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Science Sciences

National Capital Region

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SCIENCE ADVICE FROM A RISK ASSESSMENT OF FIVE SESSILE TUNICATE SPECIES

*Club Tunicate (*Styela clava*) photo by Jim Boutillier.*

*Golden Star Tunicate (*Botryllus schlosseri*). Photo from USGS (2009).*

Didemnum sp. colony. Photo by Bernard Hanby.

*Violet Tunicate (*Botrylloides violaceus*). Photo from USGS (2009).*

*Vase Tunicate (*Ciona intestinalis*) image from Cirino et al. (2002)*

Context

Tunicates are small (usually less than 16 cm in length), barrel-shaped suspension feeders that can be solitary or colonial. They have a motile larval stage, although, for most species mobility ends when the tunicate finds a suitable rock and cements itself in place. Once grown, some species develop a thick covering, called a tunic, to protect it from predators. Most tunicates are hermaphrodites with eggs kept inside their body until they hatch and sperm released into the water to fertilize other individuals. They occur on a variety of natural and artificial substrates such as algae, other organisms, rocks, aquaculture equipment, floats and ship hulls. Their phenotypic plasticity or the ability to adjust their growth and reproductive strategy in response to variable environmental conditions makes them remarkably resilient.

Nonindigenous tunicates have become a global concern, especially for the aquaculture industry where they foul equipment and can cause a loss of product. Some nonindigenous tunicates have been present in Canadian waters in low numbers for 100 years, but have recently experienced population explosions in several maritime regions. Concern raised about the impact of invasive tunicates to Canadian coastal waters initiated a risk assessment.

Fisheries and Oceans Canada's (DFO's) Centre for Aquatic Risk Assessment (CEARA) coordinated and provided guidance on a national risk assessment to determine the risk posed by five tunicate species to *the coastal waters of the Canadian Atlantic and Pacific oceans. The assessment evaluated the risk posed by the arrival, survival, establishment, spread, and impact of two solitary tunicates (Club Tunicate (Styela clava) and Vase Tunicate (Ciona intestinalis)) and three colonial forms (Golden Star Tunicate (Botryllus schlosseri); Violet Tunicate (Botrylloides violaceus) and Didemnum species). The risk assessment provides science based guidance to resource managers for the development of management options necessary to deal with tunicates in Canadian waters.*

The risk assessment was undertaken with the aid of an extensive literature search, an expert opinion survey, and environmental niche modelling (to predict the potential range of tunicate species in Canadian coastal waters). The draft risk assessment document was peer reviewed March 13-14, 2007 in Charlottetown, PEI by internal and external experts according to DFO's Canadian Science Advisory Secretariat (CSAS) peer-review guidelines. Discussions from that meeting were recorded in a CSAS proceedings document (DFO 2010) and incorporated into a finalized risk assessment document (Therriault and Herborg 2007).

SUMMARY

- Sessile tunicates (ascidians) are filter feeders whose diets consist primarily of phytoplankton, suspended particulate matter, diatoms, invertebrate larvae and suspended bacteria.
- Ascidians colonize a variety of natural hard substrates such as pebbles, gravel, cobbles, boulders, and rock outcrops, as well as anemones, barnacles, bryozoans, hydroids, limpets, macro algae, mussels, other ascidians, oysters, polychaetes, scallops, and sponges. They also colonize artificial hard substrates (concrete, metal, plastic, and wood) including automobile tires, buoys, chains, docks, floats, jetties, moorings, pilings, ropes, and boat hulls.
- A major factor in ascidians' establishment is the composition of marine epifaunal communities and the availability of suitable substrate. Typically, diverse natural communities are resistant to invasion, while newly introduced artificial substrates provide ideal habitat and ascidian populations can take advantage.
- Larval dispersal away from the parent colony is limited by the short free-swimming stage (minutes to hours) and is affected by angle of the sun, currents, water temperature, wave action, and wind exposure.
- Adult dispersal is limited to the movement of the substrate they inhabit. Fouling of aquaculture equipment, boat hulls, fishing gear, oyster and shellfish stock as well as colony fragments in ballast, dredges, fishing trawls, and floating debris are vectors of dispersal.
- In general, adult ascidians have communal, parasitic, and symbiotic organisms associated with them. Algae, amphipods, ciliates, copepods, decapods, hydroids, molluscs, nematodes, pea crab, polychaetes, protozoans, and shrimps have been found living on, or in, ascidians.
- Adults have relatively few predators due to the low nutritive value of the tunic. Larvae are susceptible to predation while planktonic and during early settlement. Ascidian predators include fishes, flatworms, polychaete worms, echinoderms (mainly sea stars), gastropods, seals, and cetaceans.
- Overall ecological risk posed by each of these species was classified as high, generally with moderate uncertainty. The exception was Vase Tunicate on the west coast where the risk was moderate with high uncertainty.
- Overall risk posed by parasites, pathogens, or fellow travelers of the evaluated tunicates was found to be low with high or very high uncertainty with the exception of the Club Tunicate. Club Tunicate is known to carry a large variety of epibiont fauna including the other tunicate species

