odlaug 1946; Bernard 1969; Grizel 1985; Steele and Mulcahy 2001; Bower 2010). In Ireland, infected oysters were associated with increased attacks by shell-boring Polydora spp. (Steele and Mulcahy 2001).

**Sources:**
Odlaug 1946   Bernard 1969   Grizel 1985   Steele and Mulcahy 2001   Bower 2010   NEMESIS; Fofonoff et al. 2003

### *4.3 Impact on ecosystem function and processes*

**Choice: D** No impact

**Score:** 0 **of** 2.5

**Ranking Rationale:**
To date, no impacts on ecosystem functions and processes have been reported for M. orientalis, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.4 Impact on high-value, rare, or sensitive species and/or communities*

**Choice: C** Limited – Has limited potential to cause degradation of one more species or communities, with limited impact and/or within a very limited region

**Score:** 0.75 **of** 2.5

**Ranking Rationale:**
Species parasitized by M. orientalis are economically and culturally important.

**Background Information:**
Causes a decrease in the condition factors (increased water, decreased fat content) of the host without directly killing it (Odlaug 1946; Bernard 1969; Grizel 1985; Steele and Mulcahy 2001; Bower 2010). Infected bivalves are also corellated with higher rates of polydora infections, that when sufficiently high, will kill the host (Steele and Mulcahy 2001). Furthermore, the distribution of M. orientalis is associated with the Pacific Oyster culture (Fofonoff et al. 2003).

**Sources:**
Odlaug 1946   Bernard 1969   Grizel 1985   Steele and Mulcahy 2001   Bower 2010   NEMESIS; Fofonoff et al. 2003

### *4.5 Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**

**Background Information:**
M. orientalis itself is a parasite of bivalves.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
To date, hybridization has not been reported for M. orientalis, and given its biology, hybridization would not be expected.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.7 Infrastructure*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on infrastructure have been reported for M. orientalis, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.1 Impact on community composition*



**Choice:** **C** Limited – Single trophic level; may cause decline but not extirpation

**Score:** 0.75 **of** 2.5

**Ranking Rationale:**
M. orientalis has been linked to decreased condition factors of oysters and mussels, but does not directly cause death.

**Background Information:**
Low condition indices of mussels and oysters has been linked to high infestation rates of M. orientalis (Katkansky et al. 1967; Korringa 1968; Paul 1983 as qtd. In NOBANIS 2016). However, long-term studies suggest that M. orientalis live as commensals and are not harmful parasites (Gee and Davey 1986 as qtd. In NOBANIS 2016;Davey and Gee 1988 as qtd. In NOBANIS 2016; Davey 1989 as qtd. In NOBANIS 2016; Steele and Mulcahy 2001). A recent study by Pogoda et al. (2012) supports this assertion – they found no correlation between infestation rate and condition index of bivalves.

**Sources:**
Katkansky et al. 1967 Korringa 1968 NOBANIS 2016 Steele and Mulcahy 2001 Pogoda et al. 2012

**Choice:** **C** Limited – Has limited potential to cause degradation to fisheries and aquaculture, and/or is restricted to a limited region

**Score:** 0.75 **of** 3

**Ranking Rationale:**
May have an adverse affect on quality and appearance (and thus price) of species important for fisheries and aquaculture.

**Background Information:**
M. orientalis is a parasite that resides in the intestinal tract of bivalves. This can alter the epithelial lining in the gut. Otherwise, effects appear to be minor beyond minimal tissue damage and decreased condition factors (Odlaug 1946; Bernard 1969; Grizel 1985; Steele and Mulcahy 2001; Bower 2010). In Ireland, infected oysters were associated with increased attacks by shell-boring Polydora spp. (Steele and Mulcahy 2001). From a consumer standpoint, macro-parasites are undesirable. Copepod parasites are easy to spot when oysters are eaten raw. This is due to the parasites bright red color and their large size (Pogoda et al. 2012).

**Sources:**
Odlaug 1946 Bernard 1969 Grizel 1985 Steele and Mulcahy 2001 Bower 2010 Pogoda et al. 2012 NEMESIS; Fofonoff et al. 2003

### *4.9 Subsistence*

**Choice:** **C** Limited – Has limited potential to cause degradation to subsistence resources, with limited impact and/or within a very limited region

**Score:** 0.75 **of** 3

**Ranking Rationale:**
Has an adverse effect on bivalves important for subsistence.

**Background Information:**
M. orientalis is a parasite that resides in the intestinal tract of bivalves. This can alter the epithelial lining in the gut. Otherwise, effects appear to be minor beyond minimal tissue damage and decreased condition factors (Odlaug 1946; Bernard 1969; Grizel 1985; Steele and Mulcahy 2001; Bower 2010). In Ireland, infected oysters were associated with increased attacks by shell-boring Polydora spp. (Steele and Mulcahy 2001).

**Sources:**
Odlaug 1946 Bernard 1969 Grizel 1985 Steele and Mulcahy 2001 Bower 2010 NEMESIS; Fofonoff et al. 2003

### *4.11 Human health and water quality*

**Choice:** **D** No impact

**Score:** **0** of **3**

**Ranking Rationale:**
To date, no impacts on human health or water quality have been reported for Mytilicola orientalis.

**Background Information:**
Macroparasites such as M. orientalis reduce monetary value of oysters because they cause discolouration in the flesh, however, they do not cite any human health concerns (Pogoda et al. 2012; Bower 2010).

**Sources:**
Pogoda et al. 2012   Bower 2010

### *4.2 Impact on habitat for other species*

**Choice:** **D** No impact

**Score:** **0** of **2.5**

**Ranking Rationale:**

**Background Information:**
M. orientalis lives inside of other bivalves and have no impact on habitat for other species.

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 3.75 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 5. Feasibility of prevention, detection and control

### 5.2 Cost and methods of management, containment, and eradication

**Choice: A** Major long-term investment, or is not feasible at this time

**Score:** of

**Ranking Rationale:**
Currently, the only effective method of control is to avoid the transfer of live mussels from infected areas.

**Background Information:**
Pesticides have been tested, but are highly toxic to other organisms as well (Blateau et al. 1992 as qtd. in NOBANIS 2016). Chlorine can kill the free-swimming stages (Korringa 1968). Currently, the most effective measure is to control the transfer of live mussels from infected areas.

**Sources:**
NOBANIS 2016 Korringa 1968 Bower 2010

### 5.3 Regulatory barriers to prevent introductions and transport

**Choice: C** Regulatory oversight and/or trade restrictions

**Score:** of

**Ranking Rationale:**
There are no species specific regulations but Mytilicola spp. are regulated by the State of Alaska. The U.K. also has regulations regarding a closely related species.

**Background Information:**
A closely related species, Myticola instestinalis, is regulated. The UK considers it a "controlled pest" and carefully monitors the transport of mussels from infected areas (Gresty 1992). To control outbreaks, it will help to decrease the stocking density of mussel farms (Blateau et al. 2002 as qtd. in NOBANIS 2016). As such, mussel farmers in France have created a union to voluntarily decrease stocking density of mussels (Mongruel and Thebaud 2006).

In Alaska, Mytilicola spp. (including M. orientalis) are listed as critical concern, and the presence of this disease must be immediately reported and subsuquently treated (Alaska Administrate Code 2016).

**Sources:**
Gresty 1992 Mongruel and Thebaud 2006 NOBANIS 2016 AAC 2016

### 5.4 Presence and frequency of monitoring programs

**Choice: A** No surveillance takes place

**Score:** of

**Ranking Rationale:**

**Background Information:**
No organized monitoring programs currently exist for M. orientalis.

**Sources:**
None listed

### *5.5 Current efforts for outreach and education*

**Choice: A** No education or outreach takes place

**Score:** of

**Ranking Rationale:**

**Background Information:**
No outreach or education efforts currently take place for M. oreintalis.

**Sources:**
None listed

### *5.1 History of management, containment, and eradication*

**Choice: B** Not attempted

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information was found in the literature regarding species-specific management efforts.

**Sources:**
None listed

**Section Total - Scored Points:**
**Section Total - Possible Points:**
**Section Total -Data Deficient Points:**

## Literature Cited for *Mytilicola orientalis*


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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Carcinus maenas*

**Common Name** *European green crab*

| | |
|---|---|
| Phylum | Arthropoda |
| Class | Malacostraca |
| Order | Decapoda |
| Family | Portunidae |

**Final Rank** 69.50

**Data Deficiency:** 0.00

Species Occurrence by Ecoregion

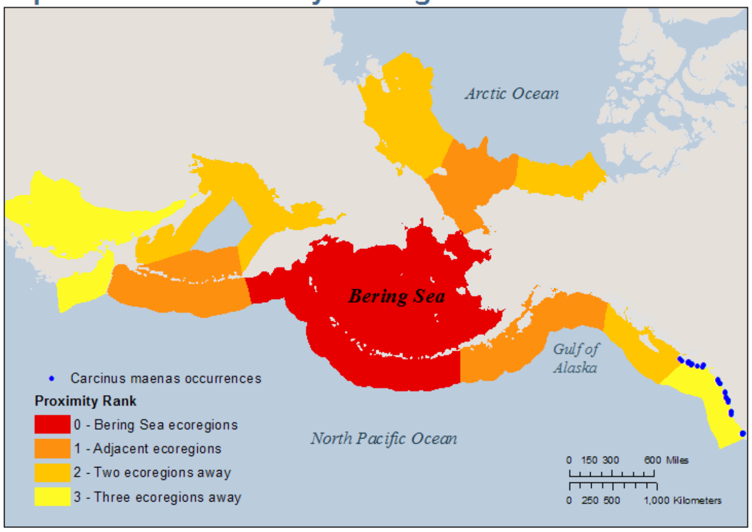


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 25 | 30 | 0 |
| Anthropogenic Influence: | 4 | 10 | 0 |
| Biological Characteristics: | 25.25 | 30 | 0 |
| Impacts: | 15.25 | 30 | 0 |
| **Totals:** | 69.50 | 100.00 | 0.00 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | -1 | Minimum Salinity (ppt) | 4 |
| Maximum Temperature (°C) | 35 | Maximum Salinity (ppt) | 54 |
| Minimum Reproductive Temperature (°C) | 9 | Minimum Reproductive Salinity (ppt) | 17 |
| Maximum Reproductive Temperature (°C) | 26 | Maximum Reproductive Salinity (ppt) | 35* |

### Additional Notes

Carapace color variable, usually mottled, dark brown to dark green, granules for the most part yellow. Adult size: From 6 to 10 cm in carapace width (Washington Department of Fish and Wildlife 2001). Adults can be dispersed by a variety of anthropogenic and natural mechanisms including: ballast water, hull fouling, hitchhiking on bivalves or packing materials (seaweeds), and transport by water currents.

**Reviewed by** Linda Shaw, NOAA Fisheries Alaska Regional Office, Juneau AK

**Review Date:** 8/31/2017

# 1. Distribution and Habitat



### 1.1 *Survival requirements - Water temperature*

**Choice:** **B**

Moderate overlap – A moderate area (≥25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 2.5 **of** 3.75

**Ranking Rationale:**
Temperatures required for year-round survival occur in a moderate area (≥25%) of the Bering Sea.

**Background Information:**
This species can tolerate temperatures ranging from -1°C to 35°C. Upper temperature limit is based on experimental data (Madeira et al. 2012).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Madeira et al. 2012

### 1.2 *Survival requirements - Water salinity*

**Choice:** **A**

Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 **of** 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
Salinity tolerance ranges from 4 to 54 ppt (Crothers 1968; NEMESIS).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 1.3 *Establishment requirements - Water temperature*

**Choice:** **B**

Moderate overlap – A moderate area (≥25%) of the Bering Sea has temperatures suitable for reproduction

**Score:** 2.5 **of** 3.75

**High uncertainty?** ☑

**Ranking Rationale:**
Temperatures required for reproduction occur in a moderate area (≥25%) of the Bering Sea. We ranked this question with "High Uncertainty" to indicate disagreements in model estimates.

**Background Information:**
Reproduction has been reported in temperatures between 3 and 26°C (Grosholz and Ruiz 2002), but temperatures of at least 9°C are needed for larval survival (Dawirs et al. 1986; Hines et al. 2004).

**Sources:**
Hines et al. 2004 Grosholz and Ruiz 2002 Dawirs et al. 1986

### 1.4 *Establishment requirements - Water salinity*

**Choice:** **A**

Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 **of** 3.75

**High uncertainty?** ☑

**Ranking Rationale:**
Although salinity thresholds are unknown, this species is a marine organism that does not require freshwater to reproduce. We therefore assume that this species can reproduce in saltwater (31 to 35 ppt). These salinities occur in a large (>75%) portion of the Bering Sea.

**Background Information:**
Larvae require at least 17-19 ppt to settle and metamorphose (Fofonoff et al. 2003). Upper reproductive salinity requirements are unknown.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.5 Local ecoregional distribution*

**Choice: C** Present in an ecoregion two regions away from the Bering Sea (i.e. adjacent to an adjacent ecoregion)

**Score:** 2.5 of 5

**Ranking Rationale:**
C. maenas has been reported as far north as British Columbia.

**Background Information:**
This species occurs from CA to BC on the west coast of North America.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.6 Global ecoregional distribution*

**Choice: A** In many ecoregions globally

**Score:** 5 of 5

**Ranking Rationale:**
This species has a global distribution and is found in many areas including both coasts of North America, temperate South America, Australia, and Japan.

**Background Information:**
The green crab's native range is from Norway and Iceland south to northern Africa. The green crab is now dispersed globally with established populations in South Africa, Japan, Australia, Argentina, and along the Atlantic and Pacific coasts of North America. On the West Coast, it occurs from CA to BC. It has failed to establish in many tropical areas including the Caribbean, Hawaii, and Sri Lanka. Its distribution may be limited by average summer surface temperature of ~22°C.

**Sources:**
NEMESIS; Fofonoff et al. 2003 U.S. Geological Survey; Fuller and Benson 2017

### *1.7 Current distribution trends*

**Choice: A** Recent rapid range expansion and/or long-distance dispersal (within the last ten years)

**Score:** 5 of 5

**Ranking Rationale:**
The green crab continues to expand its range and to be found in new areas.

**Background Information:**
The green crab has rapidly expanded its range in several introduced areas, including the Pacific coast of North America and South Africa (Grosholz and Ruiz 1996). Since its initial introduction to the West Coast in 1989, the green crab expanded its range over 750 km in less than ten years (Grosholz and Ruiz 2002). This species is predicted to become established in Alaska (Grosholz and Ruiz 2002; Hines et al. 2004). Several sites within Prince William Sound and elsewhere in Alaska appear warm enough to support self-sustaining green crab populations (Hines et al. 2004).

**Sources:**
Hines et al. 2000 NEMESIS; Fofonoff et al. 2003 Grosholz and Ruiz 1996 Grosholz and Ruiz 2002

| | |
|---|---|
| **Section Total - Scored Points:** | 25 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 2. Anthropogenic Transportation and Establishment



### 2.1 *Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice: A** Has been observed using anthropogenic vectors for transport and transports independent of any anthropogenic vector once introduced

**Score:** 4 of 4

**Ranking Rationale:**
This species can be transported by anthropogenic vectors, but can transport independently of these once introduced.

**Background Information:**
This species can disperse using several anthropogenic vectors including: ballast water, hull fouling, and hitchhiking on packing materials, aquatic vegetation, and bivalves. While long-distance, transoceanic dispersals are likely the result of human activities, the European green crab is capable of natural, short-distance dispersal (Carlton and Cohen 2003). Its dispersal from Australia to Tasmania was likely the result of natural dispersal (Darling et al. 2008).

**Sources:**
Darling et al. 2008   Carlton and Cohen 2003

### 2.2 *Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice: D** Does not use anthropogenic disturbance/infrastructure to establish

**Score:** 0 of 4

**Ranking Rationale:**
This species does not establish on anthropogenic substrates.

**Background Information:**
The green crab has colonized several natural habitats and substrates including mud, sand, vegetation, and rocks. Adult crabs live on the seafloor, while young crabs are often associated with seagrass habitat (Bedini 2002).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Bedini 2002

### 2.3 *Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice: B** No

**Score:** 0 of 2

**Ranking Rationale:**
This species is not currently farmed.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 4 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics



### *3.1 Dietary specialization*

**Choice: A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
This species is a generalist predator and feeds on taxa that are readily available in the Bering Sea.

**Background Information:**
This species preys on large and small snails, clams, algae, mussels, juvenile fishes and other organisms. Green crabs are known to consume prey from at least 158 genera.

**Sources:**
GISD 2016 NEMESIS; Fofonoff et al. 2003

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice: B** Requires specialized habitat for some life stages (e.g., reproduction)

**Score:** 3.25 of 5

**Ranking Rationale:**
This species has broad temperature and salinity ranges, and adults can occupy a variety of different habitats and substrates. Juveniles preferentially use seagrass, algal mats, or mussel beds as nursery habitat, rather than unstructured bottoms.

**Background Information:**
The green crab has a wide temperature and salinity range, although larval tolerances are more restricted (Hines et al. 2004). Juvenile crabs exhibit a habitat preference for vegetated habitat (seagrass and algae) and mussel beds, rather than unstructured substrates (Moksnes 2002). Globally, its distribution in tropical waters may be limited by an inability to colonize warmer waters (Cohen et al. 1995, qtd. in Fofonoff et al. 2003). This species inhabits a range of habitats in intertidal and subtidal zones, including mangroves, marshes, rocky shorelines and oyster reefs (Fofonoff et al. 2003). Its establishment in subtidal zones may be limited by predation and inter-specific competition.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Hines et al. 2004 Moksnes 2002

### *3.3 Desiccation tolerance*

**Choice: A** Highly tolerant (>7 days) of desiccation at one or more stages during its life cycle

**Score:** 5 of 5

**Ranking Rationale:**
This species can survive several days out of the water at very warm air temperatures. It can likely survive for more than seven days at milder temperatures.

**Background Information:**
Darbyson et al. (2009) exposed crabs to different treatments by placing crabs in crates containing a) only crabs, b) seawater, c) eelgrass, d) dry rope, or a combination therein. At 24°C, 50% of crabs stocked alone or with dry rope survived 68 h, and all crabs survived the first 48 h. Crabs in seawater or eelgrass treatments survived the whole length of the experiment (five days). In a second round of experiments at 29°C, 50% of crabs fully exposed to air survived 60 h, and a few survived for seven days.

**Sources:**
Darbyson et al. 2009

### 3.4 *Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice: B** Moderate – Exhibits one or two of the above characteristics

**Score:** 3.25 of 5

**Ranking Rationale:**
This species is dioecious and highly fecund. Eggs are fertilized internally. Generation time is relatively short.

**Background Information:**
This species is dioecious and reproduces sexually. Eggs are fertilized internally, and then brooded as a mass of eggs between the abdomen and the body. The number of eggs varies with size, but averages 185,000-200,000. Females can produce more than one clutch per year. Larvae settle and metamorphose between 25 and 90 days from hatching, depending on temperature and food availability. It typically takes 2 years to reach maturity in northern Europe, but crabs appear to mature earlier in North America and Australia.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Grosholz and Ruiz 2002 de Rivera et al. 2007

### 3.5 *Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice: A** Disperses long (>10 km) distances

**Score:** 2.5 of 2.5

**Ranking Rationale:**
Long-distance dispersal events have been documented. Both larvae and adults can disperse naturally.

**Background Information:**
Dispersal by adults and juveniles is largely localized, but dispersal distances as far as 15 km have been documented (Gomes 1991, qtd. in Bizzarro 2009). Larvae can be dispersed passively by water currents, and have the potential to disperse long distances given the longevity of the larval stage (up to 90 days). Dispersal of green crabs along the Pacific coast has been attributed to larval transport by strong ocean currents during an El Niño year (Behrens Yamada et al. 2005, qtd. in Klassen and Locke 2007). Northward-moving coastal currents transported larvae up to 50 km/day during the El Niño of 1998 (Behrens Yamada and Becklund 2004, qtd. in Klassen and Locke 2007).

**Sources:**
Klassen and Locke 2007 NEMESIS; Fofonoff et al. 2003 Bizzarro 2009

### 3.6 *Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: A** High – Exhibits two or three of the above characteristics

**Score:** 2.5 of 2.5

**Ranking Rationale:**
All life stages are capable of dispersing, and different mechanisms are used at different life stages. The larval stage is very long-lived.

**Background Information:**
Different dispersal mechanisms are possible at different life stages, including planktonic drifting, active swimming/crawling, transport in ballast water, and transport with other species. Rafting has not been documented in adults or juveniles.

**Sources:**
Klassen and Locke 2007

### 3.7 *Vulnerability to predators*

**Choice:** **B** Few predators only in its home range, and not suspected in the Bering Sea or neighboring regions

**Score:** 3.75 **of** 5

**High uncertainty?** ☑

**Ranking Rationale:**
This species is preyed upon by several taxa found in the Bering Sea. However, European green crab may be able to avoid predation by using low salinity habitats that exceed the salinity thresholds of native predators such as the red rock crab (L. Shaw, pers. comm., 31 August 2017).

**Background Information:**
Native crab species prey upon or aggressively compete with green crabs (Jensen et al. 2007). Fish predation and competition with larger crabs may be a major factor limiting C. maenas in subtidal waters (Donahue et al. 2009, qtd. in Fofonoff et al. 2003). This species is also predated upon by lobsters and birds.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Jensen et al. 2007

| | |
|---|---|
| **Section Total - Scored Points:** | 25.25 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 4. Ecological and Socioeconomic Impacts



### *4.1 Impact on community composition*

**Choice: A** High – Entire community and/or may cause extirpation or extinction at the species or trophic level

**Score:** 2.5 of 2.5

**Ranking Rationale:**
This species has severe impacts on several taxa including native bivalves, crabs, snails, fish, and eelgrass.

**Background Information:**
The green crab has had widespread and severe impacts across its range (Grosholz and Ruiz 2002), and was cited as one of the world's 100 worst invasive species by the IUCN (Lowe et al. 2000). Several native species have declined by more than 90% as the direct result of green crab predation (Grosholz et al. 2000). Species affected include several commercially important bivalve species, eelgrass, fish, and native invertebrates (Grosholz et al. 2000; Grosholz and Ruiz 2002; Malyshev and Quijón 2011; Matheson et al. 2016). In many cases, the impacts of green crab can be extreme, leading to drastic declines and extirpation. For example, underwater video surveys in Newfoundland indicated 50% to 100% declines in eelgrass percent cover since the arrival of green crab in 1998, and a tenfold decline in abundance and biomass of fish (Matheson et al. 2016). Grosholz et al. (2000) documented severe declines in the abundance of native clams and shore crabs, as well as several other invertebrates, in Bodega Bay Harbor, California, within 3 years of the green crab's arrival.

**Sources:**
Grosholz and Ruiz 2002   Matheson et al. 2016   Lowe et al. 2000   Malyshev and Quijón 2011   Grosholz et al. 2000

### *4.2 Impact on habitat for other species*

**Choice: B** Moderate – Causes or has potential to cause changes to one or more habitats

**Score:** 1.75 of 2.5

**Ranking Rationale:**
Green crabs destroy eelgrass habitat by grazing on shoots and by disrupting the sediment. We expect C. maenas to have moderate effects on habitat in the Bering Sea given the extent of eelgrass habitat in the Bering Sea and the severity of the green crab's effects,

**Background Information:**
In Newfoundland, Matheson et al. (2016) observed 50% to 100% declines in eelgrass percent cover since 1998 at sites with green crabs. In field and laboratory experiments, Malyshev and Quijón (2011) observed significant declines in eelgrass biomass as a result of uprooting and grazing by both adults and juveniles. Several other studies have reported negative impacts of green crabs on eelgrass (e.g., Davis et al. 1998; Garbary et al. 2014; Neckles 2015).

In Alaska, eelgrass ranges almost continuously from southeast Alaska, west along the Gulf of Alaska and north into the Bering Sea up to about 67°N (qtd. in Hogrefe et al. 2014). Eelgrass meadows are highly productive marine habitats that provide refuge from predators, and serve as a nursery ground to juvenile fish and shellfish, including herring (Winfree 2005; Orth et al. 2006).

**Sources:**
Matheson et al. 2016   Winfree 2005   Orth et al. 2006   Hogrefe et al. 2014   Malyshev and Quijón 2011   Davis et al. 1998   Garbary et al. 2014
Neckles 2015

### *4.3 Impact on ecosystem function and processes*

**Choice: A** High – Is known to cause moderate to severe changes to food webs and/or ecosystem functions; effects have been documented in several areas

**Score:** 2.5 of 2.5

**Ranking Rationale:**
Through predation and habitat alteration, the European green crab has been shown to impact whole ecosystems, including causing the decline of several taxa, reducing eelgrass habitat, affecting nutrients, and facilitating the establishment of other invasive species. These effects have been documented in several areas and on both coasts of North America.

**Background Information:**
The European green crab is a voracious and opportunistic predator that can cause the decline of several prey species including shellfish, crustaceans, and polychaetes (e.g. Neira et al. 2006). Moreover, by digging for prey, C. maenas alters and disrupts habitat and eelgrass meadows, with subsequent effects on invertebrate communities and nutrients (Neira et al. 2006; Lutz-Collins et al. 2016). In Atlantic Canada, C. maenas may have facilitated the spread of the invasive tunicate Styela clava and the clam Gemma gemma by predating upon their predators and competitors (Grosholz 2005; Locke et al. 2007). In San Francisco Bay, C. maenas may reinforce the ecosystem effects caused by invasive hybrid cordgrass (Spartina spp.) (Neira et al. 2007). Important ecosystem-level effects have also been documented in Newfoundland, where invasion by the European green crab led to severe eelgrass decline and impacts the abundance and composition of fish communities (Matheson et al. 2016).

**Sources:**
Neira et al. 2006   Matheson et al. 2016   Locke et al. 2007   Grosholz 2005   Lutz-Collins et al. 2016   Neira et al. 2007

### *4.4 Impact on high-value, rare, or sensitive species and/or communities*

**Choice: A** High – Is known to cause degradation of multiple species or communities and/or is expected to have severe impacts

**Score:** 2.5 of 2.5

**Ranking Rationale:**
The green crab has had significant, negative impacts on ecologically important species including eelgrass and oysters.

**Background Information:**
The green crab can drastically reduce eelgrass cover and biomass (Malyshev and Quijón 2011; Matheson et al. 2016). Green crabs have also had severe impacts on bivalves, including ecologically significant species such as Crassostrea gigas (Grosholz and Ruiz 2002).

**Sources:**
Matheson et al. 2016   Grosholz and Ruiz 2002   Malyshev and Quijón 2011

### *4.5 Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
Although the green crab can harbor parasites and diseases, negative impacts resulting from these associations have not been reported.

**Background Information:**
The green crab is host to a variety of parasites and pathogens (Grosholz and Ruiz 2002); however, negative impacts resulting from these associations have not been reported.

**Sources:**
Grosholz and Ruiz 2002

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
Hybridization with C. maenas is not expected to impact the Bering Sea because there are no native Carcinus species in the Bering Sea.

**Background Information:**
Hybridization between C. maenas and C. aestuarii may occur in regions of overlap outside of their native range. However, the existence of these hybrids has not been verified by genetic analyses, and no impacts have been reported.

**Sources:**
Galil et al. 2011

### *4.7 Infrastructure*

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact infrastructure in the Bering Sea.

**Background Information:**
No impacts have been reported. Although this species can be transported by fouling, it does not establish on anthropogenic structures.

**Sources:**
Klassen and Locke 2007

### *4.8 Commercial fisheries and aquaculture*

**Choice:** **A** High – Is known to cause degradation to fisheries and aquaculture and/or is expected to have severe impacts in the region

**Score:** 3 of 3

**Ranking Rationale:**
The shellfish industry in Alaska is estimated at $1 million, with 95% of sales coming from Pacific oysters (PSI Alaska 2017). Although it is only practiced in a limited region of the Bering Sea, we expect the green crab to have high impacts on commercial bivalves given that it has already had severe impacts in several parts of its introduced range.

**Background Information:**
Through predation, green crabs have had severe impacts on several commercially important shellfish species, including blue mussels and Pacific oysters (Grosholz and Ruiz 2002). These impacts have represented a 40% loss of production in certain years (Grosholz and Ruiz 2002). Damages to commercial shellfishery from green crab predation are estimated at $22.6 million per year on the East Coast of the United States (Lovell et al. 2007). Although current damages on the West Coast are low, the potential future damages are likely to increase to $0.84 million per year, if Green Crab invades Puget Sound (WA) and Alaska. The estimated annual value of damages to eelgrass restoration projects ranges from $60 000 to $77 000, and from $6000 to $47 000 on the East and West Coasts, respectively (Lovell et al. 2007).

**Sources:**
Grosholz and Ruiz 2002 Lovell et al. 2007 PSI Alaska 2017

### 4.9 Subsistence

**Choice: B** Moderate – Causes or has the potential to cause degradation to subsistence resources, with moderate impact and/or within only a portion of the region

**Score:** 1.5 of 3

**Ranking Rationale:**
Through predation, the green crab has had severe impacts on bivalve populations in several parts of its introduced range. In the Bering Sea, shellfish comprise a smaller percentage of subsistence catch (when measured by weight) than salmon or finfish (with the exception of the Aleutians West; Mathis et al. 2015). We expect the green crab to have moderate impacts on subsistence resources in the Bering Sea region.

**Background Information:**
Green crabs predate heavily on harvested shellfish species such as blue mussels and Pacific oysters (Grosholz and Ruiz 2002).

**Sources:**
Grosholz and Ruiz 2002   Mathis et al. 2015

### 4.101 Recreation

**Choice: C** Limited – Has limited potential to cause degradation to recreation opportunities, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
By predating upon bivalves, the green crab may impact recreational harvesting of shellfish in the Bering Sea. Given the geographic distribution of shellfish species (and their harvesters) in this region, we expect impacts on recreation to be limited.

**Background Information:**
Predation by the green crab has had dramatic impacts on harvestable species such as blue mussels and Pacific oysters (Grosholz and Ruiz 2002). These species are found and harvested in Alaska, although the recreational harvesting of shellfish is discouraged on untested beaches because of the potential for paralytic shellfish poisoning (PSP).

**Sources:**
Grosholz and Ruiz 1996

### 4.11 Human health and water quality

**Choice: C** Limited – Has limited potential to pose a threat to human health, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
This species can bioaccumulate toxins and, under rare circumstances, may cause poisoning in humans.

**Background Information:**
Green crabs can concentrate marine biotoxins consumed by bivalve prey. There has been at least one case of shellfish poisoning after ingestion of a large number of green crabs contaminated with okadaic acid.

**Sources:**
Klassen and Locke 2007   Aquenal Pty Ltd. 2008

| | |
|---|---|
| **Section Total - Scored Points:** | 15.25 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 5. Feasibility of prevention, detection and control

### *5.1 History of management, containment, and eradication*

**Choice:** **C** — Attempted; control methods are currently in development/being studied

**Score:** of

**Ranking Rationale:**
Several control methods are currently being studied.

**Background Information:**
Control methods that have been considered or attempted for green crabs include sound pulses, air exposure, chemical control, biological control, genetic manipulations, physical barriers, manual removal, harvesting, trapping, and parasitic castrators.

**Sources:**
Klassen and Locke 2007

### *5.2 Cost and methods of management, containment, and eradication*

**Choice:** **A** — Major long-term investment, or is not feasible at this time

**Score:** of

**Ranking Rationale:**
Although some methods have been successful in certain contexts, control of green crab populations has been largely unsuccessful and remains an important management priority.

**Background Information:**
Eradication is not a viable option for established populations of C. maenas because adults are highly mobile (up to 15 km; Gomes 1991 qtd. in Bizzarro 2009) and larvae are planktonic.

**Sources:**
Bizzarro 2009

### *5.3 Regulatory barriers to prevent introductions and transport*

**Choice:** **A** — Little to no regulatory restrictions

**Score:** of

**Ranking Rationale:**
Although there are regulations for ballast water and hull fouling transport, no regulations exist to reduce the spread of species that are transported by hitchhiking.

**Background Information:**

**Sources:**
CFR 2017

### 5.4 *Presence and frequency of monitoring programs*

**Choice: B** — Surveillance takes place, but is largely conducted by non-governmental environmental organizations (e.g., citizen science programs)

**Score:** of

**Ranking Rationale:**
Non-governmental organizations are conducting monitoring for this species is occurring in some parts of Alaska.

**Background Information:**
Non-governmental organizations are monitoring for this species at some sites in southeastern and southcentral Alaska (e.g. Alaska Sea Life Center, Kachemak Bay National Estuarine Research Research, Southern Southeast Regional Aquaculture Association). Government-sponsored monitoring is inactive in Alaska at this time (L. Shaw, pers. comm., 31 August 2017).

**Sources:**
USFS 2014

### 5.5 *Current efforts for outreach and education*

**Choice: C** — Educational materials are available and outreach occurs only sporadically in the Bering Sea or adjacent regions

**Score:** of

**Ranking Rationale:**
Outreach and education for this species is taking place, but outreach efforts are sporadic in Alaska.

**Background Information:**
Educational materials are available (ADF&G 2017), but outreach only occurs sporadically (L. Shaw, pers. comm., 31 August 2017).

**Sources:**
ADF&G 2017

**Section Total - Scored Points:**
**Section Total - Possible Points:**
**Section Total -Data Deficient Points:**

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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Eriocheir sinensis*

**Common Name** *Chinese mitten crab*

**Phylum** Arthropoda

**Class** Malacostraca

**Order** Decapoda

**Family** Varunidae

**Final Rank** 51.75

**Data Deficiency:** 0.00

### Species Occurrence by Ecoregion

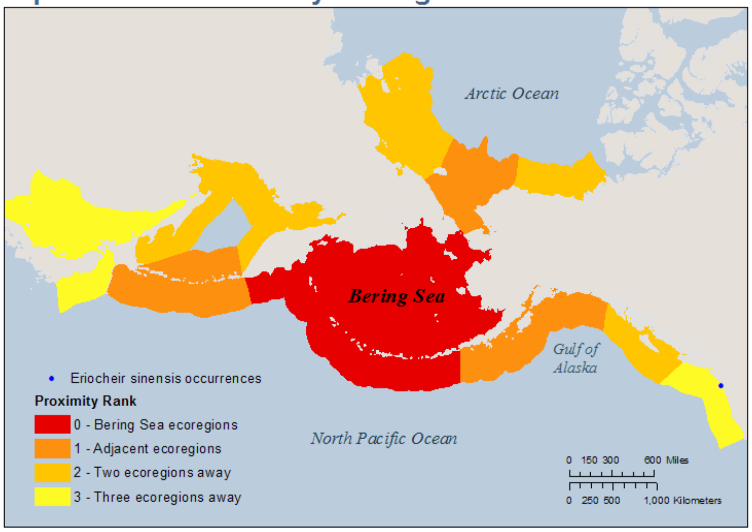


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

### Category Scores and Data Deficiencies

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 15.75 | 30 | 0 |
| Anthropogenic Influence: | 6 | 10 | 0 |
| Biological Characteristics: | 21 | 30 | 0 |
| Impacts: | 9 | 30 | 0 |
| **Totals:** | 51.75 | 100.00 | 0.00 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | 0 | Minimum Salinity (ppt) | 0 |
| Maximum Temperature (°C) | 30 | Maximum Salinity (ppt) | 35 |
| Minimum Reproductive Temperature (°C) | 12 | Minimum Reproductive Salinity (ppt) | 15 |
| Maximum Reproductive Temperature (°C) | 18 | Maximum Reproductive Salinity (ppt) | 25 |

### Additional Notes

E. sinensis is a catadromous species that lives most of its life in freshwater but spawns in estuaries. It is native to northern China and Korea, and has been widely introduced in Europe. It is also found on both coasts of North America.

# 1. Distribution and Habitat

### *1.1 Survival requirements - Water temperature*

**Choice: B** Moderate overlap – A moderate area (≥25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 2.5 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Temperatures required for year-round survival occur in a moderate area (≥25%) of the Bering Sea. We ranked this question with "High Uncertainty" to indicate disagreements in model estimates.

**Background Information:**
Adult crabs are tolerant of a wide range of temperatures, growing actively at temperatures from 7 to 30°C (Anger 1991; Rudnick et al. 2000). The lower and upper limits for survival are 0°C to 30°C (Vincent 1996 as qtd in CMCWG 2003; Rudnick et al. 2000).

**Sources:**
Anger 1991   CMCWC 2003   NEMESIS; Fofonoff et al. 2003   Rudnick et al. 2000

### *1.2 Survival requirements - Water salinity*

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
E. sinensis spawns in estuaries before migrating upstream into non-tidal portions of rivers and streams. Some crabs have been collected 1000 km from the sea. Early crab stages may spend their first winter in brackish water ranging from 15 ppt to 32 ppt. Adult crabs are tolerant of salinities ranging from 0 ppt to 35 ppt (Anger 1991; Rudnick et al. 2000).

**Sources:**
Anger 1991   NEMESIS; Fofonoff et al. 2003   Rudnick et al. 2000

### *1.3 Establishment requirements - Water temperature*

**Choice: D** No overlap – Temperatures required for reproduction do not exist in the Bering Sea

**Score:** 0 of 3.75

**Ranking Rationale:**
Temperatures above 12°C do not occur in the Bering Sea. Moreover, this species cannot grow in the Bering Sea because larvae and juvenile require brackish water.

**Background Information:**
Temperature range for successful larval development is 12°C to 18°C (Anger 1991).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Anger 1991

### *1.4 Establishment requirements - Water salinity*

**Choice: D** No overlap – Salinities required for reproduction do not exist in the Bering Sea

**Score:** 0 of 3.75

**Ranking Rationale:**
This species cannot grow in the Bering Sea because certain life stages require brackish water.

**Background Information:**
Adult crabs reproduce in brackish or saline water (Anger 1991; Hymanson et al. 1999). The first larval stage can tolerate marine waters, but subsequent stages require salinities between 5 and 25 ppt (Anger 1991; Rudnick et al. 2000).

**Sources:**
Anger 1991 NEMESIS; Fofonoff et al. 2003 Hymanson et al. 1999 Rudnick and Resh 2005

### *1.5 Local ecoregional distribution*

**Choice: D** Present in an ecoregion greater than two regions away from the Bering Sea

**Score:** 1.25 of 5

**Ranking Rationale:**
Present in southern California (three ecoregions away from the Bering Sea).

**Background Information:**
The closest known established population resides in San Francisco Bay (Fofonoff et al. 2003)

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.6 Global ecoregional distribution*

**Choice: A** In many ecoregions globally

**Score:** 5 of 5

**Ranking Rationale:**
Wide global distribution

**Background Information:**
Native to northern China and Korea, and introduced to Europe and North America. It is widespread in Europe, including northern Europe (Finland, Sweden), central Europe (Germany, Austria, Switzerland, Hungary, Czech Republic), and western Europe (France, the U.K.); it has also been reported from the Black Sea, the Caspian Sea, the Mediterranean Sea and the Persian Gulf (Herborg et al. 2003; Fofonoff et al. 2003; Galil et al. 2002 as qtd. in Fofonoff et al. 2003). In North America, adult specimens have been found on both eastern and western coasts, including Delaware Bay, Hudson River Estuary, the Great Lakes, Chesapeake Bay, and San Francisco Bay (Cohen and Carlton 1997; Rudnick et al. 2003; Fofonoff et al. 2003). Populations are established in San Francisco Bay and in Hudson River (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Herborg et al. 2003 Cohen and Carlton 1997 Rudnick et al. 2003

### 1.7 *Current distribution trends*



**Choice:** **B** History of rapid expansion or long-distance dispersal (prior to the last ten years)

**Score:** 3.25 **of** 5

**Ranking Rationale:**

Rapid range expansion has been documented in Europe and in North America.

**Background Information:**

E. sinensis spread rapidly in northern Europe at an average rate of 562 km/year between 1928 and 1938 (Herborg et al. 2003). Similarly high rates of spread occured from 1954 to 1960 in France and from 1997 to 1999 in the U.K. (Herborg et al. 2003; Herborg et al. 2005). E. sinensis was first reported in San Francisco Bay in 1992, and by 1998 had spread inland to Sacramento and San Joaquin (Rudnick et al. 2003). While specimens have been collected from several locations on the East Coast, established populations are only thought to occur in the Hudson River (Fofonoff et al. 2003).

**Sources:**

NEMESIS; Fofonoff et al. 2003 Rudnick et al. 2003 Herborg et al. 2005 Herborg et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 15.75 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 2. Anthropogenic Transportation and Establishment



### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice: A** — Has been observed using anthropogenic vectors for transport and transports independent of any anthropogenic vector once introduced

**Score:** 4 of 4

**Ranking Rationale:**
Long distance dispersal due to ballast water and illegal purchasing and release. Once introduced, can transport independently of human vectors.

**Background Information:**
Introductions are probably due to ballast water, and intentionally for seafood markets (CMCWG 2002). In Southern France, E. sinensis may have been accidentally introduced along with oysters (Herborg et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003   CMCWC 2003

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice: D** — Does not use anthropogenic disturbance/infrastructure to establish

**Score:** 0 of 4

**Ranking Rationale:**
Does not require or use marine infrastructure to establish.

**Background Information:**
Establishes on unstructured, natural bottom substrates.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice: A** — Yes

**Score:** 2 of 2

**Ranking Rationale:**
E. sinensis is farmed in Asia. It is illegal to import E. sinensis in the U.S.

**Background Information:**
E. sinensis is intensively farmed in China (Hymanson et al. 1999) where it is highly valued. In the U.S., importation of this species is banned under the Lacey act to prevent further introductions (CMCWG 2003).

**Sources:**
Cohen and Carlton 1997   NEMESIS; Fofonoff et al. 2003   Hymanson et al. 1999   CMCWC 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 6 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics



### *3.1 Dietary specialization*

**Choice:** **A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Preys on numerous taxa readily available in the Bering Sea.

**Background Information:**
Eriocheir sinensis is an opportunistic omnivore. Juvenile and adult crabs feed on detritus, algae, aquatic plants, invertebrates, and dead or trapped fishes. Stable Isotope, gut contents, and feeding studies in San Francisco Bay indicate that this species feeds heavily on aquatic derived detritus, algae, and invertebrates feeding on the sediment surface (Rudnick et al. 2000; Rudnick and Resh 2005).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Rudnick et al. 2000 Rudnick and Resh 2005

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **B** Requires specialized habitat for some life stages (e.g., reproduction)

**Score:** 3.25 of 5

**Ranking Rationale:**
Larvae complete their life stage in marine waters, but migrate to freshwater or low salinity systems as juveniles. Adults spend most of their life in freshwater.

**Background Information:**
Larvae are born at sea, but migrate to freshwater as juveniles (Rudnick et al. 2000). Although adult crabs are tolerant of a wide range of salinities and temperatures (Anger 1991; Rudnick et al. 2000), they are primarily limited to estuaries or freshwater environments. Adults return to sea once (rarely twice) to reproduce (Herborg et al. 2003). E. sinensis can survive in hypoxic conditions and is tolerant to highly polluted water (Fofonoff et al 2003).

**Sources:**
Anger 1991 NEMESIS; Fofonoff et al. 2003 Rudnick et al. 2000 Herborg et al. 2003

### *3.3 Desiccation tolerance*

**Choice:** **B** Moderately tolerant (1-7 days) during one or more stages during its life cycle

**Score:** 3.25 of 5

**Ranking Rationale:**

**Background Information:**
Adult crabs can move on land to avoid obstacles (e.g. dams). They can survive 31 to 70 hours out of the water depending on temperature and humidity (Fialho et al . 2016).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Fialho et al. 2016

### 3.4 *Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice: B** Moderate – Exhibits one or two of the above characteristics

**Score:** 3.25 of 5

**Ranking Rationale:**
Sexual reproduction, high fecundity, moderate parental investment and moderate generation time.

**Background Information:**
Females are capable of producing 100,000-1,000,000 eggs per brood (Czerniejewski and Marcello 2013). The females will carry the eggs under their abdomens until they hatch. Larvae eventually molt into the first crab stage and settles to the seafloor. This occurs 18 to 24 days after hatching (Anger 1991). These juvenile crabs then migrate to freshwater where they grow into adults. Maturity is reached at 2 to 4 years. Adults typically die after spawning (Hymanson et al. 1999; Rudnick et al. 2005a).

**Sources:**
Anger 1991 NEMESIS; Fofonoff et al. 2003 Czerniejewski and Marcello 2013 Hymanson et al. 1999 Rudnick et al. 2005a

### 3.5 *Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice: A** Disperses long (>10 km) distances

**Score:** 2.5 of 2.5

**Ranking Rationale:**
Can migrate up to 18 km per day.

**Background Information:**
Adult crabs typically move by swimming, but can survive out of water for several hours and can move on land to avoid obstacles (e.g. dams; Fialho et al . 2016). Juveniles migrate from the sea to freshwater, and can travel more than 1000 km during this migration (Dan et al. 1984, qtd. in Rudnick et al. 2000). They can migrate up to 18 km per day.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Fialho et al. 2016

### 3.6 *Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: A** High – Exhibits two or three of the above characteristics

**Score:** 2.5 of 2.5

**Ranking Rationale:**
Can disperse at numerous life stages, are highly mobile, and larval viability window is long.

**Background Information:**
Adult crabs typically disperse by swimming, but can move on land to avoid obstacles (Fialho et al . 2016). The larval stage lasts 18 to 42 days, depending on temperature (Anger 1991). Juveniles migrate from the sea to freshwater, and can travel more than 1000 km during this migration (Dan et al. 1984, qtd. in Rudnick et al. 2000).

**Sources:**
Fialho et al. 2016 Anger 1991 NEMESIS; Fofonoff et al. 2003 Rudnick et al. 2000

### 3.7 *Vulnerability to predators*

**Choice:** **D** Multiple predators present in the Bering Sea or neighboring regions

**Score:** 1.25 of 5

**Ranking Rationale:**
Numerous predators, many of which exist in the Bering Sea.

**Background Information:**
Predators may include: raccoons, bullfrogs, fishes, and birds (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 21 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 4. Ecological and Socioeconomic Impacts

### 4.1 Impact on community composition

**Choice:** **C** Limited – Single trophic level; may cause decline but not extirpation

**Score:** 0.75 of 2.5

**High uncertainty?** ✔

**Ranking Rationale:**
Largest impacts have been documented in freshwater or brackish systems. Impact to marine community is less likely. Because juvenile and adult crabs are largely restricted to freshwater or brackish ecosystems, we do not expect E. sinensis to have strong negative impacts on marine communities in the Bering Sea.