evaluated in this risk assessment. As the evaluated tunicates were found to pose a high risk, the Club Tunicate, therefore, poses a high risk for its fellow travelers.

- Since natural long distance dispersal appears very limited, increased management of human-mediated dispersal vectors could substantially reduce spread of these nonindigenous tunicate species.
- Best practice advice should be developed in collaboration with aquaculture groups, small craft operators, and other stakeholders. These efforts should be aimed at educating marine users on these species, including how they can spread, to determine suitable practices to limit further spread and associated ecological and genetic consequences.
- This risk assessment was undertaken in 2007 and is based on the best available information at that time. If vector movement patterns or global climate conditions change significantly, a re-assessment may be required.

BACKGROUND

Club Tunicate (*Styela clava*)

Biology

Club Tunicate is a solitary, cylindrical tunicate with a tough, brown covering. Its body tapers to a short stalk and resembles a club. Adults range from 90 to 160 mm in length and are highly efficient filter feeders consuming phytoplankton, zooplankton, and other suspended organic materials. It is hermaphroditic (but not self-fertile) with the ability to spawn every 24 hours and attains a maximum age of about three years. It is unable to reproduce at less than 15°C, but can survive temperatures as low as 2°C and as high as 23°C. Club Tunicate can reach maturity earlier than competing species, especially cultured bivalves and thus has the ability to reduce settlement rates of co-occurring species.

Club Tunicate typically occurs between 15 to 25 m depth and is most common in sheltered habitats with low wave action such as inlets, bays and harbours. It is found on a range of artificial and natural substrates. It occurs in densities of 50 to 100 m^{-2} on natural substrates and 500 to 1000 m^{-2} on artificial substrates. Floating habitats may be highly suitable for Club Tunicate.

Club Tunicate can survive in a wide range of environmental conditions and has behavioral adaptations to handle adverse conditions such as closing its siphons for extended periods of time. Although it is not consistently found in areas where the salinity is less than 20‰, it can survive temporary drops in salinity as low as 8‰. Larvae metamorphose between 20 to 32‰ salinity.

Known Distribution

Club Tunicate is native to the northwest Pacific Ocean from the Sea of Okhotsk through southern Siberia, Japan, Korea and northern China. It now occurs worldwide in temperate marine waters of Asia, Europe, Australia and North America. It was first reported in Canada in 1998 off of Prince Edward Island. In Atlantic Canada, it is currently known to be restricted to waters surrounding Prince Edward Island (Figure 1). Club Tunicate is also found in the waters of southern British Columbia (Figure 2).

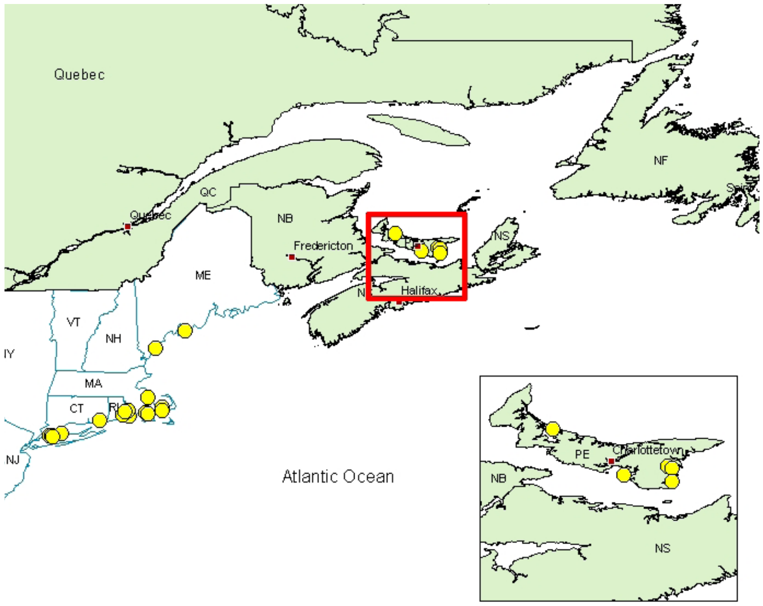


Figure 1. Distribution of Styela clava *on the east coast of North America. Small inset map shows distribution on Prince Edward Island (from Clarke and Therriault 2007).*

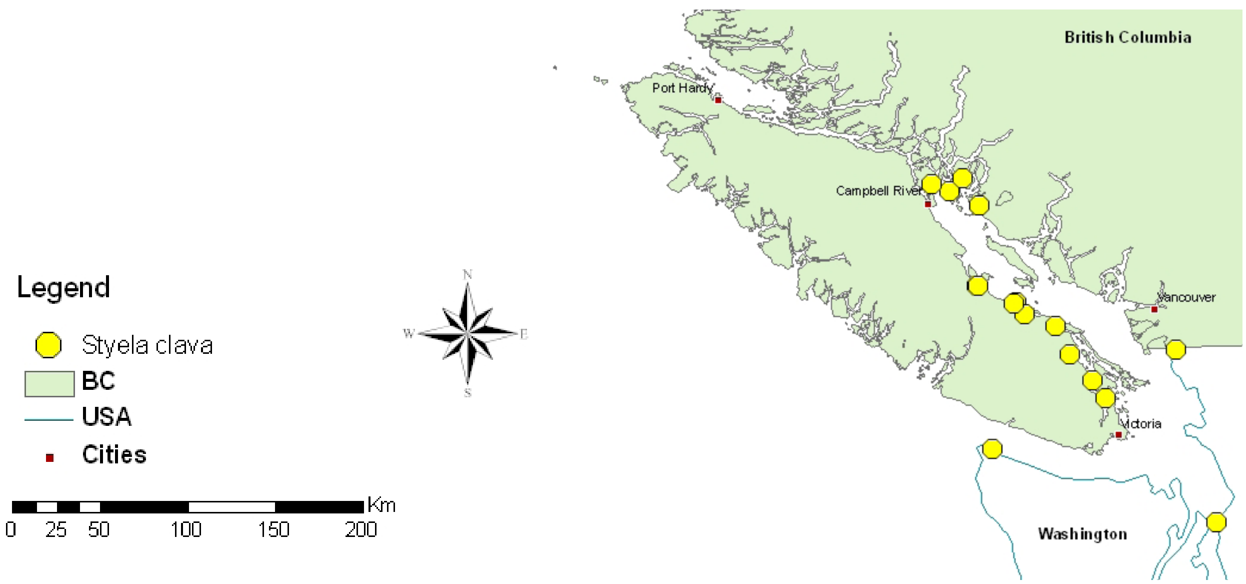


Figure 2. Distribution of Styela clava *in Pacific North America based on reference records, aquaculture site surveys, and collector plate settlement experiments by DFO (from Clarke and Therriault 2007).*

Vase Tunicate (*Ciona intestinalis*)

Biology

Vase Tunicate is a solitary, cylindrical tunicate with a gelatinous, translucent tunic, pale greenish/yellow to orange in colour. It attaches to hard substrates by short projections of the tunic which starts out soft and becomes more leathery as it ages. Vase Tunicate can grow up to 15 cm in length and 3 cm in diameter and live for 2 to 3 years. Filtration rate has been estimated from 3.5 to 4.3 L•h-1•g-1 and greater and increases with temperature up to 21°C and then declined rapidly with further temperature increase.