**Background Information:**
E. sinensis consumes surface-dwelling invertebrates and may cause a decrease in the abundance of surface invertebrates, shifting invertebrate populations deeper (Hymanson et al. 1999; Rudnick et al. 2000; Rudnick and Resh 2005).

Can cause fish mortality through crowding and clogging of irrigation facility diversion passageways. They also may prey upon fish eggs in spawning streams (Rudnick et al. 2000; CMCWG 2003).

E. sinensis may also compete with local crabs such as the Blue Crab (Callinectes sapidus) for food and space.

**Sources:**
CMCWC 2003   Bovbjerg 1970   NEMESIS; Fofonoff et al. 2003   Hymanson et al. 1999   Rudnick et al. 2000   Rudnick and Resh 2005   Rudnick et al. 2000

### 4.101 Recreation

**Choice:** **C** Limited – Has limited potential to cause degradation to recreation opportunities, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
Because juvenile and adult crabs are largely restricted to freshwater or brackish ecosystems, we do not expect E. sinensis to have strong negative impacts on recreation in the Bering Sea.

**Background Information:**
Recreational fishing opportunities have been impacted in some areas of San Francisco Bay and Europe because of bait stealing by E. sinensis (CMCWG 2003).

**Sources:**
CMCWG 2003   NEMESIS; Fofonoff et al. 2003

### 4.11 Human health and water quality

**Choice:** **C** Limited – Has limited potential to pose a threat to human health, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
Carries Asian lung fluke in some locations; this relationship is limited to areas with an Asian host snail.

**Background Information:**
In its native range, E. sinensis is a secondary host for the Asian lung fluke Paragonimus westermani. For a human to get infected they would have to eat a raw or inadequately cooked infected crab (Center for Disease Control 2006 as qtd. in Fofonoff et al. 2003). Only one host snail is established in the U.S., and the fluke has not yet been detected in Californian populations of E. sinensis (CMCWG 2003). Because of its role as predator, E. sinensis bioaccumulates contaminants that can be transferred to consumers when eaten (Che and Cheung 1998).

**Sources:**
CMCWC 2003   NEMESIS; Fofonoff et al. 2003   Che and Cheung 1998

### 4.2 *Impact on habitat for other species*

**Choice:** **C** Limited – Has limited potential to cause changes in one or more habitats

**Score:** 0.75 of 2.5

**Ranking Rationale:**
Burrowing acitvities by juvenile crabs have been linked to increased erosion and deterioration of river banks and associated sediments. Juveniles are largely restricted to freshwater or brackish ecosystems, and the only life stage that is fully marine is the planktonic larval stage. Thus, we do not expect this species to have strong negative impacts on habitat in the Bering Sea.

**Background Information:**
Juveniles create burrows in tidal portions of stream that retain water during low tide. This burrowing activity results in increased erosion, slumping, and possible collapse of river banks. In some places, these burrows removed up to 5.7% of stream bank sediment (Rudnick et al. 2005b).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Rudnick et al. 2005b

### 4.3 *Impact on ecosystem function and processes*

**Choice:** **C** Limited – Causes or potentially causes changes to food webs and/or ecosystem functions, with limited impact and/or within a very limited region

**Score:** 0.75 of 2.5

**Ranking Rationale:**
Has the potential to cause changes to the ecosystem function, however, these changes are likely limited to estuary or stream environments.

**Background Information:**
Through predation, can reduce the abundance of surface-dwelling invertebrates (Hymanson et al. 1999; Rudnick et al. 2000; Rudnick and Resh 2005).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Clark et al. 2009   Hymanson et al. 1999   Rudnick et al. 2000   Rudnick and Resh 2005

### 4.4 *Impact on high-value, rare, or sensitive species and/or communities*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
Because juvenile and adult crabs are largely restricted to freshwater or brackish ecosystems, we do not expect E. sinensis to have strong negative impacts on species in the Bering Sea.

**Background Information:**
E. sinensis can occur in such high densities that, as a possible fish egg predator, they are a concern in spawning streams (CMCWG 2003).

**Sources:**
CMCWC 2003   NEMESIS; Fofonoff et al. 2003

### 4.5 *Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice: C** Limited – Has limited potential to spread one or more organisms, with limited impact and/or within a very limited region

**Score:** 0.75 **of** 2.5

**Ranking Rationale:**
Secondary host for the Asian lung fluke Paragonimus westermani. The fluke requires a host snail species that is not currently found in the Bering Sea, and no infected crabs have been found in California.

**Background Information:**
E. sinensis is a secondary host for the Asian lung fluke Paragonimus westermani. The fluke requires host snail species that are currently established in California and Florida. The fluke has not yet been detected in California crabs (CMCWG 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003 CMCWC 2003

### 4.6 *Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice: D** No impact

**Score:** 0 **of** 2.5

**Ranking Rationale:**
To date, no hybridization has been reported for E. sinensis.

**Background Information:**
No information available in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.7 *Infrastructure*

**Choice: B** Moderate – Causes or has the potential to cause degradation to infrastructure, with moderate impact and/or within only a portion of the region

**Score:** 1.5 **of** 3

**Ranking Rationale:**
Damages infrastructure in freshwater and estuaries, but no impacts to marine infrastructure have been reported.

**Background Information:**
E. sinensis can cause erosion and riverbank collapse in canals and shipping channels. During migration, large numbers of these crabs have clogged power plants, irrigation, and water diversion systems in freshwater and estuaries in California (CMCWG 2003).

**Sources:**
CMCWC 2003 NEMESIS; Fofonoff et al. 2003

### *4.8 Commercial fisheries and aquaculture*



**Choice: B** — Moderate – Causes or has the potential to cause degradation to fisheries and aquaculture, with moderate impact in the region

**Score:** 1.5 of 3

**Ranking Rationale:**
E. sinensis steals fish bait, interferes with nets, traps, and aquaculture pods, and competes for resources with harvested species.

**Background Information:**
E. sinensis has direct impacts on fisheries by bait stealing, interfering with traps, and competition. They steal bait indiscriminately from anglers and commercial fishermen alike making fishing in some areas impossible. In large numbers, they clog, break, and eat the fish found in traps, nets, and aquaculture pods (CMCWG 2003). E. sinensis also competes for resources with commercially important species such as crayfish, shrimp, and other crabs.

**Sources:**
CMCWC 2003 NEMESIS; Fofonoff et al. 2003

### *4.9 Subsistence*

**Choice: B** — Moderate – Causes or has the potential to cause degradation to subsistence resources, with moderate impact and/or within only a portion of the region

**Score:** 1.5 of 3

**Ranking Rationale:**
Directly interferes with subsistence species and activities.

**Background Information:**
Impacts on subsistence resources are similar to those on fisheries. In addition to bait-stealing, dense populations also interfere with traps and nets by clogging and breaking them, and eating the trapped fish (CMCWG 2003). Mitten Crabs can also interfere with subsistence resources by competing for food and shelter of fished species, such as crayfish and shrimp in San Francisco Bay (CMCWG 2003), or potentially with crab fisheries.

**Sources:**
CMCWC 2003 NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 9 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 5. Feasibility of prevention, detection and control



### 5.1 *History of management, containment, and eradication*

**Choice:** **A** Attempted; control methods are not successful

**Score:** of

**Ranking Rationale:**
So far, no effective management approach has been developed and all eradication efforts have shown limited efficiency.

**Background Information:**
Due to its high abundance, high reproductive rates, and its wide range of tolerances, management of E. sinensis is difficult. In Germany, traps were installed on the upstream side of dams to capture migrating juvenile crabs. When used in conjunction with collection and disposal efforts this has the potential to drastically reduce the crab population during migration events. In California, management is focusing on preventing the spread of the crab to new areas. E. sinensis is listed as injurious wildlife under the Federal Lacey Act making it illegal to import, export, or transport between states in the U.S. without a permit.

**Sources:**
CMCWC 2003 NEMESIS; Fofonoff et al. 2003

### 5.2 *Cost and methods of management, containment, and eradication*

**Choice:** **B** Major short-term and/or moderate long-term investment

**Score:** of

**Ranking Rationale:**

**Background Information:**
So far, no effective management approach has been developed and eradication efforts have shown limited efficiency.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 5.3 *Regulatory barriers to prevent introductions and transport*

**Choice:** **E** Transport and trade are illegal

**Score:** of

**Ranking Rationale:**

**Background Information:**
Importation of the crab to the U.S. was banned under the Lacey Act in 1989 (Cohen and Carlton 1997; Hymanson et al. 1999).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Cohen and Carlton 1997 Hymanson et al. 1999

### *5.4 Presence and frequency of monitoring programs*

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**Choice: B** Surveillance takes place, but is largely conducted by non-governmental environmental organizations (e.g., citizen science programs)

**Score:** of

**Ranking Rationale:**

Monitoring for Green Crab occur throughout Alaska during which mitten crab would be identified.

**Background Information:**

Eriocheir sinensis was listed by the Invasive Species Specialist Group of the World Conservation Union (IUCN) as one of the '100 worst invasive species'. It has had economic and ecological impacts throughout its introduced range.

Several watch groups have formed in California, Oregon, and Washington aimed at fishermen who may encounter crabs in their nets. The East Coast and Great Lakes have similar groups.

The Prince William Sound Regional Citizens' Advisory Council considers Chinese Mitten Crabs as a Non-Indigenous Aquatic Species of Concern for Alaska.

The Smithsonian Environmental Research Center began efforts to monitor European Green Crab (Carcinus maenas) in Alaska in 2000. Currently trapping is done in Kachemak Bay, Prince William Sound and in Southeast Alaska and is a cooperative effort overseen by the Kachemak Bay Research Reserve, Prince William Sound Regional Citizens Advisory Council, and National Marine Fisheries in Juneau. Where possible, monitoring occurs monthly throughout the summer months at each site. These efforts could also be used to detect Chinese Mitten Crabs but no specific information on Eriocheir sinensis found.

**Sources:**

NEMESIS; Fofonoff et al. 2003   DAISIE 2009

### *5.5 Current efforts for outreach and education*

**Choice: D** Programs and materials exist and are readily available in the Bering Sea or adjacent regions

**Score:** of

**Ranking Rationale:**

**Background Information:**

Programs and materials exists for California including species watch cards, species reports and management plans (CMCWG 2003).

**Sources:**

CMCWC 2003   NEMESIS; Fofonoff et al. 2003

**Section Total - Scored Points:**

**Section Total - Possible Points:**

**Section Total -Data Deficient Points:**

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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Limnoria tripunctata*

**Common Name** *a wood-boring isopod*

| | |
|---|---|
| Phylum | Arthropoda |
| Class | Malacostraca |
| Order | Isopoda |
| Family | Limnoriidae |

**Final Rank** 50.00

**Data Deficiency:** 2.50

Species Occurrence by Ecoregion

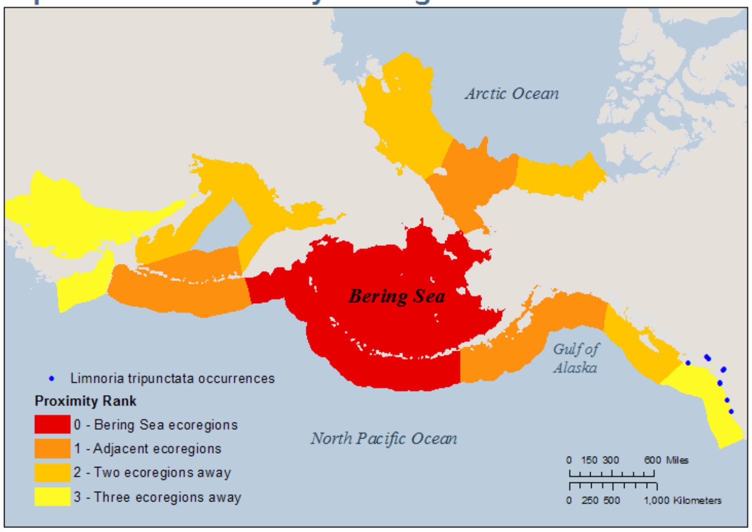


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 18.25 | 30 | 0 |
| Anthropogenic Influence: | 6.75 | 10 | 0 |
| Biological Characteristics: | 19.25 | 30 | 0 |
| Impacts: | 4.5 | 28 | 2.50 |
| **Totals:** | 48.75 | 97.50 | 2.50 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | 2 | Minimum Salinity (ppt) | 19 |
| Maximum Temperature (°C) | 30 | Maximum Salinity (ppt) | 50 |
| Minimum Reproductive Temperature (°C) | 15 | Minimum Reproductive Salinity (ppt) | 31* |
| Maximum Reproductive Temperature (°C) | 30 | Maximum Reproductive Salinity (ppt) | 35* |

### Additional Notes

Limnoria tripunctata is a small wood-boring isopod that is globally distributed. It is almost cylindrical in shape and adults are up to 3.4 mm long and white to pink in color. Distinguished from other species in the genus by the possession of three bumps on the telson that are visible under a dissecting microscope (Reish et al. 2015).

# 1. Distribution and Habitat



### *1.1 Survival requirements - Water temperature*

**Choice: C** Little overlap – A small area (<25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 1.25 of 3.75

**Ranking Rationale:**
Temperatures required for year-round survival occur in a limited area (<25%) of the Bering Sea.

**Background Information:**
Lab experiments suggest a temperature range of 2°C to 30°C required for survival, with an upper limit of 44°C (Quayle 1992; Beckman and Menzies 1960).

**Sources:**
Quayle 1992 Beckman and Menzies 1960 NEMESIS; Fofonoff et al. 2003

### *1.2 Survival requirements - Water salinity*

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
Experimental data suggests that the salinity threshold for survival of L. tripunctata is 19-50ppt (Quayle 1992). But, when salinity drops below 20 PSU, L. tripunctata is rare or absent (Becker 1971, as qtd. In Fofonoff et al. 2003; Lum 1981). In laboratory settings, optimum range appears to 36-50 PSU (Eltringham 1961; Lum 1981).

**Sources:**
Quayle 1992 NEMESIS; Fofonoff et al. 2003 Lum 1981 Eltringham 1961

### *1.3 Establishment requirements - Water temperature*

**Choice: D** No overlap – Temperatures required for reproduction do not exist in the Bering Sea

**Score:** 0 of 3.75

**Ranking Rationale:**
Temperatures required for reproduction do not exist in the Bering Sea.

**Background Information:**
Experimental studies suggest the temperature threshold for reproduction of L. tripunctata is 15 to 30°C (Quayle 1992; Beckman and Menzies 1960).

**Sources:**
Quayle 1992 Beckman and Menzies 1960 NEMESIS; Fofonoff et al. 2003

### *1.4 Establishment requirements - Water salinity*

**Choice:** **A** — Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Although salinity thresholds are unknown, this species is a marine organism that does not require freshwater to reproduce. We therefore assume that this species can reproduce in saltwater (31 to 35 ppt). These salinities occur in a large (>75%) portion of the Bering Sea.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *1.5 Local ecoregional distribution*

**Choice:** **D** — Present in an ecoregion greater than two regions away from the Bering Sea

**Score:** 1.25 of 5

**Ranking Rationale:**

**Background Information:**
Closest known occurrence is on Vancouver Island, British Columbia, from Victoria to Quadra Island (50.2°N). Recorded at various sites throughout the North American West Coast, from BC to Mexico.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.6 Global ecoregional distribution*

**Choice:** **A** — In many ecoregions globally

**Score:** 5 of 5

**Ranking Rationale:**
Wide global distribution.

**Background Information:**
Native range is unknown. Considered cryptogenic in Asia, where it is widely distributed and found in China, Japan, the Philippines, India, and several Pacific islands including Fiji, Guam, and Papua New Guinea. Recorded in Australia and New Zealand. In Africa, found off the coasts of South Africa, Kenya, and Ghana. In Europe, recorded as far north as the English Channel, south to Italy and France. Recorded in the Adriatic, Mediterranean, and Red Seas, and possibly in the Black Sea. In North America, found on the east coast from Massachusetts to the Caribbean Sea, south to Costa Rica. Also recorded in Uruguay and Argentina. On the West Coast, considered invasive from British Columbia south to the Panama Canal and Hawaii.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.7 Current distribution trends*

**Choice: B** History of rapid expansion or long-distance dispersal (prior to the last ten years)

**Score:** 3.25 **of** 5

**Ranking Rationale:**
Recent documentation of long-distance dispersal and range expansion.

**Background Information:**
First described on the West Coast from Los Angeles Harbor, CA in 1871. Appears to have extended its range north in the later decades of the 20th century. It was not found north of San Francisco in 1950s surveys, which included sampling in Coos Bay, OR and Puget Sound, WA (Menzies 1957; Wallour 1960, as qtd. In Fofonoff et al. 2003). However, it was reported in Coos Bay in 1983 (Carlton 1989, as qtd. In Fofonoff et al. 2003), Yaquina Bay, Willapa Bay and the Straits of Georgia in 1964 (Quayle 1992), and Puget Sound in 1998 (Cohen et al. 1998). Because it requires several weeks of ~15ºC to reproduce, its ability to colonize northern waters is uncertain.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Menzies 1957 Quayle 1992 Cohen et al. 1998

| | |
|---|---|
| **Section Total - Scored Points:** | 18.25 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 2. Anthropogenic Transportation and Establishment

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### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice:** **A** Has been observed using anthropogenic vectors for transport and transports independent of any anthropogenic vector once introduced

**Score:** 4 **of** 4

**Ranking Rationale:**
Most occurrences are related to hull fouling and oyster culturing.

**Background Information:**
Its spread is correlated with oyster culturing, although there are at least 5 occurrences in British Columbia that are not related to the oyster culture. It is believed that they are spread through the wooden boxes used to transport oysters (Quayle 1992). Another likely vector is hull fouling.

**Sources:**
Quayle 1992 NEMESIS; Fofonoff et al. 2003

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice:** **B** Readily establishes in areas with anthropogenic disturbance/infrastructure; occasionally establishes in undisturbed areas

**Score:** 2.75 **of** 4

**High uncertainty?** ☑

**Ranking Rationale:**
Establishes where there is wood, from either anthropogenic or natural sources. Information for this species is lacking.

**Background Information:**
L. quadripunctata, a closely related species, requires a supply of wood either from fallen trees or humans to establish (Cragg 2010). May limit the ability of wood borers to spread and establish to new sites.

**Sources:**
Cragg 2010

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice:** **B** No

**Score:** 0 **of** 2

**Ranking Rationale:**

**Background Information:**
This species is not currently farmed or intentionally cultivated.

**Sources:**
None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 6.75 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics



### *3.1 Dietary specialization*

**Choice:** **B** Generalist or specialist at different life stages and/or foods are moderately available in the study area

**Score:** 3.25 of 5

**Ranking Rationale:**
L. tripunctata is a specialist that eats primarily wood, which may be restricting, however, wood as a food source is fairly abundant in most environments.

**Background Information:**
Digests non-cellulosic carbohydrates in wood, as well as some cellulose. Fungi and bacteria found in wood may complement a wood-only diet (Quayle 1992).

**Sources:**
Quayle 1992

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **B** Requires specialized habitat for some life stages (e.g., reproduction)

**Score:** 3.25 of 5

**Ranking Rationale:**
Requires wood in the environment as food and habitat.

**Background Information:**
L. tripunctata is a shallow water species found from the water surface to 18 m deep. Deeper waters are preferred especially when surface salinity is low or when tidal fluctuation is high. It also prefers estuary benthos where it is commonly found at the bases of pilings (Hiebert 2015). It prefers rough surfaces of softer wood infected with fungi (Becker 1971 as qtd. in Fofonoff et al. 2003). It thrives in creosote treated timber as it harbors a greater number and diversity of bacteria over untreated wood (Quayle 1992). Cannot tolerate turbid waters (Shupe 2012).

**Sources:**
Shupe 2012 Hiebert 2015 NEMESIS; Fofonoff et al. 2003 Quayle 1992

### *3.3 Desiccation tolerance*

**Choice:** **B** Moderately tolerant (1-7 days) during one or more stages during its life cycle

**Score:** 3.25 of 5

**Ranking Rationale:**

**Background Information:**
Limnoria spp. can survive without water for about 24 hours and are not affected by a temporary aeration (Iljin 1992, qtd. in Shalaeva 2012).

**Sources:**
Shalaeva 2012

### 3.4 *Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice: B** Moderate – Exhibits one or two of the above characteristics

**Score:** 3.25 of 5

**Ranking Rationale:**
Sexual reproduction, low fecundity, short generation time.

**Background Information:**
Separate sexes, internal fertilization. Young are brooded by the female (Becker 1971 as qtd. In Fofonoff et al. 2003). After 2-4 weeks of development (Borges et al. 2014), they hatch as small adults with no larval stage (Boyko and Wolff 2014 as qtd. in Hiebert 2015). First brood occurs at the end of the first year with up to three broods per female per year (Johnson and Menzies 1956). Average brood size ranges from 5 to 10 eggs per female (Quayle 1992). Average lifespan is two years (Quayle 1992).

**Sources:**
Hiebert 2015 Quayle 1992 NEMESIS; Fofonoff et al. 2003 Johnson and Menzies 1956 Borges et al. 2014

### 3.5 *Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice: C** Disperses short (< 1 km) distances

**Score:** 0.75 of 2.5

**Ranking Rationale:**
Migrations are limited to a few meters.

**Background Information:**
All life history stages of Limnoria participate in both active migration and passive dispersal (Miranda and Thiel 2008). However, because this species has internal fertilization and direct development, there is no egg or planktonic larval stage that can disperse. Instead, Limnoria spp. disperse primarily as young adults; juveniles undergo a regular, seasonal “migration” (active swimming behavior) (Johnson and Menzies 1956; Eltringham and Hockley 1961). These migrations, however, typically occur over a few meters or less (Vinogradov et al. 2006, qtd. in Shalaeva 2012 – information on Limnoria spp. in general). For the wood-dwelling species L. lignorum, Johnson (1935) expressed that he “believed that the principal means of dispersal within an infected area is by regular seasonal migration. …. These migrations must not be understood as occurring over any considerable distances but rather as a matter of only a few meters or less” (qtd. in Miranda and Thiel 2008). Based on field experiments of tropical Limnoria spp. in Chile, Miranda and Thiel (2008) inferred that migrations occur over distances of meters or tens of meters.

Although adults can move freely from place to place, they are largely sessile, spending most of their time burrowed in wood (Quayle 1992). They have limited swimming abilities: maximum swimming distance was 3 m at 18°C and 28 ppt (Quayle 1992).

Transport at all stages can be assisted via infected driftwood and water currents (Quayle 1992).

**Sources:**
Eltringham and Hockley 1961 Johnson and Menzies 1956 Quayle 1992 Miranda and Thiel 2008 Shalaeva 2012

### 3.6 *Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice:** **B** Moderate – Exhibits one of the above characteristics

**Score:** 1.75 of 2.5

**Ranking Rationale:**

Ability to disperse via different modes at difference life stages, however, dispersal is extremely limited.

**Background Information:**

Direct development and internal fertilization. L. tripunctata larvae resemble small adults (though they are incapable of swimming at first; Hiebert 2015). All life stages are capable of active (swimming/crawling) and passive dispersal (e.g. via rafting or water currents), though migration is most common in juveniles (Johnson and Menzies 1956). Migration is seasonal: in England, it occurred in late May and early June (Eltringham and Hockley 1961). In addition, migration of L. tripunctata is more frequent at night than during the day (Johnson and Menzies 1956). In general, L. tripunctata has poor swimming abilities (Quayle 1992). Temporal events such as storms, as well as weather and ocean current patterns, may allow for long-distance dispersal (Miranda and Thiel 2008).

**Sources:**

Eltringham and Hockley 1961 Hiebert 2015 Johnson and Menzies 1956 Miranda and Thiel 2008 Quayle 1992

### 3.7 *Vulnerability to predators*

**Choice:** **B** Few predators only in its home range, and not suspected in the Bering Sea or neighboring regions

**Score:** 3.75 of 5

**Ranking Rationale:**

Few predators are known for this species.

**Background Information:**

There are no known natural enemies that regulate populations of limnoriids (Becker 1971 as qtd. In Fofonoff et al. 2003), but some polychaete worms are known to predate on them (Reish 1954 as qtd. In Hiebert 2015).

**Sources:**

Cragg 2010 NEMESIS; Fofonoff et al. 2003 Hiebert 2015

| | |
|---|---|
| **Section Total - Scored Points:** | 19.25 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 4. Ecological and Socioeconomic Impacts



### 4.1 *Impact on community composition*

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 4.2 *Impact on habitat for other species*

**Choice:** **C** Limited – Has limited potential to cause changes in one or more habitats

**Score:** 0.75 of 2.5

**Ranking Rationale:**
Not expected to negatively impact habitat for local species. May create new habitat for other species.

**Background Information:**
By burrowing in wood, L. tripunctata creates habitat for other species. Limnoria burrows can be inhabited by non-borers such as the commensal isopod, Caecijaera; the sphaeromatid isopod, Gnorimosphaeroma; the amphipod, Chelura; and the copepod Donsiella, none of which are borers (Menzies 1957; Hiebert 2015). The Teredo, a boring mollusk, can also co-occur in Limnoria wood burrows. Wood infested with L. tripunctata showed a community of turbellarians, nematodes, Dinophilus, Polydora, copepods, and amphipods after only 4-6 months submerged (Sleeter and Coull 1973).

**Sources:**
Hiebert 2015   Menzies 1957   Sleeter and Coull 1973

### 4.3 *Impact on ecosystem function and processes*

**Choice:** **C** Limited – Causes or potentially causes changes to food webs and/or ecosystem functions, with limited impact and/or within a very limited region

**Score:** 0.75 of 2.5

**Ranking Rationale:**
Processes wood debris, releasing energy stored in submerged wood and driftwood.

**Background Information:**
L. tripunctata is a wood-boring invertebrate which affects its environment by accelerating the degradation of wood and controlling the availability of food and space for various organisms in sunken wood communities by (1) serving as prey, (2) carving out cavities that are used as shelters by other organisms, (3) facilitating the build-up of degradation-related hydrogen sulfide, (4) promoting secondary production in the surrounding sediment, and (5) increasing the surface/volume ratio of the wood, which in turn accelerates the leaching of labile components such as proteins, tannins and terpenoids (Nishimoto et al. 2015). The crustacean isopod family Limnoriidae play key roles in wood fragmentation.

**Sources:**
Shalaeva 2012   Nishimoto et al. 2015

### *4.4 Impact on high-value, rare, or sensitive species and/or communities*

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
To date, no impacts on high-value, rare, or sensitive species have been reported for L. tripunctata, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.5 Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice: C** Limited – Has limited potential to spread one or more organisms, with limited impact and/or within a very limited region

**Score:** 0.75 of 2.5

**Ranking Rationale:**
Is host to one known parasite.

**Background Information:**
L. tripunctata is host to Mirofolliculina limnoriae, an ectoparasite which slows the feeding, swimming, and growth of L. tripunctata (Delgery et al. 2006). Effects of M. limnoriae on other species are unknown.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Delgery et al. 2006

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**

**Background Information:**
In Southampton Water, England, three species of Limnoria occur together. These species do not appear to interbreed (Eltringham and Hockley 1958, qtd. in Eltringham and Hockley 1961). No further information found.

**Sources:**
Eltringham and Hockley 1961

### 4.7 Infrastructure

**Choice: B** Moderate – Causes or has the potential to cause degradation to infrastructure, with moderate impact and/or within only a portion of the region

**Score:** 1.5 of 3

**Ranking Rationale:**
Damages wooden pilings, docks, and ship hulls.

**Background Information:**
Damage to pilings, docks, and other infrastructure by L. tripunctata has been reported in Florida, California, British Columbia, England, and Portugal. Can reduce the lifespan of a creosote-treated wood piling to approximately 6 years instead of a possible 40 years (Beckman et al. 1957, qtd. in Fofonoff et al. 2003). A piling of intermediate size has been estimated to contain a population of 200, 000 animals, each capable of consuming 20 g of wood per year (Menzies and Turner 1957, qtd. in Quayle 1992). May cause damage to important historical or heritage sites (Shalaeva 2012). No information found on economic costs.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Quayle 1992 Shalaeva 2012

### 4.8 Commercial fisheries and aquaculture

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on fisheries or aquaculture have been reported for L. tripunctata, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.9 Subsistence

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no immpacts on subsistence have been reported for L. tripunctata, and given tis ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.101 Recreation

**Choice: C** Limited – Has limited potential to cause degradation to recreation opportunities, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
Can deteriorate wooden strucures associated with recreation.

**Background Information:**
L. lignorum, a closely related species, is known to cause damage to wooden structures. This may result in unexpected failures, which may lead to impacts on recreation such as destruction of docks.

**Sources:**
Shalaeva 2012

### *4.11 Human health and water quality*



**Choice:** **D** No impact

**Score:** **0** of **3**

**Ranking Rationale:**
To date, no impacts on human health or water quality have been reported for L. tripunctata, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 4.5 |
| **Section Total - Possible Points:** | 27.5 |
| **Section Total -Data Deficient Points:** | 2.5 |

# 5. Feasibility of prevention, detection and control



### *5.1 History of management, containment, and eradication*

**Choice:** **C**

Attempted; control methods are currently in development/being studied

**Score:**

**of**

**Ranking Rationale:**

Control methods are being used and are successful.

**Background Information:**

In British Columbia, creosote-treated marine piling, properly installed and maintained, provides adequate protection against gribbles, including L. tripunctata (Quayle 1992). To combat the invasion of wood borers in Los Angeles Harbor, wood pilings were covered with 6 mm inner wrap of polyethylene and 20-30 mm of polyvinylchloride outer wrap, which killed any existing borers and fouling organisms by suffocation and prevented new infestations (Reish et al. 2015). L. tripunctata is still present in Los Angeles Harbor on wood pilings that have not been wrapped (Reish et al. 2015).

**Sources:**

Quayle 1992 Reish et al. 2015

### 5.2 *Cost and methods of management, containment, and eradication*

**Choice:** **C** Easy and inexpensive (minor investment)

**Score:** of

**Ranking Rationale:**

Prevention methods include: chemical treatment, covering, and wrapping of wooden structures, as well as switching construction materials from wood to concrete.

**Background Information:**

To prevent wood borers, pilings can be treated with creosote and other wood treatments; however, Limnoria tripunctata is capable of penetrating creosoted wood pilings (Lee and Miller 1980, qtd. in Reish et al. 2015), especially in warmer waters, which causes deterioration and leaching of creosote (Shupe 2012). Moreover, these treatments can contain toxic compounds, which add to the environmental impacts of this species (Becker 1971 as qtd. In Fofonoff et al. 2003).

The use of certain copper or tin salts can provide effective protection from Limnoria attack, but their use is limited by environmental regulations. A dual treatment consisting of a pressure treatment with copper salt (1.0 to 1.5 pcf of CCA or ACZA) followed by a pressure treatment with marine-grade creosote (20 pcf), can be effective against creosote-resistant Limnoria species. Movable wooden structures and boats can also be protected by an unbroken covering of marine paint. When borers have gained entrance into wooden vessels, they can be killed by running the boats into fresh water or dry dock for at least 30 days.

In British Columbia, creosote-treated marine piling, properly installed and maintained, provides adequate protection against gribbles, including L. tripunctata (Quayle 1992). Increased use of log barges rather than rafts for transporting logs and dry land sorting are ways to reduce marine borer populations. Replacement of float logs by pontoons of synthetic materials also helps.

To combat the invasion of wood borers in Los Angeles Harbour, creosote-treated wood pilings are covered with 6 mm inner wrap of polyethylene and 20-30 mm of polyvinylchloride outer wrap, which successfully kills any existing borers and fouling organisms by suffocation and prevents new infestations (Reish et al. 2015). Using concrete instead of wood as construction material has also helped reduce wood boring infestations. Picking up and discarding floating wood and debris may help limit the presence of wood boring species (Reish et al. 2015).

**Sources:**

Quayle 1992   Reish et al. 2015   Shupe 2012   NEMESIS; Fofonoff et al. 2003

### 5.3 *Regulatory barriers to prevent introductions and transport*

**Choice:** **A** Little to no regulatory restrictions

**Score:** of

**Ranking Rationale:**

**Background Information:**

No regulations in place to prevent spread of L. tripunctata.

**Sources:**

None listed

### *5.4 Presence and frequency of monitoring programs*

**Choice:** **A** No surveillance takes place

**Score:** of

**Ranking Rationale:**

**Background Information:**
No surveillance currently takes place for L. tripunctata.

**Sources:**
None listed

### *5.5 Current efforts for outreach and education*

**Choice:** **A** No education or outreach takes place

**Score:** of

**Ranking Rationale:**

**Background Information:**
No educational material found online.

**Sources:**
None listed

**Section Total - Scored Points:**
**Section Total - Possible Points:**
**Section Total -Data Deficient Points:**

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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Synidotea laticauda*

**Common Name** *an isopod*

| | |
|---|---|
| **Phylum** | Arthropoda |
| **Class** | Malacostraca |
| **Order** | Isopoda |
| **Family** | Idoteidae |

**Species Occurrence by Ecoregion**

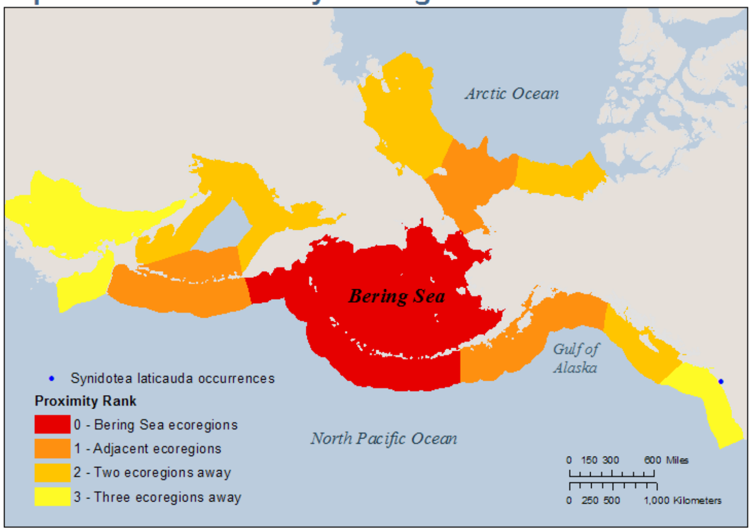


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Final Rank** 39.45

**Data Deficiency:** 8.75

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 12.5 | 26 | 3.75 |
| Anthropogenic Influence: | 4.75 | 10 | 0 |
| Biological Characteristics: | 18 | 25 | 5.00 |
| Impacts: | 0.75 | 30 | 0 |
| **Totals:** | 36.00 | 91.25 | 8.75 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | 0 | Minimum Salinity (ppt) | 1 |
| Maximum Temperature (°C) | 30 | Maximum Salinity (ppt) | 35 |
| Minimum Reproductive Temperature (°C) | 4 | Minimum Reproductive Salinity (ppt) | 10 |
| Maximum Reproductive Temperature (°C) | 33 | Maximum Reproductive Salinity (ppt) | 30 |

### Additional Notes

S. laticauda is a small (16-25 mm) isopod with a tan, oval body, large eyes, and a dark brown stripe along its back. Its native range is unknown, but it is considered introduced to North America. The taxonomic identity of this species is unresolved.

# 1. Distribution and Habitat

### *1.1 Survival requirements - Water temperature*

**Choice:** **B** Moderate overlap – A moderate area (≥25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 2.5 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Temperatures required for year-round survival occur in a moderate area (≥25%) of the Bering Sea. We ranked this question with "High Uncertainty" to indicate disagreements in model estimates.

**Background Information:**
Boyd (2008) suggests an optimal temperature range between 10 and 25ºC. No juveniles survived 24-hr exposures to 37ºC, but ~80% of adults survived 48-hr exposures at 30ºC and 15-25 PSU (Boyd 2008). 100% of adults survived 48-hour exposures at 5ºC and 25 PSU (Boyd 2008). This species was reported from the Delaware River, New Jersey where bottom temperatures ranged from ~0 to 28ºC (Bushek and Boyd 2006).

**Sources:**
Boyd 2008 Bushek and Boyd 2006

### *1.2 Survival requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
Boyd (2008) suggests that the optimal salinity range for this species is between 10 and 30 PSU, but juveniles exposed to 35 PSU for 24 hours exhibited little to no mortality at 25ºC and 10ºC. Less than 1% of adults survived short-term (up to 48 hours) exposure to 0 PSU (Boyd et al. 2008). In France, this species was reported from salinities between 0.1 and 24 ppt (Mees and Fockedey 1993, qtd. in Bushek and Boyd 2006).

**Sources:**
Bushek and Boyd 2006 Boyd 2008

### *1.3 Establishment requirements - Water temperature*

**Choice:** **U** Unknown/Data Deficient

**Score:** of

**Ranking Rationale:**
More information needed to determine reproductive temperature requirements.

**Background Information:**
At high salinity (35 PSU), 100% of juveniles survived 24 hour exposure to 4ºC water (Boyd 2008). No juveniles survived at 37ºC, but a few (10-50%) survived at 33ºC in moderate to high salinity treatments (25 to 35 PSU) (Boyd 2008).

**Sources:**
Boyd 2008 NEMESIS; Fofonoff et al. 2003

### 1.4 Establishment requirements - Water salinity



**Choice:** **D** No overlap – Salinities required for reproduction do not exist in the Bering Sea

**Score:** 0 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Although little information was found on reproductive requirements, the optimal salinity range for juveniles seems to be between 10 and 30 PSU, though some individuals were able to tolerate short-term (24 hr) exposure to 35 PSU. Salinities < 30 PSU do not occur in the Bering Sea.

**Background Information:**
In laboratory conditions, no juveniles survived 24 h exposure to freshwater. A few survived at 5 PSU. Survival increased to 100% at 10 PSU and remained high at 20 and 30 PSU. Survival dropped to 30% or lower at 35 PSU (Boyd 2008).

**Sources:**
Boyd 2008

### 1.5 Local ecoregional distribution

**Choice:** **D** Present in an ecoregion greater than two regions away from the Bering Sea

**Score:** 1.25 of 5

**Ranking Rationale:**
This species has been reported as far north as Willapa Bay, Washington.

**Background Information:**
On the West Coast of North America, this species has been found in California and Washington.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 1.6 Global ecoregional distribution

**Choice:** **B** In a moderate number of ecoregions globally

**Score:** 3.25 of 5

**High uncertainty?** ✔

**Ranking Rationale:**
This species is considered introduced in western and eastern North America, where it has a relatively restricted range, and in western Europe. Taxonomic confusion within this species' genus makes it difficult to determine its native range and the extent of its distribution.

**Background Information:**
S. laticauda is considered introduced on both coasts of North America, where it occurs in CA and WA in the west, and from NY to SC in the east. In Europe, it has been reported from Spain to the Netherlands. Because of taxonomic confusion within the Synidotea genus, the native range and geographic extent of this species is unknown.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 1.7 Current distribution trends

**Choice:** **C** Established outside of native range, but no evidence of rapid expansion or long-distance dispersal

**Score:** 1.75 of 5

**Ranking Rationale:**
This species' disconnected distribution on the east and west coasts of North America suggests a limited ability for long-distance dispersal/colonization in its introduced range.

**Background Information:**
This species has been reported in CA and from one area (Willapa Bay) in Washington. Though it can reach high densities locally, it has a similar, disconnected distribution on the east coast. We did not find information pointing to a rapid range expansion for this species.

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 12.5 |
| **Section Total - Possible Points:** | 26.25 |
| **Section Total -Data Deficient Points:** | 3.75 |

490

## 2. Anthropogenic Transportation and Establishment



### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice:** **B** — Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 of 4

**Ranking Rationale:**
This species was likely introduced to North America and to Europe by anthropogenic vectors. Its disconnected distribution in North America suggests a limited ability for independent transport.

**Background Information:**
This species is thought to have been transported via fouling or ballast water (Boyd 2008; Fofonoff et al. 2003).

**Sources:**
Boyd 2008 NEMESIS; Fofonoff et al. 2003

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice:** **B** — Readily establishes in areas with anthropogenic disturbance/infrastructure; occasionally establishes in undisturbed areas

**Score:** 2.75 of 4

**Ranking Rationale:**
In its introduced range, this species is more commonly associated with anthropogenic structures.

**Background Information:**
In Delaware Bay, NJ, S. laticauda was mostly found at sites with anthropogenic structures (Boyd 2008), and was commonly found fouling docks, ropes and buoys (Bushek and Boyd 2006). It has also been found on natural substrates (Bushek and Boyd 2006).

**Sources:**
Boyd 2008 Bushek and Boyd 2006

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice:** **B** — No

**Score:** 0 of 2

**Ranking Rationale:**
This species is not farmed or cultivated.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 4.75 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics

### *3.1 Dietary specialization*

**Choice: A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
This species is a generalist and items are readily available in the Bering Sea.

**Background Information:**
During feeding trials, individuals consumed 9 of the 12 species presented to them (Boyd 2008). This species was found to have a broad diet including bryozoans, algae, and nereid worms (Boyd 2008).

**Sources:**
Boyd 2008

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice: A** Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 of 5

**Ranking Rationale:**
This species is a habitat generalist that can tolerate a range of temperatures, salinities, and water flows.

**Background Information:**
This species can tolerate a broad range of temperatures and salinities (Boyd 2008). It was very abundant in the San Francisco estuary, which experiences strong, seasonal variations in water flow, salinity, and temperature (Gewant and Bollens 2005).

**Sources:**
Boyd 2008 Gewant and Bollens 2005

### *3.3 Desiccation tolerance*

**Choice: U** Unknown

**Score:** of

**Ranking Rationale:**
This species' dessication tolerance is unknown.

**Background Information:**
No information found.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 3.4 *Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice:** **B** Moderate – Exhibits one or two of the above characteristics

**Score:** 3.25 of 5

**High uncertainty?** ☑

**Ranking Rationale:**
This species' reproduces sexually and broods its young. Brood size is small, but the total number of broods per female is unknown. Because this species' undergoes seasonal peaks and die-offs in at least parts of its range, it likely has a relatively short generation time.

**Background Information:**
This species' has separate sexes and reproduces sexually. Eggs are brooded by the female. Females in Delaware Bay had a brood size between 12 to 70 (Boyd 2008). In the San Francisco Estuary, this species undergoes seasonal increases/declines in abundance (Gewant and Bollens 2005).

**Sources:**
Boyd 2008 Gewant and Bollens 2005

### 3.5 *Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice:** **B** Disperses moderate (1-10 km) distances

**Score:** 1.75 of 2.5

**High uncertainty?** ☑

**Ranking Rationale:**
This species undergoes direct development and consequently does not have a planktonic larval stage that may assist in its long-distance dispersal. Dispersal distances (either as a result of active or passive transport) are unknown. Given this species' patchy regional distribution, it likely has limited natural dispersal abilities.

**Background Information:**
Information on a related (perhaps synonymous?) species, Synidotea laevidorsalis, believes that this species has a limited ability for long-distance dispersal (Chapman and Carlton 1991). For one, it does not have a planktonic larval stage that would promote dispersal, and it has not been reported drifting in the oceans on wood or vegetation. Its disconnected distribution both regionally and globally suggests that this species' dispersal ability is limited without the help of anthropogenic vectors (Chapman and Carlton 1991). This species can move by swimming and crawling (Boyd 2008).

**Sources:**
Chapman and Carlton 1991 Boyd 2008

### 3.6 *Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice:** **B** Moderate – Exhibits one of the above characteristics

**Score:** 1.75 of 2.5

**Ranking Rationale:**
This species undergoes direct developement and does not have a larval stage. Eggs are brooded by the female. Although both juveniles and adults are capable of dispersal, the mechansims of dispersal are the same across these different life stages.

**Background Information:**
This species undergoes direct development and eggs are brooded (qtd. in Fofonoff et al. 2003). Adults and juveniles can swim and crawl (Boyd 2008).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Boyd 2008

### *3.7 Vulnerability to predators*

**Choice:** **D** Multiple predators present in the Bering Sea or neighboring regions

**Score:** 1.25 **of** 5

**Ranking Rationale:**
This species is eaten by several fish species in its introduced range. We expect that fish in the Bering Sea would predate upon S. laticauda as well.

**Background Information:**
Several fish species eat S. laticauda including perch, catfish, and eel (Boyd 2008).

**Sources:**
Boyd 2008

| | |
|---|---|
| **Section Total - Scored Points:** | 18 |
| **Section Total - Possible Points:** | 25 |
| **Section Total -Data Deficient Points:** | 5 |

# 4. Ecological and Socioeconomic Impacts



### *4.1 Impact on community composition*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**

**Background Information:**
No ecological impacts have been reported for this species.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.2 Impact on habitat for other species*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
Based on its biology, we do not expect this species to affect habitat in the Bering Sea.

**Background Information:**
No ecological impacts have been reported for this species.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.3 Impact on ecosystem function and processes*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**

**Background Information:**
No ecological impacts have been reported for this species.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.4 Impact on high-value, rare, or sensitive species and/or communities*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**

**Background Information:**
No ecological impacts have been reported for this species.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.5 Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not known to transport diseases, parasites, or hitchhikers.

**Background Information:**
No ecological impacts have been reported for this species.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not expected to hybridize with native species in the Bering Sea.

**Background Information:**
No ecological impacts have been reported for this species.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.7 Infrastructure*

**Choice: C** Limited – Has limited potential to cause degradation to infrastructure, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
Although no impacts have been reported, this species is known to foul docks, ships, and fishing equipment, and may have an impact if it occurs at high densities.

**Background Information:**
This species is known to foul anthropogenic structures, including equipment used for oyster cultivation (Bushek and Boyd 2006). No economic impacts have been reported. Where present, this species can reach high densities (Bushek and Boyd 2006).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Bushek and Boyd 2006

### *4.8 Commercial fisheries and aquaculture*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact commercial fishing in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.9 Subsistence*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact subsistence resources in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.101 Recreation*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact recreational opportunities in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.11 Human health and water quality*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact human health or water quality in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 0.75 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 5. Feasibility of prevention, detection and control



### 5.1 *History of management, containment, and eradication*

**Choice:** **C** Attempted; control methods are currently in development/being studied

**Score:** of

**Ranking Rationale:**
No species-specific management plans are in place for controlling this species. However, methods to reduce the spread of invasive species that are transported by ballast water and hull fouling are being studied.