Vase Tunicate is hermaphroditic with up to 15% of tested individuals self fertile. Reproductive capability is size related; 50 to 80 mm is the size required for maturity. Gametes are produced as long as temperatures are suitable (8 and 1°C have both been reported as the lower temperature limit for gamete production) and estimates of egg production range from 500 to 1000 per day. The duration of the tadpole stage is temperature dependent and estimates vary from 6 hours to 10 days. Dispersal has been estimated at 100 to 1000 m, but is dependent on local conditions. During the planktonic period they are susceptible to a range of predators, and the newly settled juveniles are prey for invertebrates and fishes. Adults are preyed upon by sea stars, crabs and some fishes.

Vase Tunicate is tolerant of a wide range of environmental conditions. Temperature tolerances vary, but it is considered a coldwater or temperate species and temperatures of 25 to 28°C are suspected of being the upper threshold. Adult mortality increases below 10°C but populations have survived several months at -1°C. Vase Tunicate is a euryhaline species that can tolerate 12 to 40‰ salinity and may be able to withstand short term salinity fluctuations. It can tolerate very low flow rates and is at a competitive advantage in low flow areas. It is able to withstand flow rates of up to three knots.

Vase Tunicate is common in enclosed or semi-protected marine embayments up to 500 m depth but is most common in shallow embayments. It may occur in dense aggregations (up to 2000 ind•m-2), often as the dominant member of the biofouling community. A major factor in its establishment is the composition of marine epifaunal communities and the availability of suitable substrate. Modelling indicates that dense populations of Vase Tunicate may significantly reduce food resources and increase the deposition of faecal matter leading to organic enrichment, anoxic sediments, accumulated hydrogen sulfide and degraded benthic communities. Vase Tunicate is known to negatively impact the abundance of microzooplankton and planktonic larvae of bivalves.

Known Distribution

Vase Tunicate is thought to be native to the north-eastern Atlantic and the Mediterranean. It is now spread throughout temperate regions of many continents (Asia, Australia, and North and South America). Its earliest recorded occurrence in Canada is for Grand Manan Island (NB) in 1852. It has been reported in the Gulf of St. Lawrence and Newfoundland. It is documented in the Canadian Arctic, but this may be a coldwater subspecies and whether it occurs along the Labrador coast and up into Hudson Bay is unknown. In the last decade, this previously rare species has undergone a population outbreak, particularly along the south coast of Nova Scotia (Figure 3) and in certain Prince Edward Island estuaries (Figure 4). Its status on the west coast is elusive as there are no recent records for shallow coastal waters.

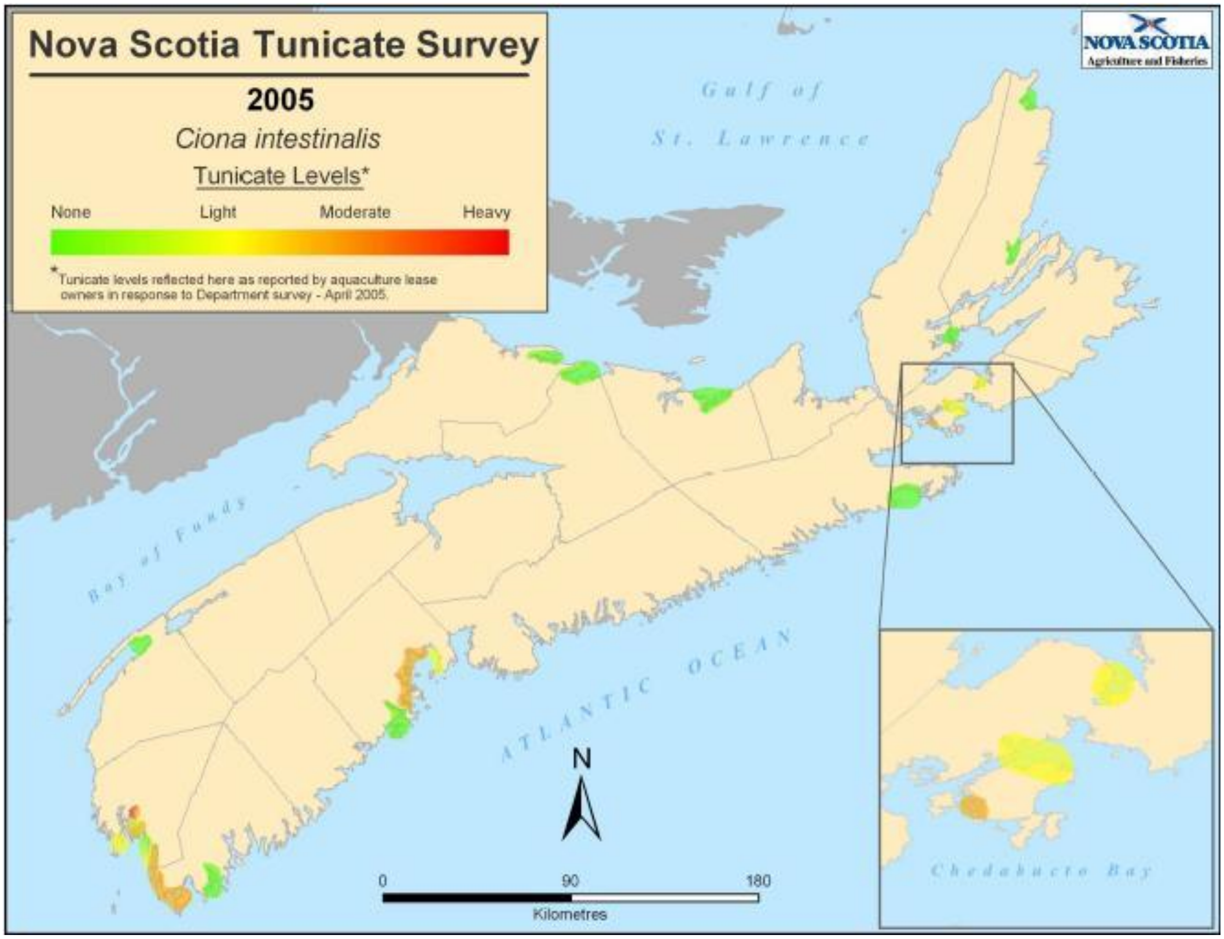


Figure 3. Results of the 2005 tunicate survey in Nova Scotia for C. intestinalis*. Survey was conducted by interviewing aquaculture lease holders (from Carver et al. 2006a).*