**Background Information:**

**Sources:**
Ruiz and Reid 2007

### 5.2 *Cost and methods of management, containment, and eradication*

**Choice:** **A** Major long-term investment, or is not feasible at this time

**Score:** of

**Ranking Rationale:**
This species is transported by ballast water and fouling. While methods to control the spread of invasive species via these vectors are being developed, they require major long-term investments.

**Background Information:**

**Sources:**
CFR 2017 Hagan et al. 2014 Zagdan 2010

### 5.3 *Regulatory barriers to prevent introductions and transport*

**Choice:** **B** Regulatory oversight, but compliance is voluntary

**Score:** of

**Ranking Rationale:**
This species is transported by multiple vectors and no species-specific regulations are currently in place. Although there are federal regulations for both ballast water and hull fouling, compliance with federal fouling regulations remains voluntary.

**Background Information:**

**Sources:**
Hagan et al. 2014 CFR 2017

### 5.4 *Presence and frequency of monitoring programs*

**Choice:** **A** No surveillance takes place

**Score:** of

**Ranking Rationale:**
No surveillance is taking place for this species.

**Background Information:**
No information found.

**Sources:**
None listed

### 5.5 *Current efforts for outreach and education*

**Choice:** **A** No education or outreach takes place

**Score:** of

**Ranking Rationale:**
No education or outreach programs are in place for this species.

**Background Information:**
No information found.

**Sources:**
None listed

**Section Total - Scored Points:**
**Section Total - Possible Points:**
**Section Total -Data Deficient Points:**

## Literature Cited for *Synidotea laticauda*


- Boyd, S.G. 2008. An ecological assessment of the non-indigenous isopod, Synidotea laticauda, in Delaware bay. M.Sc. Thesis, Rutgers University-New Brunswick, New Brunswick, NJ, U.S.A.
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- Hagan, P., Price, E., and D. King. 2014. Status of vessel biofouling regulations and compliance technologies – 2014. Maritime Environmental Resource Center (MERC) Economic Discussion Paper 14-HF-01.
- Fofonoff, P. W., G. M. Ruiz, B. Steves, C. Simkanin, and J. T. Carlton. 2017. National Exotic Marine and Estuarine Species Information System. http://invasions.si.edu/nemesis/. Accessed: 15-Sep-2017.
- Ruiz, G. M., and D. F. Reid. 2007. Current State of Understanding about the Effectiveness of Ballast Water Exchange (BWE) in Reducing Aquatic Nonindigenous Species (ANS) Introductions to the Great Lakes Basin and Chesapeake Bay, USA: Synthesis and Analysi
- Zagdan, T. 2010. Ballast water treatment market remains buoyant. Water and Wastewater International 25:14-16.

# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Eusarsiella zostericola*

**Common Name** *a free-living benthic ostracod*

| | |
|---|---|
| Phylum | Arthropoda |
| Class | Ostracod |
| Order | Myodocopida |
| Family | Sarsiellidae |

**Final Rank** 33.91

**Data Deficiency:** 13.75

Species Occurrence by Ecoregion

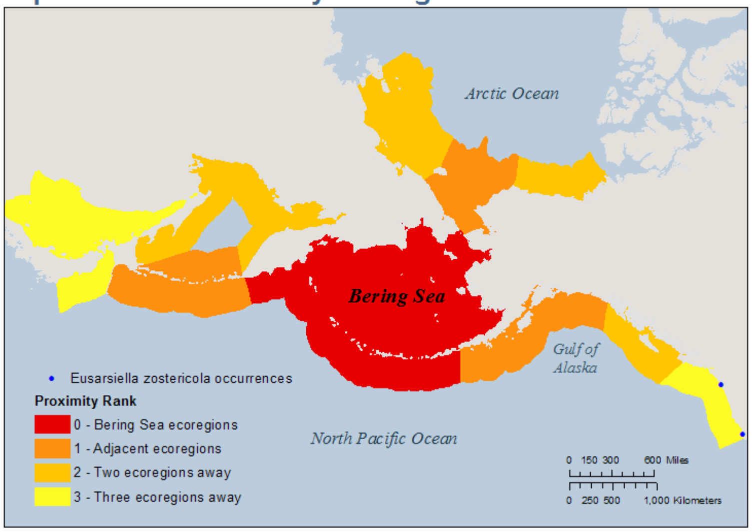


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 15 | 26 | 3.75 |
| Anthropogenic Influence: | 4.75 | 10 | 0 |
| Biological Characteristics: | 9.5 | 20 | 10.00 |
| Impacts: | 0 | 30 | 0 |
| **Totals:** | 29.25 | 86.25 | 13.75 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | 3 | Minimum Salinity (ppt) | 18 |
| Maximum Temperature (°C) | 33 | Maximum Salinity (ppt) | 42 |
| Minimum Reproductive Temperature (°C) | NA | Minimum Reproductive Salinity (ppt) | 31* |
| Maximum Reproductive Temperature (°C) | NA | Maximum Reproductive Salinity (ppt) | 35* |

### Additional Notes

Eusarsiella zostericola is a free-living benthic ostracod. It is native to the East Coast of North America (Nova Scotia to Texas) and has been introduced to California, Washington, England, and the Netherlands. The most likely vector for its introduction is historical transplants of Eastern Oysters (Crassostrea virgnica) from East Coast estuaries. It occurs in coastal marine and estuarine habitats including eelgrass beds, oyster beds, and unstructured sediments such as mud and sand. There are no known ecological and economic impacts of this species.

# 1. Distribution and Habitat



### *1.1 Survival requirements - Water temperature*

**Choice: C** Little overlap – A small area (<25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 1.25 of 3.75

**Ranking Rationale:**
Temperatures required for year-round survival occur in a limited area (<25%) of the Bering Sea.

**Background Information:**
Temperature range required for survival is 3°C to 33ºC (Kornicker 1986).

**Sources:**
Kornicker 1986 NEMESIS; Fofonoff et al. 2003

### *1.2 Survival requirements - Water salinity*

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
E. zostericola is a upper mesohaline to upper euhaline species with a salinity tolerance of 18 ppt to 42 ppt (Kornicker 1986).

**Sources:**
Kornicker 1986 NEMESIS; Fofonoff et al. 2003

### *1.3 Establishment requirements - Water temperature*

**Choice: U** Unknown/Data Deficient

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *1.4 Establishment requirements - Water salinity*

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**High uncertainty?** ☑

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Although salinity thresholds are unknown, this species is a marine organism that does not require freshwater to reproduce. We therefore assume that this species can reproduce in saltwater (31 to 35 ppt). These salinities occur in a large (>75%) portion of the Bering Sea.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *1.5 Local ecoregional distribution*

**Choice: D** Present in an ecoregion greater than two regions away from the Bering Sea

**Score:** 1.25 of 5

**Ranking Rationale:**
Closest known occurrence is in Washington.

**Background Information:**
E. zostericola was first observed on the West Coast in the San Francisco Bay, California in 1953 (Kornicker 1967; Kornicker 1975) where it is widespread and abundant (Foss 2009; Peterson and Vaysierres 2010). It has also been discovered in Humboldt Bay, California (California Department of Fish and Wildlife 2014); and in Willapa Bay Washington in 1999 (Wilson and Partidge 2007; Cohen et al. 2001). It is an invader that was probably introduced with the transplant of the Eastern Oyster at the end of the 19th century (Kornicker 1975).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Kornicker 1967   Kornicker 1975   Foss 2009   Peterson and Vayssieres 2010   California Department of Fish and Wildlife 2014   Wilson and Partridge 2007   Cohen et al. 2001

### *1.6 Global ecoregional distribution*

**Choice: B** In a moderate number of ecoregions globally

**Score:** 3.25 of 5

**Ranking Rationale:**
Distribution is currently limited to North America, England, and the Netherlands.

**Background Information:**
E. zostericolas native range is the East Coast of North America ranging from Nova Scotia to Texas. At the end of the 19th century the Eastern Oyster (Crassotrea virginica) was transplanted to several locations around the world for aquaculture purposes, bringing E. zostericola with it. It is now found where the Eastern Oyster was transplanted in San Francisco Bay, California; Humboldt Bay, California;  Willapa Bay, Washington; the English Channel; and the Netherlands (Kornicker 1975; Cohen et al. 2001; California Department of Fish and Wildlife 2014; Bamber 1987; Faasse 2013).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Kornicker 1975   Cohen et al. 2001   California Department of Fish and Wildlife 2014   Bamber 1987   Faasse 2013

### *1.7 Current distribution trends*

**Choice: C** Established outside of native range, but no evidence of rapid expansion or long-distance dispersal

**Score:** 1.75 of 5

**Ranking Rationale:**
Small-scale expansion has been observed in localized areas of invasion.

**Background Information:**
Little potential for long-term dispersal as it has limited swimming ability and is rare in ballast water (Carlton and Geller 1993).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Carlton and Geller 1993

| | |
|---|---|
| **Section Total - Scored Points:** | 15 |
| **Section Total - Possible Points:** | 26.25 |
| **Section Total -Data Deficient Points:** | 3.75 |

## 2. Anthropogenic Transportation and Establishment



### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice:** **B** Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 of 4

**Ranking Rationale:**

**Background Information:**
Transportation of E. zostericola is likely related to transplants of Eastern Oysters (Crassostrea virgnica), from East Coast estuaries to the West Coast and Europe, in the late 19th and early 20th centuries (Kornicker 1975).

**Sources:**
Kornicker 1975 NEMESIS; Fofonoff et al. 2003

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice:** **B** Readily establishes in areas with anthropogenic disturbance/infrastructure; occasionally establishes in undisturbed areas

**Score:** 2.75 of 4

**High uncertainty?** ✔

**Ranking Rationale:**
Given its limited dispersal ability, this species likely retains a close association with anthropogenic habitats in its introduced range. Information on this distribution and spread of this species is lacking.

**Background Information:**
This species was likely accidentally introduced to the west coast of North America with the introduction of Eastern Oysters (Crassostrea virginica) for aquaculture (Fofonoff et al. 2003). Habitats include unstructured sediments (e.g. silt, sand), oyster beds, eelgrass, and hydroids (Fofonoff et al. 2003). This species has limited swimming and dispersal ability.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice:** **B** No

**Score:** 0 of 2

**Ranking Rationale:**

**Background Information:**
This species is not currently farmed or intentionally cultivated.

**Sources:**
None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 4.75 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics



### 3.1 Dietary specialization

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
Information on E. zostericola prey and forage is lacking in the literature. It is thought to be a carnivore, as one reported specimen contained a harpacticoid copepod (Wass 1972; Kornicker 1967; Kornicker 1986).

**Sources:**
Kornicker 1986   NEMESIS; Fofonoff et al. 2003   Wass 1972   Kornicker 1967

### 3.2 Habitat specialization and water tolerances

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **A** Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 of 5

**Ranking Rationale:**
Can tolerate a wide range of temperatures and salinities and has been recorded in a variety of habitats.

**Background Information:**
E. zostericola has a wide range of temperature and salinity tolerances at 3 to 33°C and 18 to 42 ppt (Kornicker 1986). It is also found at a wide range depths of 0.18 to 44.5 m. Its habitats include unstructured sediments, oyster beds, eelgrass, beds, mangroves, and hydroids.

**Sources:**
Kornicker 1986   NEMESIS; Fofonoff et al. 2003

### 3.3 Desiccation tolerance

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 3.4 Likelihood of success for reproductive strategy

i. Asexual or hermaphroditic   ii. High fecundity (e.g. >10,000 eggs/kg)   iii. Low parental investment and/or external fertilization   iv. Short generation time

**Choice:** **C** Low – Exhibits none of the above characteristics

**Score:** 1.75 of 5

**Ranking Rationale:**
Sexual reproduction, low fecundity, internal fertilization, generation time unknown.

**Background Information:**
Eusarsiella zostericola has separate sexes and internal fertilization. Females have 5 to 16 eggs that are brooded (Kornicker 1967; Bamber 1987).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Kornicker 1967   Bamber 1987

### 3.5 *Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice:** **C** Disperses short (< 1 km) distances

**Score:** 0.75 of 2.5

**Ranking Rationale:**

**Background Information:**
Benthic ostracods have limited swimming ability and dispersal rates (Kornicker 1967).

**Sources:**
Kornicker 1967

### 3.6 *Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice:** **C** Low – Exhibits none of the above characteristics

**Score:** 0.75 of 2.5

**High uncertainty?** ☑

**Ranking Rationale:**
Low mobility, larval viability window is unknown, dispersal is through swimming very short distances.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 3.7 *Vulnerability to predators*

**Choice:** **D** Multiple predators present in the Bering Sea or neighboring regions

**Score:** 1.25 of 5

**Ranking Rationale:**
Numerous predatory, many of which exist in the Bering Sea.

**Background Information:**
Consumed by fishes and invertebrates (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 9.5 |
| **Section Total - Possible Points:** | 20 |
| **Section Total -Data Deficient Points:** | 10 |

## 4. Ecological and Socioeconomic Impacts



### *4.1 Impact on community composition*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**

**Background Information:**
There are no known ecological impacts of Eusarsiella zostericola (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.2 Impact on habitat for other species*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**

**Background Information:**
There are no known ecological impacts of Eusarsiella zostericola (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.3 Impact on ecosystem function and processes*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**

**Background Information:**
There are no known ecological impacts of Eusarsiella zostericola (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.4 Impact on high-value, rare, or sensitive species and/or communities*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**

**Background Information:**
There are no known ecological impacts of Eusarsiella zostericola (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.5 Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice:** **D** No impact

**Score:** **0** **of** **2.5**

**Ranking Rationale:**

**Background Information:**
The are no known diseases, parasites or travelers associated with E. zostericola (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice:** **D** No impact

**Score:** **0** **of** **2.5**

**Ranking Rationale:**

**Background Information:**
There are no known genetic impacts associated with E. zostericola (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.7 Infrastructure*

**Choice:** **D** No impact

**Score:** **0** **of** **3**

**Ranking Rationale:**

**Background Information:**
There are no documented cases of impact on infrastructure by E. zostericola (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.8 Commercial fisheries and aquaculture*

**Choice:** **D** No impact

**Score:** **0** **of** **3**

**Ranking Rationale:**

**Background Information:**
There are no documented cases of impact on commercial fisheries or aquaculture by E. zostericola (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.9 Subsistence*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**

**Background Information:**
There are no documented cases of impact on subsistence activities by E. zostericola (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.101 Recreation*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**

**Background Information:**
There are no documented cases of impact on recreation by E. zostericola (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.11 Human health and water quality*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**

**Background Information:**
There are no documented cases of impact on human health or water quality by E. zostericola (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 0 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 5. Feasibility of prevention, detection and control

### *5.1 History of management, containment, and eradication*

**Choice:** **B** Not attempted

**Score:** of

**Ranking Rationale:**

**Background Information:**
There is no indication in the literature that management, containment or eradication efforts exist for E. zostericola.

**Sources:**
None listed

### *5.2 Cost and methods of management, containment, and eradication*

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
Restrictions on oyster farming would be a form of preventative management, however, the cost of these efforts is unknown.

**Sources:**
None listed

### *5.3 Regulatory barriers to prevent introductions and transport*

**Choice:** **A** Little to no regulatory restrictions

**Score:** of

**Ranking Rationale:**

**Background Information:**
Regulations exist restricting the trade and movement of oysters and oyster seed for cultivation, however, no regulations pertaining to E. zostericola in particular exist.

**Sources:**
None listed

### *5.4 Presence and frequency of monitoring programs*

**Choice:** **A** No surveillance takes place

**Score:** of

**Ranking Rationale:**

**Background Information:**
No species-specific monitoring programs exist for E. zostericola.

**Sources:**
None listed

### *5.5 Current efforts for outreach and education*



**Choice: A** No education or outreach takes place

**Score:** of

**Ranking Rationale:**

**Background Information:**

No species-specific efforts for outreach or education exist.

**Sources:**

None listed

**Section Total - Scored Points:**

**Section Total - Possible Points:**

**Section Total -Data Deficient Points:**

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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Palaemon macrodactylus*

**Common Name** *oriental shrimp*

| | |
|---|---|
| **Phylum** | Arthropoda |
| **Class** | Malacostraca |
| **Order** | Decapoda |
| **Family** | Palaemonidae |

**Final Rank** 49.87

**Data Deficiency:** 3.75

### Species Occurrence by Ecoregion

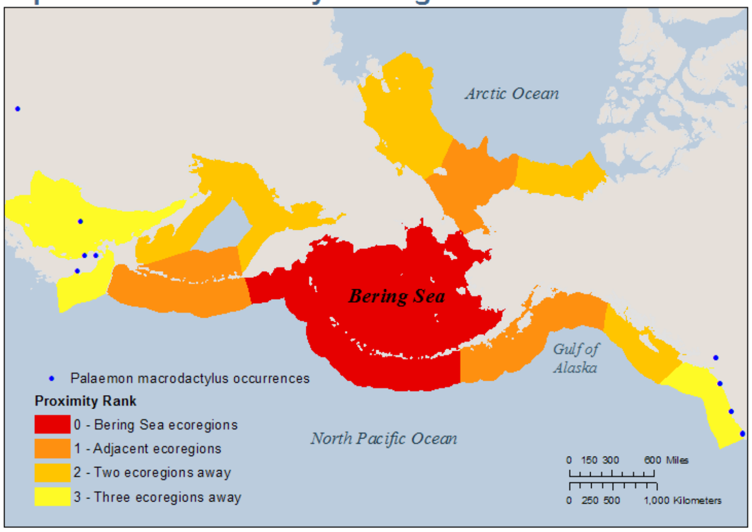


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 20 | 26 | 3.75 |
| Anthropogenic Influence: | 6.75 | 10 | 0 |
| Biological Characteristics: | 20.5 | 30 | 0 |
| Impacts: | 0.75 | 30 | 0 |
| **Totals:** | 48.00 | 96.25 | 3.75 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | 2 | Minimum Salinity (ppt) | 0.7 |
| Maximum Temperature (°C) | 33 | Maximum Salinity (ppt) | 51 |
| Minimum Reproductive Temperature (°C) | NA | Minimum Reproductive Salinity (ppt) | 3 |
| Maximum Reproductive Temperature (°C) | NA | Maximum Reproductive Salinity (ppt) | 34 |

### Additional Notes

Palaemon macrodactylus is commonly known as the Oriental shrimp. Its body is transparent with a reddish hue in the tail fan and antennary area. Females tend to be larger than males and have more pigmentation, with reddish spots all over their body, and a whitish longitudinal stripe that runs along the back. Females reach a maximum size of 45-70 mm, compared to 31.5-45 mm for males (Vazquez et al. 2012, qtd. in Fofnoff et al. 2003).

# 1. Distribution and Habitat



### 1.1 Survival requirements - Water temperature

**Choice:** **C** Little overlap – A small area (<25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 1.25 of 3.75

**Ranking Rationale:**
Temperatures required for year-round survival occur in a limited area (<25%) of the Bering Sea.

**Background Information:**
The optimal temperature range for survival is between 14 and 26°C (Newman 1963). However, this species can tolerate temperatures from 2°C (Ashelby 2011) to 33°C (experimental data, Lejeusne et al. 2014).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Ashelby 2011 Lejeusne et al. 2014 Newman 1963

### 1.2 Survival requirements - Water salinity

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
The salinity threshold for survival of P. macrodactylus is 0.7 PSU to 51 PSU.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 1.3 Establishment requirements - Water temperature

**Choice:** **U** Unknown/Data Deficient

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 1.4 Establishment requirements - Water salinity

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for reproduction occur over a large (>75%) area of the Bering Sea.

**Background Information:**
The salinity threshold for reproduction of P. macrodactylus is 3 to 34 PSU (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

## *1.5 Local ecoregional distribution*



**Choice: D** Present in an ecoregion greater than two regions away from the Bering Sea

**Score:** 1.25 of 5

**Ranking Rationale:**
Closest known occurences in British Columbia and the Sea of Japan.

**Background Information:**
On North America's Pacific coast, currently ranges from Boundary Bay, British Columbia (49ºN) south to the Tijuana Estuary (San Diego County), California. Also found in the Sea of Japan, north to Peter the Great Bay.

**Sources:**
Ashelby et al. 2013

## *1.6 Global ecoregional distribution*

**Choice: A** In many ecoregions globally

**Score:** 5 of 5

**Ranking Rationale:**
Wide global distribution.

**Background Information:**
Native to northeast Asia (Japan, Korea, Peter the Great Bay in southern Russia). First introduction was in San Francisco Bay in 1957. Now found in Australia, Atlantic and North Sea coasts of Europe (south to Spain), the Black Sea, the Mediterranean Sea, Argentina, and the eastern U.S.

**Sources:**
Ashelby et al. 2013

## *1.7 Current distribution trends*

**Choice: A** Recent rapid range expansion and/or long-distance dispersal (within the last ten years)

**Score:** 5 of 5

**Ranking Rationale:**
Recent documentation of long-distance dispersal and recent range expansion.

**Background Information:**
First found in San Francisco Bay in 1957. 5 years later it was discovered in Los Angeles Harbor in 1962 (Cohen and Carlton 1995). This may be due to introductions from either San Francisco Bay or Asia (Standing 1981), or as a natural dispersal event, going undetected in between the two locations (Ashelby et al. 2013).

**Sources:**
Ashelby et al. 2013   Cohen and Carlton 1995   Standing 1981

| | |
|---|---|
| **Section Total - Scored Points:** | 20 |
| **Section Total - Possible Points:** | 26.25 |
| **Section Total -Data Deficient Points:** | 3.75 |

## 2. Anthropogenic Transportation and Establishment



*2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice: B** Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 of 4

**Ranking Rationale:**
Readily transported in ballast water with an ability to disperse once established.

**Background Information:**
As most recent records are from the vicinity of large, international harbors, it is most likely that introduction to these regions is shipping mediated, as a result of transport in ballast water or as a fouling organism within sea water intakes or sea chests. However, there are some reports that suggest P. macrodactylus has dispersed to areas independently of human activities (Lavesque et al. 2010).

**Sources:**
Ashelby et al. 2013   Lavesque et al. 2010

*2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice: B** Readily establishes in areas with anthropogenic disturbance/infrastructure; occasionally establishes in undisturbed areas

**Score:** 2.75 of 4

**Ranking Rationale:**
Frequently establishes in ports or harbors, with few records outside of known shipping areas.

**Background Information:**
Often uses manmade structures e.g. pilings, walls, debris as habitat (Crooks et al. 2016). In its introduced range, most records are near international harbours or in areas of high shipping traffic, but others, such as France's Arcachon Bay, may be the result of passive transport by water currents (Lavesque et al. 2010).

**Sources:**
Lavesque et al. 2010   Crooks et al. 2016   NEMESIS; Fofonoff et al. 2003

*2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice: A** Yes

**Score:** 2 of 2

**Ranking Rationale:**

**Background Information:**
P. macrodactylus is sold as food in Japan (Fofonoff et al. 2003). No market currently exists in North America.

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 6.75 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics

### *3.1 Dietary specialization*

**Choice:** **A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Feeds on numerous taxa readily available in the Bering Sea.

**Background Information:**
P. macrodactylus predates on mysids, copepods, amphipods, barnacles, polychaetes, small bivalves, fish larvae, and insect larvae. While they are omnivorous, majority of their diet is made up of animals (Ashelby et al. 2013).

**Sources:**
Ashelby et al. 2013

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **A** Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 of 5

**Ranking Rationale:**
Tolerates a wide range of temperatures and salinities and has been recorded in multiple habitats.

**Background Information:**
Tolerates wide ranges of temperature and salinity and is particularly tolerant of hypoxic conditions (González-Ortegón and Cuesta 2006). P. macrodactylus has been captured in freshwater (Siegfried 1980), whereas in Argentina, it inhabits fully saline (32-37PSU) conditions (Vázquez et al. 2012). In Mar del Plata Harbor, environmental conditions correspond to those of a polluted site with high water turbidity, low dissolved oxygen and low pH (Vázquez et al. 2012).

P. macrodactylus prey mainly at night. During the day, can often be found hiding under or in between rocks and crevices, reefs built by shellfish or polychaetes, or in dense algal vegetation.

**Sources:**
Ashelby et al. 2013   González-Ortegón and Cuesta 2006   Micu and Niţă 2009   Vázquez et al. 2012

### *3.3 Desiccation tolerance*

**Choice:** **C** Little to no tolerance (<1 day) of desiccation during its life cycle

**Score:** 1.75 of 5

**Ranking Rationale:**
Survives less than a day out of water.

**Background Information:**
No species-specific information was found in the literature regarding the desiccation tolerance of P. macrodactylus. Laboratory studies for other shrimp species suggest desiccation tolerances of up to 90 minutes (Athyaephyra desmaresti; Banha and Anastácio 2012) and 5 to 10 hours (Marsupenaeus japonicas; Duan et al. 2016).

**Sources:**
Banha and Anastácio 2012   Duan et al. 2016

### *3.4 Likelihood of success for reproductive strategy*



i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice: B** Moderate – Exhibits one or two of the above characteristics

**Score:** 3.25 of 5

**Ranking Rationale:**

Sexual reproduction, internal fertilization, high fecundity, high parental investment and internal fertilization, short generation time.

**Background Information:**

P. macrodactylus have sexual reproduction during a long spawning season lasting from mid-April to October (Omori and Chida 1988). Females can spawn 1- 2 times per season in their first year. This increases to 5-9 times per season in their second year with a lifespan of two to three years (Omori and Chida 1988; Micu and Niţă 2009; Ashelby et al. 2013). Brood sizes range from 100 to 2000 (Siegfried 1980).

**Sources:**

Ashelby et al. 2013 Micu and Niţă 2009 Omori and Chida 1988 Siegfried 1980 Vázquez et al. 2009 NEMESIS; Fofonoff et al. 2003

### *3.5 Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice: A** Disperses long (>10 km) distances

**Score:** 2.5 of 2.5

**Ranking Rationale:**

Can disperse up to 71 km.

**Background Information:**

Eggs are brooded internally and hatch as planktonic larvae. Larvae undergo 5 to 7 stages of development before metamorphosis into post-larvae or juveniles, which they reach between 10 to 18 days after hatching (Little 1969). Both larvae and post-larvae can swim; post-larvae can also crawl on the benthos (Little 1969).

Lavesque et al. (2010) proposed that adult and/or larvae P. macrodactylus could disperse to new sites up to 71 km for a source location over several years, if assisted by water currents. Ashelby et al. (2013) propose that colonization of new sites in Australia could have been achieved by natural dispersal: distances between the source location and new sites (20 to 50 km) are well within the natural dispersal distances proposed by Lavesque et al. (2010) based on European spread, and could have been easily achieved in the 10 years that elapsed between the introduction to Newcastle and the discovery at Vales Point. Similarly, Lejeusne et al. (2014b) propose that populations in the Guadalquivir River may have naturally dispersed to the Guadiana River (100 km west) over the course of 10 years.

Micu and Niţă (2009) suggest that adults are not extremely mobile: under laboratory conditions, they observed that the Asian prawn is more benthic and cryptic than native species, preferring to walk rather than swim whenever possible, hiding in deep and narrow recesses during the day, and hunting only at night. According to Ashelby (2011), P. macrodactylus is unlikely to reach distant locations via natural means, but once introduced to a region can spread naturally via larval dispersal or short migrations.

**Sources:**

Ashelby 2011 Ashelby et al. 2013 Lavesque et al. 2010 Lejeusne et al. 2014 Micu and Niţă 2009 Little 1969

### 3.6 *Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: B** Moderate – Exhibits one of the above characteristics

**Score:** 1.75 of 2.5

**Ranking Rationale:**
Can disperse at more than one life stage but are not highly mobile, larval viability window (planktonic larval stage) is long, different modes of dispersal are achieved at different life stages, however, significant migrations do not occur in this species.

**Background Information:**
No potential for egg dispersal, as fertilization is internal and eggs are brooded. Planktonic larval stage is long-lived (10 to 18 days), and all life stages are mobile. Larvae and adults can swim and/or crawl, and both can be passively transported by water currents (Lavesque et al. 2010). Significant migrations do not occur in this species, but annual expansions and contractions of the spatial distribution of this species within a waterway has been observed, as the species follows preferred salinity gradients (Béguer et al. 2011).

**Sources:**
Ashelby 2011 Lavesque et al. 2010 Béguer et al. 2011

### 3.7 *Vulnerability to predators*

**Choice: D** Multiple predators present in the Bering Sea or neighboring regions

**Score:** 1.25 of 5

**Ranking Rationale:**
Numerous predators, many of which exist in the Bering Sea.

**Background Information:**
In California, P. macrodactylus is an important prey item for the striped bass (Ganssle 1966 as qtd. in Ashelby 2011; Ricketts et al. 1968 as qtd. in Ashelby 2011). Its larvae is also a prey item for Crangon franciscorum (Siegfried 1980). Around the world it is likely that P. macrodactylus is preyed upon by fish and birds with its larvae preyed upon by other estuarine planktivores.

**Sources:**
Ashelby 2011 Siegfried 1980

| | |
|---|---|
| **Section Total - Scored Points:** | 20.5 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 4. Ecological and Socioeconomic Impacts

### 4.1 Impact on community composition

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
May cause a decrease in local populations due to competitive effects.

**Background Information:**
In the Gironde Estuary, France, it was first noted that P. macrodactylus exploits a niche that is under-utilized by the native P. longiriostris (Béguer et al. 2011). However, competition between these two species was cited as a possible reason for the decline in abundance of P. longirostris (Béguer et al. 2012). This may be due to P. macrodactylus having a higher tolerance to hypoxia, a wider temperature range, and a more efficient metabolism than the native species (Gonzalez-Ortegon et al. 2010; Lejeusne et al. 2014).

In San Francisco Bay, crangonid shrimp dominate. P. macrodactylus, a palaemonid shriimp, is expected to have little impact as it occupies a different ecological niche. However, it has been noted that the two species do have a dietary overlap (Sitts and Knight 1979; Siegfried 1980). As of 1986 P. macrodactylus is now more numerous than the larger native Crangon spp. (Ricketts et al. 1968 as qtd. in Ashelby et al. 2013).

**Sources:**
Ashelby et al. 2013   Siegfried 1980   Gonzalez-Ortegon et al. 2010   Lejeusne et al. 2014   Béguer et al. 2011   Béguer et al. 2012   Sitts and Knight 1979

### 4.2 Impact on habitat for other species

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
To date, no impacts on habitat for other species have been reported for P. macrodactylus.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 4.3 Impact on ecosystem function and processes

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
To date, no impacts ecosystem functions and processes have been reported for P. macrodactylus.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.4 Impact on high-value, rare, or sensitive species and/or communities*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
To date, no impacts on high-value, rare, or sensitive species have been reported for P. macrodactylus.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.5 Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice:** **C** Limited – Has limited potential to spread one or more organisms, with limited impact and/or within a very limited region

**Score:** 0.75 of 2.5

**Ranking Rationale:**
P. macrodactylus is known to carry parasites and disease, however, transmission to native species has not been documented yet.

**Background Information:**
In Argentina, P. macrodactylus had high instances of infection by white spot syndrome virus (Martorelli et al. 2012). It also plays a role as a second intermediate host for Odhneria sp, a parasite (Martorelli et al. 2012). The spread of these parasites to native species has not yet been documented.

**Sources:**
Ashelby et al. 2013 Martorelli et al. 2012

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
To date, no hybridization has been reported for P. macrodactylus.

**Background Information:**
A laboratory study observed hybridization between two Palaemon species (P. adspersus × P. squilla), however, viable offspring were not supported (Berglund). No species-specific studies have investigated the hybridization of P. macrodactylus, and no records of hybridization with native species have been reported.

**Sources:**
Berglund 1984

### *4.7 Infrastructure*



**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on infrastructure have been reported for P. macrodactylus.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.8 Commercial fisheries and aquaculture*

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on fisheries and aquaculture have been reported for P. macrodactylus.

**Background Information:**
There are no known negative economic impacts; however, its potential effect on fisheries of native shrimp species should be monitored. In France, P. longirostris is fished, and samples from commercial fishermen in 2005 and 2007 showed that approximately 95% of the collected shrimps belong to the native species P. longirostris (Béguer et al. 2011).

**Sources:**
Ashelby et al. 2013 Béguer et al. 2011

### *4.9 Subsistence*

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on subsistence have been reported for P. macrodactylus.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.101 Recreation*

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on recreation have been reported for P. macrodactylus.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.11 Human health and water quality*



**Choice:** **D** No impact

**Score:** **0** of **3**

**Ranking Rationale:**

To date, no impacts on human health or water quality have been reported for P. macrodactylus.

**Background Information:**

No information available in the literature.

**Sources:**

None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 0.75 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 5. Feasibility of prevention, detection and control



### *5.1 History of management, containment, and eradication*

**Choice:** **B** Not attempted

**Score:** of

**Ranking Rationale:**

**Background Information:**
There are no published accounts of attempts to manage, contain or eradicate this species.

**Sources:**
None listed

### *5.2 Cost and methods of management, containment, and eradication*

**Choice:** **A** Major long-term investment, or is not feasible at this time

**Score:** of

**Ranking Rationale:**
Eradication is most likely impossible.

**Background Information:**
P. macrodactylus is hard to control as it is a mobile species with pelagic larvae. As such, no species specific containment strategies have been suggested, tried, or developed. Non specific control measures would have an adverse effect on other fauna as well as P. macrodactylus.

**Sources:**
Ashelby 2011

### *5.3 Regulatory barriers to prevent introductions and transport*

**Choice:** **A** Little to no regulatory restrictions

**Score:** of

**Ranking Rationale:**
No regulation exist fro P. macrodactylus.

**Background Information:**
There are no monitoring programs specifically designed for detection or monitoring the spread of P. macrodactylus. This species my also be overlooked during routine monitoring surveys and rapid assessments. For example, in the UK, routine invertebrate sampling uses methods that would be unlikely to detect the species, while trawl and net samples that are capable of detecting this species are often examined for fish only.

**Sources:**
Ashelby 2011

### *5.4 Presence and frequency of monitoring programs*

**Choice:** **A** No surveillance takes place

**Score:** of

**Ranking Rationale:**

**Background Information:**
No surveillance or monitoring programs currently exist for P. macrodactylus.

**Sources:**
None listed

### 5.5 *Current efforts for outreach and education*



**Choice: A** No education or outreach takes place

**Score:** of

**Ranking Rationale:**

**Background Information:**

There are currently no education or outreach programs associated with raising awareness about P. macrodactylus. Ashelby (2011) suggests that awareness of P. macrodactylus is still largely confined to the scientific community and even within the scientific community, it is generally unknown and not present in most standard identification guides, therefore it may be easily overlooked.

**Sources:**

Ashelby 2011

**Section Total - Scored Points:**

**Section Total - Possible Points:**

**Section Total -Data Deficient Points:**

## Literature Cited for *Palaemon macrodactylus*


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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Sinelobus cf. stanfordi*

**Common Name** *a tube-building crustacean*

| | |
|---|---|
| **Phylum** | Arthropoda |
| **Class** | Malacostraca |
| **Order** | Tanaidacea |
| **Family** | Tanaididae |

**Final Rank** 50.42

**Data Deficiency:** 11.25

### Species Occurrence by Ecoregion

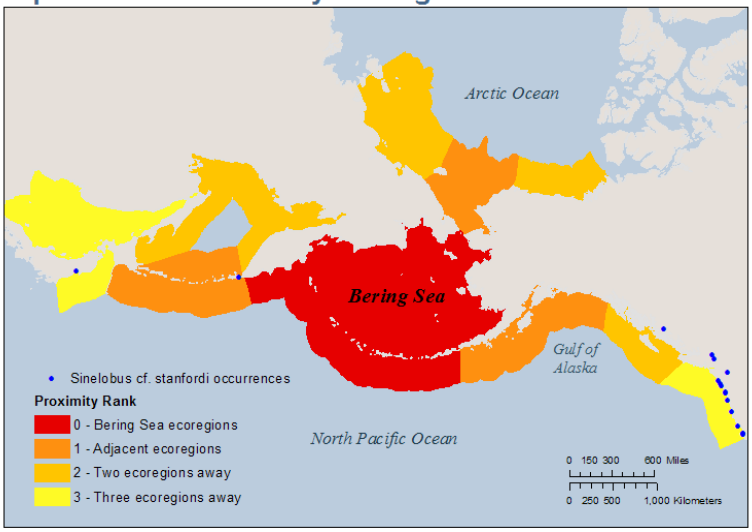


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 23.25 | 26 | 3.75 |
| Anthropogenic Influence: | 4.75 | 10 | 0 |
| Biological Characteristics: | 16 | 25 | 5.00 |
| Impacts: | 0.75 | 28 | 2.50 |
| **Totals:** | 44.75 | 88.75 | 11.25 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | -2 | Minimum Salinity (ppt) | 0 |
| Maximum Temperature (°C) | 27 | Maximum Salinity (ppt) | 52 |
| Minimum Reproductive Temperature (°C) | NA | Minimum Reproductive Salinity (ppt) | 31* |
| Maximum Reproductive Temperature (°C) | NA | Maximum Reproductive Salinity (ppt) | 35* |

### Additional Notes

S. stanfordi is tanaid crustacean with a cylindrical body comprised of three sections: a cephalothorax, a thorax and an abdomen. Native range is unknown and is considered cyptogenic throughout its range except on the North American West Coast where it is considered an invader. It is a tube-building species that prefers soft substrates and can be found around the world due to a wide range of temperature and salinity tolerances.

# 1. Distribution and Habitat



### 1.1 *Survival requirements - Water temperature*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 3.75 **of** 3.75

**Ranking Rationale:**
Temperatures required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
The temperature range for survival of S. stanfordi is -2°C to 27°C (Levings and Rafi 1978; Cohen et al. 2002).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Levings and Rafi 1978 Cohen et al. 2002

### 1.2 *Survival requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 **of** 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
According to field measurements, the salinity range for survival is 3.7 ppt to 36.5 ppt (Levings and Rafi 1978; Cohen et al. 2002). While 3.7 ppt is the lowest reported value for Sinelobus cf. stanfordi, other Sinelobus spp. have established in freshwater.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Levings and Rafi 1978 Cohen et al. 2002

### 1.3 *Establishment requirements - Water temperature*

**Choice:** **U** Unknown/Data Deficient

**Score:** **of**

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 1.4 *Establishment requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**High uncertainty?** ☑

**Score:** 3.75 **of** 3.75

**Ranking Rationale:**
Although salinity thresholds are unknown, this species is a marine organism that does not require freshwater to reproduce. We therefore assume that this species can reproduce in saltwater (31 to 35 ppt). These salinities occur in a large (>75%) portion of the Bering Sea.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *1.5 Local ecoregional distribution*

**Choice: B** Present in an ecoregion adjacent to the Bering Sea

**Score:** 3.75 of 5

**Ranking Rationale:**

**Background Information:**
Reported in the Sea of Okhotsk. Also found on the North American west coast from California to British Columbia.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.6 Global ecoregional distribution*

**Choice: A** In many ecoregions globally

**Score:** 5 of 5

**Ranking Rationale:**
Wide global distribution.

**Background Information:**
Native distribution is unknown, but first described from a species collected in southern Mexico. Occurs along the Pacific and Atlantic coasts of central and southern America. In North America, is considered an invader in a few East and West coast states and provinces, including British Columbia, California, Oregon, Washington, and South Carolina. It has also been collected in New Zealand, in the South China Sea, in Japan, and the Sea of Okhotsk. In Europe, occurs in the Netherlands, Belgium, and Germany (van Haaren and Soors 2009; Bamber 2014).

**Sources:**
NEMESIS; Fofonoff et al. 2003 van Haaren and Soors 2009 Bamber 2014

### *1.7 Current distribution trends*

**Choice: B** History of rapid expansion or long-distance dispersal (prior to the last ten years)

**Score:** 3.25 of 5

**Ranking Rationale:**
Rapid expansion along the west coast between 1943 and 2001. No recent information on expansion or dispersal.

**Background Information:**
S. stanfordi has likely been transported around the world for hundreds of years due to solid ballast, hull fouling, ballast water, and aquaculture transplants (Sytsma et al. 2004).

**Sources:**
van Haaren and Soors 2009 Sytsma et al. 2004

| | |
|---|---|
| **Section Total - Scored Points:** | 23.25 |
| **Section Total - Possible Points:** | 26.25 |
| **Section Total -Data Deficient Points:** | 3.75 |

## 2. Anthropogenic Transportation and Establishment



### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice:** **B** — Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 **of** 4

**Ranking Rationale:**
Is readily transported through ballast water and hull fouling, however, S. stanfordi has poor natural dispersal abilities.

**Background Information:**
Dispersal vectors include ballast water and hull fouling (van Haaren and Soors 2009). Natural dispersal ability low as it has no larval form of dispersal, no pelagic stage, and limited swimming capacity (Larsen et al. 2014).

**Sources:**
van Haaren and Soors 2009   Larsen et al. 2014

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice:** **B** — Readily establishes in areas with anthropogenic disturbance/infrastructure; occasionally establishes in undisturbed areas

**Score:** 2.75 **of** 4

**High uncertainty?** ☑

**Ranking Rationale:**
Given the poor dispersal ability of individuals, populations likely stay close to their point of introduction.

**Background Information:**
S. stanfordi has been observed primarily in harbors, estuaries and ports where they have been brought in via anthropogenic vectors. Individuals have also been collected from bivalves, plants (e.g. algae, rushes), rocks, and within the canals of sponges (Gardiner 1975).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Gardiner 1975

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice:** **B** — No

**Score:** 0 **of** 2

**Ranking Rationale:**

**Background Information:**
This species is not currently farmed or intentionally cultivated.

**Sources:**
None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 4.75 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics



### 3.1 Dietary specialization

**Choice:** **A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Consumes several taxa, many of which are readily available in the Bering Sea.

**Background Information:**
S. stanfordi is a deposit feeder that feeds on detritus and benthic microalgae (Barnes 1983 as qtd. In Fofonoff et al. 2003; Heiman et al. 2008). It has also been reported feeding on hydroids (Toniollo and Masunari 2007).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Heiman et al. 2008 Toniollo and Masunari 2007

### 3.2 Habitat specialization and water tolerances

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **A** Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 of 5

**Ranking Rationale:**
Tolerant of a wide range of temperatures and salinities and recorded in several different habitats.

**Background Information:**
S. stanfordi is able to withstand a wide range of temperatures and salinities, living in a habitat that fluctuated daily from 3.6 to 32.5 PSU (van Haaren and Soors 2009). As a tube-building species it prefers silt and fine sediments but can also be found on mangroves, coral rock, aquatic vegetation, canals, and freshwater lakes and streams (Gardiner 1975; Quinn and Hickey 1990; García-Madrigal et al. 2004; Hendrickx and Ibarra 2008; van Haaren and Soors 2009).

Is sensitive to anthropogenic pollution. In Argentina abundance of S. stanfordi was significantly lower in sites with high levels of nutrient or oxygen demands (Ambrosio et al. 2014). Turbidity and conductivity did not appear to limit distribution (Ambrosio et al. 2014).

**Sources:**
NEMESIS; Fofonoff et al. 2003 van Haaren and Soors 2009 Gardiner 1975 Quinn and Hickey 1990 García-Madrigal et al. 2004 Hendrickx and Ibarra 2008

### 3.3 Desiccation tolerance

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 3.4 *Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice: B** Moderate – Exhibits one or two of the above characteristics

**Score:** 3.25 of 5

**Ranking Rationale:**
Sexual reproduction, moderate parental investment, internal fertilization, short generation time.

**Background Information:**
Reproduces sexually. Brood is kept in maternal pouch. Laboratory experiments suggest that females can breed at least twice during their 35-day lifespan (Toniollo and Masunari 2007).

**Sources:**
Toniollo and Masunari 2007

### 3.5 *Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice: C** Disperses short (< 1 km) distances

**Score:** 0.75 of 2.5

**Ranking Rationale:**

**Background Information:**
Tanaids have a poor dispersal ability as they have direct development, no pelagic stage, and a limited swimming capacity (Larsen et al. 2014).

**Sources:**
Larsen et al. 2014

### 3.6 *Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: C** Low – Exhibits none of the above characteristics

**Score:** 0.75 of 2.5

**Ranking Rationale:**
Direct development from egg (borne in maternal pouch) to juvenile/adult life stage. Low dispersal potential at all life stages.

**Background Information:**
S. stanfordi have no larval dispersal, no pelagic stage, and only limited swimming ability (Larsen et al. 2014).

**Sources:**
Larsen et al. 2014

### *3.7 Vulnerability to predators*



**Choice: D** Multiple predators present in the Bering Sea or neighboring regions

**Score:** 1.25 **of** 5

**Ranking Rationale:**
Numerous predators, many of which exist in the Bering Sea.

**Background Information:**
Important prey item for fishes and shorebirds such as the Mississippi Silverside (50% of diet), Yellowfin Goby (25% of diet), and Western Sandpiper (Howe and Simenstad 2007; Cohen and Bollens 2008; Sewell 1996).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Howe and Simenstad 2007 Cohen and Bollens 2008 Sewell 1996

| | |
|---|---|
| **Section Total - Scored Points:** | 16 |
| **Section Total - Possible Points:** | 25 |
| **Section Total -Data Deficient Points:** | 5 |

# 4. Ecological and Socioeconomic Impacts



### 4.1 *Impact on community composition*

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
To date, no ecological impacts have been reported (Fofonoff et al. 2003).

**Background Information:**
Given abundance, are likely a very important food item for predators. Can occur in very high densities, and collection samples on natural substrates often include over 1000 individuals (and sometimes over 10 000; van Haaren and Soors 2009). On silt, clay or sandy bottoms their numbers are lower. In The Netherlands, Belgium, Japan, and Canada (BC), S. stanfordi was observed co-occurring with one or more Corophiidae amphipods. In the Gamo lagoon, Japan, the tubes of Corophium uenoi were built on a different substrate (filamentous algae) than the tubes of S. stanfordi (concrete embankment). van Haaren and Soors (2009) write that competition between corophiid species and S. stanfordi should not be excluded, as they both build their silty tubes on hard substrates and probably feed on the same food.

**Sources:**
NEMESIS; Fofonoff et al. 2003 van Haaren and Soors 2009

### 4.2 *Impact on habitat for other species*

**Choice: C** Limited – Has limited potential to cause changes in one or more habitats

**Score:** 0.75 of 2.5

**Ranking Rationale:**
At high densities, there is the potential for S. stanfordi to degrade habitat for other species.

**Background Information:**
In West Coast estuaries, can reach high densities up 68,000 m3. could also be a potential prey item for fishes and shorebirds (Levings and Rafi 1978).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Levings and Rafi 1978

### 4.3 *Impact on ecosystem function and processes*

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No ecological or economic impacts have been reported (Fofonoff et al. 2003).