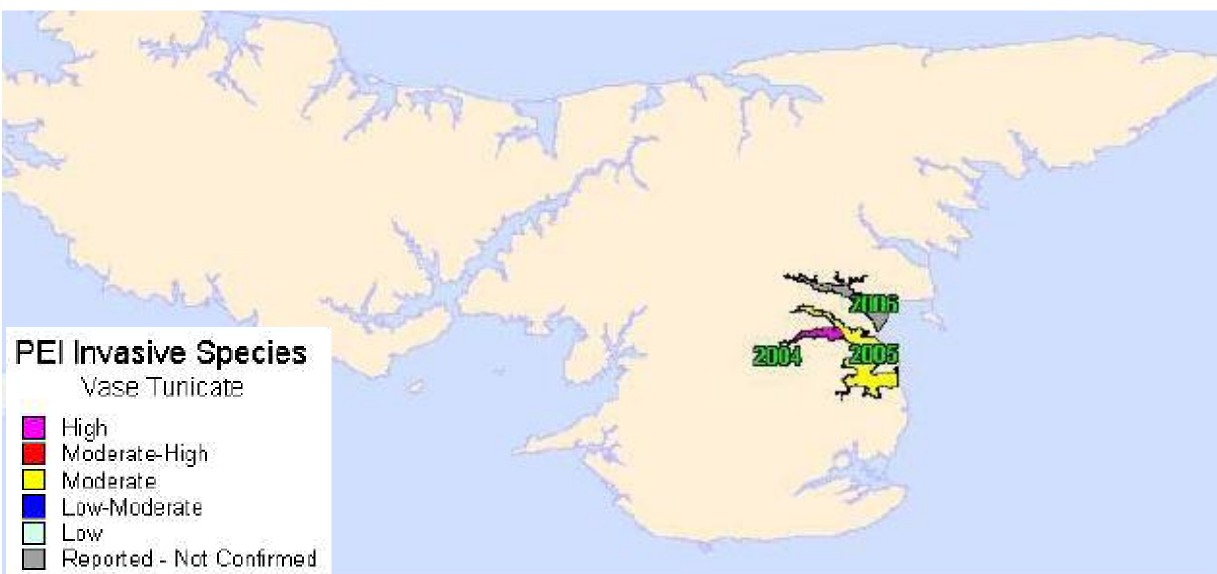


Figure 4. Distribution of C. intestinalis *in P.E.I. as of February 2006 (from Carver et al. 2006a).*

Golden Star Tunicate (*Botryllus schlosseri*)

Biology

Golden Star Tunicate is a colonial tunicate with a smooth, fleshy texture that may be purple, green, red or orange in colour. Colonies may form a thin flat mats or thick irregular lobes depending on the shape of the substrate. Individual zooids (1 to 2 mm) are arranged in a common gelatinous matrix or tunic. Although self-fertilization is possible, it is thought to be rare due to the timing of ripening eggs and sperm. After internal egg fertilization, tadpole larvae are released into the common cavity where they stay approximately a week before being released. After a tadpole is released it may swim freely for up to 36 hours before it settles and metamorphoses into the adult form. Larvae may settle near a colony and fuse into it or initiate their own colony. Most larvae remain within a few meters of the parental colony. Additionally, the vascular system of the shared matrix can bud to recreate the colony if all zooids are lost.

Colony growth occurs primarily by asexual budding. As buds mature and begin to feed, the parent zooid is reabsorbed and new buds are formed. Timing of the budding and re-absorption is synchronous throughout the colony and occurs in a 5 to 7 day cycle ending in a massive mortality. The number of new buds formed is dependent on environmental conditions. Sexual reproduction occurs every 5 to 10 asexual growth cycles during a breeding season that varies with temperature and food availability. Sperm are apparently quiescent until taken up by feeding zooids and only activated when exposed to ovulated eggs. Zooids can concentrate sperm thereby increasing probability of fertilization at low sperm concentrations. Colonial life span is 3 to 18 months.

Golden Star Tunicate is found subtidally to 200 m depth. It is a mucus filter feeder that feeds on particles as small as 0.5 µm. It is tolerant of a wide range of environmental conditions.

Known Distribution

The Golden Star Tunicate most likely originated in the Mediterranean Sea but is now found on all continents except Antarctica. It was reported in San Francisco Bay in the early 1940s and appeared in Washington State in the 1970s. It now occurs throughout the Puget Sound area and is common in harbours at the southern end of Vancouver Island, but is not considered a major fouling pest. On the east coast it was observed in the Gulf of Maine south to Chesapeake Bay in the 1970s. It has been documented in Bay of Fundy and in the Estuary and Gulf of St. Lawrence and the west coast of Newfoundland. It is generally indicated as rare. A survey of colonial tunicates in east central Nova Scotia found a patchy distribution on nautical buoys (Figure 5). In the early 2000s it was reported for the first time in Prince Edward Island embayments (Figure 6).