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.4 Impact on high-value, rare, or sensitive species and/or communities*



**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No ecological or economic impacts have been reported (Fofonoff et al. 2003).

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.5 Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No impacts due to diseases, parasites or travelers have been reported for S. stanfordi.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
"Needs Reference"

### *4.7 Infrastructure*

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
No ecological or economic impacts have been reported (Fofonoff et al. 2003).

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.8 Commercial fisheries and aquaculture

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
No ecological or economic impacts have been reported (Fofonoff et al. 2003).

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.9 Subsistence

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
No ecological or economic impacts have been reported (Fofonoff et al. 2003).

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.101 Recreation

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on recreation have been reported for S. standfordi, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 4.11 Human health and water quality

**Choice:** **D** No impact

**High uncertainty?** ✔

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts to health and/or water quality have been reported for S. standfordi, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 0.75 |
| **Section Total - Possible Points:** | 27.5 |
| **Section Total -Data Deficient Points:** | 2.5 |

# 5. Feasibility of prevention, detection and control



## 5.1 History of management, containment, and eradication

**Choice:** **C** Attempted; control methods are currently in development/being studied

**Score:** of

### Ranking Rationale:

No species-specific management efforts are in place for S. stanfordi, however, this species is likely transported in ballast water and on ships' hulls as part of the fouling community. Hull fouling technologies that treat and/or safely dispose of marine organisms are currently being studied.

While BWE can be highly effective at reducing the abundance of coastal organisms, efficacy varies across taxonomic groups, and residual organisms still remain in ballast tanks following exchange (Ruiz and Reid 2007). As a result, ballast water exchange is commonly viewed as a short-term or "stop-gap" option that is immediately available for use on most ships, but that will gradually be phased out as more effective, technology-based methods become available (Ruiz and Reid 2007).

BWTS are replacing BWE as a method for reducing the risk of introductions. However, a review of current BWMS concluded that no system achieves complete sterilization or removal of all living organisms (Science Advisory Board 2011). Additionally, performance standards still allow for a certain number of organisms to exist in treated ballast water, such that vessels carrying large volumes of ballast water (e.g. ≥ 100,000 tons) may still discharge a high number of organisms, with potential risk of introductions (Gollasch et al. 2007).

### Background Information:

Ballast water exchange (BWE) can be highly effective at replacing coastal ballast water with mid-ocean water (88-99% replacement of original water) and reducing coastal planktonic organisms (80-95% reduction in concentration) across ship types, when conducted according to guidelines and regulations (Ruiz and Reid 2007). However, presently, there is no way to verify the extent to which BWE occurred, and whether exchange approached the 100% empty-refill or 300% flow-through as required (Ruiz and Reid 2007). Moreover, because efficacies are < 100%, coastal organisms still remain in ballast tanks following exchange. Several studies have found coastal organisms in ships that had reportedly undertaken BWE (qtd. in Ruiz and Reid 2007). Oceanic species added to tanks during exchange can pose additional invasion risk if recipient ports are saltwater (Cordell et al., 2009; Roy et al., 2012, qtd. in Bailey 2015).

Treatment of ballast water is replacing ballast water exchange as a method for preventing the spread of aquatic invasive species. In the U.S., treatment systems must be approved by the U.S. Coast Guard. As of Dec. 23rd 2016, USCG has approved 3 ballast water management system (BWMS) and 56 alternate management systems (to be replaced by a BWMS within 5 years of compliance date). These systems must meet certain water performance standards.

Hull fouling has historically been addressed by applying anti-fouling paints and coatings. However, the chemicals used in these paints can leach environmentally harmful toxins into the water. The use of tributyl tin (TBT) paints have been banned globally for this reason. While different types of paints and coatings have been developed, ships also need to engage in regular cleaning to fully address the invasive species issues (Hagan et al. 2014). In large vessels, hull cleaning is currently conducted to improve vessel functioning and fuel efficiency. Reducing the spread of invasive species is therefore not the primary objective. Current methods such as hull cleaning during dry-docking does not address all the areas in which fouling organisms may establish (e.g. sea chests, water pipes; Hagan et al. 2014). Hull cleaning conducted in-water would allow for a more frequent cleaning schedule. Currently, underwater cleaning is performed by divers or machines using brushes, scrapers, or pressure washers. While these methods may improve a ship's performance, they do not treat or collect the waste. Consequently, these methods may actually exacerbate, rather than reduce, the spread of invasive species (Hagan et al. 2014). Technologies that collect the debris, and/or that kill the fouling organisms, are currently being studied (Hagan et al. 2014).

### Sources:

Ruiz and Reid 2007   Hagan et al. 2014

### 5.2 *Cost and methods of management, containment, and eradication*



**Choice:** **B** Major short-term and/or moderate long-term investment

**Score:** of

**Ranking Rationale:**

To comply with ballast water regulations, vessels will have to equip themselves with an onboard ballast water treatment system. These systems represent a major short-term cost for vessel owners (up to $3 million), with additional costs over time to maintain and replace equipment (e.g. chemicals, filters, UV light bulbs).

Current hull fouling technologies that address invasive species require purchasing of specialized equipment and regular cleaning.

**Background Information:**

The costs associated with purchasing a ballast water treatment system depend on the volume of water that needs to be treated. Systems with a pump capacity of 200-250 $m^3/h$ can cost from $175,000 to $490,000. The estimated price for larger systems with a pump capacity of around 2000 $m^3/h$ range from $650,000 to nearly $3 million.

According to Franmarine Underwater Services (2013), a company that supplies an in-water hull cleaning system, the cost of dry docking (including cleaning and “loss of business” costs) varies from AUD $62 200 to more than $1.3 million, depending on vessel size. The Franmarine cleaning system, which collects, treats, and disposes of biological waste (e.g., organisms) has a purchasing cost between AUD ~ $500 000 to $750 000, depending on vessel size. In-water cleaning costs range from AUD $18 800 to $255 000+ (for offshore cleaning of large vessels), with cleaning times estimated between 16 to 48 hours. Hagan et al. (2014) proposed similar estimates for the cost and time of in-water cleaning.

**Sources:**

Franmarine 2013   Hagan et al. 2014   Zagdan 2010

### 5.3 *Regulatory barriers to prevent introductions and transport*

**Choice:** **B** Regulatory oversight, but compliance is voluntary

**Score:** of

**Ranking Rationale:**

Compliance with fouling regulations voluntary.

**Background Information:**

Compliance with fouling regulations are voluntary. Alaska does not have state regulations on ballast water management, but two federal regulations (USCG and EPA) require mandatory reporting and management. International regulations by the International Maritime Organization (IMO) are expected to come into effect in 2017. While most vessels only conduct ballast water exchange, new regulations are requiring vessels to use ballast water management systems. Treated water must meet US Coast Guard/IMO performance standards. However, all management methods that are currently available reduce, but do not eliminate, the risk of introducing new species (Bailey 2005; Gollasch et al. 2007). In Alaska, data from 2009-2012 show moderate to high compliance with USCG reporting requirements (qtd. in Verna et al. 2016). There are currently no data available to evaluate compliance with water performance standards.

**Sources:**

Verna et al. 2016

### 5.4 *Presence and frequency of monitoring programs*

**Choice: A** No surveillance takes place

**Score:** of

**Ranking Rationale:**

**Background Information:**
No species-specific monitoring for S. stanfordi occurs, and no regular monitoring effort currently exists for hull fouling.

**Sources:**
None listed

### 5.5 *Current efforts for outreach and education*

**Choice: A** No education or outreach takes place

**Score:** of

**Ranking Rationale:**

**Background Information:**
No educational or outreach materials exist.

**Sources:**
None listed

**Section Total - Scored Points:**

**Section Total - Possible Points:**

**Section Total -Data Deficient Points:**

## Literature Cited for *Sinelobus cf. stanfordi*


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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Crassostrea gigas*

**Common Name** *Pacific oyster*

| | |
|---|---|
| **Phylum** | Mollusca |
| **Class** | Bivalvia |
| **Order** | Ostreoida |
| **Family** | Ostreidae |

**Final Rank** 74.25

**Data Deficiency:** 0.00

### Species Occurrence by Ecoregion

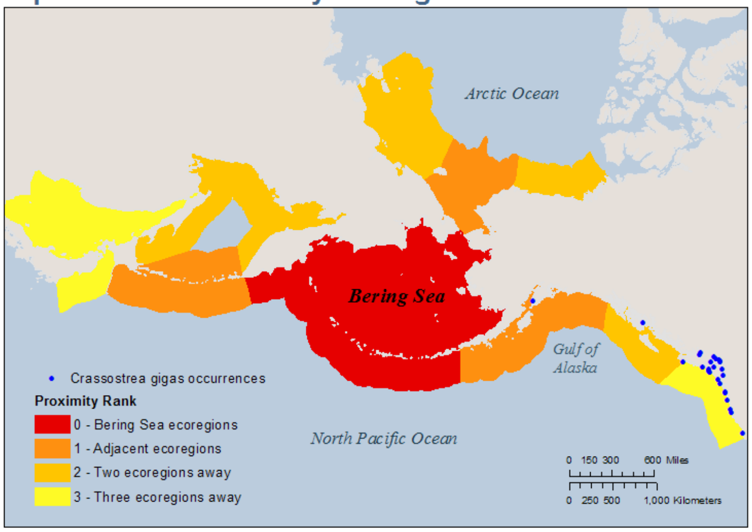


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 22.5 | 30 | 0 |
| Anthropogenic Influence: | 10 | 10 | 0 |
| Biological Characteristics: | 26.25 | 30 | 0 |
| Impacts: | 15.5 | 30 | 0 |
| **Totals:** | 74.25 | 100.00 | 0.00 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | -2 | Minimum Salinity (ppt) | 5 |
| Maximum Temperature (°C) | 25 | Maximum Salinity (ppt) | 41 |
| Minimum Reproductive Temperature (°C) | 16 | Minimum Reproductive Salinity (ppt) | 20 |
| Maximum Reproductive Temperature (°C) | 30 | Maximum Reproductive Salinity (ppt) | 30 |

### Additional Notes

Similar in appearance to other oysters. Shells can be white to gray, and sometimes have brown or purple on the ridges. The outer surface of both valves are strongly rippled. Interior of the shell is smooth and white, with a purple muscle scar. Can grow up to 400-450 mm. The Pacific oyster is native to the Northwest Pacific, including Russia, China, and Korea. It is the most widely cultivated and harvested shellfish species in the world, and has been introduced to at least 52 countries. In introduced locations, C. gigas often starts by being confined to culture areas, but later becomes a major biomass component and ecosystem engineer. This species may pose risks to native oyster populations through competition, hybridization, and introductions of associated organisms. It also presents economic opportunities for commercial cultivation.

**Reviewed by** Nora R. Foster, NRF Taxonomic Services, Fairbanks AK

**Review Date:** 9/27/2017

# 1. Distribution and Habitat



### 1.1 *Survival requirements - Water temperature*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 3.75 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Temperatures required for year-round survival occur over a large (>75%) area of the Bering Sea. Thresholds are based on geographic distribution, which may not represent physiological tolerances; we therefore ranked this question with "High uncertainty".

**Background Information:**
Based on geographic distribution and estimated water temperatures, Carrasco and Barón (2010) estimate a temperature range of -1.9°C to 29°C. However, an experimental study found that temperatures above 25°C inhibited feeding in adults and led to weight loss; the authors suggest 25°C as the upper limit for feeding activities (Bourlès et al. 2009).

**Sources:**
Bourlès et al. 2009   Carrasco and Barón

### 1.2 *Survival requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
Pacific oysters have a salinity range between 5 and 41 ppt (qtd. in Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 1.3 *Establishment requirements - Water temperature*

**Choice:** **D** No overlap – Temperatures required for reproduction do not exist in the Bering Sea

**Score:** 0 of 3.75

**Ranking Rationale:**
Temperatures required for reproduction do not exist in the Bering Sea.

**Background Information:**
Larvae were found to exhibit optimal growth at 30°C (His et al. 1989). Minimum spawning temperature is 16°C (Mann et al. 1991). Growth has been observed at low temperatures (5-15°C), but only in the presence of phytoplankton blooms, which provide an abundant food supply (Bourlès et al. 2009). No growth was observed at 8°C when phytoplankton biomass was low (Bourlès et al. 2009). Cold water temperatures may be limiting the establishment of Crassostrea gigas in Alaska (RaLonde 1993). However, climate change has recently been attributed to the establishment of Pacific oyster populations in Espevik, Norway (60°N), as well as in Denmark and Sweden (Wrange et al. 2010).

**Sources:**
Bourlès et al. 2009   Mann et al. 1991   His et al. 1989   RaLonde 1993   Wrange et al. 2010

### *1.4 Establishment requirements - Water salinity*

**Choice: C** Little overlap – A small area (<25%) of the Bering Sea has salinities suitable for reproduction

**Score:** 1.25 of 3.75

**Ranking Rationale:**
Salinities required for reproduction occur in a limited area (<25%) of the Bering Sea.

**Background Information:**
Salinity range for growth is between 10 and 42 ppt, and between 10 to 30 ppt for spawning (Mann et al. 1991). Larvae have lower optimum salinity ranges than spat (Nell and Holliday 1988).

**Sources:**
Mann et al. 1991   Nell and Holliday 198

### *1.5 Local ecoregional distribution*

**Choice: B** Present in an ecoregion adjacent to the Bering Sea

**Score:** 3.75 of 5

**Ranking Rationale:**
This species is currently farmed in the Gulf of Alaska.

**Background Information:**

**Sources:**
RaLonde 1993

### *1.6 Global ecoregional distribution*

**Choice: A** In many ecoregions globally

**Score:** 5 of 5

**Ranking Rationale:**
This species is found worldwide. It has been introduced in over 52 countries.

**Background Information:**
The Pacific oyster is native to the northwest Pacific (Russia, China, Korea). It has been introduced worldwide including both coasts of North America, Australia, New Zealand, Argentina, Brazil, South Africa, and in Europe from Norway to Spain, and east to Turkey.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.7 Current distribution trends*

**Choice: A** Recent rapid range expansion and/or long-distance dispersal (within the last ten years)

**Score:** 5 of 5

**Ranking Rationale:**
The Pacific oyster has undergone a rapid northward expansion in the last ten years.

**Background Information:**
A monitoring program from 2003 to 2005 found evidence for rapid range expansion in the Wadden Sea (Brandt et al. 2008). Unusually warm water temperatures in the Wadden Sea and in Scandinavia are thought to have promoted the establishment of Pacific oyster populations in these northern regions (Diederich et al. 2005; Wrange et al. 2010). This species now occurs as far north as 60°N (Wrange et al. 2010).

**Sources:**
Wrange et al. 2010   Brandt et al. 2008   Diederich et al. 2005

| | |
|---|---|
| **Section Total - Scored Points:** | 22.5 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

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## 2. Anthropogenic Transportation and Establishment

### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice:** **A** — Has been observed using anthropogenic vectors for transport and transports independent of any anthropogenic vector once introduced

**Score:** 4 **of** 4

**Ranking Rationale:**
Once introduced, larvae or spat can "escape" from aquaculture sites and disperse naturally.

**Background Information:**
Wild oyster populations are often the result of aquaculture larvae spreading into the environment.

**Sources:**
RaLonde 1993

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice:** **A** — Readily establishes in areas with anthropogenic disturbance/infrastructure and in natural, undisturbed areas

**Score:** 4 **of** 4

**Ranking Rationale:**
Can establish in anthropogenic areas (e.g. in cultivation) and in undisturbed areas.

**Background Information:**
Established outside of aquaculture operations in many locations where it was introduced, including Argentina, Hawaii, Germany, and Scandinavia.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice:** **A** — Yes

**Score:** 2 **of** 2

**Ranking Rationale:**
This species has been intentionally introduced around the world for aquaculture.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 10 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics



### *3.1 Dietary specialization*

**Choice:** **A** — Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Food items for this species are readily available in the Bering Sea.

**Background Information:**
The Pacific oyster is a suspension feeder that feeds on plankton, algae, and particles in the water column.

**Sources:**
NEMESIS; Fofonoff et al. 2003   Padilla 2010

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **A** — Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 of 5

**Ranking Rationale:**
This species can tolerate and establish in a wide range of temperatures, salinities, and substrates.

**Background Information:**
The Pacific oyster tolerates a wide range of temperatures and salinities. This species is commonly found in estuaries and protected coastal areas. It prefers firm bottom substrates, but can also be found on muddy or sandy bottoms. Adults are sessile and attach themselves to rocks, reefs, woody debris, and docks. The Pacific oytser is usually found in the lower intertidal zone, to depths of 40 m.

**Sources:**
RaLonde 1993   NEMESIS; Fofonoff et al. 2003   Troost 2010

### *3.3 Desiccation tolerance*

**Choice:** **A** — Highly tolerant (>7 days) of desiccation at one or more stages during its life cycle

**Score:** 5 of 5

**Ranking Rationale:**
Adults can survive exposure to air for several weeks.

**Background Information:**
A study testing the desiccation tolerances of five fouling species found that adult Pacific oysters were the most desiccation-tolerant taxon tested. Pacific oysters survived 16 days in natural conditions and 34 days under controlled conditions (Hopkins et al. 2016).

**Sources:**
Hopkins et al. 2016

### *3.4 Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice: A** High – Exhibits three or four of the above characteristics

**Score:** 5 of 5

**Ranking Rationale:**
This species is hermaphroditic, exhibits external fertilization, and is highly fecund.

**Background Information:**
Pacific oysters are cyclical hermaphrodites with external fertilization. They are highly fecund, producing 50 million eggs in a single spawning (Troost 2010). C. gigas reaches sexual maturity in < 1 year (Brandt et al. 2008).

**Sources:**
Brandt et al. 2008 Troost 2010

### *3.5 Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice: A** Disperses long (>10 km) distances

**Score:** 2.5 of 2.5

**Ranking Rationale:**
Although adults are sessile, larvae can disperse over several kilometers.

**Background Information:**
Larvae are free-swimming and can disperse between 5 and 15 km, though some may be carried even further (Troost 2010). Larvae can disperse into the environment from oyster farms and establish wild populations (Troost 2010).

**Sources:**
Troost 2010

### *3.6 Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: A** High – Exhibits two or three of the above characteristics

**Score:** 2.5 of 2.5

**Ranking Rationale:**
Larval stage is long-lived and highly mobile.

**Background Information:**
Larvae are free-swimming and can be dispersed by water currents. Once settled, adults may be dispersed by fouling.

**Sources:**
Brandt et al. 2008 NEMESIS; Fofonoff et al. 2003

### 3.7 *Vulnerability to predators*



**Choice:** **D** — Multiple predators present in the Bering Sea or neighboring regions

**Score:** 1.25 **of** 5

**Ranking Rationale:**

This species is predated upon by several taxonomic groups that occur in the Bering Sea.

**Background Information:**

Predated upon by fish, birds, and invertebrates including shrimp, crabs, sea stars, and flatworms. However, in its introduced range, not all predators are able to successfully detach and open them (Troost 2010). Pacific oysters are also susceptible to disease.

**Sources:**

NEMESIS; Fofonoff et al. 2003   Troost 2010

| | |
|---|---|
| **Section Total - Scored Points:** | 26.25 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

# 4. Ecological and Socioeconomic Impacts



## 4.1 Impact on community composition

**Choice:** **A** High – Entire community and/or may cause extirpation or extinction at the species or trophic level

**Score:** 2.5 of 2.5

**Ranking Rationale:**
Pacific oysters affect several species and communities, including native oysters, eelgrass, polychaetes, and phytoplankton.

**Background Information:**
Several effects have been documented, including: overgrowing and replacing blue mussels Mytilus edulis, reducing recruitment of Sabellaria polychaete, decreasing growth of eelgrass Zostera marina, and outcompeting native oysters such as the Olympia oyster and the Sydney rock oyster (reviewed in Padilla 2010). Effects seem most pronounced in soft-bottom habitats such as mudflats (Fofonoff et al. 2003). At the same time, by growing over hard substrata, Pacific oysters can overgrow native, sessile invertebrates and algae. Selective feeding can also affect phytoplankton communities (Prins et al. 1998, qtd. in Padilla 2010). Competition between native bivalves may be density-dependent and/or moderated by resource partitioning, and coexistence between Pacific oysters and other species has been recorded (Diederich 2005; Troost 2010). By creating habitat, Pacific oysters can increase biodiversity; they can also improve limpet survival (Padilla 2010).

**Sources:**
Troost 2010   Diederich 2005   NEMESIS; Fofonoff et al. 2003   Padilla 2010

## 4.2 Impact on habitat for other species

**Choice:** **B** Moderate – Causes or has potential to cause changes to one or more habitats

**Score:** 1.75 of 2.5

**Ranking Rationale:**
Oyster reefs can drastically change the habitat, especially in sandy or muddy sites where hard substrates are limiting.

**Background Information:**
Modifies habitats by constructing large, three-dimensional oyster reefs, which provide other species with protection from predation, heat, and desiccation (Padilla 2010; Troost 2010). The habitat created increases biodiversity by providing substrate for mussel and barnacle settlement, and by providing refuge for other marine organisms (Padilla 2010).

**Sources:**
Padilla 2010   Troost 2010

### 4.3 Impact on ecosystem function and processes

**Choice: A** — High – Is known to cause moderate to severe changes to food webs and/or ecosystem functions; effects have been documented in several areas

**Score:** 2.5 of 2.5

**Ranking Rationale:**
The Pacific oyster has a large impact on ecosystem functions by forming oyster reefs and through its feeding, filtering, and excretory activities.

**Background Information:**
The Pacific oyster is often cited as an ecosystem engineer. It forms dense beds known as oyster reefs, which create habitat for other species, and affect water flow and turbulence (Padilla 2010; Troost 2010). Oysters can also alter the organic content, accumulation rate, and grain size of sediments by removing particles from the water and depositing them on the sea floor as pseudofeces (Padilla 2010). Pseudofeces can accumulate around the oyster beds, creating anoxic zones and negatively affecting vegetation such as eelgrass (Kelly et al. 2008; Troost 2010). Deposits of pseudofeces can also increase the diversity and abundance of deposit feeders (LeJart and Hily 2011, qtd. in Fofonoff et al. 2003). It can affect water clarity through feeding.

**Sources:**
Troost 2010   Padilla 2010   NEMESIS; Fofonoff et al. 2003   Kelly et al. 2008

### 4.4 Impact on high-value, rare, or sensitive species and/or communities

**Choice: B** — Moderate – Causes or has potential to cause degradation of one or more species or communities, with moderate impact

**Score:** 1.75 of 2.5

**Ranking Rationale:**
The Pacific oyster may affect valuable native bivalves in the Bering Sea through competition.

**Background Information:**
Although the Pacific oyster can compete with native oysters, Diederich (2005) found that the Pacific oyster and the blue mussel were capable of coexistence. However, the faster growth rate and larger size of C. gigas may restrict habitat use by native mussels (Diederich 2006).

**Sources:**
Diederich 2005   Diederich 2006

### *4.5 Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice: A** High – Is known to spread multiple organisms and/or is expected to have severe impacts and/or will impact the entire region

**Score:** 2.5 of 2.5

**Ranking Rationale:**
The Pacific oyster has introduced several organisms (e.g., the Japanese oyster drill) that may affect native bivalves in the Bering Sea.

**Background Information:**
The introduction of Pacific oysters has been accompanied by the accidental introduction of a number of pests and parasites including the Japanese oyster drill (Ocinebrella inornata), the oyster flatworm (Pseudostylochus ostreophagus), and the copepod parasite Mytilicola orientalis, as well as three viruses and three bacterial diseases. Some of these species have had negative impacts on oysters and surrounding communities, but a study by Buhle and Ruesink (2009) found that predation by the Japanese oyster drill could not account for the high mortality rates experienced by Olympia oysters.

C. gigas may have introduced the protist Haplosporidium nelsoni to the East Coast of North America (Burreson et al. 2000). H. nelsoni infects the Pacific Oyster with minimal symptoms, but produces the symptoms of the MSX disease in the Eastern oyster (C. virginica). Outbreaks of this disease have caused high mortalities in several areas along the East Coast (Burreson et al. 2000).

**Sources:**
Burreson et al. 2000   Buhle and Ruesink 2009

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
There are no native Crassostrea species in the Bering Sea. Hybridization with other bivalve genera has not been reported.

**Background Information:**
There have been many attempts at hybridization of Crassostrea species, but these attempts rarely lead to viable offspring (Gaffney and Allen 1993). Natural hybridization between Pacific oysters and Portuguese oysters (C. angulata) have been reported (Huvet et al. 2004; Leitão et al. 2007). Although the rates of hybridization seem low, the extent and impacts are still unknown.

**Sources:**
Huvet et al. 2004   Gaffney and Allen 1993   Leitão et al. 2007

### *4.7 Infrastructure*

**Choice: B** Moderate – Causes or has the potential to cause degradation to infrastructure, with moderate impact and/or within only a portion of the region

**Score:** 1.5 of 3

**Ranking Rationale:**
The Pacific oyster is a fouling organism that is known to affect anthropogenic infrastructure.

**Background Information:**
The Pacific oyster can foul cooling systems in coastal power stations (Rajagopal et al. 2005).

**Sources:**
Rajagopal et al. 2005

### *4.8 Commercial fisheries and aquaculture*

**Choice: C** Limited – Has limited potential to cause degradation to fisheries and aquaculture, and/or is restricted to a limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
Through competition, Pacific oysters may impact other commercial shellfish species, such as the blue mussel. Shellfish farming only occurs in a limited region of the Bering Sea.

**Background Information:**
Pacific oysters are a very important aquaculture species worldwide and in Alaska, and have many positive impacts on the economy. Shellfish farming is a small, but growing industry in Alaska, and the Pacific oyster is one of the main species farmed (Mathis et al. 2015)

**Sources:**
Mathis et al. 2015   NEMESIS; Fofonoff et al. 2003

### *4.9 Subsistence*

**Choice: C** Limited – Has limited potential to cause degradation to subsistence resources, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
Through competition, may affect other shellfish species that are harvested for subsistence.

**Background Information:**
Compared to salmon and finfish, shellfish such as oysters, clams, and mussels comprise a smaller percentage of subsistence catch in the Bering Sea (when measured by weight; Mathis et al. 2015). Although shellfish harvesting represented almost 20% catch in the Aleutians West, most municipalities in the Bering Sea recorded low percentages (< 5%) of subsistence shellfish (Mathis et al. 2015).

**Sources:**
Mathis et al. 2015

### *4.101 Recreation*

**Choice: C** Limited – Has limited potential to cause degradation to recreation opportunities, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
Through competition, may affect other shellfish species that are recreationally harvested.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.11 Human health and water quality*



| Choice: | | Score: |
|---|---|---|
| C | Limited – Has limited potential to pose a threat to human health, with limited impact and/or within a very limited region | 0.75 of 3 |

**Ranking Rationale:**

Cases of PSP and other shellfish syndromes are rare in Alaska. Current regulations and safety procedures greatly reduce the risk of bacterial transmission, especially in cultivated mussels. Recreational harvesting of shellfish in the Bering Sea is limited.

**Background Information:**

All bivalves can bioaccumulate toxins in their tissues as a result of consuming toxic dinoflagellates. Consuming raw or cooked bivalves can lead to Paralytic Shellfish Poisoning (PSP), which can cause health issues and even death (NIMPIS 2009). The state of Alaska discourages harvesting on untested beaches (ADEC 2013).

**Sources:**

NIMPIS 2009 ADEC 2013

| | |
|---|---|
| **Section Total - Scored Points:** | 15.5 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 5. Feasibility of prevention, detection and control



### 5.1 History of management, containment, and eradication

**Choice:** **C** Attempted; control methods are currently in development/being studied

**Score:** of

**Ranking Rationale:**
Research to control populations is ongoing.

**Background Information:**
Control of small populations through hand culling has been successfully carried out in England and in Northern Ireland (Guy and Roberts 2010; McKnight and Chudleigh 2015). In New South Wales and Australia, biologists have exploited differences in desiccation tolerance between C. gigas and the native Sydney rock oyster to control C. gigas (Ruesink et al. 2005). Attempts to control C. gigas where it is established and abundant (e.g. Wadden Sea) have not been successful. Attempts to control Pacific oysters in power plants, using heat treatments were unsuccessful because this species has a very high temperature tolerance and is capable of developing resistance when exposed to sub-lethal high temperatures (Rajagopal et al. 2005).

**Sources:**
Guy and Roberts 2010 McKnight and Chudleigh 2015 Ruesink et al. 2005 Rajagopal et al. 2005

### 5.2 Cost and methods of management, containment, and eradication

**Choice:** **B** Major short-term and/or moderate long-term investment

**Score:** of

**Ranking Rationale:**
Several methods have been developed in attempts to control or eradicate C. gigas. Most of these methods need to be repeated in order to be effective, therefore requiring moderate long-term investment.

**Background Information:**
In areas where oysters occur at low densities, manual removal is laborious but effective (McKnight and Chudleigh 2015). Complete eradication would likely be expensive and would have to be repeated (Kochmann 2012). Oyster dredging has been successfully applied to reduce population densities of other bivalve species (Blanchard 2009, qtd. in Kochmann 2012). Other eradication methods for controlling bivalves, e.g. species-specific pellets “BioBullets”, are only useful for closed facilities. The aquaculture industry is actively researching ways to prevent the spread of larvae and disease. Triploid oysters, which do not produce larvae, have been developed, although 100% triploidy is often not achieved (Ruesink et al. 2005)

**Sources:**
McKnight and Chudleigh 2015 Kochmann 2012 Ruesink et al. 2005

### 5.3 Regulatory barriers to prevent introductions and transport

**Choice:** **C** Regulatory oversight and/or trade restrictions

**Score:** of

**Ranking Rationale:**
In Alaska, there are regulations that restrict the transport and trade of aquatic invertebrate species such as C. gigas.

**Background Information:**
In Alaska, oyster farms require an Aquatic Farm Operation Permit (issued by ADF&G), and only oyster seeds ≤ 20mm can be imported from approved providers. The transport or trade of live invertebrates is prohibited, unless a permit is obtained from ADF&G. Federal regulations are in place to prevent the spread of species by ballast water.

**Sources:**
AAC 2017

### *5.4 Presence and frequency of monitoring programs*



**Choice: A** No surveillance takes place

**Score:** of

**Ranking Rationale:**
Pacific oysters have been intentionally introduced as an aquaculture species in Alaska. No surveillance takes place.

**Background Information:**

**Sources:**
None listed

### *5.5 Current efforts for outreach and education*

**Choice: B** Some educational materials are available and passive outreach is used (e.g. signs, information cards), or programs exist outside Bering Sea and adjacent regions

**Score:** of

**Ranking Rationale:**
Pacific oysters were intentionally introduced in Alaska, and oyster farming is a growing industry. No education or outreach programs concerning this species' status as an invasive species are in place.

**Background Information:**
Educational material is available, but this material is produced in areas where Pacific oysters are considered a threat to native ecosystems. In Europe, education and outreach is directed at a small subset of the population (e.g. environmentalists, people against or concerned by the aquaculture industry). Advocacy groups such as Coastwatch Europe and SWAN provide educational material about native oysters and coastal ecosystems, and list C. gigas as a threat (Dubsky 2014). In the US, NOAA has a strong outreach program aimed at restoring oyster habitat, but unlike European publications, their monitoring handbook does not mention C. gigas as a threat to native oyster populations.

**Sources:**
McKnight and Chudleigh 2015 Dubsky 2014

**Section Total - Scored Points:**

**Section Total - Possible Points:**

**Section Total -Data Deficient Points:**

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# Bering Sea Marine Invasive Species Assessment

## Alaska Center for Conservation Science

**Scientific Name:** *Macoma petalum*

**Common Name** *Atlantic macoma*

| | |
|---|---|
| **Phylum** | Mollusca |
| **Class** | Bivalvia |
| **Order** | Veneroida |
| **Family** | Tellinidae |

**Final Rank** 46.75

**Data Deficiency:** 0.00

### Species Occurrence by Ecoregion

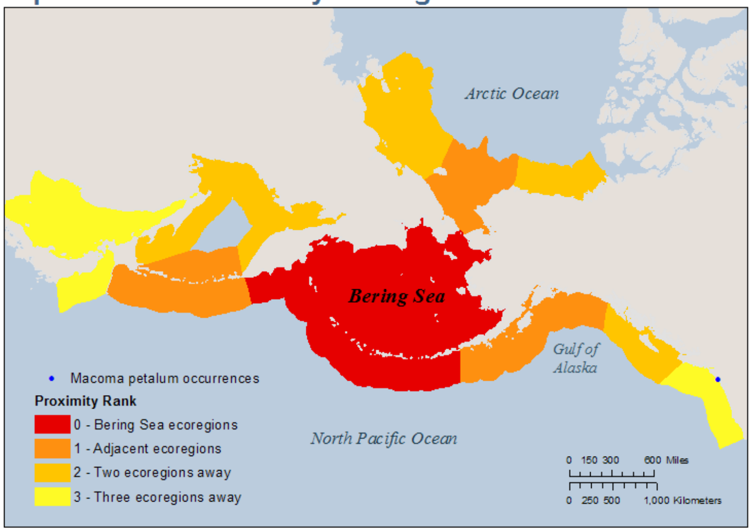


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 16 | 30 | 0 |
| Anthropogenic Influence: | 4 | 10 | 0 |
| Biological Characteristics: | 24.5 | 30 | 0 |
| Impacts: | 2.25 | 30 | 0 |
| **Totals:** | 46.75 | 100.00 | 0.00 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | 0 | Minimum Salinity (ppt) | 2.5 |
| Maximum Temperature (°C) | 33 | Maximum Salinity (ppt) | 35 |
| Minimum Reproductive Temperature (°C) | 10 | Minimum Reproductive Salinity (ppt) | 31* |
| Maximum Reproductive Temperature (°C) | 14 | Maximum Reproductive Salinity (ppt) | 35* |

### Additional Notes

Macoma petalum is an oval shaped, laterally compressed clam. The shell is an off-white color with a chalky texture and sometimes has a rosy hue. Adults range in size from 1 to 30 mm. M. petalum was formerly considered a synonym of M. balthica (the Baltic clam) but is now recognized as a genetically distinct species. Distinguishing the two requires molecular methods.

**Reviewed by** Nora R. Foster, NRF Taxonomic Services, Fairbanks AK

**Review Date:** 9/27/2017

# 1. Distribution and Habitat



### *1.1 Survival requirements - Water temperature*

**Choice:** **B** Moderate overlap – A moderate area (≥25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 2.5 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Temperatures required for year-round survival occur in a moderate area (≥25%) of the Bering Sea. We ranked this question with "High Uncertainty" to indicate disagreements in model estimates.

**Background Information:**
The temperature threshold for survival of M. petalum is 0 to 33ºC (Abbott 1974 as qtd. In Fofonoff et al. 2003; Kennedy and Mihursky 1971).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Kennedy and Mihursky 1971

### *1.2 Survival requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
The salinity range for survival of M. petalum is between 2.5 and 35 ppt (Castagna and Chanley 1973; Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Castagna and Chanley 1973

### *1.3 Establishment requirements - Water temperature*

**Choice:** **C** Little overlap – A small area (<25%) of the Bering Sea has temperatures suitable for reproduction

**Score:** 1.25 of 3.75

**Ranking Rationale:**
Temperatures required for reproduction occur in a limited area (<25%) of the Bering Sea.

**Background Information:**
The temperature threshold for reproduction of M. petalum 10 to 14ºC (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.4 Establishment requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Although salinity thresholds are unknown, this species is a marine organism that does not require freshwater to reproduce. We therefore assume that this species can reproduce in saltwater (31 to 35 ppt). These salinities occur in a large (>75%) portion of the Bering Sea.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *1.5 Local ecoregional distribution*

**Choice:** **D** Present in an ecoregion greater than two regions away from the Bering Sea

**Score:** 1.25 **of** 5

**Ranking Rationale:**
Found as far north as Washington state.

**Background Information:**
Introduced populations have been recorded from California (San Francisco Bay) to Washington (Grays Harbor) (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.6 Global ecoregional distribution*

**Choice:** **C** In few ecoregions globally

**Score:** 1.75 **of** 5

**Ranking Rationale:**

**Background Information:**
Native to the eastern coast of North America, from North Carolina to New Brunswick, Canada. Introduced in Washington and California (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.7 Current distribution trends*

**Choice:** **C** Established outside of native range, but no evidence of rapid expansion or long-distance dispersal

**Score:** 1.75 **of** 5

**Ranking Rationale:**

**Background Information:**
No information found to suggest rapid colonization or range expansion.

**Sources:**
None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 16 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 2. Anthropogenic Transportation and Establishment



### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice:** **A**

Has been observed using anthropogenic vectors for transport and transports independent of any anthropogenic vector once introduced

**Score:** 4 of 4

**Ranking Rationale:**

Can be transported in ballast water and as accidental introductions. Larvae can disperse naturally over long distances.

**Background Information:**

Introductions to the west coast of North America are likely due to accidental transport with the Eastern oyster for cultivation (Cohen and Carlton 1995). Introduction through ballast water is also suspected (Fofonoff et al. 2003). Adults have limited mobility and spend most of their time buried in the substrate, but larvae can be dispersed passively by water currents.

**Sources:**

NEMESIS; Fofonoff et al. 2003 Cohen and Carlton 1995

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice:** **D**

Does not use anthropogenic disturbance/infrastructure to establish

**Score:** 0 of 4

**Ranking Rationale:**

Does not use anthropogenic disturbance or infrastructure for establishment.

**Background Information:**

Typical habitat includes shallow, muddy, subtidal to upper intertidal zones (Gosner 1978 as qtd. In Fofonoff et al. 2003).

**Sources:**

NEMESIS; Fofonoff et al. 2003

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice:** **B**

No

**Score:** 0 of 2

**Ranking Rationale:**

**Background Information:**

M. petalum is not currently farmed or intentionally cultivated.

**Sources:**

None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 4 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics

### *3.1 Dietary specialization*

**Choice: A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Consumes taxa that are readily available in the Bering Sea.

**Background Information:**
M. petalum is both a deposit-feeder and a suspension-feeder. It mostly consumes microalgae (Thompson and Nichols 1988; Poulton et al. 2004).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Thompson and Nichols 1988 Poulton et al. 2004

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice: B** Requires specialized habitat for some life stages (e.g., reproduction)

**Score:** 3.25 of 5

**Ranking Rationale:**
Limited to shallow subtidal or upper intertidal zones.

**Background Information:**
Typically found in shallow subtidal to upper intertidal zones, often in muddy or silty brackish waters (Gosner 1978 as qtd. in Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *3.3 Desiccation tolerance*

**Choice: A** Highly tolerant (>7 days) of desiccation at one or more stages during its life cycle

**Score:** 5 of 5

**Ranking Rationale:**

**Background Information:**
In an experiment, average survival time out of water was about 22 days (de Zwaan and Babarro 2001).

**Sources:**
de Zwaan and Babarro 2001

### *3.4 Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice: A** High – Exhibits three or four of the above characteristics

**Score:** 5 **of** 5

**Ranking Rationale:**
Sexual reproduction, high fecundity, external fertilization, short generation time.

**Background Information:**
In San Francisco Bay, spawns from January to March (Poulton et al. 2004). Can have reproductive failure during years when water temperature stays relatively warm or when salinity is low (Poulton et al. 2004). Macoma clams (not species-specific) release eggs and sperm into the water column (Chesapeake Bay Program 2016). After being fertilized, eggs develop into larvae with two tiny, transparent shells and a small foot. Larvae float in the currents for a few weeks before eventually settling to the bottom (Chesapeake Bay Program 2016).

The closely related species, M. balthica, can produce several thousands to tens of thousands of eggs (Honkoop and van der Meer 1997). The lowest average recorded for one site was 4744, though all others were above 30 000. The maximum average was 57,780 (Honkoop and van der Meer 1997). Sexual maturity is dependent on shell size rather than age, but usually occurs between 10 and 22 months (~4 mm; Tyler 2016). Lifespan is, on average, 5 to 10 years.

**Sources:**
Chesapeake Bay Program   Honkoop and van der Meer 1997   Poulton et al. 2004   Tyler 2016

### *3.5 Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice: A** Disperses long (>10 km) distances

**Score:** 2.5 **of** 2.5

**Ranking Rationale:**
Can disperse greater than 10 km.

**Background Information:**
Larvae are free-swimming and planktotrophic (Bos et al. 2007). A closely related species, M. balthica,disperses during its 2–5 week pelagic larval phase (Drent 2002), and during its first winter when it may drift with the use of a mucoid (byssus) thread (Beukema 1993; Hiddink et al. 2002; qtd. in Luttikhuizen et al. 2003). Experiments in the field revealed that individuals up to a size of 9 mm can be transported in this fashion over distances up to 24 km, although the density of M. bathica decreases with increasing distance from the source, suggesting that active migration – especially of adults > 1 year old – is possible, but uncommon (Beukema and de Vlas 1989). Tyler (2016) lists adult dispersal distance as short (between 100 to 1000 m) and larval dispersal potential as > 10 km, but does not provide references to support this claim.

**Sources:**
Tyler 2016   Drent 2002   Luttikhuizen et al. 2003   Bos et al. 2007   Beukema and de Vlas 1989

### *3.6 Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: A** High – Exhibits two or three of the above characteristics

**Score:** 2.5 of 2.5

**Ranking Rationale:**
Can disperse at more than one life stage, long larval viability window, different modes of dispersal for different life stages.

**Background Information:**
Although the larval stage is the most common stage of dispersal, adults of up to 9 mm can undergo active migration using byssus threads. The larval stage is long-lived and free-swimming. M. balthica is a broadcast spawner, and spawning has been observed multiple times in one season (Drent and Luttikhuizen 2003). In general, adults are not highly mobile, and remain buried underneath the substrate.

**Sources:**
Drent and Luttikhuizen 2003

### *3.7 Vulnerability to predators*

**Choice: D** Multiple predators present in the Bering Sea or neighboring regions

**Score:** 1.25 of 5

**Ranking Rationale:**
Numerous predators, many of which exist in the Bering Sea.

**Background Information:**
Numerous predators including crabs, fishes and birds (Cohen and Carlton 1995).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Cohen and Carlton 1995

| | |
|---|---|
| **Section Total - Scored Points:** | 24.5 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

# 4. Ecological and Socioeconomic Impacts



## 4.1 *Impact on community composition*

**Choice:** **C** Limited – Single trophic level; may cause decline but not extirpation

**Score:** 0.75 **of** 2.5

**Ranking Rationale:**
Occurs at relatively low abundances. Has been negatively correlated the amethyst gem clam.

**Background Information:**
M. petalum appears to be negatively correlated with the amethyst gem clam, Gemma gemma (Thompson 1982). This is possibly due to feeding competition or alteration of sediment due to M. petalum production of pseudofeces (Thompson 1982). M. balthica, a closeley related species, caused a decline in harpacticoid copepods with little effect on other meiofaunal species (Ólafsson et al. 1993). Webb (1993) conducted a microcosm experiment to examine the influence of M. balthica on chlorophyll a concentrations, and found that M. balthica had no persistent effect on sedimentary chlorophyll a levels at natural bivalve field densities.

**Sources:**
NEMESIS; Fofonoff et al. 2003   Ólafsson et al. 1993   Webb 1993   Thompson 1982

## 4.2 *Impact on habitat for other species*

**Choice:** **D** No impact

**Score:** 0 **of** 2.5

**Ranking Rationale:**

**Background Information:**
No impacts to habitat have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003   Thompson 1982

## 4.3 *Impact on ecosystem function and processes*

**Choice:** **C** Limited – Causes or potentially causes changes to food webs and/or ecosystem functions, with limited impact and/or within a very limited region

**Score:** 0.75 **of** 2.5

**Ranking Rationale:**
To date, no impacts on ecosystem function or processes have been reported for M. petalum. May impact sediment composition through production of pseudofeces.

**Background Information:**
May alter sediment composition through production of pseudofeces (Thompson 1982), but no specific impacts have been reported.

**Sources:**
Thompson 1982

### *4.4 Impact on high-value, rare, or sensitive species and/or communities*

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
To date, no impacts have been reported.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.5 Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
To date, no diseases, parasites, or travelers have been reported for M. petalum.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
To date, no hybridization with native species has been reported for M. petalum.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.7 Infrastructure*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
No impacts on infrastructure have been reported to date.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 4.8 Commercial fisheries and aquaculture

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
No impacts on commercial fisheries or aquaculture have been reported to date.

**Background Information:**
No information available in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.9 Subsistence

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
No impacts on subsistence activities have been reported to date.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 4.101 Recreation

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
No impacts on recreation have been reported to date.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 4.11 Human health and water quality

**Choice:** **C** Limited – Has limited potential to pose a threat to human health, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
Cases of PSP and other shellfish syndromes are rare in Alaska. Current regulations and safety procedures greatly reduce the risk of bacterial transmission, especially in cultivated mussels. Recreational harvesting of shellfish in the Bering Sea is limited.

**Background Information:**
All bivalves can bioaccumulate toxins in their tissues as a result of consuming toxic dinoflagellates. Consuming raw or cooked bivalves can lead to Paralytic Shellfish Poisoning (PSP), which can cause health issues and even death (NIMPIS 2009). The state of Alaska discourages harvesting on untested beaches (ADEC 2013).

**Sources:**
NIMPIS 2009 ADEC 2013

| | |
|---|---|
| **Section Total - Scored Points:** | 2.25 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 5. Feasibility of prevention, detection and control



### 5.1 History of management, containment, and eradication

**Choice:** **C** Attempted; control methods are currently in development/being studied

**Score:** of

**Ranking Rationale:**
Controlling the spread of invasive species that use anthropogenic vectors for transport is an active area of research (e.g. Ruiz and Reid 2007, Hagan et al. 2014).

**Background Information:**
No information found to suggest management has been attempted for this species in particular. M. petalum can be introduced to new areas via transport in ballast water or by hitchhiking.

**Sources:**
Ruiz and Reid 2007 Hagan et al. 2014

### 5.2 Cost and methods of management, containment, and eradication

**Choice:** **A** Major long-term investment, or is not feasible at this time

**Score:** of

**Ranking Rationale:**
Methods to control the spread of marine invasive species transported via ballast water are being studied, and currently necessitate major long-term investments (Zagdan 2010).