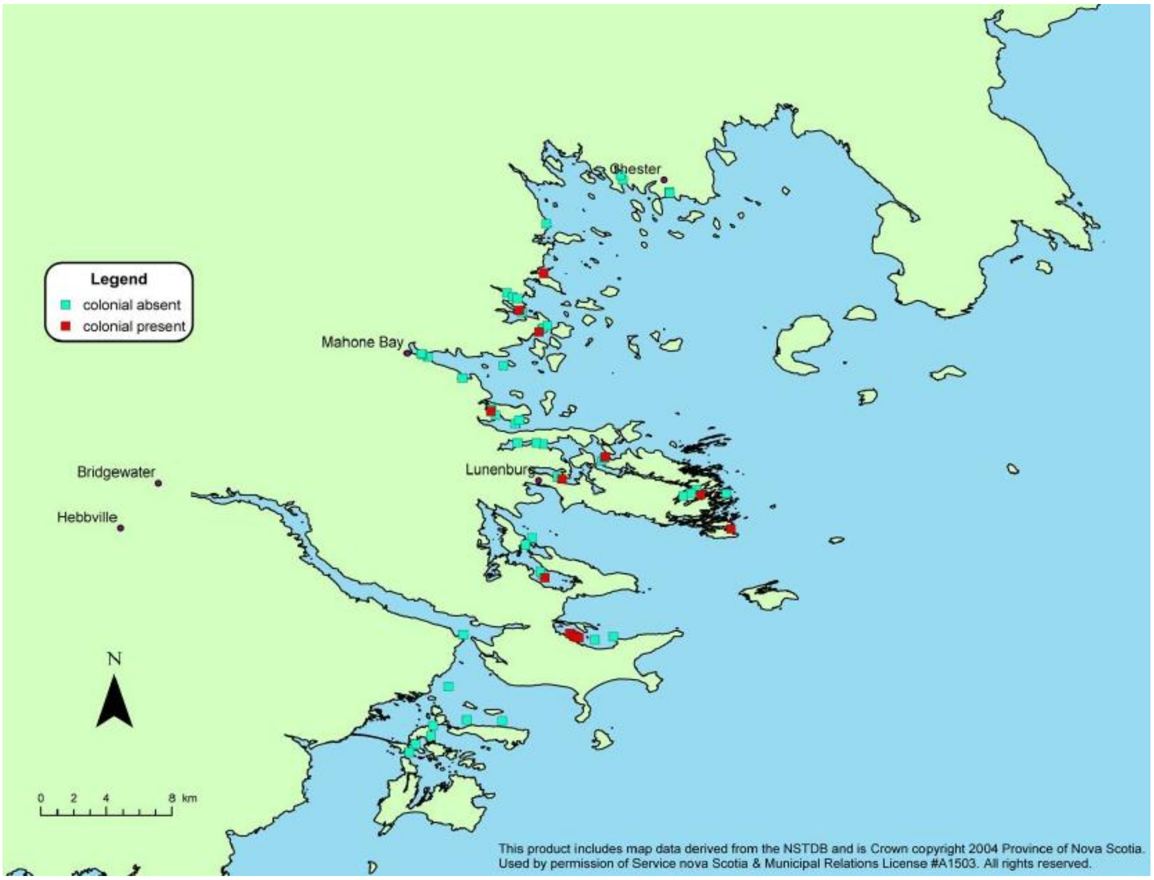


Figure 5. Results of the November 2005 small nautical buoy survey between LaHave and Chester, N.S. Note the patchiness of the distribution of B. schlosseri *and* B. violaceus*, referred to as "colonial" tunicates in the legend (from Carver et al. 2006b).*