**Background Information:**
No information available for M. petalum in particular.

**Sources:**
Zagdan 2010

### 5.3 Regulatory barriers to prevent introductions and transport

**Choice:** **A** Little to no regulatory restrictions

**Score:** of

**Ranking Rationale:**
This species can be introduced by ballast water or by hitchhiking. There are no regulatory restrictions in place to address hitchhikers.

**Background Information:**
In the U.S., ballast water management is mandatory and regulated by the U.S. Coast Guard (CFR 33 § 151.2). However, there are no regulations for species that are accidentally transported as hitchhikers, as is the case with M. petalum.

**Sources:**
CFR 2017

### 5.4 Presence and frequency of monitoring programs

**Choice:** **A** No surveillance takes place

**Score:** of

**Ranking Rationale:**
To our knowledge, this species is not currently monitored.

**Background Information:**
No information found.

**Sources:**
None listed

### *5.5 Current efforts for outreach and education*



**Choice:** **A** No education or outreach takes place

**Score:** of

**Ranking Rationale:**

**Background Information:**
No education or outreach materials were found during our literature search.

**Sources:**
None listed

**Section Total - Scored Points:**
**Section Total - Possible Points:**
**Section Total -Data Deficient Points:**

## Literature Cited for *Macoma petalum*


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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Mya arenaria*

**Common Name** *softshell clam*

| | |
|---|---|
| **Phylum** | Mollusca |
| **Class** | Bivalvia |
| **Order** | Myoida |
| **Family** | Myidae |

**Final Rank** 59.50

**Data Deficiency:** 0.00

## Species Occurrence by Ecoregion

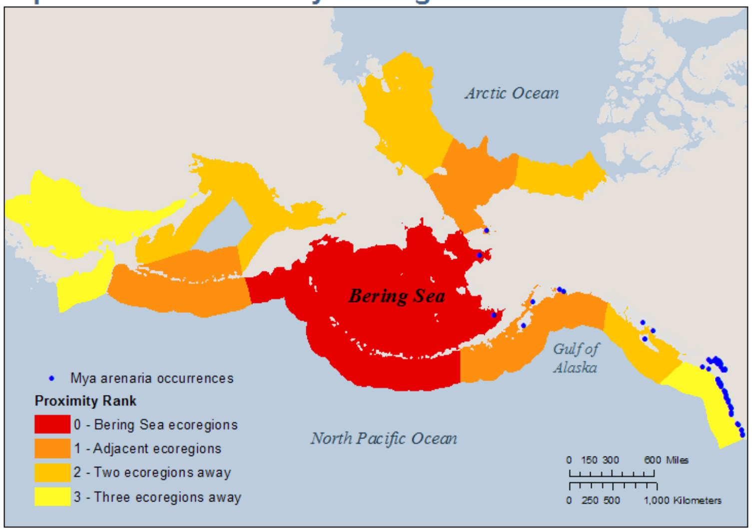


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

### Category Scores and Data Deficiencies

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 25.25 | 30 | 0 |
| Anthropogenic Influence: | 6 | 10 | 0 |
| Biological Characteristics: | 22.75 | 30 | 0 |
| Impacts: | 5.5 | 30 | 0 |
| **Totals:** | 59.50 | 100.00 | 0.00 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | -0.2 | Minimum Salinity (ppt) | 3 |
| Maximum Temperature (°C) | 32.5 | Maximum Salinity (ppt) | 35 |
| Minimum Reproductive Temperature (°C) | 4 | Minimum Reproductive Salinity (ppt) | 10 |
| Maximum Reproductive Temperature (°C) | 23 | Maximum Reproductive Salinity (ppt) | 35* |

### Additional Notes

Mya arenaria is a burrowing bivalve that buries deeply in soft-bottom substrates. It is an important species in its native range in eastern North America, where it supports both commercial and recreational fisheries. On the West Coast, it historically supported commercial fisheries in San Francisco Bay and elsewhere, but is now largely taken by recreational harvesters (Cohen and Carlton 1995). In many areas where M. arenaria has been introduced, it has become a dominant member of the infaunal community (Warwick and Price, 1975; Beukema, 1982, 1992; Brey, 1991), and has apparently had little to no negative effects on the endemic fauna (Strasser, 1999).

The paleontological record suggests that M. arenaria occupied many areas in the northeast Pacific during the Miocene and Pliocene, before becoming extirpated (Powers et al. 2006). However, over the last 300 to 700 years, M. arenaria has successfully reinvaded many areas within its paleontological range through intentional and unintentional introductions, and range expansions. Introductions of M. arenaria on the northeastern Pacific coast is recent, and occurred via plantings of Eastern oysters (Crassostrea virginica) from the eastern Unites States in the late 1800s and early 1900s (Powers et al. 2006). Although M. arenaria may have occurred in Alaska 5 mya, today it is considered as an invasive species in southcentral Alaska (Powers et al. 2006).

**Reviewed by** Nora R. Foster, NRF Taxonomic Services, Fairbanks AK

**Review Date:** 9/27/2017

# 1. Distribution and Habitat

### *1.1 Survival requirements - Water temperature*

**Choice: B** Moderate overlap – A moderate area (≥25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 2.5 of 3.75

**High uncertainty?** ☑

**Ranking Rationale:**
Temperatures required for year-round survival occur in a moderate area (≥25%) of the Bering Sea. We ranked this question with "High Uncertainty" to indicate disagreements in model estimates. This species is already found in the Bering Sea.

**Background Information:**
Temperature range: -0.2 to 32.5°C. Upper limit is based on 24-hour experiment (qtd. in Fofonoff et al. 2003). Relatively high abundances of juveniles were observed following winters with average water temperatures of -0.2°C (Möller 1986).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Möller 1986

### *1.2 Survival requirements - Water salinity*

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
Can tolerate salinity ranges from 3 to 35 PSU (Fofonoff et al. 2003), but lower salinities may lead to reduced growth and survivorship (Powers et al. 2006). Powers et al. (2006) found lowest abundances of M. arenaria at a site of freshwater outflow with high turbidity and salinity between 2 and 26 PSU.

**Sources:**
NEMESIS; Fofonoff et al. 2003   Powers et al. 2006

### *1.3 Establishment requirements - Water temperature*

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has temperatures suitable for reproduction

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Temperatures required for reproduction occur over a large (>75%) area of the Bering Sea.

**Background Information:**
This species' reproductive temperature range ranges from 4 to 23°C (qtd. in Fofonoff et al. 2003). Some authors have suggested that this species requires spawning temperatures between 10 and 12°C; however, a spawning peak was observed in Massachusetts at temperatures of 4 to 6°C, and a water temperature of 10°C is rarely reached in Labrador, where this species is established (qtd. in Strasser 1999). Stickney (1964) observed high mortality and poor development at temperatures 8°C and below, with optimal larval development occuring between 17 and 23°C (qtd. in Stasser 1999).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Strasser 1999

### 1.4 *Establishment requirements - Water salinity*

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for reproduction occur over a large (>75%) area of the Bering Sea.

**Background Information:**
This species' reproductive salinity range is from 10 to 35 PSU (qtd. in Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 1.5 *Local ecoregional distribution*

**Choice: A** Present in the Bering Sea

**Score:** 5 of 5

**Ranking Rationale:**
This species is already present in the Bering Sea.

**Background Information:**
This species has been recorded north to Bristol Bay and Norton Sound. Established populations are already present in southcentral Alaska (Prince William Sound).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Powers et al., 2006

### 1.6 *Global ecoregional distribution*

**Choice: B** In a moderate number of ecoregions globally

**Score:** 3.25 of 5

**Ranking Rationale:**
This species is found in subarctic, cold temperate, and some warm temperate ecoregions.

**Background Information:**
Mya arenaria is native to North America’s Atlantic coast, from Newfoundland to North Carolina. It was introduced to the West Coast, and now occurs from California north to Alaska. Globally, it has a circumpolar distribution from Iceland to the Barents Sea (Norway to eastern Russia). In Europe, it is found along the Atlantic coast, from Scandinavia to Portugal, Italy, and Greece. In Asia, it is established from the Yellow Sea to the Bering Sea.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Powers et al. 2006

### 1.7 *Current distribution trends*

**Choice: B** History of rapid expansion or long-distance dispersal (prior to the last ten years)

**Score:** 3.25 **of** 5

**Ranking Rationale:**
Both rapid range expansion and natural, long-distance dispersal have been proposed to explain the low genetic variability amongst some populations of Mya arenaria. These expansion events took place several (> 10) years ago.

**Background Information:**
Strasser and Barber (2009) found low genetic diversity across populations in the Northwest Atlantic. The authors proposed either natural, long-distance dispersal (promoted by strong oceanic currents) or population expansion to explain their findings. Lasota et al. (2004) found similarly low levels of genetic variability amongst European populations, and point to rapid range expansion, high gene flow or allele neutrality as possible explanatory mechanisms. Neither of these expansion events took place in the last ten years.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Lasota et al., 2004 Strasser and Barber 2009

| | |
|---|---|
| **Section Total - Scored Points:** | 25.25 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 2. Anthropogenic Transportation and Establishment



***2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport***

**Choice: A** Has been observed using anthropogenic vectors for transport and transports independent of any anthropogenic vector once introduced

**Score:** 4 **of** 4

**Ranking Rationale:**
Can be transported using several anthropogenic vectors including intentional introductions for aquaculture, hitchhiking, and ballast water. Once introduced, can disperse naturally.

**Background Information:**
This species has been intentionally introduced in certain parts of its non-native range. It can also be accidentally introduced when transporting or introducing Eastern oysters. Its long-lived larval stage can be transported in ballast water. Its current range in Europe is largely the result of natural range expansions (Strasser 1999).

**Sources:**
Strasser 1999

***2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish***

**Choice: D** Does not use anthropogenic disturbance/infrastructure to establish

**Score:** 0 **of** 4

**Ranking Rationale:**
This species establishes on natural, soft-bottom substrates.

**Background Information:**
Its current range in Europe is largely the result of natural range expansions (Strasser 1999). It can establish in undisturbed areas on sand, mud, and gravel substrates.

**Sources:**
Strasser 1999 NEMESIS; Fofonoff et al. 2003

***2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?***

**Choice: A** Yes

**Score:** 2 **of** 2

**Ranking Rationale:**
This species is commercially and/or recreationally harvested in its native and introduced range.

**Background Information:**
In its native range, it is an important shellfish species and supports both commercial and recreational fisheries. It was intentionally introduced to the west coast of North America for aquaculture (Strasser 1999).

**Sources:**
Strasser 1999

| | |
|---|---|
| **Section Total - Scored Points:** | 6 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics



### *3.1 Dietary specialization*

**Choice: A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Phytoplankton is readily available in the Bering Sea.

**Background Information:**
This species is a suspension feeder that feeds on phytoplankton. An experiment by Bacon et al. (1998) found that Mya arenaria was able to retain high feeding rates even in habitats with high concentrations of low quality particles.

**Sources:**
NEMESIS; Fofonoff et al. 2003   Bacon et al., 1998

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice: A** Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 of 5

**Ranking Rationale:**
Can tolerate a wide range of temperatures, salinities, and water depths, as well as high nitrogen loads. Adults can survive in anaerobic environments for several days.

**Background Information:**
Commonly found in intertidal and shallow subtidal areas with sandy or muddy substrates. Tolerates wide tidal ranges and salinities better than many native clams (Fofonoff et al. 2003). In estuaries such as Chesapeake Bay and brackish seas such as the Baltic, softshell clams can be abundant at salinities as low as 4-5 PSU; however, some studies have found that M. arenaria exhibits reduced growth at low salinities (Kube et al. 1996, qtd. in Powers et al. 2006; Carmichael et al. 2004). Locations with clean, fast-flowing water sustain the highest populations of M. arenaria (Tyler-Walters, 2003, qtd. in GISD 2007).

High nitrogen loads (e.g., as a result of eutrophication) were found to be beneficial for the shell growth of clams, because of increased food supply driven by N enrichment (Carmichael et al. 2004).

Adult clams are very tolerant of anaerobic environments and can survive in an oxygen depleted environment for up to 8 days (Cohen 2005, qtd. in GISD 2007). However, low oxygen concentrations may reduce juvenile survival (Carmichael et al. 2004).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Carmichael et al. 2004   GISD 2016   Leblanc and Miron   Powers et al. 2006

### 3.3 *Desiccation tolerance*

**Choice: B** Moderately tolerant (1-7 days) during one or more stages during its life cycle

**Score:** 3.25 of 5

**High uncertainty?** ☑

**Ranking Rationale:**
This species can be exposed to air for at least 54 hours without showing signs of stress. The exposure time required to cause mortality is unknown. Exposure to air with < 100% humidity may elicit stress responses sooner.

**Background Information:**
A study exposing M. arenaria to air for 54 h at 10°C and 100% humidity found that these conditions were not stressful enough to alter the clam's burying behavior, or to cause a change in various biochemical markers (proteins, glycogen, and lipid classes) (Picard et al. 2014). Clams were able to burrow into sediment as soon as they were re-immersed in water. Picard et al. (2014) suggest that bivalves' ability to reduce their metabolism and activity during air exposure allows them to conserve their energy reserves, which are then still available to them when they are re-immersed. Experiments were conducted on young clams with an average shell length of 22.6 mm.

**Sources:**
Picard et al. 2014

### 3.4 *Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice: B** Moderate – Exhibits one or two of the above characteristics

**Score:** 3.25 of 5

**Ranking Rationale:**
This species is highly fecund, has low parental investment, and fertilization is external. Hermaphroditic individuals are rare. This species is long-lived, and age to sexual maturity is high.

**Background Information:**
Sexual reproduction with external fertilization. Sexes are separate, but there are low incidences of hermaphroditism. No parental investment. The number of eggs per female varies from 120 000 to 5 million, depending on the environment and size of the female (Strasser 1999). Less than 0.1 % of the eggs produced in a spawning season result in successful settlement (Newell and Hidu 1986, qtd. in Abgrall et al. 2010).

Sexuality maturity and lifespan: Size appears more important than age in determining maturity. Maturity occurs at about 20 mm length (about 1 to 4 years, depending on the length of each growing season). Growth is dependent on water temperature. In Alaska, the softshell clam grows ~50 mm every 6 to 7 years (Abraham and Dillon 1986; Council PWSRCA 2004 – qtd. in NIMPIS 2016). The typical lifespan is between 10 to 12 years, but some can live up to 28 years (Cohen 2005, qtd. in GISD 2007).

**Sources:**
Strasser 1999 Abgrall et al. 2010

### *3.5 Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice:** **A** Disperses long (>10 km) distances

**Score:** 2.5 **of** 2.5

**Ranking Rationale:**

Larvae are long-lived and can disperse across long distances. Juveniles can disperse over small to moderate spatial scales.

**Background Information:**

This species has a long, free-swimming larval stage (2 to 5 weeks). Shanks (2009) estimated a mean larval dispersal distance of 35 km. Juveniles can be transported with sediment even after initial settlement. Jennings and Hunt (2009) reported dispersal distances of up to 50 cm during short (3.5 - 5 hours) field observations. A dispersal model by Hunt et al. (2009) estimated that transport by sediment could alter distribution patterns over a scale of several kilometers in one month. If disturbed, young clams can re-burrow, but adults have limited mobility because of their large shell size (Tyler-Walters 2003, qtd. in GISD 2007).

**Sources:**

Shanks 2009 Jennings and Hunt Hunt et al. 2009 GISD 2016

### *3.6 Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice:** **A** High – Exhibits two or three of the above characteristics

**Score:** 2.5 **of** 2.5

**Ranking Rationale:**

This species can disperse at various life stages: eggs (external fertilization), larvae, juveniles. Planktonic larval stage is long-lived (2 to 5 weeks). Eggs and larvae can disperse passively with water currents. Larvae are free-swimming. Juveniles are mobile, but movement is limited.

**Background Information:**

The larval stage in this species is long-lived. Larvae are free-swimming and spend 2 to 5 weeks moving in the water column before metamorphosizing and settling to the bottom of the sea floor. Shanks et al. (2009) estimated that larvae disperse an average of 35 km. Larvae then spend another 2 to 5 weeks in this juvenile stage moving small distances along the sea floor or temporarily attaching themselves to objects, before burrowing in the substrate. Juvenile dispersal can be facilitated by sediment transport (e.g., erosion). Once burrowed, young adults may be able to move if they are disturbed, but older individuals have limited mobility because of their large shell (Tyler-Walters 2003, qtd. in GISD 2007).

**Sources:**

Shanks 2009 GISD 2016

### *3.7 Vulnerability to predators*

| Choice: | | Score: |
|---|---|---|
| **D** | Multiple predators present in the Bering Sea or neighboring regions | **1.25** of **5** |

**Ranking Rationale:**

Several taxa found in the Bering Sea prey upon larvae and juveniles.

**Background Information:**

Larvae and newly settled spat are very vulnerable to predation. Small clams are eaten by fishes, crabs, clam worms (Nereidae), moon snails (Naticidae), ducks, shorebirds, and fishes. Clams are less vulnerable to predation when they reach ~ 60 mm in length (Newell and Hidu 1986, qtd. in Fofonoff et al. 2003).

**Sources:**

NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 22.75 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

# 4. Ecological and Socioeconomic Impacts



## 4.1 *Impact on community composition*

**Choice:** **C**

Limited – Single trophic level; may cause decline but not extirpation

**Score:** 0.75 **of** 2.5

**Ranking Rationale:**

This species may compete with and reduce populations of native bivalves. These effects may be more pronounced in areas where Mya arenaria occurs at very high densities.

**Background Information:**

Introduced populations of Mya arenaria may outcompete native bivalves, including Macoma balthica in the Baltic Sea (Obolewski and Piesik 2005), Lentidium mediterraneum and Corbula mediterranea in the Black Sea (Gollasch and Leppakoski 1999, qtd. in NIMPIS 2016; Skolka and Preda 2010), and Cerastoderma edule in Sweden (Möller 1986). In the case of C. edule, competition was reciprocal, with one species or the other having heavy recruitment in some years, and inhibiting recruitment of the other (Möller 1986). In San Francisco Bay, where it occurs at high densities (100 to >1000 clams/m2), it is reported to have replaced populations of the native bent-nosed clam (Macoma nasuta) (qtd. in Molnar et al. 2008). The impacts of M. arenaria are difficult to determine in many regions because it has been present for several hundred years (Jensen 2010).

**Sources:**

Jensen 2010   NEMESIS; Fofonoff et al. 2003   Molnar et al. 2008   Möller 1986   NIMPIS 2009   Obolewski and Piesik 2005   Skolka and Preda 2010

## 4.2 *Impact on habitat for other species*

**Choice:** **B**

Moderate – Causes or has potential to cause changes to one or more habitats

**Score:** 1.75 **of** 2.5

**Ranking Rationale:**

This species' has the potential to change habitat through its burrowing activities. Its shell provides hard habitat for other marine organisms.

**Background Information:**

Mya arenaria burrows deeply (10 to 25 cm) in soft substrate habitats. In doing so, it increases habitat availability for other organisms such as nematodes by enabling them to penetrate deeper in the sediment layer (Urban-Malinga et al. 2016). Mya arenaria often dies in situ, forming “death assemblages” (Strasser 1999), which can persist for more than 100 years and serve as habitats for other species (Palacios et al., 2000, qtd. in Jensen 2010).

**Sources:**

Jensen 2010   Urban-Malinga et al. 2016   Strasser 1999

### 4.3 *Impact on ecosystem function and processes*

**Choice: C** Limited – Causes or potentially causes changes to food webs and/or ecosystem functions, with limited impact and/or within a very limited region

**Score:** 0.75 of 2.5

**Ranking Rationale:**
Through its burrowing, excretory, and feeding activities, Mya arenaria can impact water clarity and sedimentation.

**Background Information:**
As a powerful burrower and filterer, it has the potential to alter ecosystem characteristics through bioturbation and deposition of pseudofeces, as well as through suspension feeding, which can increase water clarity and light penetration (Obolewski and Piesik 2005; Forster and Zettler 2004; de Moura Queiros et al. 2011; Zaiko et al. 2011). In addition, water leaking from its shell can irrigate the sediment in which it is burrowed, with potential impacts on sediment biogeochemistry (Forster and Zettler 2004). In Poole Harbour, UK, Mya arenaria was considered to be most important bioturbator (de Moura Queiros et al. 2011).

Microcosm experiments on several bivalve species, including M. arenaria, found no overall effect on total meiobenthic densities (Urban-Malinga et al. 2016). However, the burrowing activities of M. arenaria might facilitate meiobenthos to penetrate to deeper sediment layers. In addition, the faeces and pseudofaeces deposited at the sediment surface might increase microbial activity and sulfur reduction rates, and promote microbial communities (Hansen et al. 1996; Urban-Malinga et al. 2016). The microbial community in turn supports rotifers and bivalves species (Urban-Malinga et al. 2016).

Skolka and Preda (2010) claim that Mya arenaria induced structural changes in ecosystems previously dominated by Lentidium mediterraneum, but the authors do not provide any additional information.

**Sources:**
Zaiko et al. 2011   Obolewski and Piesik 2005   Forster and Zettler 2004   de Moura Queiros et al. 2011   Urban-Malinga et al. 2016   Hansen et al. 1996   Skolka and Preda 2010

### 4.4 *Impact on high-value, rare, or sensitive species and/or communities*

**Choice: C** Limited – Has limited potential to cause degradation of one more species or communities, with limited impact and/or within a very limited region

**Score:** 0.75 of 2.5

**High uncertainty?** ✔

**Ranking Rationale:**
Two native Mya species occur in the Bering Sea. One of them (M. truncata) is the major food source for the Pacific walrus. Although no studies have been conducted on the interaction between these native species and M. arenaria, M. arenaria is known to compete and replace native bivalves in some parts of its introduced range.

**Background Information:**
Two native Mya species occur in the Bering Sea: Mya truncata and M. pseudoarenaria; both are found in soft sediments in upper intertidal to subtidal zones (N. Foster, pers. comm., 27 September 2017). Although we are not aware of any studies on the potential effects of M. arenaria on these two species, M. arenaria is known to compete with native bivalves in parts of its introduced range. Competition with M. truncata could have implications for Bering Sea food webs because M. truncata is the main food source for the Pacific walrus (Odobenus rosmarus).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.5 *Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No impacts have been reported.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.6 *Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No impacts have been reported.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.7 *Infrastructure*

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
No impacts have been reported. This species is not known to foul ships or infrastructure.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.8 *Commercial fisheries and aquaculture*

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
Mya arenaria is an important commercial shellfish species. No negative impacts on other commercial fisheries have been reported.

**Background Information:**
In its native range, Mya arenaria is an important commercial shellfish species. In New Brunswick, Canada, the estimated mean annual landing value of the commercial softshell clam fishery reached $700,000 in 2003 (Fisheries and Oceans Canada 2005a, qtd. in Abgrall et al. 2010).

**Sources:**
Abgrall et al. 2010

### 4.9 *Subsistence*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
No impacts have been reported.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.101 *Recreation*

**Choice: C** Limited – Has limited potential to cause degradation to recreation opportunities, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
Accumulations of dead individuals can reduce the aesthetic value of shorelines.

**Background Information:**
The accumulation of dead (and foul-smelling) individuals along shorelines can reduce recreational opportunities. This problem has been reported in tourist areas around the Black Sea (Gollasch and Leppakoski 1999, qtd. in NIMPIS).

**Sources:**
NIMPIS 2009

### 4.11 *Human health and water quality*

**Choice: C** Limited – Has limited potential to pose a threat to human health, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
Cases of PSP and other shellfish syndromes are rare in Alaska. Current regulations and safety procedures greatly reduce the risk of bacterial transmission, especially in cultivated mussels. Recreational harvesting of shellfish in the Bering Sea is limited.

**Background Information:**
All bivalves can bioaccumulate toxins in their tissues as a result of consuming toxic dinoflagellates. Consuming raw or cooked bivalves can lead to Paralytic Shellfish Poisoning (PSP), which can cause health issues and even death (NIMPIS 2009). The state of Alaska discourages harvesting on untested beaches (ADEC 2013).

**Sources:**
NIMPIS 2009 ADEC 2013

| | |
|---|---|
| **Section Total - Scored Points:** | 5.5 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

# 5. Feasibility of prevention, detection and control

## *5.1 History of management, containment, and eradication*

**Choice:** **C** Attempted; control methods are currently in development/being studied

**Score:** of

**Ranking Rationale:**
To our knowledge, there have been no attempts to control or eradicate soft-shell clams. More generally, controlling the spread of invasive species that use anthropogenic vectors for transport is an active area of research (e.g. Ruiz and Reid 2007, Hagan et al. 2014).

**Background Information:**

**Sources:**
Ruiz and Reid 2007 Hagan et al. 2014

## *5.2 Cost and methods of management, containment, and eradication*

**Choice:** **A** Major long-term investment, or is not feasible at this time

**Score:** of

**Ranking Rationale:**
Because this species is well-established in its introduced range, eradication is not currently feasible.

**Background Information:**
This species is well-established in its non-native range, which makes eradication unfeasible (Hoagland & Jin 2006, qtd. in GISD 2007).

**Sources:**
GISD 2016

## *5.3 Regulatory barriers to prevent introductions and transport*

**Choice:** **C** Regulatory oversight and/or trade restrictions

**Score:** of

**Ranking Rationale:**
This species has been intentionally introduced, and accidentally introduced with other species such as the Eastern oyster. Ballast water is likely the most prevalent vector for introductions today. The management of ballast water in Alaska is regulated by the U.S. Coast Guard and the Environmental Protection Agency.

**Background Information:**
In the U.S., ballast water management is mandatory and regulated by the U.S. Coast Guard, with additional permitting by the Environmental Protection Agency (CFR 33 § 151.2; EPA 2013; EPA 2014). Certain vessels are exempted from USCG and EPA regulations.

A study by Briski et al. (2012) found Mya arenaria present in ballast water samples. Mid-ocean ballast water exchange did not affect occurrence, which suggests that exchange of ballast water is ineffective for this taxonomic group.

**Sources:**
CFR 2017 Briski et al. 2012 EPA 2013 EPA 2014

### 5.4 *Presence and frequency of monitoring programs*

**Choice: A** No surveillance takes place

**Score:** of

**Ranking Rationale:**
This species is not currently monitored.

**Background Information:**
No information found.

**Sources:**
None listed

### 5.5 *Current efforts for outreach and education*

**Choice: A** No education or outreach takes place

**Score:** of

**Ranking Rationale:**
No outreach or education is currently taking place for this species.

**Background Information:**
No information found.

**Sources:**
None listed

**Section Total - Scored Points:**
**Section Total - Possible Points:**
**Section Total -Data Deficient Points:**

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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Mytilus galloprovincialis*

**Common Name** *Mediterranean mussel*

| | |
|---|---|
| **Phylum** | Mollusca |
| **Class** | Bivalvia |
| **Order** | Mytiloida |
| **Family** | Mytilidae |

**Final Rank** 67.75

**Data Deficiency:** 0.00

### Species Occurrence by Ecoregion

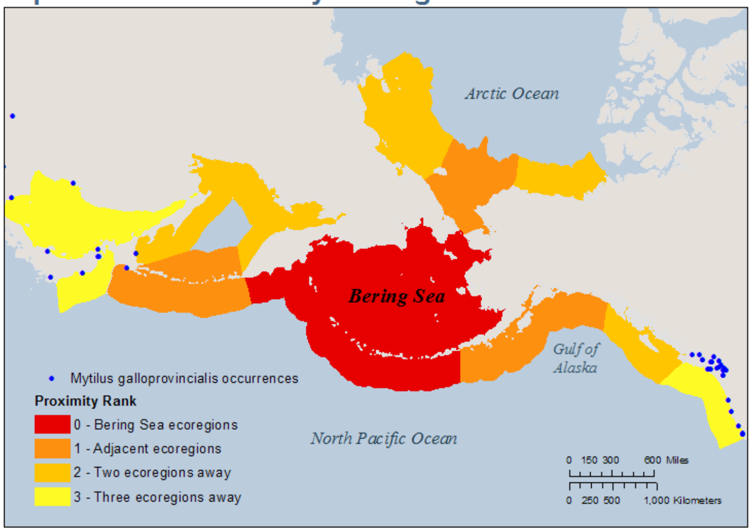


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 21.25 | 30 | 0 |
| Anthropogenic Influence: | 10 | 10 | 0 |
| Biological Characteristics: | 23.75 | 30 | 0 |
| Impacts: | 12.75 | 30 | 0 |
| **Totals:** | 67.75 | 100.00 | 0.00 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | 7 | Minimum Salinity (ppt) | 10 |
| Maximum Temperature (°C) | 31 | Maximum Salinity (ppt) | 38 |
| Minimum Reproductive Temperature (°C) | 15 | Minimum Reproductive Salinity (ppt) | 20 |
| Maximum Reproductive Temperature (°C) | 25 | Maximum Reproductive Salinity (ppt) | 38 |

### Additional Notes

Mytilus galloprovincialis (the Mediterranean Mussel) is native to the Mediterranean Sea and has been intentionally and accidentally introduced worldwide. It is an important aquaculture species due to its high growth rate and reproductive output.

**Reviewed by** Nora R. Foster, NRF Taxonomic Services, Fairbanks AK

**Review Date:** 9/27/2017

# 1. Distribution and Habitat



### 1.1 *Survival requirements - Water temperature*

**Choice:** **D**

No overlap – Temperatures required for survival do not exist in the Bering Sea

**Score:** **0** **of** **3.75**

**Ranking Rationale:**
Year-round temperature requirements do not exist in the Bering Sea.

**Background Information:**
M. galloprovincialis is a cold-temperate to warm-temperate species. It can tolerate temperatures up to 31°C for short periods of time (< 1 month), but exhibits stress responses above 24°C (Anestis et al. 2007; Schneider 2008). A minimum threshold of ~7°C has been suggested based on experiments and geographic distribution (DAFF 2016).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Schneider 2008   DAFF 2016   Anestis et al. 2007

### 1.2 *Survival requirements - Water salinity*

**Choice:** **A**

Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** **3.75** **of** **3.75**

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
The salinity range for survival is 10 ppt to 38 ppt (Shurova 2001; Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Shurova 2001

### 1.3 *Establishment requirements - Water temperature*

**Choice:** **D**

No overlap – Temperatures required for reproduction do not exist in the Bering Sea

**Score:** **0** **of** **3.75**

**Ranking Rationale:**
Temperatures required for reproduction do not exist in the Bering Sea.

**Background Information:**
The reproductive temperature range for M. galloprovincialis is 15°C to 26°C (His et al. 1989).

**Sources:**
NEMESIS; Fofonoff et al. 2003   His et al. 1989

### 1.4 *Establishment requirements - Water salinity*

**Choice:** **A**

Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** **3.75** **of** **3.75**

**Ranking Rationale:**
Salinities required for reproduction occur over a large (>75%) area of the Bering Sea.

**Background Information:**
The salinity profile for reproduction of M. galloprovinicialis is 20 PSU to 38 PSU (His et al. 1989).

**Sources:**
NEMESIS; Fofonoff et al. 2003   His et al. 1989

### *1.5 Local ecoregional distribution*

**Choice:** **B** Present in an ecoregion adjacent to the Bering Sea

**Score:** 3.75 of 5

**Ranking Rationale:**
Found in the Sea of Okhotsk.

**Background Information:**
Found in the Sea of Okhotsk, Japan, Hong Kong, and Korea. In North America, it occurs in California, Washington, Oregon, and British Columbia.

**Sources:**
Branch and Steffani 2004

### *1.6 Global ecoregional distribution*

**Choice:** **A** In many ecoregions globally

**Score:** 5 of 5

**Ranking Rationale:**
Found in ecoregions worldwide, but restricted to temperate regions.

**Background Information:**
Its native range is the Mediterranean Sea, mainly on the northern shore. Introduced populations occur from Morocco to the U.K. (McDonald et al. 1991 as qtd. in Fofonoff et al. 2003; Hilbish et al. 2000; Smietanka et al. 2004), South Africa, New Zealand, Japan, Hong Kong, northeastern Russia, southwest South America, and the West Coast of North America (Fofonoff et al. 2003). M. galloprovinicialis is cryptogenic in southern South America, Australia, and New Zealand (Fofonoff et al. 2003).

**Sources:**
Hilbish et al. 2000 NEMESIS; Fofonoff et al. 2003 Smietanka et al. 2004

### *1.7 Current distribution trends*

**Choice:** **A** Recent rapid range expansion and/or long-distance dispersal (within the last ten years)

**Score:** 5 of 5

**Ranking Rationale:**
Rapid colonization and long-distance dispersal have been documented.

**Background Information:**
Rapid colonization and long-distance dispersal have been documented (Branch and Steffani 2004). All introductions so far have been in temperate regions and at localities where there are large shipping ports (Branch and Steffani 2004).

**Sources:**
Branch and Steffani 2004

| | |
|---|---|
| **Section Total - Scored Points:** | 21.25 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 2. Anthropogenic Transportation and Establishment



*2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice: A** — Has been observed using anthropogenic vectors for transport and transports independent of any anthropogenic vector once introduced

**Score:** 4 of 4

**Ranking Rationale:**
Transported by numerous anthropogenic vectors and capable of transporting during the larval stage on their own.

**Background Information:**
Can be introduced via ship hull fouling and transport of ballast water (Geller et al., 1994 as qtd. in Branch and Steffani 2004). In Japan and in China, where it is widely cultivated, it has spread as a result of larval dispersal from mussel farms.

**Sources:**
Branch and Steffani 2004   GISD 2016b   NEMESIS; Fofonoff et al. 2003

*2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice: A** — Readily establishes in areas with anthropogenic disturbance/infrastructure and in natural, undisturbed areas

**Score:** 4 of 4

**Ranking Rationale:**
Can establish in anthropogenic areas (e.g. in cultivation) and in undisturbed areas.

**Background Information:**
Larvae can escape from farms and establish wild populations. Areas of introduction are associated with large shipping ports, but once introduced, readily expands its range (Branch and Steffani 2004).

**Sources:**
Branch and Steffani 2004   GISD 2016b

*2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice: A** — Yes

**Score:** 2 of 2

**Ranking Rationale:**

**Background Information:**
Widely cultivated in China, Japan, South Africa, Australia, and from California to British Columbia.

**Sources:**
GISD 2016b   NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 10 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics



### 3.1 Dietary specialization

**Choice:** **A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Consumes numerous taxa, many of which exist in the Bering Sea.

**Background Information:**
Filter feeder, feeds on a wide range of planktonic organisms. Shown to be a generalist and adaptive feeder over a wide range of plankton concentrations and water flow velocities (Denis et al. 1999).

**Sources:**
Denis et al. 1999   GISD 2016b

### 3.2 Habitat specialization and water tolerances

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **B** Requires specialized habitat for some life stages (e.g., reproduction)

**Score:** 3.25 of 5

**Ranking Rationale:**
Current distribution mostly restricted to temperate regions. Habitat and food is likely available in the Bering Sea, but reproduction and growth cycles require water temperatures not readily found in the Bering Sea.

**Background Information:**
Low tolerance to siltation and low salinity (below 18PSU). Prefers semi-exposed or exposed habitats with a high rate of water flow; in South Africa, rarely became established at sheltered sites in spite of rapid colonization and spread (Branch and Steffani 2004). In South Africa, known to exist where temperatures can drop to a minimum of approximately 7°C during peak upwelling season. However, optimal water temperature for larval growth occurred at 20°C (His et al. 1988). Low tolerance for warm waters limits its expansion into subtropical areas, where water temperatures are between 22-27°C (Assis et al. 2015). An ecotoxicology study conducted in a heavily industrial area found that M. galloprovincialis showed signs of stress in response to anthropogenic pollution (Cappello et al. 2013).

**Sources:**
Assis et al. 2015   Branch and Steffani 2004   Cappello et al. 2013   GISD 2016b   His et al. 1989   NEMESIS; Fofonoff et al. 2003

### 3.3 Desiccation tolerance

**Choice:** **A** Highly tolerant (>7 days) of desiccation at one or more stages during its life cycle

**Score:** 5 of 5

**Ranking Rationale:**
High dessication tolerance.

**Background Information:**
Very high desiccation tolerance. Individuals that were continuously exposed to air for up to 7 days exhibited 92% survivorship (Branch and Steffani 2004).

**Sources:**
Branch and Steffani 2004   GISD 2016b

### 3.4 *Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice: A** High – Exhibits three or four of the above characteristics

**Score:** 5 **of** 5

**Ranking Rationale:**
Sexual reproduction, high fecundity, external fertilization, short generation time.

**Background Information:**
Sexual reproduction with external fertilization. High fecundity, with millions of gametes released during spawning events (DAFF 2016). Long spawning season. In some regions, can spawn year-round (Seed 1969). Individuals reach maturity within one year.

**Sources:**
Branch and Steffani 2004 DAFF 2016 GISD 2016b NEMESIS; Fofonoff et al. 2003 Seed 1969

### 3.5 *Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice: A** Disperses long (>10 km) distances

**Score:** 2.5 **of** 2.5

**Ranking Rationale:**
M. galloprovincialis disperses an average of 35 km.

**Background Information:**
Larvae can disperse passively via surface currents generated by wind (Branch and Steffani 2004). On the coast of San Diego County, larvae dispersed an average of 35 km, though a large proportion settled more locally. A few (1.5%) dispersed for more than 125 km. There was extensive genetic exchange between bays and between open-coast and bay populations (Lopez-Duarte et al. 2012). In South Africa, M. galloprovincialis had spread along 223km of coastline within three years of its introduction (Branch and Steffani 2004).

**Sources:**
Branch and Steffani 2004 Lopez-Duarte et al. 2012 NEMESIS; Fofonoff et al. 2003

### 3.6 *Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: B** Moderate – Exhibits one of the above characteristics

**Score:** 1.75 **of** 2.5

**Ranking Rationale:**
M. galloprovincialis has a relatively long planktonic larval stage and limited dispersal ability as an adult.

**Background Information:**
Adults are mostly sessile (though they do have a muscular foot which allows them to crawl if microhabitat is unfavourable; Cáceres-Martínez et al. 1994). Adults can potentially be transported overland if attached to fishing or shipping gear. Larvae are suspended in the water column and can disperse via wind-generated water currents (Branch and Steffani 2004). For three Mytilus spp. in western North America: Temporal variability in recruitment rates, dependent on peak reproduction period: in Oregon, this peak occurred in late summer-early fall, but switched to wintertime in northern and central California (Broitman et al. 2008).

**Sources:**
Branch and Steffani 2004 Broitman et al. 2008 Caceres-Martinez et al. 1994

### *3.7 Vulnerability to predators*



**Choice:** **D** Multiple predators present in the Bering Sea or neighboring regions

**Score:** 1.25 **of** 5

**Ranking Rationale:**
Numerous predators, many of which exist in the Bering Sea.

**Background Information:**
In South Africa, where it was introduced, whelk and oystercatchers were important predators that readily exploited M. galloprovincialis as a food resource (Branch and Steffani 2004). In California, common intertidal predators include seastars, crabs, and dog whelk (Shinen 2007).

**Sources:**
Branch and Steffani 2004   Shinen 2007

| | |
|---|---|
| **Section Total - Scored Points:** | 23.75 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

# 4. Ecological and Socioeconomic Impacts

## 4.1 *Impact on community composition*

**Choice: A** High – Entire community and/or may cause extirpation or extinction at the species or trophic level

**Score:** 2.5 of 2.5

**Ranking Rationale:**
Competes with similar species for food and space.

**Background Information:**
In California and in Japan, has replaced the closely related native mussel M. trossulus and Septifer virgatus (Geller 1999). In South Africa, competes with 3 native mussel species, but only competition with A. atar is considered to be of serious concern (DAFF 2016). Invasion by M. galloprovincialis led to an 80% reduction in A. atar at monitored sites near Saldanha Bay (Branch and Steffani 2004). Replacement of M. trossulus by M. galloprovincialis may not have severe impacts, as the two species support similar levels of species richness and diversity, indicating functional redundancy (Shinen 2007).

In Japan, outcompetes many other native species, including the Pacific oyster, a small barnacle, and an edible seaweed species (Chavanich et al. 2010). Competes for space with shore species including limpets, anemones, and seaweeds (Fofonoff et al. 2003; Branch and Steffani 2004).

In Langebaan Lagoon, South Africa, mussel beds of M. galloprovincialis replaces naturally-occurring sandbank communities with communities more typical of rocky shores (Robinson and Griffiths 2002).

Provides habitat to species small enough to live and reproduce on mussels and mussel beds. Provides an additional source of food for predators (Branch and Steffani 2004).

**Sources:**
Branch and Steffani 2004   Chavanich et al. 2010   DAFF 2016   Shinen 2007   Geller 1999   NEMESIS; Fofonoff et al. 2003   Robinson and Griffiths 2002

## 4.2 *Impact on habitat for other species*

**Choice: B** Moderate – Causes or has potential to cause changes to one or more habitats

**Score:** 1.75 of 2.5

**Ranking Rationale:**

**Background Information:**
By creating mussel beds, provides habitat for infaunal species, increasing overall infaunal biomass and abundance (Branch and Steffani 2004).

**Sources:**
Branch and Steffani 2004

### 4.3 *Impact on ecosystem function and processes*

**Choice:** **C**

Limited – Causes or potentially causes changes to food webs and/or ecosystem functions, with limited impact and/or within a very limited region

**Score:** 0.75 **of** 2.5

**Ranking Rationale:**
M. galloprovinicialis usually replaces very similar native organisms in function. Effects on ecosystems is likely to be most pronounced in areas with no native mussel species.

**Background Information:**
Impacts seem most pronounced in ecosystems where no native mussel species were present. For example, in central and southern Japan, invasion of M. galloprovincialis resulted in the mass deposition of pseudofeces in the sediment, creating hypoxic conditions (Chavanich et al. 2010). A study of mussel farms in the Iberian Peninsula showed that production of biodeposits increased natural sedimentation rates in the area, but this effect was partially counteracted by swift water currents (Zúñiga et al. 2014). Mussel biodeposits are high in nutrients and an important part of nutrient cycling in marine environments. Indeed, a study by Jansen et al. (2012) found that 1/3 of organic nutrients in biodeposits can be mineralized and thereby become available for primary producers. Through filter feeding, improves water quality.

**Sources:**
Jansen et al. 2012   NEMESIS; Fofonoff et al. 2003   Zuniga et al. 2014

### 4.4 *Impact on high-value, rare, or sensitive species and/or communities*

**Choice:** **D**

No impact

**Score:** 0 **of** 2.5

**Ranking Rationale:**
To date, no impacts on high-value, rare, or sensitive species have been reported for M. galloprovincialis.

**Background Information:**
No information found.

**Sources:**
None listed

### 4.5 *Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice:** **C**

Limited – Has limited potential to spread one or more organisms, with limited impact and/or within a very limited region

**Score:** 0.75 **of** 2.5

**High uncertainty?** ☑

**Ranking Rationale:**
Has been shown to host parasites in other locations. Unsure as to whether these parasites would survive or propagate in the Bering Sea.

**Background Information:**
Experimentally cultured mussels were found to host the parasites Marteilia refringens and the trematode Proctoeces maculatus (Villalba et al. 1997). M. refringens can also infect the blue mussel M. edulis. While mussels are usually not adversely affected by this parasite,  in France mortalities up to 100% were associated with heavy infection rates.

**Sources:**
Villalba et al. 1997   Culloty et al. 1999

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice:** **B**

Moderate – Causes or has potential to cause genetic changes in one or more species, with moderate impact and/or within only a portion of the region

**Score:** 1.75 **of** 2.5

**Ranking Rationale:**

Has been known to hybridize with numerous Mytilus species.

**Background Information:**

In Britain and Ireland, hybridizes with M. edilus. In western North America and in the northwest Pacific, hybridizes with M. trossulus, sometimes at very high frequencies (up to 70%). Although rates of F1 (first-generation hybrids) are often high, frequency of F2 hybrids is small, indicating that little genetic exchange is occurring between the two species (Rawson et al. 1999; Brannock and Hilbish 2010). This result could indicate poor survival or reduced fertility of hybrids, due to genetic incompatibility (Rawson et al. 1999). However, introgression between M. galloprovincialis and M. trossulus has been quite limited, and effects of hybridization with M. trossulus and M. edilus do not seem to go beyond the hybrid zone (Rawson et al. 1999; Hilbish et al. 2002). Hybridization has also been observed between native Southern Hemisphere M. galloprovincialis and introduced Northeast Atlantic lineages at several locations near ports in New Zealand. This introgression is considered a threat to the genetic biodiversity of native mussel populations, particularly on remote southern ocean islands, which harbors unique genetic lineages (Gardner et al. 2016).
In South Africa, hybridization with indigenous species is deemed unlikely (DAFF 2016).

**Sources:**

Branch and Steffani 2004 Brannock and Hilbish 2010 DAFF 2016 Gardner et al. 2016 Hilbish et al. 2002

### *4.7 Infrastructure*

**Choice:** **A**

High – Is known to cause degradation to infrastructure and/or is expected to have severe impacts and/or will impact the entire region

**Score:** 3 **of** 3

**Ranking Rationale:**

Fouling organism found on ships, docks, jetties, pipes, and industrial water systems.

**Background Information:**

Mytilus spp. are abundant and common fouling organisms on ships, docks, jetties, pipes, and industrial water systems (Woods Hole 1952). M. galloprovincialis has been found in Japanese power plants causing major expenses due to damage and cleaning (Iwasaki 2006). Its impacts on infrastructure may be difficult to recognize in areas where it has replaced M. trossulus.

**Sources:**

Woods Hole 1952 Iwasaki 2006 NEMESIS; Fofonoff et al. 2003

### 4.8 Commercial fisheries and aquaculture



**Choice:** **C** — Limited – Has limited potential to cause degradation to fisheries and aquaculture, and/or is restricted to a limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
Can cause a decrease in the abundance of other aquaculture species.

**Background Information:**
Interferes with aquaculture of other species, such as oysters (Chavanich et al. 2010). In Japan, growth of M. galloprovincialis led to a 35% reduction of oyster aquaculture (worth about 500 million Japanese yen). At the same time, cultivation of M. galloprovincialis is extensive in Japan. No negative impacts on commercial fisheries have been reported in South Africa (DAFF 2016). Introduction is usually positive from an economic perspective, because of its higher growth rates compared to native mussels (Fofonoff et al. 2003; DAFF 2016).

**Sources:**
Chavanich et al. 2010   DAFF 2016   NEMESIS; Fofonoff et al. 2003

### 4.9 Subsistence

**Choice:** **C** — Limited – Has limited potential to cause degradation to subsistence resources, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
Linked to declines of bait species.

**Background Information:**
In South Africa, M. galloprovincialis has had a negative impact on the limpet S. granularis, a bait species employed by traditional artisanal fishers (DAFF 2016). Higher growth rates of M. galloprovincialis relative to the local mussel species, has almost certainly contributed significantly to the success of the local mussel culture operations.

**Sources:**
DAFF 2016

### 4.101 Recreation

**Choice:** **D** — No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on recreation have been reported.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.11 Human health and water quality*



**Choice:** **C**

Limited – Has limited potential to pose a threat to human health, with limited impact and/or within a very limited region

**Score:** **0.75** **of** **3**

**Ranking Rationale:**

Cases of PSP and other shellfish syndromes are rare in Alaska. Current regulations and safety procedures greatly reduce the risk of bacterial transmission, especially in cultivated mussels. Recreational harvesting of shellfish in the Bering Sea is limited.

**Background Information:**

All bivalves can bioaccumulate toxins in their tissues as a result of consuming toxic dinoflagellates. Consuming raw or cooked bivalves can lead to Paralytic Shellfish Poisoning (PSP), which can cause health issues and even death (NIMPIS 2009). The state of Alaska discourages harvesting on untested beaches (ADEC 2013).

**Sources:**

NIMPIS 2009 ADEC 2013

| | |
|---|---|
| **Section Total - Scored Points:** | 12.75 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 5. Feasibility of prevention, detection and control

### 5.1 *History of management, containment, and eradication*

**Choice: C** Attempted; control methods are currently in development/being studied

**Score:** of

**Ranking Rationale:**
Controlling the spread of invasive species that use anthropogenic vectors for transport is an active area of research (e.g. Ruiz and Reid 2007, Hagan et al. 2014).

**Background Information:**
Mussels populations are hard to control for due to their large distributions, high fecundity and easily dispersed larvae (Picker and Griffiths 2011 as qtd. in DAFF 2016). Difficulty differentiating between M. galloprovinicialis and native Mytilus species may complicate control efforts. There is also the potential of further introductions through pathways such as ballast water. In areas where M. galloprovincialis is farmed, the use of sterile triploid and tetraploid mussels, which have been recently developed by the aquaculture industry, helps prevent the spread of larvae into the wild.

**Sources:**
DAFF 2016   Ruiz and Reid 2007   Hagan et al. 2014

### 5.2 *Cost and methods of management, containment, and eradication*

**Choice: A** Major long-term investment, or is not feasible at this time

**Score:** of

**Ranking Rationale:**
Methods to control the spread of marine invasive species (e.g. through ballast water treatment or vessel cleaning) are being studied, and currently necessitate major long-term investments (Zagdan 2010; Hagan et al. 2014).

**Background Information:**
Treatment of ballast water and anti-fouling methods would help prevent spread.

**Sources:**
GISD 2016b   Zagdan 2010   Hagan et al. 2014

### 5.3 *Regulatory barriers to prevent introductions and transport*

**Choice: B** Regulatory oversight, but compliance is voluntary

**Score:** of

**Ranking Rationale:**
This species can be transported by several anthropogenic vectors. Currently, compliance with hull fouling regulations are largely voluntary.

**Background Information:**
Regulations exist regarding the transport and introduction of shellfish in water bodies. Under Alaska law, a permit must be obtained from the Alaska Department of Fish and Game (ADF&G) in order to collect, possess, or transport shellfish for educational, scientific, or propagative uses. Ballast water management is mandatory and regulated by the U.S. Coast Guard (CFR 33 § 151.2). However, compliance with ship fouling regulations are largely voluntary (Hagan et al. 2014).

**Sources:**
Hagan et al. 2014   CFR 2017

### 5.4 *Presence and frequency of monitoring programs*

**Choice: A** No surveillance takes place

**Score:** of

**Ranking Rationale:**

**Background Information:**
No informations available in the literature.

**Sources:**
None listed

### 5.5 *Current efforts for outreach and education*

**Choice: A** No education or outreach takes place

**Score:** of

**Ranking Rationale:**

**Background Information:**
No education or outreach material found. Not on the list of 50 priority species by the Washington Invasive Species Council. Not listed on the Oregon Department of Fish and Wildlife website or on the Invasive Species Council of British Columbia website. This species often co-occurs with native mussels and is hard to differentiate from other Mytilus species.

**Sources:**
NEMESIS; Fofonoff et al. 2003

**Section Total - Scored Points:**
**Section Total - Possible Points:**
**Section Total -Data Deficient Points:**

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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Petricolaria pholadiformis*

**Common Name** *false angelwing*

| | |
|---|---|
| **Phylum** | Mollusca |
| **Class** | Bivalvia |
| **Order** | Veneroida |
| **Family** | Petricolidae |

**Final Rank** 44.11

**Data Deficiency:** 8.75

Species Occurrence by Ecoregion

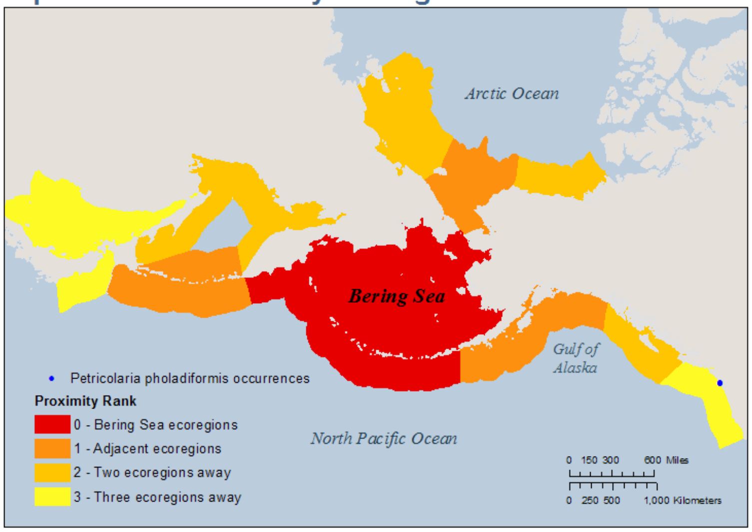


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 13.5 | 26 | 3.75 |
| Anthropogenic Influence: | 4 | 10 | 0 |
| Biological Characteristics: | 19.5 | 25 | 5.00 |
| Impacts: | 3.25 | 30 | 0 |
| **Totals:** | 40.25 | 91.25 | 8.75 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | 1 | Minimum Salinity (ppt) | 10 |
| Maximum Temperature (°C) | 26 | Maximum Salinity (ppt) | 35 |
| Minimum Reproductive Temperature (°C) | NA | Minimum Reproductive Salinity (ppt) | 31* |
| Maximum Reproductive Temperature (°C) | NA | Maximum Reproductive Salinity (ppt) | 35* |

### Additional Notes

Petricolaria pholadiformis is a bivalve with an elongated white shell. Many lines radiate from the umbo, and the first ten of these are rather well-defined. The shell is also marked by concentric growth lines. Adult shells measure ~55 mm. Adults live burrowed in substrates such as mud, soft rock, or clay. P. pholadiformis is native to eastern North America, and has been introduced to Europe and the western coast of North America. The most likely vectors of introduction for this species are accidental transport with the Eastern oyster (Crassostrea virginica), and transport via ballast water.

## 1. Distribution and Habitat

### *1.1 Survival requirements - Water temperature*

**Choice:** **C** Little overlap – A small area (<25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 1.25 **of** 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Temperatures required for year-round survival occur in a limited area (<25%) of the Bering Sea. Thresholds are based on geographic distribution, which may not represent physiological tolerances; we therefore ranked this question with "High uncertainty".

**Background Information:**
This species has been reported from Penobscot Bay, ME where water temperatures range from 1.1 to 14.1°C (NERACOOS 2016). In its native range, this species occurs as far south as Padre Island, TX (in the Gulf of Mexico), where water temperatures >26°C have been recorded (NOAA 2017).

**Sources:**
NERACOOS 2016   NOAA 2017

### *1.2 Survival requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 **of** 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
Based on its geographic distribution, this species can tolerate salinities up to 35 ppt (Fofonoff et al. 2003). Although it is a marine species, it is usually associated with sites that have some freshwater inflow. Experiments by Castagna and Chalney (1973, qtd. in Fofonoff et al. 2003) found high (90%) survival rates in individuals exposed to 10 ppt water for 52 to 92 days.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.3 Establishment requirements - Water temperature*

**Choice:** **U** Unknown/Data Deficient

**Score:** **of**

**Ranking Rationale:**
More information is needed to establish reproductive temperature requirements for this species.

**Background Information:**
Duval (1963) observed larvae and spawning at water temperatures between 16 and 19°C.

**Sources:**
NEMESIS; Fofonoff et al. 2003   Duval 1963

### 1.4 Establishment requirements - Water salinity

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 of 3.75

**High uncertainty?** ☑

**Ranking Rationale:**
Although salinity thresholds are unknown, this species is a marine organism that does not require freshwater to reproduce. We therefore assume that this species can reproduce in saltwater (31 to 35 ppt). These salinities occur in a large (>75%) portion of the Bering Sea.

**Background Information:**
No information found.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 1.5 Local ecoregional distribution

**Choice: D** Present in an ecoregion greater than two regions away from the Bering Sea

**Score:** 1.25 of 5

**Ranking Rationale:**
This species is found in southern BC and in WA.

**Background Information:**
On the west coast of North America, this species occurs in WA and southern BC. Individuals have been found in CA, but it is unknown whether there are established populations.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 1.6 Global ecoregional distribution

**Choice: C** In few ecoregions globally

**Score:** 1.75 of 5

**Ranking Rationale:**
This species has only been reported from a few ecoregions, mostly in northern Europe and in limited areas of western North America.

**Background Information:**
This species has a broad native range, from PEI to FL, and west to TX. On the west coast of North America, populations are established in WA and BC. In Europe, this species has been found in England, and in the North Sea off the coasts of Belgium, Denmark, and Norway. It is also present in western Sweden. Populations have also been found in Greece, where they were likely introduced by ballast water.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.7 Current distribution trends*



**Choice:** **C**

Established outside of native range, but no evidence of rapid expansion or long-distance dispersal

**Score:** **1.75** **of** **5**

**Ranking Rationale:**
This species has failed to establish in CA. Introductions have been attributed to transport by anthropogenic vectors, rather than natural dispersal. This species has a restricted worldwide distribution, and we have not found evidence of a rapid range expansion for this species.

**Background Information:**
This species has likely been introduced accidentally with Eastern oysters, or by ballast water (Fofonoff et al. 2003). Individuals have been found in CA, but do not seem to have established populations there. Zenetos et al. (2009) rejected the possibility that this soecies was introduced to the Mediterranean by natural dispersal.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Zenetos et al. 2009

| | |
|---|---|
| **Section Total - Scored Points:** | 13.5 |
| **Section Total - Possible Points:** | 26.25 |
| **Section Total -Data Deficient Points:** | 3.75 |

## 2. Anthropogenic Transportation and Establishment

### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice: A** Has been observed using anthropogenic vectors for transport and transports independent of any anthropogenic vector once introduced

**Score:** 4 of 4

**Ranking Rationale:**
This species is believed to be transported by hitchhiking or ballast water. Its spread in northern Europe has been attributed to natural, larval dispersal.

**Background Information:**
Introduced outside of its native range by hitchhiking or by ballast water (Fofonoff et al. 2003). Rosenthal (1980) claims that this species spread through northern Europe naturally. In Greece, however, this species has a very disjunct distribution, occurring there and nowhere else along the Mediterranean. For this reason, Zenetos et al. (2009) believe that P. pholadiformis was introduced in Greece by human vectors.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Zenetos et al. 2009 Rosenthal 1980

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice: D** Does not use anthropogenic disturbance/infrastructure to establish

**Score:** 0 of 4

**Ranking Rationale:**
This species burrows and establishes in natural substrates.

**Background Information:**
Burrows in natural substrates including mud, peat, clay, and wood (Zenetos et al. 2009).

**Sources:**
Zenetos et al. 2009

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice: B** No

**Score:** 0 of 2

**Ranking Rationale:**
This species is not farmed or cultivated.

**Background Information:**
Although this species is edible, it is not farmed.

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 4 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics

### *3.1 Dietary specialization*

**Choice:** **A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Food items for this species are readily available in the Bering Sea.

**Background Information:**
This species is a filter feeder that consumes phytoplankton and other particles.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **A** Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 of 5

**Ranking Rationale:**
This species can tolerate a range of environmental conditions and substrate types.

**Background Information:**
This species requires a burrows in moderately soft substrates (e.g., clay, mud, chalk, wood) (Tillin and Budd 2008; Zenetos et al. 2009). However, this species is not a boring specialist and cannot burrow into very hard substrates or in soft, loose mud (Tillin and Budd 2008; Jensen 2010). It usually inhabits shallow depths, but has been reported from a range of tidal zones (Tillin and Budd 2008; Zenetos et al. 2009). It is usually associated with sites that receive freshwater input (Zenetos et al. 2009). This species can tolerate a broad range of temperatures and salinities.

**Sources:**
Zenetos et al. 2009 Tillin and Budd 2008 Jensen 2010

### *3.3 Desiccation tolerance*

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**
The desiccation tolerance of this species is unknown.

**Background Information:**
No information found.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 3.4 *Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice: B** Moderate – Exhibits one or two of the above characteristics

**Score:** 3.25 of 5

**Ranking Rationale:**
This species is dioecious and exhibits sexual reproduction, external fertilization, and high fecundity.

**Background Information:**
This species reproduces sexually and exhibits external fertilization. Hermaphoriditism has not been observed (Duval 1963). Fecundity estimates for this species vary widely: ranging from ~ 325 000 to > 3 million eggs (Brousseau 1981, qtd. in Fofonoff et al. 2003; Duval 1963). P. pholadiformis can live up to 10 years, and Duval (1963) estimate they reach sexual maturity at 3 years or later.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Duval 1963

### 3.5 *Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice: A** Disperses long (>10 km) distances

**High uncertainty?** ☑

**Score:** 2.5 of 2.5

**Ranking Rationale:**
Although dispersal distances for this species are unknown, given the longevity of the planktonic larval stage, we assume that this species is capable of long-distance dispersal under favorable hydrologic conditions.

**Background Information:**
This species has a long-lived, planktonic larval stage that can last between 10 to 14 days (Duval 1963). Larval dispersal is thought to have contributed to the spread of P. pholadiformis in northern Europe (Rosenthal 1980).

**Sources:**
Duval 1963 Rosenthal 1980

### 3.6 *Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: A** High – Exhibits two or three of the above characteristics

**Score:** 2.5 of 2.5

**Ranking Rationale:**
This species has a long-lived, planktonic larval stage. Larvae and eggs can be passively dispersed by water currents. Although adults are sessile, they may be disperse by drifting on wood.

**Background Information:**
The larval stage is planktonic, and is estimated to last between 10 to 14 days (Duval 1963). Adults are largely sessile and burrow in substrates, including wood; thus, they may be transported by drifting (Zenetos et al. 2009).

**Sources:**
Duval 1963 Zenetos et al. 2009

### *3.7 Vulnerability to predators*

**Choice: D** Multiple predators present in the Bering Sea or neighboring regions

**Score:** 1.25 of 5

**Ranking Rationale:**
This species is preyed upon by several taxa that occur in the Bering Sea.

**Background Information:**
P. pholadiformis can be eaten by crabs, fishes, birds, and fossorial mammals.

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 19.5 |
| **Section Total - Possible Points:** | 25 |
| **Section Total -Data Deficient Points:** | 5 |

# 4. Ecological and Socioeconomic Impacts

### *4.1 Impact on community composition*

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No impacts have been reported in its introduced range, and this species is not expected to impact communities in the Bering Sea.

**Background Information:**
P. pholadiformis was believed to have replaced the native white piddock, Barnea candida, in Belgium, but B. candida is now much more abundant in Belgium than P. pholadiformis (Jensen 2010). It has had minimal impacts on the west coast of North America (Fofonoff et al. 2003).

**Sources:**
Jensen 2010   NEMESIS; Fofonoff et al. 2003

### *4.2 Impact on habitat for other species*

**Choice: B** Moderate – Causes or has potential to cause changes to one or more habitats

**Score:** 1.75 of 2.5

**Ranking Rationale:**
This species can alter habitats by burrowing in the substrate.

**Background Information:**
As a result of this species' burrowing activities, Duval (1963) observed semi-permanent mounds of sand that marks the entrance of burrows. Duval (1963) documented tunnel lengths between 2.7 and 14.5 cm deep. The burrows of Pholadidae species increase habitat complexity and, in so doing, increase species' diversity (qtd. in Pinn et al. 2005). Upon an individual's death, the burrows that were created may be used as habitat by other organisms (Fofonoff et al. 2003).

**Sources:**
Duval 1963   NEMESIS; Fofonoff et al. 2003   Pinn et al. 2005

### *4.3 Impact on ecosystem function and processes*

**Choice: C** Limited – Causes or potentially causes changes to food webs and/or ecosystem functions, with limited impact and/or within a very limited region

**Score:** 0.75 of 2.5

**High uncertainty?** ☑

**Ranking Rationale:**
This species' burrowing behavior may increase siltation and erosion rates, especially in soft-bottomed habitats. However, themagnitude of this species' effects on ecosystems is unknown.

**Background Information:**
A study on the burrowing impacts of other piddocks suggests that piddocks may significantly contribute to erosion, especially in soft substrate habitats (Pinn et al. 2005). However, erosion estimates by Pinn et al. (2005) may be overly liberal for P. pholadiformis, because they were based on maximum burrowing depths > 80 cm. In a study on P. pholadiformis, Duval (1963) documented relatively short tunnel lengths between 2.7 and 14.5 cm deep. Through its burrowing activities, this species may also alter ecosystems by increasing siltation (Tillin and Budd 2008).

**Sources:**
Tillin and Budd 2008   Duval 1963   Pinn et al. 2005

### *4.4 Impact on high-value, rare, or sensitive species and/or communities*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not expected to impact high-value species in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.5 Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not known to transport diseases, parasites, or hitchhikers.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not expected to hybridize with native species in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.7 Infrastructure*

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact infrastructure in the Bering Sea.

**Background Information:**
This species can bore into moderately hard material such as rock, wood, chalk, and limestone. However, no impacts to infrastructure have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.8 Commercial fisheries and aquaculture

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact commercial fishing in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.9 Subsistence

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact subsistence resources in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.101 Recreation

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact recreational opportunities in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.11 Human health and water quality

**Choice:** **C** Limited – Has limited potential to pose a threat to human health, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
Cases of PSP and other shellfish syndromes are rare in Alaska.

**Background Information:**
All bivalve species can bioaccumulate toxins in their tissues as a result of consuming toxic dinoflagellates. Consuming raw or cooked bivalves can lead to Paralytic Shellfish Poisoning (PSP), which can cause health issues and even death (NIMPIS 2009).

**Sources:**
NIMPIS 2009

| | |
|---|---|
| **Section Total - Scored Points:** | 3.25 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

# 5. Feasibility of prevention, detection and control

## *5.1 History of management, containment, and eradication*

**Choice:** **C** Attempted; control methods are currently in development/being studied

**Score:** of

**Ranking Rationale:**

No attempts have been made to control or eradicate this species. This species can be transported by ballast water. Research to reduce the spread of species in ballast water in ongoing.

**Background Information:**

Ballast water exchange is the method currently used by most ships to reduce the spread of species by ballast water. However, it is considered a short-term or "stop-gap" option until more effective, technology-based methods become available e.g., ballast water treatment systems (Ruiz and Reid 2007). The treatment of ballast water is an active area of research as vessels are forced to comply with new regulations.

**Sources:**

Ruiz and Reid 2007

## *5.2 Cost and methods of management, containment, and eradication*

**Choice:** **B** Major short-term and/or moderate long-term investment

**Score:** of

**Ranking Rationale:**

To comply with ballast water regulations, vessels will have to equip themselves with an onboard ballast water treatment system. These systems represent a major short-term cost for vessel owners (up to $3 million), with additional costs over time to maintain and replace equipment (e.g. chemicals, filters, UV light bulbs).

**Background Information:**

The costs associated with purchasing a ballast water treatment system depend on the volume of water that needs to be treated. Systems with a pump capacity of 200-250 $m^3/h$ can cost from $175,000 to $490,000. The estimated price for larger systems with a pump capacity of around 2000 $m^3/h$ range from $650,000 to nearly $3 million.

**Sources:**

Zagdan 2010

## *5.3 Regulatory barriers to prevent introductions and transport*

**Choice:** **C** Regulatory oversight and/or trade restrictions

**Score:** of

**Ranking Rationale:**

Alaska does not have state regulations on ballast water management, but two federal regulations (USCG and EPA) require mandatory reporting and ballast water treatment or exchange.

**Background Information:**

In the U.S., ballast water management (treatment or exchange) and record-keeping is mandatory and regulated by the USCG, with additional permitting by the Environmental Protection Agency (EPA). Certain vessels (e.g. small vessels or those traveling within 1 Captain of the Port Zone) are exempt from USCG and EPA regulations.

Alaska does not have a state regulations related to the management of aquatic invasive species in discharged ballast water. It relies on the U.S. Coast Guard (USCG) to enforce national standards. In Alaska, data from 2009-2012 show moderate to high compliance with USCG reporting requirements (Verna et al. 2016).

**Sources:**

CFR 2017 EPA 2013 Verna et al. 2016

### *5.4 Presence and frequency of monitoring programs*

**Choice: A** No surveillance takes place

**Score:** of

**Ranking Rationale:**
No surveillance is taking place for this species.

**Background Information:**

**Sources:**
None listed

### *5.5 Current efforts for outreach and education*

**Choice: A** No education or outreach takes place

**Score:** of

**Ranking Rationale:**
No education or outreach efforts are in place for this species.

**Background Information:**

**Sources:**
None listed

**Section Total - Scored Points:**
**Section Total - Possible Points:**
**Section Total -Data Deficient Points:**

## Literature Cited for *Petricolaria pholadiformis*


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# Bering Sea Marine Invasive Species Assessment
Alaska Center for Conservation Science

**Scientific Name:** *Teredo navalis*

**Common Name** *naval shipworm*

| | |
|---|---|
| **Phylum** | Mollusca |
| **Class** | Bivalvia |
| **Order** | Myoida |
| **Family** | Teredinidae |

**Final Rank** 54.00

**Data Deficiency:** 0.00

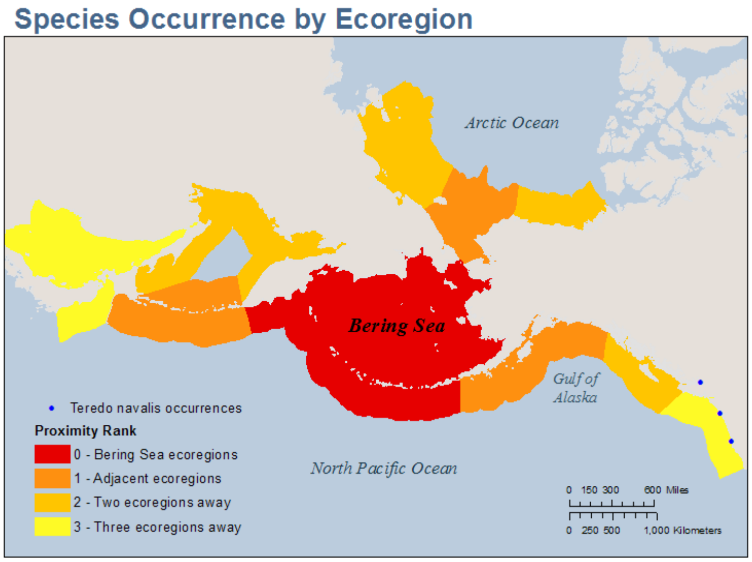


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 20.5 | 30 | 0 |
| Anthropogenic Influence: | 3.25 | 10 | 0 |
| Biological Characteristics: | 22.5 | 30 | 0 |
| Impacts: | 7.75 | 30 | 0 |
| **Totals:** | 54.00 | 100.00 | 0.00 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | 0 | Minimum Salinity (ppt) | 5 |
| Maximum Temperature (°C) | 30 | Maximum Salinity (ppt) | 45 |
| Minimum Reproductive Temperature (°C) | 11 | Minimum Reproductive Salinity (ppt) | 9 |
| Maximum Reproductive Temperature (°C) | 30 | Maximum Reproductive Salinity (ppt) | 35* |

### Additional Notes

Teredo navalis is a highly modified bivalve adapted for boring into wood. The shell is reduced to two small, ridged valves that cover the head and are used for grinding and tearing wood. The body is naked and elongated, and ends with two siphons. It can reach up to 1000 mm in length (qtd. in Fofonoff et al. 2003). T. navalis bores into and damages boats, docks, pilings, and other wooden structures. This species has a global distribution and is one of the most widespread marine wood-borers in the world. Although its native range is unknown, it has been introduced to the East and West coasts of the United States, Brazil, Argentina, South Africa, and Australia. This species can be dispersed in wood, and in ballast water during its larval stage.

**Reviewed by** Nora R. Foster, NRF Taxonomic Services, Fairbanks AK

**Review Date:** 9/27/2017

# 1. Distribution and Habitat

## *1.1 Survival requirements - Water temperature*

**Choice:** **B**

Moderate overlap – A moderate area (≥25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 2.5 **of** 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Temperatures required for year-round survival occur in a moderate area (≥25%) of the Bering Sea. Thresholds are based on geographic distribution, which may not represent physiological tolerances; moreover, models disagree with respect to their estimates of suitable area. We therefore ranked this question with "High uncertainty".

**Background Information:**
T. navalis has been recorded as far north as Iceland (65°N) and the Faroe Islands (62°N). Based on geographic distribution, adults can tolerate temperatures between 0°C and 30°C. Optimal temperatures are between 15-25°C (Tuente et al 2002).

**Sources:**
Tuente et al. 2002   NEMESIS; Fofonoff et al. 2003   NIMPIS 2009

## *1.2 Survival requirements - Water salinity*

**Choice:** **A**

Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 **of** 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
Salinity tolerance ranges from 5 to 45 ppt (based on field and experimental data).

**Sources:**
NEMESIS; Fofonoff et al. 2003

## *1.3 Establishment requirements - Water temperature*

**Choice:** **C**

Little overlap – A small area (<25%) of the Bering Sea has temperatures suitable for reproduction

**Score:** 1.25 **of** 3.75

**Ranking Rationale:**
Temperatures required for reproduction occur in a limited area (<25%) of the Bering Sea.

**Background Information:**
Culliney (1975) observed larvae being released at temperatures from 13° to 30°C. Appelqvist et al. (2015) report that minimum temperatures of 11°C and 12°C are needed for reproduction and larval metamorphosis, respectively. Larval swimming performance is poor below 10°C, and growth does not occur below 5°C (Fofonoff et al. 2003; Appelqvist et al. 2015).

**Sources:**
Appelqvist et al. 2015   Culliney 1975   NEMESIS; Fofonoff et al. 2003

### *1.4 Establishment requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 of 3.75

**High uncertainty?** ☑

**Ranking Rationale:**
Although upper salinity thresholds are unknown, this species is a marine organism that does not require freshwater to reproduce. We therefore assume that this species can reproduce in saltwater up to 35 ppt. These salinities occur in a large (>75%) portion of the Bering Sea.

**Background Information:**
In a study by Culliney (1975), T. navalis released their offspring at salinities between 20 and 30 ppt. This species requires a minimum reproductive salinity of 9 ppt (qtd. in Fofonoff et al. 2003).

**Sources:**
Culliney 1975 NEMESIS; Fofonoff et al. 2003

### *1.5 Local ecoregional distribution*

**Choice:** **C** Present in an ecoregion two regions away from the Bering Sea (i.e. adjacent to an adjacent ecoregion)

**Score:** 2.5 of 5

**Ranking Rationale:**
This species is found in southern BC and in southern Russia.

**Background Information:**
Found in southern British Columbia (East Redonda Island). Cryptogenic in southern Russia and in the Sea of Japan.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.6 Global ecoregional distribution*

**Choice:** **A** In many ecoregions globally

**Score:** 5 of 5

**Ranking Rationale:**
This species has a widespread, global distribution. It has been introduced to both coasts of North America, and is widely distributed in Atlantic Europe and in Asia. It has also been reported in parts of South America and southern Africa.

**Background Information:**
Cryptogenic throughout Europe and Asia. In Europe, it is found from Iceland and the Norwegian Sea, south to the Mediterranean Sea and north Africa. In Asia, it occurs in India, Indonesia, the Philippines, China, Japan, southern Russia, and some Pacific islands. T. navalis has been introduced to both coasts of North America. On the West Coast, it occurs from San Diego, CA to southern British Columbia. It is considered introduced in South Africa, Australia, and the Atlantic coast of South America.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 1.7 *Current distribution trends*

**Choice:** **C**

Established outside of native range, but no evidence of rapid expansion or long-distance dispersal

**Score:** 1.75 **of** 5

**Ranking Rationale:**

This species is well-established outside of its native range, but its spread is linked to anthropogenic vectors, and no rapid expansions have been reported.

**Background Information:**

This species' long-distance dispersal is largely the result of anthropogenic vectors. Although sporadic, localized range expansions have been reported, they are probably due to fluctuating environmental conditions. A modelling exercise in the Baltic Sea found no evidence for climate-change related shifts in the distribution of T. navalis, and no evidence for increased risk of spread in the near-future for that region (Appelqvsit et al. 2015).

**Sources:**

Appelqvist et al. 2015 NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 20.5 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 2. Anthropogenic Transportation and Establishment

### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice: B** Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 of 4

**Ranking Rationale:**
This species requires anthropogenic vectors for transport.

**Background Information:**
T. navalis requires wood for habitat and food. It may occasionally be transported on drifting logs or wooden debris, but dispersal is largely the result of anthropogenic vectors.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice: C** Uses anthropogenic disturbance/infrastructure to establish; never observed establishing in undisturbed areas

**Score:** 1.25 of 4

**High uncertainty?** ☑

**Ranking Rationale:**
T. navalis relies on anthropogenic substrates for establishment. Information is lacking for this species.

**Background Information:**
While some Teredinidae species live in natural habitats such as mangroves, T. navalis appears restricted to anthropogenic substrates, including ships, wooden docks, drifting logs and wooden debris. We did not find any sources that listed natural habitats for T. navalis, but information on this species is scarce.

**Sources:**
Voight 2015

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice: B** No

**Score:** 0 of 2

**Ranking Rationale:**
This species is not currently farmed.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 3.25 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics

### 3.1 *Dietary specialization*

**Choice:** **A** — Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
A recent study suggests that this species is a filter feeder with a generalist diet.

**Background Information:**
Larvae are free-swimming and feed on plankton. Shipworms obtain most of their nutrition by filter feeding (Paalvast and van der Velde 2013), but may also eat wood.

**Sources:**
Paalvast and van der Velde 2013   NIMPIS 2009

### 3.2 *Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **C** — Specialist; dependent on a narrow range of habitats for all life stages

**Score:** 1.75 of 5

**Ranking Rationale:**
T. navalis requires wood to bore in.

**Background Information:**
Although the larval stage is planktonic, this species needs wood habitat to complete its life cycle. T. navalis exhibits wide temperature and salinity tolerances. It has a low tolerance for pollution.

**Sources:**
DAISIE 2016   NEMESIS; Fofonoff et al. 2003

### 3.3 *Desiccation tolerance*

**Choice:** **A** — Highly tolerant (>7 days) of desiccation at one or more stages during its life cycle

**Score:** 5 of 5

**Ranking Rationale:**
If bored in wood, this species can withstand air exposure for several days to > 1 week.

**Background Information:**
T. navalis can survive up to six weeks of anoxic conditions by suspending its feeding activities, metabolizing stored energy reserves, and staying in its wood burrows (qtd. in Appelqvist et al. 2015). Preliminary experiments on thin, infested pieces of wood found that some individuals were still alive after a week's exposure to air. Complete mortality was observed after 10 days' exposure (Grave 1928). Survival varied from 3 days to >1 week based on thickness of wood and exposure to the sun (Grave 1928).

**Sources:**
Grave 1928   Appelqvist et al. 2015

### 3.4 *Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice: B** Moderate – Exhibits one or two of the above characteristics

**Score:** 3.25 of 5

**Ranking Rationale:**

T. navalis is highly fecund and hermaphroditic. Fertilization is external, but eggs are brooded for 2 to 3 weeks. This species exhibits a relatively short generation time.

**Background Information:**

T. navalis individuals are protandrous hermaphrodites i.e., they begin life as male and later become female. Sources disagree on whether this species can self-fertilize (Hoppe 2002; Fofonoff et al. 2003). Fertilization is external, but eggs are brooded in the females' gills for 2 to 3 weeks. Eggs hatch and are released as larvae in 5 to 8 days (Culliney 1975; Hoppe 2002). Depending on water temperatures, females may have several reproductive events per season, and can release 50,000–2,000,000 eggs per event (qtd. in Appelqvist et al. 2015). Free-swimming larvae feed on plankton in the water column before settling and beginning to bore into wood. This species can live between 1 and 3 years, and reaches sexual maturity within 6 to 8 weeks.

**Sources:**

Appelqvist et al. 2015 Hoppe 2002 Culliney 1975 NEMESIS; Fofonoff et al. 2003

### 3.5 *Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice: A** Disperses long (>10 km) distances

**High uncertainty?** ☑

**Score:** 2.5 of 2.5

**Ranking Rationale:**

Although T. navalis larvae are poor swimmers, larvae are planktonic and the larval stage can last several weeks. Consequently, we expect this species to be capable of long-distance dispersal under favorable oceanic conditions.

**Background Information:**

Larval stage is planktonic and can last anywhere for 2 to 4 weeks before settlement. Under experimental conditions, larval swimming speed increased with size; the average speed for pediveliger larvae (200 µm) was estimated at 2 mm/s (Toth et al. 2015). This speed was approximately one order of magnitude less than the water velocity (Toth et al. 2015). Long-distance dispersal is therefore more likely to depend upon water currents than directional swimming. Based on current velocities, Scheltema (1971) suggested that shipworm larvae may be dispersed many hundreds of kilometers. Dispersal simulations by Appelqvist et al. (2015) predicted a predominance of localized dispersal events, with long-distance dispersal resulting in larvae dispersed to unfavorable sites; however, the resolution of the model was at a relatively coarse scale (3.7 km).

**Sources:**

Appelqvist et al. 2015 Toth et al. 2015 Scheltema 1971

### *3.6 Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice:** **A** High – Exhibits two or three of the above characteristics

**Score:** 2.5 of 2.5

**Ranking Rationale:**
T. navalis has a long-lived, planktonic larval stage. It can disperse at more than one life stage, either by drifting in the water column (as larvae) or in wood pieces.

**Background Information:**
This species can disperse passively as larvae or as adults by rafting on wood (Appelqvist et al. 2015). Larvae are pelagic and long-lived, swimming in the water column anywhere from 2 to 4 before settlement.

**Sources:**
Appelqvist et al. 2015

### *3.7 Vulnerability to predators*

**Choice:** **C** Few predators suspected present in the Bering Sea and neighboring regions, and/or multiple predators in native range

**Score:** 2.5 of 5

**Ranking Rationale:**
Because of its biology, this species is likely protected against predators throughout most of its life.

**Background Information:**
As long as their piece of wood is intact, shipworms have few predators. If the wood disintegrates, they are rapidly eaten by fishes, crabs, and other predators. They are vulnerable to protozoan parasites, such as Minchinia teredinis, which can cause extensive mortality.

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 22.5 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 4. Ecological and Socioeconomic Impacts

### *4.1 Impact on community composition*

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not expected to affect marine communities in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.2 Impact on habitat for other species*

**Choice: C** Limited – Has limited potential to cause changes in one or more habitats

**Score:** 0.75 of 2.5

**Ranking Rationale:**
By boring into wood, this species may simultaneously destroy and create wood habitat and tunnels for other species. However, because this species is not known to bore into natural habitats (e.g., coastal forests), we expect it to have a limited impact in the Bering Sea ecoregion.

**Background Information:**
This species damages and destroys wood and, in so doing, may destroy habitat for other species (e.g., fouling organisms). Conversely, it can create habitat for burrowing organisms by creating holes and tunnels.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.3 Impact on ecosystem function and processes*

**Choice: C** Limited – Causes or potentially causes changes to food webs and/or ecosystem functions, with limited impact and/or within a very limited region

**Score:** 0.75 of 2.5

**Ranking Rationale:**
This species may accelerate decomposition and nutrient recycling, especially along woody, vegetated coastlines. However, because this species is typically associated with anthropogenic substrates and has limited dispersal abilities, we do not expect T. navalis to exert strong effects on natural ecosystems in the Bering Sea.

**Background Information:**
T. navalis speeds the breakdown and recycling of wood in estuaries and coastal ecosystems.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.4 Impact on high-value, rare, or sensitive species and/or communities*

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not expected to impact high-value species or communities in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.5 Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice: B** Moderate – Spreads or has potential to spread one or more organisms, with moderate impact and/or within only a portion of region

**Score:** 1.75 of 2.5

**High uncertainty?** ☑

**Ranking Rationale:**
Although no specific species have been reported, the boring behavior of T. navalis may create habitat for burrowing organisms in anthropogenic substrates, which would greatly facilitate their long-distance dispersal.

**Background Information:**
Shipworms can facilitate the transport of other species by creating holes and tunnels in wood, providing burrowing spaces for other organisms.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not expected to hybridize with native species in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.7 Infrastructure*

**Choice: A** High – Is known to cause degradation to infrastructure and/or is expected to have severe impacts and/or will impact the entire region

**Score:** 3 of 3

**Ranking Rationale:**
This species has caused several million dollars' worth of damage to ships and wooden infrastructure, and is expected to have severe impacts in the Bering Sea.

**Background Information:**
T. navalis has a long history of damaging ships and structures such as piers and marinas. In the 1920s, an outbreak of T. navalis in San Francisco Bay caused an estimated $615 million dollars (in 1992 currency rates) in damage. In 1946, shipworms were reported to cause an annual $55 million ($500 million in current dollars) of damage to waterfront structures in the United States. In 1990, a floating restaurant in the US sank due to shipworm burrowing activities. In New York Harbor, where T. navalis has caused extensive damage, there are plans to spend $200 million over the next few decades to encase and preserve piers to be used as part of waterfront parks (Foderaro 2011). In the Baltic Sea, a different concern is the destruction of archaeologically important shipwrecks, which up to now were preserved from borers by low salinity (Hoppe 2002). By boring into logs, T. navalis can also be problematic for the lumber industry in coastal areas where logging occurs.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Hoppe 2002 Foderaro 2011 NIMPIS 2009

### 4.8 *Commercial fisheries and aquaculture*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
Given its biology, this species is not expected to impact commercial fishing in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.9 *Subsistence*

**Choice: C** Limited – Has limited potential to cause degradation to subsistence resources, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
T. navalis may damage wooden equipment used for subsistence harvesting.

**Background Information:**
T. navalis can damage wooden traps used to catch shellfish such as lobsters and oysters. Nowadays, traps are made from wire rather than wood, but wooden traps may still be used.

**Sources:**
Grave 1928

### 4.101 *Recreation*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to affect recreational opportunities in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.11 *Human health and water quality*

**Choice: C** Limited – Has limited potential to pose a threat to human health, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
There are a limited number of wooden waterfront structures in the Bering Sea ecoregion, and few large human settlements. We therefore expect T. navalis to have a limited impact on human health in this region. T. navalis has a low tolerance for pollution, and no impacts to water quality have been reported.

**Background Information:**
T. navalis can cause waterfront structures to collapse. This is a serious safety concern to public and private waterfront property used in recreation, entertainment, and tourism. New York City is planning to spend $200 million over the next few decades to encase and preserve piers to be used as part of waterfront parks (Foderaro 2011).

**Sources:**
Foderaro 2011

| | |
|---|---|
| **Section Total - Scored Points:** | 7.75 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

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## 5. Feasibility of prevention, detection and control



### *5.1 History of management, containment, and eradication*

**Choice:** **C** Attempted; control methods are currently in development/being studied

**Score:** of

**Ranking Rationale:**
Methods that are effective, cost-efficient, and environmentally-friendly are being researched.

**Background Information:**
Control methods include wrapping structures in plastic, or applying a chemical coating to them. Chemical control is probably the most effective method, but is also environmentally toxic.

**Sources:**
DAISIE 2009 Foderaro 2011

### *5.2 Cost and methods of management, containment, and eradication*

**Choice:** **B** Major short-term and/or moderate long-term investment

**Score:** of

**Ranking Rationale:**
Transitioning from wood to other materials such as metal, concrete, fiberglass, and plastic inevitably gets rid of shipworms. However, replacing or protecting existing infrastructure is very expensive.

**Background Information:**
New York City intends to spend $200 million over the next few decades to encase and preserve piers to be used as part of waterfront parks (Foderaro 2011).

**Sources:**
Foderaro 2011

### *5.3 Regulatory barriers to prevent introductions and transport*

**Choice:** **A** Little to no regulatory restrictions

**Score:** of

**Ranking Rationale:**
Currently, there are no regulations to prevent or reduce the spread of boring organisms.

**Background Information:**

**Sources:**
CFR 2017

### *5.4 Presence and frequency of monitoring programs*

**Choice:** **A** No surveillance takes place

**Score:** of

**Ranking Rationale:**
No surveillance takes place for this species.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *5.5 Current efforts for outreach and education*

**Choice:** **A** No education or outreach takes place

**Score:** of

**Ranking Rationale:**
No outreach or education is taking place for this species.

**Background Information:**
An online search for educational materials or outreach programs did not return any results.

**Sources:**
NEMESIS; Fofonoff et al. 2003

**Section Total - Scored Points:**
**Section Total - Possible Points:**
**Section Total -Data Deficient Points:**

## Literature Cited for *Teredo navalis*


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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Venerupis philippinarum*

**Common Name** *Japanese littleneck*

| | |
|---|---|
| **Phylum** | Mollusca |
| **Class** | Bivalvia |
| **Order** | Veneroida |
| **Family** | Veneridae |

**Final Rank** 63.24

**Data Deficiency:** 7.50

### Species Occurrence by Ecoregion

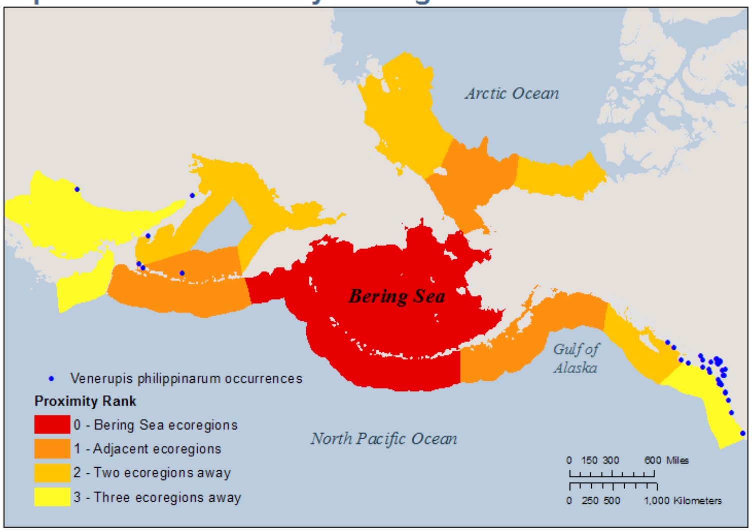


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

### Category Scores and Data Deficiencies

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 22.5 | 30 | 0 |
| Anthropogenic Influence: | 10 | 10 | 0 |
| Biological Characteristics: | 21.25 | 25 | 5.00 |
| Impacts: | 4.75 | 28 | 2.50 |
| **Totals:** | 58.50 | 92.50 | 7.50 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | 0 | Minimum Salinity (ppt) | 12 |
| Maximum Temperature (°C) | 37 | Maximum Salinity (ppt) | 50 |
| Minimum Reproductive Temperature (°C) | 18 | Minimum Reproductive Salinity (ppt) | 24 |
| Maximum Reproductive Temperature (°C) | NA | Maximum Reproductive Salinity (ppt) | 35 |

### Additional Notes

V. philippinarum is a small clam (40 to 57mm) with a highly variable shell color; however, the shell is often predominantly cream-colored or gray. It is often variegated, with concentric brown lines, or patches. The interior margins are deep purple, while the center of the shell is pearly white, and smooth

**Reviewed by** Nora R. Foster, NRF Taxonomic Services, Fairbanks AK

**Review Date:** 9/27/2017

# 1. Distribution and Habitat

### *1.1 Survival requirements - Water temperature*

**Choice:** **B** Moderate overlap – A moderate area (≥25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 2.5 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Temperatures required for year-round survival occur in a moderate area (≥25%) of the Bering Sea. Lower threshold is based on geographic distribution, which may not represent physiological tolerances; moreover, models disagree with respect to their estimates of suitable area. We therefore ranked this question with "High uncertainty".

**Background Information:**
Based on field observations, the lower temperature tolerance is 0°C (Kamenev and Nekrasov 2012). Based on experiments, the upper temperature tolerance is 37°C (Shin et al. 2000 qtd. in Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Kamenev and Nekrasov 2012

### *1.2 Survival requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
Based on experiments, the lower limit of salinity tolerance is 12. 5 ppt (Elston et al. 2003) with survival decreasing below 19.2 PSU (Shin et al. 2000 qtd. in Fofonoff et al. 2003; Carregosa et al. 2014). Based on field observations, the upper limit of salinity tolerance is 50 ppt (Breber 2002 qtd in Fofonoff et al. 2003; Carregosa et al. 2014).

**Sources:**
Elston et al. 2003 Carregosa et al. 2014 NEMESIS; Fofonoff et al. 2003

### *1.3 Establishment requirements - Water temperature*

**Choice:** **D** No overlap – Temperatures required for reproduction do not exist in the Bering Sea

**Score:** 0 of 3.75

**Ranking Rationale:**
Temperatures required for reproduction do not exist in the Bering Sea.

**Background Information:**
The temperature range required for reproduction of V. philippinarum is 18°C to 30°C (Toba et al. 1992 as qtd. in Inoue et al. 2012).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Inoue et al. 2012

### *1.4 Establishment requirements - Water salinity*

**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for reproduction occur over a large (>75%) area of the Bering Sea.

**Background Information:**
The salinity range required for reproduction of V. philippinarum is experimentally determined to be 24 ppt to 35 ppt (Food and Agricultural Organization 2003).

**Sources:**
FAO 2013 NEMESIS; Fofonoff et al. 2003

### *1.5 Local ecoregional distribution*

**Choice: C** Present in an ecoregion two regions away from the Bering Sea (i.e. adjacent to an adjacent ecoregion)

**Score:** 2.5 of 5

**Ranking Rationale:**

**Background Information:**
Found in British Columbia (Vancouver Island). This species is native to the Sea of Okhotsk (Kuril and Sakhalin Islands in southern Russia).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.6 Global ecoregional distribution*

**Choice: A** In many ecoregions globally

**Score:** 5 of 5

**Ranking Rationale:**
Wide global distribution.

**Background Information:**
It has a wide native range from southern Russia to India, Sri Lanka, and the Philippines. It has been introduced to Hawaii, the West Coast of North America (from California to British Columbia's Vancouver Island), Europe (English Channel to southern Italy), the Mediterranean, Tahiti and Fiji.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.7 Current distribution trends*



**Choice: A** Recent rapid range expansion and/or long-distance dispersal (within the last ten years)

**Score:** 5 of 5

**Ranking Rationale:**
Evidence of recent range expansion and long-distance dispersal.

**Background Information:**
In British Columbia: First found in Ladysmith Harbour in 1936. In 30 years, spread throughout the Strait of Georgia and along the entire western coast of Vancouver Island and have become one of the major intertidal bivalves. In the 1960s, clams spread to the Queen Charlotte Strait and in 1970s to the central coastal area (Bendell 2014). Further expansion in B.C. may be limited by thermal tolerance thresholds.

Following introduction in northern Italy's Venice Lagoon, V. philippinarum spread naturally along the Adriatic coast at a rate of 30 km/year (Breber 2002, qtd. in Sweet and Sewell 2011).

**Sources:**
Bendell 2014   Sweet and Sewell 2011

| | |
|---|---|
| **Section Total - Scored Points:** | 22.5 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 2. Anthropogenic Transportation and Establishment



***2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport***

**Choice:** **A** — Has been observed using anthropogenic vectors for transport and transports independent of any anthropogenic vector once introduced

**Score:** 4 **of** 4

**Ranking Rationale:**
Long-distance dispersal due to anthropogenic means. Can also disperse naturally.

**Background Information:**
In British Columbia, was unintentionally introduced, having "hitch-hiked" on Pacific oyster seed in the mid-1930s (Quayle and Bourne 1972, qtd. in Bendell 2014). Can also be transported via ballast water. Natural spread from aquaculture nets to wild habitat has been reported. Currently found in southern Russia and Japan, and along the west coast of North America from B.C. to California.

**Sources:**
Bendell 2014   NEMESIS; Fofonoff et al. 2003

***2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish***

**Choice:** **A** — Readily establishes in areas with anthropogenic disturbance/infrastructure and in natural, undisturbed areas

**Score:** 4 **of** 4

**Ranking Rationale:**
Can establish in anthropogenic areas (e.g. in cultivation) and in undisturbed areas.

**Background Information:**
Spread to multiple sites in British Columbia following accidental introduction in 1936. Natural spread following introduction has also occurred in northern Italy (Breber 2002, qtd. in Sweet and Sewell 2011). Natural spread from aquaculture nets to wild habitat has been reported.

**Sources:**
Bendell 2014   Sweet and Sewell 2011

***2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?***

**Choice:** **A** — Yes

**Score:** 2 **of** 2

**Ranking Rationale:**

**Background Information:**
Is intensively farmed and recreationally harvested in both its native and introduced range.

**Sources:**
FAO 2013   NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 10 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics

### *3.1 Dietary specialization*

**Choice: A**

Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Consumes numerous taxa, many of which exist in the Bering Sea.

**Background Information:**
Filter feeder. Larvae and juveniles feed mostly on phytoplankton. In adults, range of feeding habits has been reported: phytoplankton, benthic microalgae (primarily pennate diatoms), and terrestrial organic matter (Breber 2002 qtd. In Fofonoff et al. 2003; Kasai et al. 2004; Sakamaki and Richardson 2008). The importance of these items varies by site, suggesting opportunistic feeding.

**Sources:**
Kasai et al. 2004 NEMESIS; Fofonoff et al. 2003 Sakamaki and Richardson 2008

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice: A**

Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 of 5

**Ranking Rationale:**
Tolerant of a wide range of temperatures and salinities.

**Background Information:**
V. philippinarum is a burrowing bivalve that prefers coarse sand and gravel. It can be found in shallow, subtropical to cool temperate areas. It also has wide temperature and salinity tolerances.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *3.3 Desiccation tolerance*

**Choice: U**

Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *3.4 Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice: A** High – Exhibits three or four of the above characteristics

**Score:** 5 of 5

**Ranking Rationale:**
Sexual reproduction, high fecundity, low parental investment, external fertilization, short generation time.

**Background Information:**
V. philippinarum undergoes sexual, external fertilization. First spawning can occur as early as 1 year, especially in warmer climates where it occurs year round. In cooler climates first spawn may not occur until 2 to 3 years and only once or twice a year (Yap 1977; Ponurovsky and Yakolev 1992). Females can produce up to 2.4 million eggs that, when fertilized, develop into a planktonic larvae that settles to the sediment as a clam in 12 to 24 days (Toba et al. 1992 qtd. in Inoue et al. 2012).

**Sources:**
Inoue et al. 2012 NEMESIS; Fofonoff et al. 2003 Ponurovsky and Yakolev 1992 Yap 1977

### *3.5 Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice: A** Disperses long (>10 km) distances

**Score:** 2.5 of 2.5

**Ranking Rationale:**
Disperses widely at planktonic stage. Populations were observed expanding up to 30 km/year.

**Background Information:**
V. philippinarum is a broadcast spawner. Adults are sessile and shallowly burrowed on the sea floor, but larvae are planktonic, long-lived (~ 2 weeks), and disperse widely (Kasuya et al. 2004). Larvae are capable of active swimming. A modeling exercise showed that vertical swimming behaviour over relatively short distances (metres) could potentially affect dispersion patterns over many kilometres (Herbert et al. 2012). Realized dispersal distance is highly dependent on currents (Herbert et al. 2012). Following introduction to the Venice Lagoon, V. philippinarum has spread along the Adriatic coast at a rate of 30 km/year (Breber 2002, qtd. in Sweet and Sewell 2011).

**Sources:**
Herbert et al. 2012 Kasuya et al. 2004 Sweet and Sewell 2011

### *3.6 Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: A** High – Exhibits two or three of the above characteristics

**Score:** 2.5 of 2.5

**Ranking Rationale:**
Highly mobile as larvae, larval viability window is long.

**Background Information:**
Broadcast spawning and a free-swimming, planktonic larval stage that lasts ~2-3 weeks. Once larvae have attached to the substrate, are more or less sessile (though they can move vertically in the substrate).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *3.7 Vulnerability to predators*



**Choice:** **D** Multiple predators present in the Bering Sea or neighboring regions

**Score:** **1.25** **of** **5**

**Ranking Rationale:**

Numerous predators, many of which exist in the Bering Sea.

**Background Information:**

Due to its relatively shallow burrows and shorter siphon, V. philippinarum has been widely predated upon by snails, starfish, crabs, fishes, diving ducks, shorebirds, sea otters, and raccoons (Cohen 2005; Dudas et al. 2005; Cloern et al. 2007; Lewis et al. 2007; Gillespie et al. 2012).

**Sources:**

Cloern et al. 2007   Cohen 2005   Dudas et al. 2005   Gillespie et al. 2012   Lewis et al. 2007   NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 21.25 |
| **Section Total - Possible Points:** | 25 |
| **Section Total -Data Deficient Points:** | 5 |

## 4. Ecological and Socioeconomic Impacts



### 4.1 *Impact on community composition*

**Choice:** **C** Limited – Single trophic level; may cause decline but not extirpation

**Score:** 0.75 **of** 2.5

**Ranking Rationale:**

Effect on phytoplankton i.e. more than one trophic level is purely speculative. Declines, but not extirpation, of native bivalves have been reported. In many cases, this decline has been linked to the artificially high densities of V. philippinarum and other factors such as pollution and disease have not been ruled out.

**Background Information:**

V. philippinarum has outcompeted and replaced native species such as the Pacific Littleneck (Leukona staminea) in British Columbia and the clam Ruditapes decussatus in Europe (Bendell 2014; Pranovi et al. 2006).

Other studies have also pointed out that at lower densities, that occur outside of farmed locations, V. philippinarum has little to no direct negative impacts on the Pacific littleneck or Ruditapes decussatus (Byers 2005 qtd. in Sweet and Sewell 2011; Bidegain and Juanes 2013).

**Sources:**

Bendell 2014 Bidegain and Juanes 2013 NEMESIS; Fofonoff et al. 2003 Pranovi et al. 2006 Sweet and Sewell 2011

### 4.2 *Impact on habitat for other species*

**Choice:** **C** Limited – Has limited potential to cause changes in one or more habitats

**Score:** 0.75 **of** 2.5

**Ranking Rationale:**

Documented changes in habitat are caused by destructive aquaculture practices. to V. philippinarum's farming practices. The effects of “wild” V. philippinarum on habitat is unknown.

**Background Information:**

The use of vibrating rakes for cultivation causes disturbance and resuspension of sediments (Nunes and Markandya 2008).

**Sources:**

NEMESIS; Fofonoff et al. 2003 Nunes and Markandya 2008

### 4.3 *Impact on ecosystem function and processes*

**Choice:** **B** Moderate – Causes moderate changes to food webs or ecosystem functions in several areas, or causes severe effects in only one or a few areas (e.g., in areas where species occurs at high densities)

**Score:** 1.75 **of** 2.5

**Ranking Rationale:**

Impacts nutrient flows, favoring algal growth. Burrowing activities increase sediment erosion.

**Background Information:**

A comparison between farmed and unfarmed sites in northern Italy, where V. philippinarum occurs at very high densities (2000-2500 individuals/m2), found that the presence of V. philippinarum had a strong impact on nutrient flows through respiration and excretion activities, and by reducing surface sediments. Rapid nutrient recycling stimulated by the high biodegradability of clam feces and pseudofeces could favour macroalgal growth, while demand for O2 and production of CO2 could lead to anoxia (Bartoli et al. 2001).

Laboratory experiments studying the relationship between bioturbation and sediment stability found a significant correlation between mean erosion rate and density of V. philippinarum (Sgro et al. 2005). Effects of density on sediment erosion were more pronounced at the lower current velocities. Study concluded that burrowing activity of V. philippinarum reduces sediment stability, particularly at relatively low current velocities (25 cm/s), and at densities below those currently found in some clam cultivation areas (Sgro et al. 2005).

**Sources:**

Bartoli et al. 2001 NEMESIS; Fofonoff et al. 2003 Sgro et al. 2005

### *4.4 Impact on high-value, rare, or sensitive species and/or communities*

**Choice:** **U** Unknown

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.5 Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice:** **C** Limited – Has limited potential to spread one or more organisms, with limited impact and/or within a very limited region

**Score:** 0.75 of 2.5

**Ranking Rationale:**
Carries lots of disease and parasites, but all seem native to Pacific Northwest, and mostly detrimental to Europe.

**Background Information:**
Supports numerous parasites, including a variety of bacteria, protozoans, trematodes, and the introduced parasitic copepod Mytilicola orientalis (Bower et al. 1992; Marshall et al. 2003; Gillespie et al. 2012). M. orientalis is considered an invasive species in western North America. M. orientalis (red worm) parasitizes mussels, including Mytilus edilus (blue mussel), which is found in Alaska.

Is also associated with Perkinsus protozoan parasites and Brown Ring Disease (BRD) that are responsible for mass mortalities of both V. philippinarum and R. desussatus in Spain, and France (Sagrista et al. 1996; Cigarria et al. 1997; Bower 2007 qtd. in Sweet and Sewell 2011).

**Sources:**
Bower et al. 1992   Cigarria et al. 1997   Gillespie et al. 2012   Marshall et al. 2003   NEMESIS; Fofonoff et al. 2003   Sagrista et al. 1996   Sweet and Sewell 2011

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
Hybridization occurs with other Venerupis spp. No native Venerupis spp. in Bering Sea.

**Background Information:**
The only report of hybridization is with V. decussata in Ria de Vigo, Spain. The extent and significance of this is unknown (Hurtado et al. 2011).

**Sources:**
Hurtado et al. 2011   NEMESIS; Fofonoff et al. 2003

### 4.7 *Infrastructure*



**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
No impacts have been reported to date. Given its ecology, we do not expect this species to impact infrastructure in the Bering Sea.

**Background Information:**
No information to suggest impact on infrastructure. V. philippinarum burrows in the substrate and is therefore not a fouling organism like other bivalves.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.8 *Commercial fisheries and aquaculture*

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
Has no negative impact on commercial fisheries and positive effects on aquaculture.

**Background Information:**
V. philippinarum is one of the most widely cultivated clam species in the world, including in its introduced ranges, because it can be cultured in dense populations in shallow waters (Breber 2002 qtd. in Sweet and Sewell 2011; Gillespie et al. 2012; Food and Agricultural Organization 2013).

No negative impacts on other commercial fisheries has been reported. In some parts of Europe, V. philippinarum was introduced to make up for declining or highly variable yields of native clam species.

**Sources:**
FAO 2013   Gillespie et al. 2012   NEMESIS; Fofonoff et al. 2003   Sweet and Sewell 2011

### 4.9 *Subsistence*

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on subsistence have been reported for V. philippinarum, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### 4.101 *Recreation*

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**

**Background Information:**
Frequently harvested by recreational shellfishers in British Columbia, Washington, and California.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.11 Human health and water quality*

| Choice: | | Score: |
|---|---|---|
| C | Limited – Has limited potential to pose a threat to human health, with limited impact and/or within a very limited region | 0.75 of 3 |

**Ranking Rationale:**

Cases of PSP and other shellfish syndromes are rare in Alaska. Current regulations and safety procedures greatly reduce the risk of bacterial transmission, especially in cultivated mussels. Recreational harvesting of shellfish in the Bering Sea is limited.

**Background Information:**

All bivalves can bioaccumulate toxins in their tissues as a result of consuming toxic dinoflagellates. Consuming raw or cooked bivalves can lead to Paralytic Shellfish Poisoning (PSP), which can cause health issues and even death (NIMPIS 2009). The state of Alaska discourages harvesting on untested beaches (ADEC 2013).

**Sources:**

NIMPIS 2009 ADEC 2013

| | |
|---|---|
| **Section Total - Scored Points:** | 4.75 |
| **Section Total - Possible Points:** | 27.5 |
| **Section Total -Data Deficient Points:** | 2.5 |

## 5. Feasibility of prevention, detection and control



### 5.1 *History of management, containment, and eradication*

**Choice:** **A** Attempted; control methods are not successful

**Score:** of

**Ranking Rationale:**
Control methods were tested and unsuccessful.

**Background Information:**
To prevent spread due to cultivation, it has been suggested to use triploid V. philippinarum as they show reduced fecundity. Unfortunately, sterilization is not reliably achieved (Laing and Utting 1994; Jensen et al. 2005 qtd. in Sweet and Sewell 2011).

Eradication measures are also extreme as removal requires dredging, which is not even guaranteed to be successful on top of the expense and damage to the local environment (Sweet and Sewell 2011).

**Sources:**
Laing and Utting 1994 Sweet and Sewell 2011

### 5.2 *Cost and methods of management, containment, and eradication*

**Choice:** **A** Major long-term investment, or is not feasible at this time

**Score:** of

**Ranking Rationale:**

**Background Information:**
There are no proven methods of control or eradication for this species. Dredging is a possible eradication method, but would cause massive and unacceptable environmental harm.

**Sources:**
Sweet and Sewell 2011

### 5.3 *Regulatory barriers to prevent introductions and transport*

**Choice:** **C** Regulatory oversight and/or trade restrictions

**Score:** of

**Ranking Rationale:**
Transport of bivalve species is regulated in Alaska. U.S. federal regulations require mandatory reporting and ballast water treatment or exchange.

**Background Information:**
Regulations exist regarding the transport and introduction of shellfish in water bodies. Under Alaska law, a permit must be obtained from the Alaska Department of Fish and Game (ADF&G) in order to collect, possess, or transport shellfish for educational, scientific, or propagative uses. Ballast water management is mandatory and regulated by the U.S. Coast Guard (CFR 33 § 151.2).

**Sources:**
ADF&G 2016

### *5.4 Presence and frequency of monitoring programs*

**Choice: A** No surveillance takes place

**Score:** of

**Ranking Rationale:**

**Background Information:**
No specific efforts for V. phillipinarum found.

**Sources:**
None listed

### *5.5 Current efforts for outreach and education*

**Choice: A** No education or outreach takes place

**Score:** of

**Ranking Rationale:**

**Background Information:**
No specific efforts for V. phillipinarum found.

**Sources:**
None listed

**Section Total - Scored Points:**

**Section Total - Possible Points:**

**Section Total -Data Deficient Points:**

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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Batillaria attramentaria*

**Common Name** *Japanese false cerith*

**Phylum** Mollusca

**Class** Gastropoda

**Order** Neotaenioglossa

**Family** Batillariidae

**Final Rank** 46.00

**Data Deficiency:** 12.50

**Species Occurrence by Ecoregion**

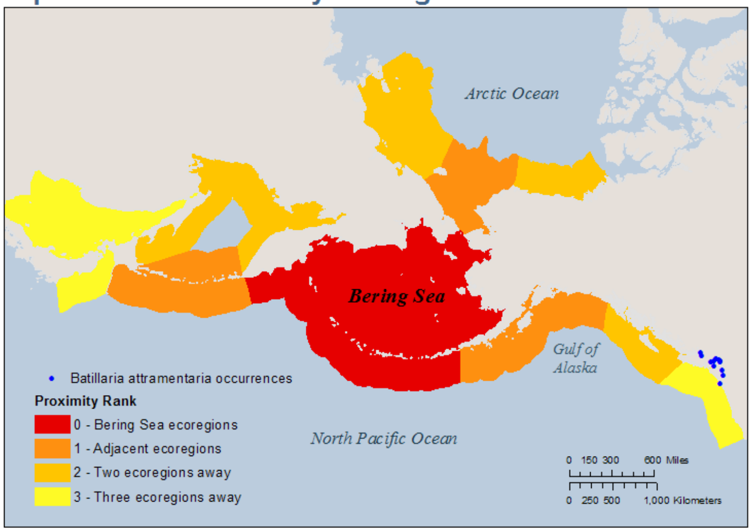


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 12.25 | 23 | 7.50 |
| Anthropogenic Influence: | 6 | 10 | 0 |
| Biological Characteristics: | 17 | 25 | 5.00 |
| Impacts: | 5 | 30 | 0 |
| **Totals:** | 40.25 | 87.50 | 12.50 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | -2 | Minimum Salinity (ppt) | 7 |
| Maximum Temperature (°C) | 40 | Maximum Salinity (ppt) | 33 |
| Minimum Reproductive Temperature (°C) | | Minimum Reproductive Salinity (ppt) | |
| Maximum Reproductive Temperature (°C) | | Maximum Reproductive Salinity (ppt) | |

### Additional Notes

Size of adult shells ranges from 10 to 34 mm. The shell is usually gray-brown, often with a white band below the suture, but can range from light brown to dirty-black. Historically introduced with the Pacific oyster, Crassostrea gigas, but in recent years, it has been found in areas where oysters are not cultivated. Nevertheless, its spread has been attributed to anthropogenic vectors rather than natural dispersal.

# 1. Distribution and Habitat



### *1.1 Survival requirements - Water temperature*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 3.75 **of** 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Temperatures required for year-round survival occur over a large (>75%) area of the Bering Sea. Thresholds are based on geographic distribution, which may not represent physiological tolerances; we therefore ranked this question with "High uncertainty".

**Background Information:**
Based on its geographic distribution, B. attramentaria can tolerate temperatures from -2°C to 40°C.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.2 Survival requirements - Water salinity*

**Choice:** **B** Moderate overlap – A moderate area (≥25%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 2.5 **of** 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Salinities required for year-round survival occur in a moderate area (≥25%) of the Bering Sea. Thresholds are based on geographic distribution, which may not represent physiological tolerances; moreover, models disagree with respect to their estimates of suitable area. We therefore ranked this question with "High uncertainty".

**Background Information:**
This species' salinity tolerance ranges from 7 to 33 PSU (based on geographic distribution).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.3 Establishment requirements - Water temperature*

**Choice:** **U** Unknown/Data Deficient

**Score:** **of**

**Ranking Rationale:**
Reproductive temperature requirements are unknown.

**Background Information:**
No information found.

**Sources:**
None listed

### *1.4 Establishment requirements - Water salinity*

**Choice:** **U** Unknown/Data Deficient

**Score:** **of**

**Ranking Rationale:**
Reproductive salinity requirements are unknown.

**Background Information:**
No information found.

**Sources:**
None listed

### *1.5 Local ecoregional distribution*

**Choice: C** Present in an ecoregion two regions away from the Bering Sea (i.e. adjacent to an adjacent ecoregion)

**Score:** 2.5 **of** 5

**Ranking Rationale:**
This species occurs in southern BC and in southern Russia.

**Background Information:**
This species is found on Vancouver Island, BC and in southern Russia.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.6 Global ecoregional distribution*

**Choice: C** In few ecoregions globally

**Score:** 1.75 **of** 5

**Ranking Rationale:**
Currently, this species is limited to temperate waters on either coasts of the Pacific Ocean.

**Background Information:**
This species is native to the Northwest Pacific, including Russia, Japan, Taiwan and Hong Kong. It has been introduced to the west coast of North America. It was first found in Washington in 1924, but has since spread to other areas in Washington and to California. In its native range, it extends as far north as the southern Sakhalin and Kuril Islands in the Sea of Okhotsk. Its northern limit in its introduced range is Vancouver Island in southern BC.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.7 Current distribution trends*

**Choice: C** Established outside of native range, but no evidence of rapid expansion or long-distance dispersal

**Score:** 1.75 **of** 5

**Ranking Rationale:**
This species spread slowly across the western coast of North America, where it was introduced. Its spread has been attributed to transport by anthropogenic vectors rather than natural dispersal.

**Background Information:**
This species was first reported in North America (Washington state) in 1924. By 1964, it had spread north to Comox, on BC's Vancouver Island. By 2007, it had reached Pendrell Sound, about ~100 km north of Comox. Its spread has been attributed to anthropogenic vectors (notably Pacific oyster culture), rather than natural dispersal. Large populations have been reported in San Francisco Bay, CA.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Behrens Yamada 1982

| | |
|---|---|
| **Section Total - Scored Points:** | 12.25 |
| **Section Total - Possible Points:** | 22.5 |
| **Section Total -Data Deficient Points:** | 7.5 |

## 2. Anthropogenic Transportation and Establishment



### *2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice:** **B** — Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 of 4

**Ranking Rationale:**
This species can be transported by hull fouling and hitchhiking. Its spread has been attributed to transport by anthropogenic vectors rather than natural dispersal.

**Background Information:**
B. attramentaria was unintentionally introduced to North America with Pacific oysters (Crassostrea gigas). Although it has recently been found in areas where no oysters are being cultivated, anthropogenic vectors such as boat trailers, fishing gear, or boots – rather than natural dispersal – are thought to be responsible for its spread.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Miura et al. 2006

### *2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice:** **A** — Readily establishes in areas with anthropogenic disturbance/infrastructure and in natural, undisturbed areas

**Score:** 4 of 4

**Ranking Rationale:**
This species can establish in natural and anthropogenic habitats following its introduction.

**Background Information:**
Its spread has largely been attributed to accidental introduction with Pacific oysters. Once introduced, it establishes on natural substrates in salt marshes and tidal pools in bays and estuaries (Byers 1999).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Byers 1999

### *2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice:** **B** — No

**Score:** 0 of 2

**Ranking Rationale:**
This species is not currently farmed.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 6 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

# 3. Biological Characteristics

### *3.1 Dietary specialization*

**Choice:** **A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 **of** 5

**Ranking Rationale:**
B. attramentaria is a generalist, and prey items are readily available in the Bering Sea.

**Background Information:**
B. attramentaria is both a suspension and deposit feeder (Kamimura and Tsuchiya 2004). It feeds on plant and animal particles, detritus, and benthic diatoms. It feeds by crawling and grazing on sediments (Swinbanks and Murray 1981).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Kamimura and Tsuchiya 2004   Swinbanks and Murray 1981

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **A** Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 **of** 5

**Ranking Rationale:**
This species has broad environmental tolerances. Competition and low dispersal abilities may limit habitat use in its introduced range.

**Background Information:**
This species has wide salinity and temperature tolerances, and a high tolerance for low oxygen levels (Byers 2000). In its natural range, it occurs on sand, mud, and rocky substrates (Adachi and Wada 1999). In its introduced range, it occupies a narrower range of habitats, and appears confined to tidal marshes and mudflats.

**Sources:**
NEMESIS; Fofonoff et al. 2003   Byers 2000   Adachi and Wada 1999

### *3.3 Desiccation tolerance*

**Choice:** **U** Unknown

**Score:** **of**

**Ranking Rationale:**
The desiccation tolerance of this species is unknown.

**Background Information:**
To avoid desiccation during low tide, B. attramentaria buries itself headfirst in the sand (Swinbanks and Murray 1981). Across a gradient of tidal zones, highest densities occurred at underwater sites, though some were found at drier sites (Swinbanks and Murray 1981).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Swinbanks and Murray 1981

### *3.4 Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice:** **B** Moderate – Exhibits one or two of the above characteristics

**Score:** 3.25 of 5

**Ranking Rationale:**
This species is dioecious. It reproduces sexually and has low parental investment. This species has low fecundity and a relatively long generation time.

**Background Information:**
This species is dioecious and exhibits sexual reproduction. Eggs have direct development and hatch into crawling (non-planktonic) larvae. Byers and Goldwasser (2001) used field observations on another species to estimate a relationship between shell length and fecundity; based on this relationship and an average shell size of 18.4 mm, an individual female is expected to produce 205 eggs/year. B. attramaentaria can reproduce more than once over the course of its life (Lin 2006).
This species can live between 6 to 10 years (Behrens Yamada 1982), and reaches sexual maturity when it reaches ~1.3-2 mm in length (usually between 1 and 2 years old).

**Sources:**
Behrens Yamada 1982 NEMESIS; Fofonoff et al. 2003 Lin 2006 Byers and Goldwasser 2001

### *3.5 Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice:** **C** Disperses short (< 1 km) distances

**Score:** 0.75 of 2.5

**High uncertainty?** ☑

**Ranking Rationale:**
Although data on dispersal are lacking, preliminary movement estimates, as well as biological and ecological information suggest that this species has limited capacity for natural dispersal.

**Background Information:**
Dispersal ability is relatively limited because it produces non-planktonic larvae (qtd. in Byers 1999). Juvenile snails of small shell size can disperse locally by floating on the water surface, but high wave intensity likely impedes floating ability (Adachi and Wada 1999). Adults are mobile and capable of crawling. A preliminary mark-recapture experiment found that this species moved an average of 1 m/day (Dewar et al. 2008). However, given their locomotion style and patchy distribution, they likely do not disperse long distances (Behrens Yamada 1982). The distribution of B. attramentaria is largely (though not exclusively) restricted to bays in which it was introduced with C. gigas (Byers 1999).

**Sources:**
Adachi and Wada 1999 Behrens Yamada 1982 Dewar et al. 2008 Byers 1999 NEMESIS; Fofonoff et al. 2003

### *3.6 Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: B** Moderate – Exhibits one of the above characteristics

**Score:** 1.75 of 2.5

**Ranking Rationale:**
This species lacks a planktonic larval stage, and data suggest that it has limited mobility. All life stages can disperse by crawling. Juveniles can also disperse by floating.

**Background Information:**
This species undergoes direct development and eggs hatch into crawling (non-planktonic) larvae. Juvenile snails of small shell size can disperse locally by floating on the water surface (Adachi and Wada 1999). Adults are mobile and capable of crawling. A preliminary mark-recapture experiment found that this species moved an average of 1 m/day (Dewar et al. 2008).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Byers 1999 Adachi and Wada 1999 Dewar et al. 2008

### *3.7 Vulnerability to predators*

**Choice: D** Multiple predators present in the Bering Sea or neighboring regions

**Score:** 1.25 of 5

**Ranking Rationale:**
Several taxa found in the Bering Sea are likely to prey upon this species.

**Background Information:**
This species is predated upon by birds, crabs, and fishes.

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 17 |
| **Section Total - Possible Points:** | 25 |
| **Section Total -Data Deficient Points:** | 5 |

## 4. Ecological and Socioeconomic Impacts



### *4.1 Impact on community composition*

**Choice: C** Limited – Single trophic level; may cause decline but not extirpation

**Score:** 0.75 of 2.5

**Ranking Rationale:**

Through competition, B. attramentaria may extirpate native snail populations, especially in areas where suitable habitat (e.g., marshes, mudflats) is limited. This species may also facilitate the establishment of other invasive species, or act in conjunction with other grazers to affect eelgrass. However, its impacts in natural ecological settings have so far been limited.

**Background Information:**

Because of competition with B. attramentaria, populations of the native snail Cerithidea californica declined an average of 27% over a 3-year period in northern California (Byers 1999). A modelling exercise by Byers and Goldwasser (2001) suggest that, while displacement is slow, it may lead to extinction of C. californica in northern California within 55 to 90 years. Southern populations do not seem to be under threat because there is more available habitat, and because Batillaria is currently not found south of Elkhorn Slough. C. californica is host to 10 native and species-specific trematode species, which could also become locally extinct if B. attramentaria were to extirpate C. californica (Torchin et al. 2005; Lin 2006).

In manipulative experiments, B. attramentaria increased the abundance of mud snail Nassarius fraterculus and % cover of eelgrass Zostera japonica (Wonham et al. 2005). Both are introduced species from the NW Pacific.

In Boundary Bay, BC, Swinbanks and Murray (1981) suggest that B. attramentaria cannot, by itself, limit the extent of the algal mat zone. However, the grazing activities of Batillaria, combined with the effects of two other species (Abarenicola sp. and Callianassa californiensis), might limit the extent of algal mats (Swinbanks and Murray 1981).

**Sources:**

Byers 1999   Byers and Goldwasser 2001   Wonham et al. 2005   Lin 2006   Torchin et al. 2005   Swinbanks and Murray 1981   NEMESIS; Fofonoff et al. 2003

### *4.2 Impact on habitat for other species*

**Choice: B** Moderate – Causes or has potential to cause changes to one or more habitats

**Score:** 1.75 of 2.5

**Ranking Rationale:**

Because of its shell, B. attramentaria creates hard substrate habitat that can be used by other species. This trait may be especially important in areas where B. attramentaria occurs at high densities, and where hard substrates are limited (e.g., on mudflats).

**Background Information:**

In Padilla Bay, WA, the shells of B. attramentaria provided habitat for two introduced species, the slipper shell Crepidula convexa and the anemone Diadumene lineata, and two native hermit crabs Pagurus hirsutiusculus and P. granosimanus (Wonham et al. 2005). Given the high densities of B. attramentaria in this area (>1400 individuals/m2), the authors estimate that B. attramentaria provided 600 cm of available habitat per m2 (Wonham et al. 2005).

**Sources:**

Wonham et al. 2005

### 4.3 *Impact on ecosystem function and processes*

**Choice:** **C** Limited – Causes or potentially causes changes to food webs and/or ecosystem functions, with limited impact and/or within a very limited region

**Score:** 0.75 of 2.5

**High uncertainty?** ✔

**Ranking Rationale:**
Through bioturbation and deposition of pseudofeces, this species may affect nutrient and oxygen concentrations. The effects of B. attramentaria on ecosystem processes has not been directly measured, and so the magnitude of its effects is unknown. These effects are likely to be most pronounced in areas where B. attramentaria occur at high densities.

**Background Information:**
When resting and feeding, B. attramentaria creates shallow trails in the soft substrate habitats where it occurs (Swinbanks and Murray 1981). This species also deposits pseudofeces. These behaviors may affect nutrient and oxygen levels; Wonham et al. (2005) suggest that these ecosystem effects may explain why percent cover of the seagrass Zostera japonica was higher in experimental enclosures where B. attramentaria was present. The study by Wonham et al. (2005) occurred in an area of high snail density (>1400 individuals/m2).

**Sources:**
Swinbanks and Murray 1981 Wonham et al. 2005

### 4.4 *Impact on high-value, rare, or sensitive species and/or communities*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
Although this species grazes on eelgrass, it has not been shown to have significant negative impacts. We do not expect this species to impact high-value species or communities in the Bering Sea.

**Background Information:**
In Boundary Bay, BC, Swinbanks and Murray (1981) suggest that B. attramentaria cannot, by itself, limit the extent of the algal mat zone. However, the grazing activities of Batillaria, combined with the effects of two other species (Abarenicola sp. and Callianassa californiensis), might limit the extent of algal mats (Swinbanks and Murray 1981).

**Sources:**
Swinbanks and Murray 1981

### 4.5 *Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice:** **B** Moderate – Spreads or has potential to spread one or more organisms, with moderate impact and/or within only a portion of region

**Score:** 1.75 of 2.5

**High uncertainty?** ✔

**Ranking Rationale:**
B. attramentaria is host to several parasites, only one of which (C. batillariae) has been found in introduced populations. This parasite cannot be transmitted from one snail to another, but its effect on other intermediate and final hosts (fishes and birds) is unknown.

**Background Information:**
In Asian waters, B. attramentaria hosts a variety of parasites, but only one, Cercaria batillariae, has been found in North America populations (Torchin et al. 2005). B. attramentaria, and several species of fishes, are intermediate hosts of C. batillariae, while fish-eating birds are probably the final hosts (Torchin et al. 2005). C. batillariae cannot be transmitted from one snail to another, and is unlikely to affect native snail populations (Lin 2006).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Lin 2006 Torchin et al. 2002 Torchin et al. 2005

### *4.6 Level of genetic impact on native species*



Can this invasive species hybridize with native species?

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not expected to hybridize with native species in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.7 Infrastructure*

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact infrastructure in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.8 Commercial fisheries and aquaculture*

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact commercial fishing in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.9 Subsistence*

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to affect subsistence resources in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.101 Recreation*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to affect recreational opportunities in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.11 Human health and water quality*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact human health and water quality in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 5 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 5. Feasibility of prevention, detection and control



### 5.1 *History of management, containment, and eradication*

**Choice:** **C** Attempted; control methods are currently in development/being studied

**Score:** of

**Ranking Rationale:**
Control of this species has been attempted, and methods to do so are currently being studied.

**Background Information:**
Attempts to eradicate populations in Loch Lomond Marina (San Francisco Bay) and Bodega Harbor were unsuccessful. Control methods are currently being studied (e.g., Houle 2011).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Houle 2011

### 5.2 *Cost and methods of management, containment, and eradication*

**Choice:** **B** Major short-term and/or moderate long-term investment

**Score:** of

**Ranking Rationale:**
Current methods are labor-intensive, and need to be repeated in order to be effective. They are unlikely to work in areas where B. attramentaria occurs at high densities.

**Background Information:**
Hand removal has been used as a control method. Hand removal is labor-intensive and is unlikely to achieve complete eradication, especially in high density areas (Houle 2011). Other physical removal methods have been tested, but have not been more successful than hand removal (Houle 2011).

**Sources:**
Houle 2011 GISD 2016

### 5.3 *Regulatory barriers to prevent introductions and transport*

**Choice:** **A** Little to no regulatory restrictions

**Score:** of

**Ranking Rationale:**
This species is transported by numerous vectors and no species-specific regulations are currently in place. No regulations exist to prevent the spread of invasive species by hitchhiking.

**Background Information:**

**Sources:**
CFR 2017

### 5.4 *Presence and frequency of monitoring programs*

**Choice:** **B** Surveillance takes place, but is largely conducted by non-governmental environmental organizations (e.g., citizen science programs)

**Score:** of

**Ranking Rationale:**
Surveillance takes place in parts of its introduced range, and is conducted by scientists and volunteers. We did not find information on state or federal monitoring programs for this species.

**Background Information:**
Researchers and volunteers were involved in monitoring and removal of B. attramentaria in Bodega Harbor.

**Sources:**
Houle 2011

### 5.5 *Current efforts for outreach and education*

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**Choice:** **A** No education or outreach takes place

**Score:** of

**Ranking Rationale:**

Very little information exists on B. attramentaria, and no information was found to suggest that education or outreach is taking place.

**Background Information:**

**Sources:**

None listed

**Section Total - Scored Points:**

**Section Total - Possible Points:**

**Section Total -Data Deficient Points:**

## Literature Cited for *Batillaria attramentaria*


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- Torchin, M. E., Lafferty, K. D., and A. M. Kuris. 2002. Parasites and marine invasions. Parasitology 124:S137-S151.

# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Crepidula onyx*

**Common Name** *onyx slippersnail*

| | |
|---|---|
| Phylum | Mollusca |
| Class | Gastropoda |
| Order | Neotaenioglossa |
| Family | Calyptraeidae |

**Final Rank** 46.84

**Data Deficiency:** 5.00

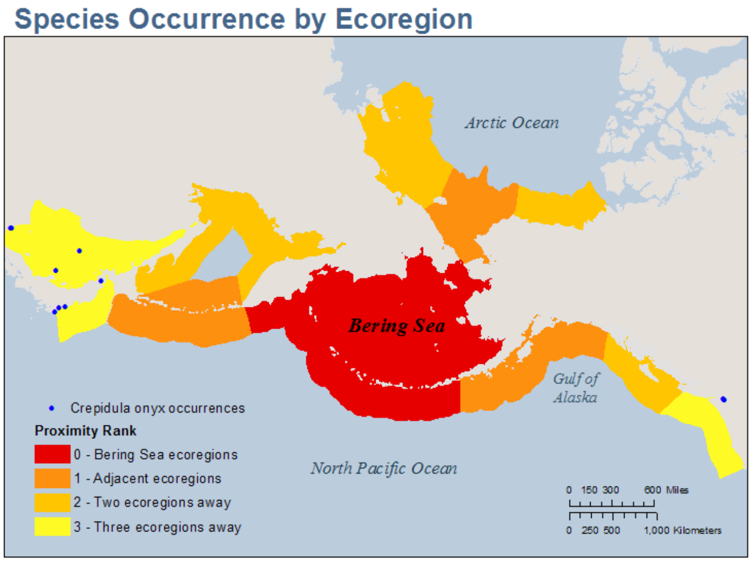


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 13.75 | 30 | 0 |
| Anthropogenic Influence: | 8 | 10 | 0 |
| Biological Characteristics: | 20.5 | 25 | 5.00 |
| Impacts: | 2.25 | 30 | 0 |
| **Totals:** | 44.50 | 95.00 | 5.00 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | 10 | Minimum Salinity (ppt) | 10 |
| Maximum Temperature (°C) | 30 | Maximum Salinity (ppt) | 45 |
| Minimum Reproductive Temperature (°C) | 15 | Minimum Reproductive Salinity (ppt) | 15 |
| Maximum Reproductive Temperature (°C) | NA | Maximum Reproductive Salinity (ppt) | 45 |

### Additional Notes

Crepidula onyx is a marine snail with a thick, oval shell. The shell has concentric growth lines and its color ranges from tan to dark brown. The inside of the shell is brown and glossy. Shells can measure up to 60 mm. It inhabits intertidal and shallow subtidal areas, and attaches itself to a variety of substrates, including rock, mud, and mollusk shells. Individuals may even grow on top of one another. It is native to the west coast of America from California to Peru.

# 1. Distribution and Habitat



### *1.1 Survival requirements - Water temperature*

**Choice:** **D** No overlap – Temperatures required for survival do not exist in the Bering Sea

**Score:** 0 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Temperature requirements do not exist year-round in the Bering Sea. Thresholds are based on geographic distribution, which may not represent physiological tolerances; we therefore ranked this question with "High uncertainty".

**Background Information:**
This species is found in warm-temperate and tropical waters. Its distribution suggests that it cannot tolerate low water temperatures. Temperature tolerances of 10 to 22°C have been cited (SWIMS 2017), but it is obviously capable of tolerating higher temperatures. It has been introduced in Hong Kong where water temperatures range between 15 and 30°C, and larvae have been successfully reared at temperatures between 20 and 30°C (Zhao 2002).

**Sources:**
Zhao 2002 SWIMS 2017

### *1.2 Survival requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
Crepidula onyx is a marine species. Preliminary experiments by Zhao (2002) found that C. onyx could not survive at salinities below 10 ppt. Adults have been cultured at 35 ppt (Zhao et al. 2003). 30% and >15% of larvae reached metamorphosis when exposed to salinities of 35 and 45 ppt, suggesting that this species has a high tolerance to elevated salinities (Zhao 2002).

**Sources:**
Zhao 2002 Zhao et al. 2003

### *1.3 Establishment requirements - Water temperature*

**Choice:** **D** No overlap – Temperatures required for reproduction do not exist in the Bering Sea

**Score:** 0 of 3.75

**Ranking Rationale:**
Temperatures required for reproduction do not exist in the Bering Sea.

**Background Information:**
Experiments by Zhao (2002) on Hong Kong populations found that no larvae metamorphosed at 15°C. Larvae exposed to temperatures of 20, 25, and 30°C all underwent metamorphosis. Higher temperatures were associated with faster development rates (Zhao 2002).

**Sources:**
Zhao 2002

## *1.4 Establishment requirements - Water salinity*



**Choice: A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for reproduction occur over a large (>75%) area of the Bering Sea.

**Background Information:**
Can tolerate a broad range of salinities. Under controlled conditions, larvae were able to metamorphose at salinities between 15 and 32 ppt (Zhao 2002). Neither larvae nor juveniles exhibited stress responses when exposed to salinities > 30 ppt. ~30% and >15% of larvae reached metamorphosis when exposed to salinities of 35 and 45 ppt, respectively (Zhao 2002).

**Sources:**
Zhao 2002

## *1.5 Local ecoregional distribution*

**Choice: D** Present in an ecoregion greater than two regions away from the Bering Sea

**Score:** 1.25 of 5

**Ranking Rationale:**
This species has been reported in WA.

**Background Information:**
Crepidula onyx is native to the west coast of the America, from southern California to Peru. It has been introduced to Puget Sound, WA but is reported as rare. Its establishment in WA may be dependent upon warmer waters in restricted areas of the bay.

**Sources:**
NEMESIS; Fofonoff et al. 2003

## *1.6 Global ecoregional distribution*

**Choice: C** In few ecoregions globally

**Score:** 1.75 of 5

**Ranking Rationale:**
This species is largely restricted to warm-temperate and tropical waters on both coasts of the Pacific Ocean.

**Background Information:**
Crepidula onyx is a warm-temperate and tropical species. It is native to the west coast of the America, from southern California to Peru. It has been introduced to Puget Sound, WA. It has also been introduced in Asia, where it has been reported in Japan, Hong Kong, China, and South Korea.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.7 Current distribution trends*

**Choice: B** — History of rapid expansion or long-distance dispersal (prior to the last ten years)

**Score:** 3.25 **of** 5

**Ranking Rationale:**

This species spread rapidly in eastern Asia following its discovery in the late 1970s, but no recent expansions have been reported.

**Background Information:**

This species spread rapidly in Japan, China, and Korea following its introduction to the west Pacific (Fofonoff et al. 2003). A recent assessement in Hong Kong reported that C. onyx had not expanded its range in the region since the 1980s (Astudillo et al. 2014). Although it is found in WA, it is considered rare and its expansion northward is likely limited by its low tolerance for cold water temperatures (Fofonoff et al. 2003). No reports of recent range expansions were found.

**Sources:**

NEMESIS; Fofonoff et al. 2003   Astudillo et al. 2014

| | |
|---|---|
| **Section Total - Scored Points:** | 13.75 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 2. Anthropogenic Transportation and Establishment



*2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice: A** Has been observed using anthropogenic vectors for transport and transports independent of any anthropogenic vector once introduced

**Score:** 4 of 4

**High uncertainty?** ☑

**Ranking Rationale:**
This species uses anthropogenic vectors for transport, but it can disperse naturally once introduced. There is a lack of information on its natural movements and dispersal patterns.

**Background Information:**
This species can be transported by hull fouling and ballast water (Fofonoff et al. 2003; Molnar et al. 2008). This species can disperse locally through its planktonic larval stage (Molnar et al. 2008).

**Sources:**
Molnar et al. 2008   NEMESIS; Fofonoff et al. 2003

*2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice: A** Readily establishes in areas with anthropogenic disturbance/infrastructure and in natural, undisturbed areas

**Score:** 4 of 4

**Ranking Rationale:**
This species has been found growing on anthropogenic and natural substrates in its introduced range.

**Background Information:**
Adults attach themselves to natural and anthropogenic substrates including rocks, bivalve shells, and ship hulls. In Hong Kong, this species was found in areas associated with high human activity (piers, marinas), but individuals were seen on rocks rather than on the pier (Astudillo et al. 2014).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Astudillo et al. 2014

*2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice: B** No

**Score:** 0 of 2

**Ranking Rationale:**
This species is not intentionally farmed.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 8 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics

### *3.1 Dietary specialization*

**Choice: A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Food items are readily available in the Bering Sea.

**Background Information:**
C. onyx is a filter feeder. It eats phytoplankton and detritus.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice: A** Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 of 5

**Ranking Rationale:**
This species can establish on a variety of substrates in lower tidal zones, and can tolerate high levels of human disturbance and a broad range of salinities. Its northward expansion may be limited by its higher temperature requirements.

**Background Information:**
This species can grow on a variety of a substrates. It has a broad salinity range, but it is likely sensitive to cold temperatures (Fofonoff et al. 2003). It has been reported for low intertidal to subtidal zones (Zhao and Qian 2002). This species is common in Hong Kong, an area with high levels of human disturbance and strong seasonal fluctuations in salinity and temperature (Astudillo et al. 2014). This species has a tolerance to mild levels of hypoxia; however, dissolved oxygen (DO) levels below 2 mg O2/l is lethal for larvae (Li and Chiu 2013).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Zhao and Qian 2002 Astudillo et al. 2014 Li and Chiu 2013

### *3.3 Desiccation tolerance*

**Choice: U** Unknown

**Score:** of

**Ranking Rationale:**
This species' tolerance to desiccation is unknown.

**Background Information:**
No information found. This species is associated with low intertidal and subtidal habitats (Zhao and Qian 2002), which may suggest that this species has a low tolerance to desiccation.

**Sources:**
Zhao and Qian 2002

### 3.4 *Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice: A** High – Exhibits three or four of the above characteristics

**Score:** 5 of 5

**Ranking Rationale:**
C. onyx is cyclically hermaphroditic and highly fecund. Eggs are brooded. This species grows rapidly and has a short generation time.

**Background Information:**
C. onyx is a protandic hermaphrodite with a pelagic larval stage (Zhao 2002). Eggs are brooded by the female for about 10 days (Zhao et al. 2003). In its native range, C. onyx produced 6 to 8 broods per year with 5000 to 20 000 larvae in each brood (Coe 1949, qtd. in Zhao 2002). This species lives 2 to 3 years (Coe 1942, qtd. in Woodruff et al. 1986). It grows rapidly, reaching a shell length of 6 to 60 mm within its first year (Woodruff et al. 1986). Males are sexually mature at minimum shell lengths of 6 to 10 mm (Woodruff et al. 1986).

**Sources:**
Zhao 2002 Woodruff et al. 1986

### 3.5 *Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice: A** Disperses long (>10 km) distances

**High uncertainty?** ☑

**Score:** 2.5 of 2.5

**Ranking Rationale:**
The dispersal potential of C. onyx is unknown. However, genetic studies on a closely related species with similar reproductive traits suggest that the larval stage of this species may be able to disperse long (>10 km) distances.

**Background Information:**
In both its native and introduced range, adults have an aggregated distribution and are often found growing close or on top of each other (Zhao 2002). A study on a closely related species, Crepidula fornicata, was found to have strong dispersal abilities, with populations more than 100 km apart showing no significant genetic differentiation (Viard et al. 2006).

**Sources:**
Zhao 2002 Viard et al. 2006

### 3.6 *Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: B** Moderate – Exhibits one of the above characteristics

**Score:** 1.75 of 2.5

**Ranking Rationale:**
This species' has a long-lived larval stage that is likely capable of long-distance dispersal.Eggs are brooded by females and adults are largely sessile.

**Background Information:**
Adults are capable of localized movement by crawling on the substrate. Larvae are long-lived and free-swimming. Eggs are brooded by females.

**Sources:**
Zhao 2002 NEMESIS; Fofonoff et al. 2003

### 3.7 *Vulnerability to predators*



**Choice:** **D** Multiple predators present in the Bering Sea or neighboring regions

**Score:** 1.25 of 5

**High uncertainty?** ☑

**Ranking Rationale:**
While no species-specific information was found, information on a closely related species suggest that C. onyx would have many predators in the Bering Sea.

**Background Information:**
No species-specific information found. A closely related species, C. fornicata, is preyed upon by starfish, crabs, fish, and marine snails (CABI 2017).

**Sources:**
CABI 2017

| | |
|---|---|
| **Section Total - Scored Points:** | 20.5 |
| **Section Total - Possible Points:** | 25 |
| **Section Total -Data Deficient Points:** | 5 |

## 4. Ecological and Socioeconomic Impacts



### *4.1 Impact on community composition*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No impacts have been reported for this species.

**Background Information:**
This species has been found attached to the shells of oysters and mussels, but does not seem to have any negative impacts on these species.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Molnar et al. 2008

### *4.2 Impact on habitat for other species*

**Choice:** **C** Limited – Has limited potential to cause changes in one or more habitats

**Score:** 0.75 of 2.5

**Ranking Rationale:**
Although no impacts have been reported, this speciesis a common fouling organism and is known to occur at high densities. By fouling substrates, this species may reduce available habitat for some organisms or, conversely, create secondary settlement habitat.

**Background Information:**
No impacts have been reported. Dense aggregations of individuals have been reported for this species (Huang et al. 1999, qtd. in Zhao 2002).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Molnar et al. 2008 Zhao 2002

### *4.3 Impact on ecosystem function and processes*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No impacts have been reported for this species.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Molnar et al. 2008

### *4.4 Impact on high-value, rare, or sensitive species and/or communities*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No impacts have been reported for this species.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Molnar et al. 2008

### 4.5 *Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not known to transport diseases, parasites, or hitchhikers.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003 Molnar et al. 2008

### 4.6 *Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not expected to hybridize with native species in the Bering Sea.

**Background Information:**
No impacts have been reported. We did not find reports of hybridization between any Crepidula species. There are a few Crepidula species in Alaska.

**Sources:**
None listed

### 4.7 *Infrastructure*

**Choice: C** Limited – Has limited potential to cause degradation to infrastructure, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
Although no species-specific impacts have been reported, this species can foul anthropogenic substrates such as docks and ship hulls. Fouling organisms can impose high maintenance costs.

**Background Information:**
No impacts have been reported, but C. onyx is a common member of the fouling community (Fofonoff et al. 2003; Astudillo et al. 2014). Fouling organisms on ships cause drag and reduce maneuverability. They are estimated to cost the U.S. Navy over $50 million a year in fuel costs due to increased drag (Cleere 2001).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Astudillo et al. 2014 Cleere 2001

### *4.8 Commercial fisheries and aquaculture*

**Choice: C** Limited – Has limited potential to cause degradation to fisheries and aquaculture, and/or is restricted to a limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
Because this species fouls oyster and mussel shells, it may impact the growth and/or commercial value of this species. Shellfish aquaculture is currently a small industry in Alaska that occurs only in a restricted area of the Bering Sea.

**Background Information:**
Although no species-specific impacts have been reported, this species is known to foul oyster and mussel shells (Zhao 2002; Fofonoff et al. 2003). A closely related species, Crepidula fornicata, has had economic impacts on shellfish farming in Europe (CABI 2017).

**Sources:**
Zhao 2002 NEMESIS; Fofonoff et al. 2003 CABI 2017

### *4.9 Subsistence*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact subsistence resources in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.101 Recreation*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact recreational opportunities in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.11 Human health and water quality*

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact human health or water quality in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 2.25 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 5. Feasibility of prevention, detection and control



### *5.1 History of management, containment, and eradication*

**Choice: C** Attempted; control methods are currently in development/being studied

**Score:** of

**Ranking Rationale:**
No species-specific plans are in place to control or eradicate this species. This species is transported by ballast water and ship fouling. Controlling the spread of invasive species that use these vectors for transport is an active area of research.

**Background Information:**
We did not find any management plans that were specific to this species.

**Sources:**
Hagan et al. 2014 Ruiz and Reid 2007

### *5.2 Cost and methods of management, containment, and eradication*

**Choice: A** Major long-term investment, or is not feasible at this time

**Score:** of

**Ranking Rationale:**
This species can be transported by ballast water and ship fouling. Methods to control the spread of invasive species via these vectors are being developed, and currently necessitate major long-term investments.

**Background Information:**

**Sources:**
Zagdan 2010 Hagan et al. 2014

### *5.3 Regulatory barriers to prevent introductions and transport*

**Choice: B** Regulatory oversight, but compliance is voluntary

**Score:** of

**Ranking Rationale:**
This species is transported by numerous vectors and no species-specific regulations are currently in place. Although there are federal regulations for both ballast water and hull fouling, compliance with federal fouling regulations remains voluntary.

**Background Information:**

**Sources:**
CFR 2017 Hagan et al. 2014

### *5.4 Presence and frequency of monitoring programs*

**Choice: A** No surveillance takes place

**Score:** of

**Ranking Rationale:**
No surveillance takes place for this species.

**Background Information:**

**Sources:**
None listed

### *5.5 Current efforts for outreach and education*

679

**Choice: A** No education or outreach takes place

**Score:** of

**Ranking Rationale:**
There are no outreach or education programs developed for this species.

**Background Information:**

**Sources:**
None listed

**Section Total - Scored Points:**

**Section Total - Possible Points:**

**Section Total -Data Deficient Points:**

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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Ilyanassa obsoleta*

**Common Name** *eastern mudsnail*

| | |
|---|---|
| **Phylum** | Mollusca |
| **Class** | Gastropoda |
| **Order** | Neogastropoda |
| **Family** | Nassariidae |

**Final Rank** 46.41

**Data Deficiency:** 2.50

### Species Occurrence by Ecoregion

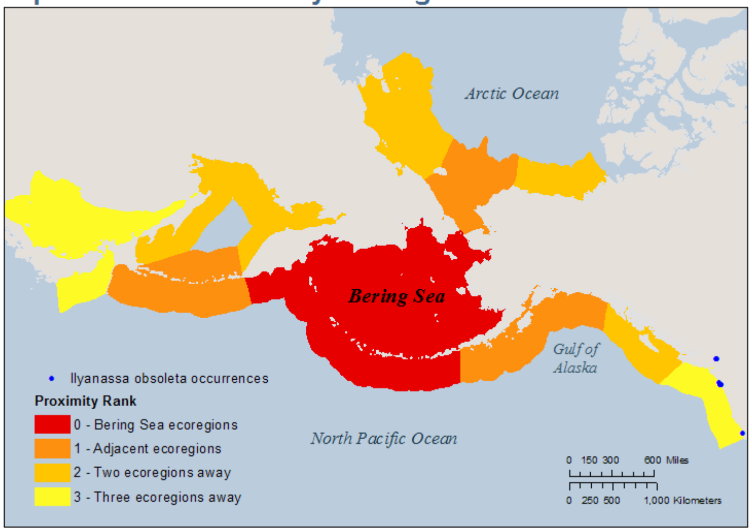


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 14.75 | 30 | 0 |
| Anthropogenic Influence: | 4.75 | 10 | 0 |
| Biological Characteristics: | 20.25 | 30 | 0 |
| Impacts: | 5.5 | 28 | 2.50 |
| **Totals:** | 45.25 | 97.50 | 2.50 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | 0 | Minimum Salinity (ppt) | 10 |
| Maximum Temperature (°C) | 30 | Maximum Salinity (ppt) | 35 |
| Minimum Reproductive Temperature (°C) | 16.5 | Minimum Reproductive Salinity (ppt) | 21 |
| Maximum Reproductive Temperature (°C) | 28 | Maximum Reproductive Salinity (ppt) | 35* |

### Additional Notes

Ilyanassa obsoleta is a medium-sized benthic snail. Adult shells are dark brown to black and reach 25 to 30 mm in size. I. obsoleta is native to the Northwest Atlantic and the Gulf of Mexico, and was introduced to the California, Washington and British Columbia, most likely in association with the transportation of the Eastern Oyster (Fofonoff et al. 2003). Synonyms include Nassarius obsoletus and a recent genetic study proposed a name change to Tritia obsoleta (Galindo et la. 2016).

# 1. Distribution and Habitat



### *1.1 Survival requirements - Water temperature*

**Choice:** **B** Moderate overlap – A moderate area (≥25%) of the Bering Sea has temperatures suitable for year-round survival

**Score:** 2.5 of 3.75

**High uncertainty?** ✔

**Ranking Rationale:**
Temperatures required for year-round survival occur in a moderate area (≥25%) of the Bering Sea. We ranked this question with "High Uncertainty" to indicate disagreements in model estimates.

**Background Information:**
The temperature threshold for survival of I. obsoleta is 0°C to 30°C (based on experimental studies). I. obsoleta has a limited tolerance for freezing (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Murphy 1979

### *1.2 Survival requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for year-round survival occur over a large (>75%) area of the Bering Sea.

**Background Information:**
The salinity threshold for survival of I. obsoleta is 10 to 35 ppt (Scheltema 1965, qtd. in Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Scheltema 1965

### *1.3 Establishment requirements - Water temperature*

**Choice:** **D** No overlap – Temperatures required for reproduction do not exist in the Bering Sea

**Score:** 0 of 3.75

**Ranking Rationale:**
Temperatures required for reproduction do not exist in the Bering Sea.

**Background Information:**
The temperature threshold for reproduction of I. obsoleta is 16.5°C to 28°C (based on experimental studies; Scheltema 1967).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Scheltema 1967

### *1.4 Establishment requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Salinities required for reproduction occur over a large (>75%) area of the Bering Sea.

**Background Information:**
Metamorphosis requires salinity above 20.9 ppt to complete (Scheltema 1965).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Scheltema 1965

### *1.5 Local ecoregional distribution*



**Choice: D** Present in an ecoregion greater than two regions away from the Bering Sea

**Score:** 1.25 of 5

**Ranking Rationale:**

**Background Information:**
Occurrences are documented for California, Washington and British Columbia (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.6 Global ecoregional distribution*

**Choice: C** In few ecoregions globally

**Score:** 1.75 of 5

**Ranking Rationale:**
Species is restricted to North America.

**Background Information:**
I. obsoleta is native to the eastern coast of North America, from Quebec to western Florida (Bousfield 1960 as qtd. In Fofonoff et al. 2003; Abbott 1974 as qtd. In Fofonoff et al. 2003). It was accidentally introduced on the west coast, and now populates regions of California as well as Washington (Willapa Bay) and British Columbia (Boundary Bay) (Carlton 1979; Wonham and Carlton 2005).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Carlton 1979 Wonham and Carlton 2005

### *1.7 Current distribution trends*

**Choice: C** Established outside of native range, but no evidence of rapid expansion or long-distance dispersal

**Score:** 1.75 of 5

**Ranking Rationale:**
Is largely restricted to Willapa and Boundary Bay in introduced range.

**Background Information:**
In British Columbia and Washington, remains largely restricted to the Willapa and Boundary Bay areas where it was introduced more than 50 years ago. More widespread in California, but still only occurs along a < 200 mi stretch from Bodega to Moss Landing. Has not been reported in Oregon.

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 14.75 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 2. Anthropogenic Transportation and Establishment



***2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport***

**Choice:** **B** Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

**Score:** 2 **of** 4

**Ranking Rationale:**

**Background Information:**
Transportation of I. obsoleta is associated with the anthropogenic movements of Atlantic oysters to the Pacific coast for aquaculture. I. obsoleta lays its eggs on Atlantic oysters which facilitates its movements (Cohen 2005).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Cohen 2005

***2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish***

**Choice:** **B** Readily establishes in areas with anthropogenic disturbance/infrastructure; occasionally establishes in undisturbed areas

**Score:** 2.75 **of** 4

**Ranking Rationale:**
In its introduced range, this species is largely associated with anthropogenic infrastructure.

**Background Information:**
Commonly associated with mudflats and other soft-sediment habitats. While it does not rely on marine infrastructure to establish, it has not been observed outside of anthropogenic areas in its introduced range.

**Sources:**
NEMESIS; Fofonoff et al. 2003

***2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?***

**Choice:** **B** No

**Score:** 0 **of** 2

**Ranking Rationale:**

**Background Information:**
I. obsoleta is not intentially farmed or cultivated.

**Sources:**
None listed

| | |
|---|---|
| **Section Total - Scored Points:** | 4.75 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

## 3. Biological Characteristics



### 3.1 *Dietary specialization*

**Choice:** **A**

Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 of 5

**Ranking Rationale:**
Consumes several taxa, many of which are available in the Bering Sea.

**Background Information:**
I. obsoleta is an omnivorous facultative scavenger and deposit feeder. Young snails in aquaria graze on algae and probably feed this way in the wild. Adults ingest large quantities of sediment, together with organic matter and benthic diatoms, worms, fish and crustacean remains. Also feed on decaying algae, and are strongly attracted to carrion (dead fish and mollusks). Do not attack or feed on living bivalves (Scheltema 1964).

**Sources:**
NEMESIS; Fofonoff et al. 2003   GISD 2016   Scheltema 1964

### 3.2 *Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **B**

Requires specialized habitat for some life stages (e.g., reproduction)

**Score:** 3.25 of 5

**Ranking Rationale:**
Can live on a variety of substrates but is restricted to sheltered, soft-sediment habitats.

**Background Information:**
Abundant in estuaries, mudflats, and sheltered soft-sediment habitats. Can live on a wide range of substrates, from sand to anoxic muds (Levinton 1995). Also able to tolerate a range of temperatures and salinities. Experiments suggest that I. obsoleta actively avoids exposure to strong water flow, either by burrowing in the substrate or by crawling to lower velocity areas (Levinton et al. 1995).

**Sources:**
NEMESIS; Fofonoff et al. 2003   Levinton et al. 1995

### 3.3 *Desiccation tolerance*

**Choice:** **B**

Moderately tolerant (1-7 days) during one or more stages during its life cycle

**Score:** 3.25 of 5

**Ranking Rationale:**
Can survive 3 to 20 days outside of water.

**Background Information:**
Adults of I. obsoleta acclimated to a warmer temperature can tolerate a greater level of cellular dehydration when exposed to air. In air with a relative humidity of 35%, the time required for 50% of 18°C acclimated snails to die was 116 hours (±9), whereas the LT50 value for the 3°C acclimated snails was 76 hours (±8).

**Sources:**
Murphy and McCausland 1980

### *3.4 Likelihood of success for reproductive strategy*



i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice:** **B** Moderate – Exhibits one or two of the above characteristics

**Score:** 3.25 of 5

**Ranking Rationale:**

Sexual reproduction, low fecundity, low parental investment and a moderate generation time.

**Background Information:**

I. obsoleta breeds during autumn and spring via internal fertilization between males and females. Sexuality maturity and reproductive capacity is dependent on body size, with individuals maturing at approximately 12 to 14 mm with takes approximately 3 years (Scheltema 1964). Small, medium, and large females laid means of 31, 55, and 79 egg capsules, respectively (Schwab 2012). Eggs are often deposited on living substrates such as oysters and mussels. Eggs hatch into planktonic veligers (larvae), which take 10 to 22 days to develop at 17.5 to 25°C. The veligers settle and metamorphose when they reach about 650-750 µm in size (between 20-30 days, although this may be delayed until they find a suitable substrate) (Scheltema 1962; Cohen 2005). Adults live to be approximately 5 to 10 years old (Scheltema 1964; Curtis 2002), with some individuals estimated to be 30 to 40 years old (Curtis 2002).

**Sources:**

NEMESIS; Fofonoff et al. 2003 Curtis 2002 GISD 2016 Scheltema 1962 Scheltema 1964 Schwab 2012

### *3.5 Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice:** **B** Disperses moderate (1-10 km) distances

**Score:** 1.75 of 2.5

**Ranking Rationale:**

Studies report various results ranging from meters to miles. The lack of spatial spread of introduced populations may support the former as a more reliable dispersal distance.

**Background Information:**

All age classes undergo short-distance, seasonal migrations between intertidal and subtidal regions, probably to avoid temperature variations (Cranford 1988). In the winter, may migrate into water as deep as five meters, and remain there for several months before returning to intertidal sites (Scheltema 1964).

In their native range, I. obsoleta were found up to 100 m from their site of release after 10 days (Curtis 2005). After initial dispersal, most snails were found ~15 m away from the release point in the first year of study, and between 30-40 m in the second year. Maximum observed distance moved in a single day was 46 m (Curtis 2005).

Egg capsules are armed with spiny flanges, and are attached to the substrate. Larvae are free swimming, but rely primarily on currents for transport. Fuchs et al. (2004) found that larvae tended to sink more frequently in turbulent than in calm waters. Larval sinking in turbulent, coastal zones could potentially affect horizontal transport of larvae over spatial scales of tens of kilometers by enhancing the retention of sinking larvae in coastal inlets (Fuchs et al. 2004). However, Gooch et al. (1972) found evidence of extensive gene flow in populations sampled along a transect from MA to NC. They propose dispersal of planktonic larvae as an explanation, and suggest that larvae can travel a maximum of 265 mi before settling (Gooch et al. 1972).

**Sources:**

Cranford 1988 Curtis 2005 Fuchs et al. 2004 GISD 2016 Gooch et al. 1972

### 3.6 *Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: A** High – Exhibits two or three of the above characteristics

**Score:** 2.5 **of** 2.5

**Ranking Rationale:**
Can disperse as adults or larva, larval viability window is relatively long, and different modes of dispersal are achieved at different life stages.

**Background Information:**
Long planktonic larval stage: Larval viability depends on temperature, and lasts a minimum of ~10 to 22 days. If conditions are unsuitable, the veliger is followed by a pre-adult "creeping-swimming" stage, which can postpone settlement for several days. Experimentally, the total larval period may reach at least 53 days if sediment is withheld (Scheltema, pers. comm., qtd. in Gooch et al. 1972). Adults do move, and undergo seasonal migrations, though movements are likely more restricted than larvae. Eggs are attached to substrates.

**Sources:**
Curtis 2005 NEMESIS; Fofonoff et al. 2003 Gooch et al. 1972

### 3.7 *Vulnerability to predators*

**Choice: D** Multiple predators present in the Bering Sea or neighboring regions

**Score:** 1.25 **of** 5

**Ranking Rationale:**
Numerous predators, many of which exist in the Bering Sea.

**Background Information:**
Preyed upon by fish, crabs and birds (Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 20.25 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 4. Ecological and Socioeconomic Impacts

### *4.1 Impact on community composition*

**Choice:** **C** Limited – Single trophic level; may cause decline but not extirpation

**Score:** 0.75 **of** 2.5

**Ranking Rationale:**
Is linked to declines in native snails and annelids.

**Background Information:**
Field experiments in its native range showed that high densities of I. obsoleta led to significant reductions in annelid species. Seven out of eight of the most common annelids showed decreases in average abundance in response to greater snail densities, and annelid abundance overall decreased by about 50%. In San Francisco Bay,California, it has displaced the California hornsnail (Cerithidea calofornica) through competitive interactions and predation on C. californica's eggs and larvae. This has restricted C. californica to salt pans, where the salinity is beyond I. obsoleta's tolerance (Race 1982)

**Sources:**
NEMESIS; Fofonoff et al. 2003 GISD 2016 Race 1982

### *4.2 Impact on habitat for other species*

**Choice:** **U** Unknown

**Score:** **of**

**Ranking Rationale:**

**Background Information:**
The presence of I. obsoleta often leads to a decrease in populations of other annelid species, however, this is most likely due to predation on eggs and larvae, and competitive exclusion rather than habitat impacts.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.3 Impact on ecosystem function and processes*

**Choice:** **C** Limited – Causes or potentially causes changes to food webs and/or ecosystem functions, with limited impact and/or within a very limited region

**Score:** 0.75 **of** 2.5

**High uncertainty?** ☑

**Ranking Rationale:**

**Background Information:**
In Washington and British Columbia, where there are dense populations and no native equivalents, it may have an impact on sediment characteristics and foodwebs, however, these impacts have not been studied.

**Sources:**
NEMESIS; Fofonoff et al. 2003 GISD 2016 Race 1982

### *4.4 Impact on high-value, rare, or sensitive species and/or communities*

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
To date, no impacts on high-value, rare, or sensitive species have been reported for I. obsoleta, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *4.5 Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice: A** High – Is known to spread multiple organisms and/or is expected to have severe impacts and/or will impact the entire region

**Score:** 2.5 of 2.5

**High uncertainty?** ✔

**Ranking Rationale:**
Carries numerous parasites that are transferrable to numerous host species, however, the effect on the host is unknown.

**Background Information:**
I. obsoleta is a host to many parasite species. Blakeslee et al. (2012) found nine species of trematodes in I. obsoleta from its native range. Four of these had birds as hosts, four had fishes, and one had a turtle. In San Francisco Bay, the introduction of I. obsoleta resulted in the transport of five trematode species, three of which reached Willapa Bay, and two reached Boundary Bay. The adult hosts of these parasites are birds and fishes, but the effects of these parasites on the hosts are unknown (Blakeslee et al. 2012). The trematode responsible for swimmers' itch, Austrobilharzia variglandis, is believed to have been introduced to the San Francisco Bay with I. obsoleta (Grodhaus and Keh 1958).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Blakeslee et al. 2012 Grodhaus and Keh 1958

### *4.6 Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice: D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
To date no hybridization has been reported for I. obsoleta.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.7 Infrastructure*



**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on infrastructure have been reported for I. obsoleta, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.8 Commercial fisheries and aquaculture*

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on commercial fisheries or aquaculture have been reported for I. obsoleta, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.9 Subsistence*

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
To date, no impacts on subsistence have been reported for I. obsoleta, and given its ecology, none would be expected.

**Background Information:**
No information available in the literature.

**Sources:**
None listed

### *4.101 Recreation*

**Choice:** **C** Limited – Has limited potential to cause degradation to recreation opportunities, with limited impact and/or within a very limited region

**Score:** 0.75 of 3

**Ranking Rationale:**
Can impact recreational swimming in areas.

**Background Information:**
I. obsoleta acts as an intermediate host to the trematod Austrobilharzia variglandis, which is known to cause swimmer's itch. Outbreaks in San Francisco Bay were traced to the larvae of this blood-fluke which is thought to have been introduced with I. obsoleta (Grodhaus and Keh 1958, qtd. in Fofonoff et al. 2003).

**Sources:**
NEMESIS; Fofonoff et al. 2003 Grodhaus and Keh 1958

### *4.11 Human health and water quality*



**Choice:** **C**

Limited – Has limited potential to pose a threat to human health, with limited impact and/or within a very limited region

**Score:** 0.75 **of** 3

**Ranking Rationale:**

Is host to the parasite that causes swimmer's itch in humans.

**Background Information:**

I. obsoleta is a host to the trematode that causes swimmer's itch in humans, Austrobilharzia variglandis. In San Francisco, outbreaks of swimmer's itch were linked to this trematode and are believed to have been introduced with I. obsoleta (Grodhaus and Keh 1958). A. variglandis only causes itching and irritation in humans as it cannot complete its lifecycle in humans.

**Sources:**

NEMESIS; Fofonoff et al. 2003 Grodhaus and Keh 1958

| | |
|---|---|
| **Section Total - Scored Points:** | 5.5 |
| **Section Total - Possible Points:** | 27.5 |
| **Section Total -Data Deficient Points:** | 2.5 |

## 5. Feasibility of prevention, detection and control



### 5.1 *History of management, containment, and eradication*

**Choice:** **B** Not attempted

**Score:** of

**Ranking Rationale:**

**Background Information:**
No information found to suggest eradication or control has been attempted.

**Sources:**
None listed

### 5.2 *Cost and methods of management, containment, and eradication*

**Choice:** **A** Major long-term investment, or is not feasible at this time

**High uncertainty?** ☑

**Score:** of

**Ranking Rationale:**
Current control methods are unstudied or labor-intensive.

**Background Information:**
No information found on I. obsoleta. The New Zealand mudsnail, a similar species, is an invasive freshwater gastropod. It has been proposed to use either physical or chemical methods to eradicate or control populations. Physical methods include exposing populations to freezing or desiccation in instances where draining the water body is an option. Chemical methods involve the use of biocides to kill individuals; however, these methods may be unfeasible in large and/or open (non-isolated) water bodies. Hand removal of adults (shells) may be another option for gastropod control; however, this option can be very labor and time-intensive, and may not lead to complete eradication if larvae are present in the water column (Culver and Kuris 2000).

**Sources:**
NZMMP 2000   Culver and Kuris 2000

### 5.3 *Regulatory barriers to prevent introductions and transport*

**Choice:** **A** Little to no regulatory restrictions

**Score:** of

**Ranking Rationale:**

**Background Information:**
No species-specific regulatory barriers exist.

**Sources:**
None listed

### 5.4 *Presence and frequency of monitoring programs*

693

**Choice:** **B** — Surveillance takes place, but is largely conducted by non-governmental environmental organizations (e.g., citizen science programs)

**Score:** of

**Ranking Rationale:**

**Background Information:**
The Elkhorn Slough National Estuarine Research Reserve in California trains volunteers to identify and conduct monitoring for low-priority ("least wanted") alien species. I. obsoleta is one of the 24 species on the list (Nagy 2016).

**Sources:**
Nagy 2016

### 5.5 *Current efforts for outreach and education*

**Choice:** **B** — Some educational materials are available and passive outreach is used (e.g. signs, information cards), or programs exist outside Bering Sea and adjacent regions

**Score:** of

**Ranking Rationale:**

**Background Information:**
The Elkhorn Slough National Estuarine Research Reserve in California trains volunteers to identify and conduct monitoring for low-priority ("least wanted") alien species. I. obsoleta is one of the 24 species on the list.

**Sources:**
Nagy 2016

**Section Total - Scored Points:**
**Section Total - Possible Points:**
**Section Total -Data Deficient Points:**

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# Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

**Scientific Name:** *Philine auriformis*

**Common Name** *tortellini snail*

| | |
|---|---|
| **Phylum** | Mollusca |
| **Class** | Gastropoda |
| **Order** | Cephalaspidea |
| **Family** | Philinidae |

**Final Rank** 49.71

**Data Deficiency:** 12.50

### Species Occurrence by Ecoregion

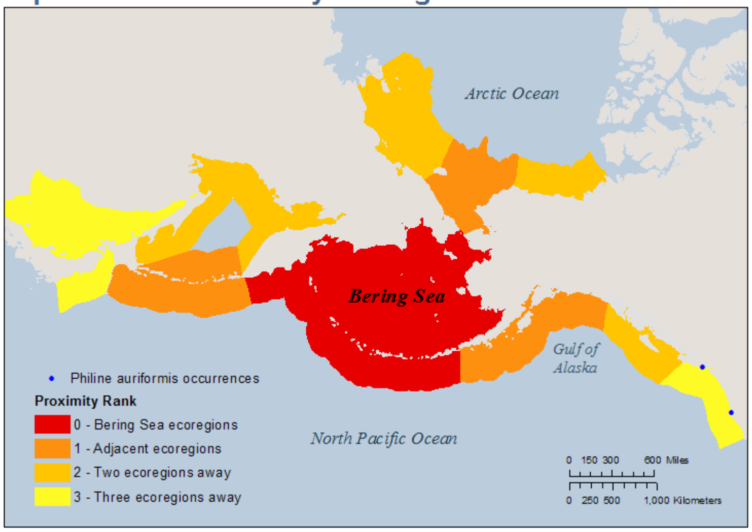


Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

**Category Scores and Data Deficiencies**

| Category | Score | Total Possible | Data Deficient Points |
|---|---|---|---|
| Distribution and Habitat: | 13.75 | 23 | 7.50 |
| Anthropogenic Influence: | 8 | 10 | 0 |
| Biological Characteristics: | 20.25 | 25 | 5.00 |
| Impacts: | 1.5 | 30 | 0 |
| **Totals:** | 43.50 | 87.50 | 12.50 |

## General Biological Information

### Tolerances and Thresholds

| | | | |
|---|---|---|---|
| Minimum Temperature (°C) | NA | Minimum Salinity (ppt) | 18 |
| Maximum Temperature (°C) | NA | Maximum Salinity (ppt) | 35 |
| Minimum Reproductive Temperature (°C) | NA | Minimum Reproductive Salinity (ppt) | 31* |
| Maximum Reproductive Temperature (°C) | NA | Maximum Reproductive Salinity (ppt) | 35* |

### Additional Notes

Philine auriformis is a carnivorous sea slug that measures between 15 to 30 mm. Its body is transluscent white to off-white in color. At least two invasive Philine species occur in the western US, and it can be difficult to differentiate between these species.

# 1. Distribution and Habitat



### 1.1 *Survival requirements - Water temperature*

**Choice:** **U** Unknown/Data Deficient

**Score:** of

**Ranking Rationale:**
Temperatures required for survival are unknown.

**Background Information:**
P. auriformis inhabits warm- to cold-temperate climates in its native and introduced range. Its temperature tolerance is unknown.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 1.2 *Survival requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival

**Score:** 3.75 of 3.75

**High uncertainty?** ☑

**Ranking Rationale:**
Although salinity thresholds are unknown, this species is a marine organism. We therefore assume that it can survive in saltwater (31 to 35 ppt); these salinities occur in a large (>75%) portion of the Bering Sea.

**Background Information:**
P. auriformis is a marine species. Its salinity requirements are unknown.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 1.3 *Establishment requirements - Water temperature*

**Choice:** **U** Unknown/Data Deficient

**Score:** of

**Ranking Rationale:**
Reproductive temperature requirements are unknown.

**Background Information:**
No information found.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 1.4 *Establishment requirements - Water salinity*

**Choice:** **A** Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction

**Score:** 3.75 of 3.75

**Ranking Rationale:**
Although salinity thresholds are unknown, this species is a marine organism that does not require freshwater to reproduce. We therefore assume that this species can reproduce in saltwater (31 to 35 ppt). These salinities occur in a large (>75%) portion of the Bering Sea.

**Background Information:**
No Information found.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.5 Local ecoregional distribution*



**Choice: D** Present in an ecoregion greater than two regions away from the Bering Sea

**Score:** 1.25 of 5

**Ranking Rationale:**
This species occurs as far north as southern British Columbia.

**Background Information:**
This species is found in California, Oregon, and on Vancouver Island (BC).

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.6 Global ecoregional distribution*

**Choice: C** In few ecoregions globally

**Score:** 1.75 of 5

**Ranking Rationale:**
This species is native to New Zealand and has only been reported to the west coast of North America.

**Background Information:**
This species is native to New Zealand. It is introduced and established in California and Oregon, and has been found on Vancouver Island, BC. No other introductions have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### *1.7 Current distribution trends*

**Choice: B** History of rapid expansion or long-distance dispersal (prior to the last ten years)

**Score:** 3.25 of 5

**Ranking Rationale:**
This species' spread rapidly along the coast of the western United States following its introduction in the 1990s.

**Background Information:**
This species was introduced to CA in the 1990s, and spread rapidly from San Francisco Bay, CA to Coos Bay, OR in five years (Krug et al. 2012). Based on genetic analyses, Krug et al. (2012) believe that there was only one site of introduction, and that the spread of P. auriformis along the coast was due to natural dispersal.

**Sources:**
Krug et al. 2012

| | |
|---|---|
| **Section Total - Scored Points:** | 13.75 |
| **Section Total - Possible Points:** | 22.5 |
| **Section Total -Data Deficient Points:** | 7.5 |

## 2. Anthropogenic Transportation and Establishment



*2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport*

**Choice: A** Has been observed using anthropogenic vectors for transport and transports independent of any anthropogenic vector once introduced

**Score:** 4 of 4

**Ranking Rationale:**
This species was first introduced to the western United States via anthropogenic vectors, but has spread naturally since then.

**Background Information:**
Krug et al. (2012) suggests that it was transported on ship hulls; however, because P. auriformis prefers soft substrates, Gosliner (1995) thinks transport via ballast water is a more likely vector. Based on genetic analyses, Krug et al. (2012) believe that the spread of P. auriformis along the US West Coast was due to natural dispersal.

**Sources:**
Krug et al. 2012 Gosliner 1995

*2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish*

**Choice: A** Readily establishes in areas with anthropogenic disturbance/infrastructure and in natural, undisturbed areas

**Score:** 4 of 4

**Ranking Rationale:**
Populations have been found in both anthropogenic and natural sites.

**Background Information:**
P. auriformis prefers soft-bottom substrates and open-ocean sites, and is not a fouling species. It has been recorded from many harbours in CA, but is also found in Elkhorn Slough, a research reserve and relatively remote natural area (Wasson et al. 2001).

**Sources:**
Wasson et al. 2001

*2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?*

**Choice: B** No

**Score:** 0 of 2

**Ranking Rationale:**
This species is not farmed or cultivated.

**Background Information:**

**Sources:**
NEMESIS; Fofonoff et al. 2003

| | |
|---|---|
| **Section Total - Scored Points:** | 8 |
| **Section Total - Possible Points:** | 10 |
| **Section Total -Data Deficient Points:** | 0 |

# 3. Biological Characteristics



### *3.1 Dietary specialization*

**Choice:** **A** Generalist at all life stages and/or foods are readily available in the study area

**Score:** 5 **of** 5

**Ranking Rationale:**
This species is an opportunistic predator and prey items are readily available in the Bering Sea.

**Background Information:**
P. auriformis preferentially prey on small, infaunal bivalves, but they are flexible and opportunistic consumers that eat foraminifera, gastropods and ophiuroids when bivalves are scarce (Gosliner 1995; Krug et al. 2012).

**Sources:**
Krug et al. 2012 Gosliner 1995

### *3.2 Habitat specialization and water tolerances*

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

**Choice:** **A** Generalist; wide range of habitat tolerances at all life stages

**Score:** 5 **of** 5

**Ranking Rationale:**
This species has been collected from a range of habitats and is found from intertidal zones to depths > 300 m. It can tolerate a broad range of salinities, and has been reported in high-nutrient areas caused by human activities.

**Background Information:**
Found in intertidal areas on in the open ocean (>300 m depth), and on soft-bottom substrates including mudflats and eelgrass beds (Fofonoff et al. 2003; Krug et al. 2012). As an adult, Philine auriformis burrows in the substrate. The burying depth is unknown – some authors claim that it is shallowly buried (i.e. upper inch of the substrate), but others say it is often found at a depth of six inches below the sediment (qtd. in Cadian and Ranasinghe 2003). Based on trawling surveys, Cadien and Ranasinghe (2003) suggest that P. auriformis can occupy a wide range of substrate types.

P. auriformis has been recorded in Elkhorn Slough, an area where water quality is influenced by runoff from adjacent farmlands, and where extremely high nutrient, pesticide, and coliform bacterial levels have been documented (Wasson et al. 2001).

It can likely tolerate a wide range of salinities (18 to 30 PSU), but its temperature tolerance is unknown. This species has a restricted global distribution: has only been recorded in New Zealand, Australia (where it is not established), and along the west coast of the United States.

**Sources:**
Wasson et al. 2001 Krug et al. 2012 NEMESIS; Fofonoff et al. 2003 Cadien and Ranasinghe 2003

### *3.3 Desiccation tolerance*

**Choice:** **U** Unknown

**Score:** **of**

**Ranking Rationale:**
This species' desiccation tolerance is unknown.

**Background Information:**
No information found.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 3.4 *Likelihood of success for reproductive strategy*

i. Asexual or hermaphroditic ii. High fecundity (e.g. >10,000 eggs/kg) iii. Low parental investment and/or external fertilization iv. Short generation time

**Choice: B** Moderate – Exhibits one or two of the above characteristics

**Score:** 3.25 of 5

**High uncertainty?** ☑

**Ranking Rationale:**
This species is hermaphroditic and short-lived. Fertilization is internal. Fecundity is unknown.

**Background Information:**
P. auriformis is a simultaneous hermaphrodite, but is not known to self-fertilize. Fertilization is internal (Fofonoff et al. 2003). Individuals lay one or more egg masses that are attached to the substrate by a long thin stalk. Eggs hatch into larvae and are probably plankotrophic (Gosliner 1995). Most individuals appear to live for about a year (M. Chow, pers. comm., qtd. in Cadien and Ranasinghe 2003), though some individuals can survive for at least two years. Estimates on fecundity could not be found.

**Sources:**
Gosliner 1995 Cadien and Ranasinghe 2003

### 3.5 *Likelihood of long-distance dispersal or movements*

Consider dispersal by more than one method and/or numerous opportunities for long or short distance dispersal e.g. broadcast, float, swim, carried in currents; vs. sessile or sink.

**Choice: A** Disperses long (>10 km) distances

**Score:** 2.5 of 2.5

**Ranking Rationale:**
This species has a long-lived larval stage and is predicted to have long-distance dispersal abilities. Genetic analyses confirm that this species spread naturally from southern California to British Columbia.

**Background Information:**
Shanks (2009) estimates that the larval duration of Philine spp. is 30-40 days, and estimates a dispersal distance of 260 km. Genetic analyses reveal that this species was introduced once to the United States (San Francisco Bay), and subsequently spread all the way to Vancouver Island (Krug et al. 2012). The long-lived larval stage is believed to have facilitated this species' rapid dispersal (Krug et al. 2012). Adults burrow in the substrate. Most nudibranchs move by crawling or gliding on the ocean floor, though some can swim short distances by flexing their muscles (Rudman 2001).

**Sources:**
Shanks 2009 Krug et al. 2012 Rudman 2001

### 3.6 *Likelihood of dispersal or movement events during multiple life stages*

i. Can disperse at more than one life stage and/or highly mobile ii. Larval viability window is long (days v. hours) iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)

**Choice: C** Low – Exhibits none of the above characteristics

**Score:** 0.75 of 2.5

**Ranking Rationale:**
This species has a long-lived larval stage. Natural dispersal likely only occurs during this larval stage.

**Background Information:**
Larval stage is long-lived (30-40 days), and is likely the main life stage at which dispersal occurs (Shanks 2009). Based on general information on nudibranchs, adult stage is likely not very mobile (Rudman 2001). Eggs are attached to the substrate, and there are no reports about egg masses detaching and drift away.

**Sources:**
Shanks 2009 Rudman 2001

### 3.7 *Vulnerability to predators*

**Choice: B** Few predators only in its home range, and not suspected in the Bering Sea or neighboring regions

**Score:** 3.75 **of** 5

**High uncertainty?** ☑

**Ranking Rationale:**
This species appears to have few predators in its introduced range.

**Background Information:**
P. auriformis has few natural predators. Philine spp. secrete an acidic discharge making them unpalatable to predators (Chow 2001, qtd. in Krug et al. 2012). Cadien and Ranasinghe (2003) noted an apparent lack of predators when P. auriformis first invaded the Southern California Bight.

**Sources:**
Cadien and Ranasinghe 2003 Krug et al. 2012

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| **Section Total - Scored Points:** | 20.25 |
| **Section Total - Possible Points:** | 25 |
| **Section Total -Data Deficient Points:** | 5 |

## 4. Ecological and Socioeconomic Impacts

### 4.1 *Impact on community composition*

**Choice:** **C** Limited – Single trophic level; may cause decline but not extirpation

**Score:** 0.75 **of** 2.5

**Ranking Rationale:**
This species may have caused the decline of small bivalves when it was first introduced and occurred at very high densities. Populations of P. auriformis have declined since then, and no further impacts have been reported.

**Background Information:**
In Palo Verde, CA, a significant decline in the densities of small infaunal bivalves (the preferred prey of P. auriformis) was correlated with the introduction of Philine auriformis (Cadien and Ranasinghe 2003). However, the initial high population density and large individual sizes of P. auriformis populations in the Southern California Bight region did not persist. By 1996 had declined to relatively low levels (Cadien and Ranasinghe 2003). Moreover, while prey populations have declined, these declines were localized in areas where bivalve populations were unnaturally dense due to organic enrichment. As an opportunistic predator, P. auriformis may have impacts on other prey species (Krug et al. 2012), but no further impacts have been reported.

**Sources:**
Cadien and Ranasinghe 2003   Krug et al. 2012

### 4.2 *Impact on habitat for other species*

**Choice:** **D** No impact

**Score:** 0 **of** 2.5

**Ranking Rationale:**
This species is not expected to alter habitat in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.3 *Impact on ecosystem function and processes*

**Choice:** **C** Limited – Causes or potentially causes changes to food webs and/or ecosystem functions, with limited impact and/or within a very limited region

**Score:** 0.75 **of** 2.5

**Ranking Rationale:**
This species is an opportunistic predator that could potentially affect benthic food webs in intertidal and open ocean sites. Adults burrow in the substrate, and in so doing, may increase bioturbation.

**Background Information:**
When bivalves are scarce, P. auriformis easily switches to other prey items including foraminifera, gastropods, and brittle stars (Krug et al. 2012).

**Sources:**
Krug et al. 2012

### 4.4 *Impact on high-value, rare, or sensitive species and/or communities*

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
No impacts have been reported for this species.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.5 *Introduction of diseases, parasites, or travelers*

What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other nonnative organisms?)

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not known to transport diseases, parasites, or hitchhikers.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.6 *Level of genetic impact on native species*

Can this invasive species hybridize with native species?

**Choice:** **D** No impact

**Score:** 0 of 2.5

**Ranking Rationale:**
This species is not expected to hybridize with native species in the Bering Sea.

**Background Information:**
No impacts have been reported. There are no native Philine species in Alaska.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.7 *Infrastructure*

**Choice:** **D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact infrastructure in the Bering Sea.

**Background Information:**
This species is not a member of the fouling community and no impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.8 Commercial fisheries and aquaculture

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact commercial fishing in the Bering Sea.

**Background Information:**
This species does not feed on commercially important bivalve species, and no impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.9 Subsistence

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact subsistence resources in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.101 Recreation

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact subsistence resources in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

### 4.11 Human health and water quality

**Choice: D** No impact

**Score:** 0 of 3

**Ranking Rationale:**
This species is not expected to impact human health or water quality in the Bering Sea.

**Background Information:**
No impacts have been reported.

**Sources:**
NEMESIS; Fofonoff et al. 2003

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|---|---|
| **Section Total - Scored Points:** | 1.5 |
| **Section Total - Possible Points:** | 30 |
| **Section Total -Data Deficient Points:** | 0 |

## 5. Feasibility of prevention, detection and control



### *5.1 History of management, containment, and eradication*

**Choice:** **C** Attempted; control methods are currently in development/being studied

**Score:** of

**Ranking Rationale:**
No species-specific plans are in place to control or eradicate this species. This species is believed to be transported by ballast water or ship fouling. Controlling the spread of invasive species that use these vectors for transport is an active area of research.

**Background Information:**
We did not find any management plans that were specific to this species.

**Sources:**
Hagan et al. 2014 Ruiz and Reid 2007

### *5.2 Cost and methods of management, containment, and eradication*

**Choice:** **A** Major long-term investment, or is not feasible at this time

**Score:** of

**Ranking Rationale:**
This species can be transported by numerous vectors. Methods to control the spread of invasive species via these vectors are being developed, and currently necessitate major long-term investments.

**Background Information:**

**Sources:**
Hagan et al. 2014 Zagdan 2010

### *5.3 Regulatory barriers to prevent introductions and transport*

**Choice:** **B** Regulatory oversight, but compliance is voluntary

**Score:** of

**Ranking Rationale:**
This species is transported by numerous vectors and no species-specific regulations are currently in place. Although there are federal regulations for both ballast water and hull fouling, compliance with federal fouling regulations remains voluntary.

**Background Information:**

**Sources:**
CFR 2017 Hagan et al. 2014

### *5.4 Presence and frequency of monitoring programs*

**Choice:** **A** No surveillance takes place

**Score:** of

**Ranking Rationale:**
No surveillance is taking place for this species.

**Background Information:**
No information found.

**Sources:**
None listed

### 5.5 *Current efforts for outreach and education*

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**Choice:** **A** No education or outreach takes place

**Score:** of

**Ranking Rationale:**
No outreach or education programs are in place for this species.

**Background Information:**
No information found.

**Sources:**
None listed

**Section Total - Scored Points:**

**Section Total - Possible Points:**

**Section Total -Data Deficient Points:**

## Literature Cited for *Philine auriformis*


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