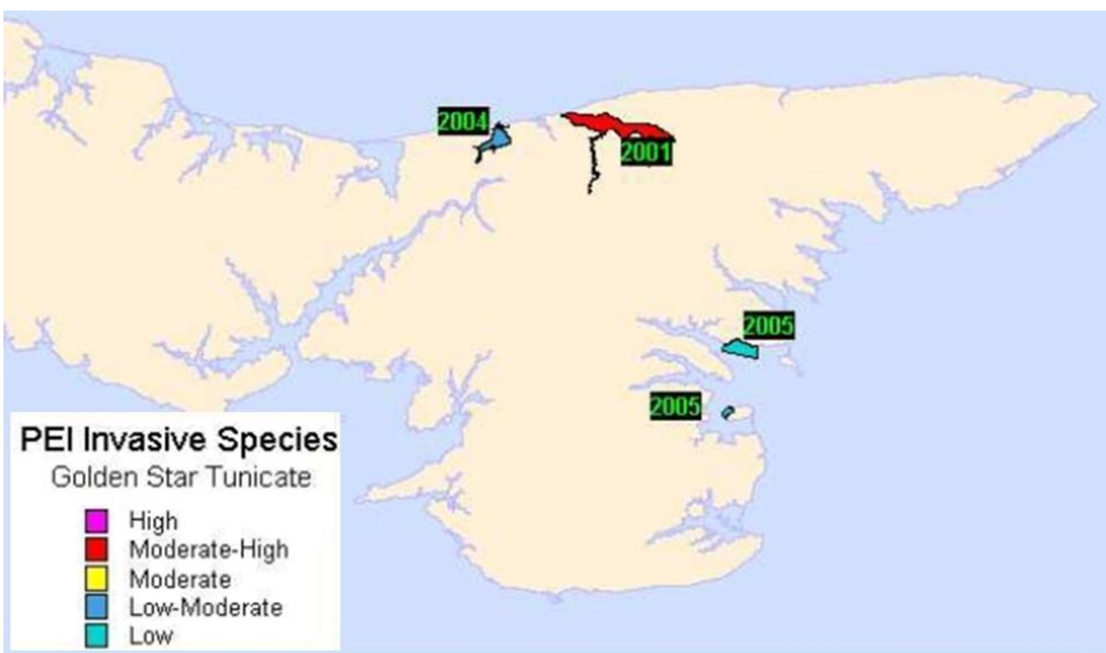


Figure 6. Distribution of B. schlosseri *in P.E.I. as of February 2006 (from Carver et al. 2006b).*

Violet Tunicate (*Botrylloides violaceus*)

Biology

Violet Tunicate is a soft, smooth and fleshy textured, colonial tunicate that may form thin, flat mats or thick, irregular lobes depending on the shape of the substrate it covers. Colonies are often monocoloured and can be bright orange, burgundy, dull pink, lavender, or purple. These sessile, filter-feeding colonies are made up of relatively large zooids (2 to 4 mm) arranged in elongated, irregular rows around a shared aperture. By sharing a common vascular system and common exhalent canal, the number of zooids in a given area is maximized.

Violet Tunicate is hermaphroditic and reproduces sexually by releasing an egg into the common atrial cavity where it enters a brood pouch and becomes fertilized. The brood pouch becomes incorporated into the colonial tunic where the embryo grows for 1 month supported by the colony. The mother zooid disintegrates approximately 5 days after ovulation. The free swimming tadpole larvae are relatively large (1.7 mm) and break through the pouch to reach the exterior of the colony. Larvae swim for a brief period (4 to 10 h) before attaching to a suitable substrate to start their own colony or fuse with an existing colony. The mean number of zooids exceeded 100 per colony within 2 weeks at 20 to 25°C and 4 weeks at 14 to 20°C. There is little data available on temperature and salinity tolerances of Violet Tunicate. Colony growth is primarily asexual by budding. As buds mature and begin to feed, the parent zooid is reabsorbed and new buds are formed. Sexual reproduction may be triggered by substrate space limitation or by a minimum water temperature. In Prince Edward Island mature eggs were found in all samples collected from mid-April to mid-September.

Violet Tunicate occurs in sheltered areas on natural or artificial substrates and is generally restricted to zones <50 m deep. Colonies are very susceptible to desiccation, and are rarely observed in intertidal areas and then, only in damp shaded zones. Violet Tunicate can apparently outcompete other fouling organisms under suboptimal adverse conditions, including high sewage and heavy metal concentrations.

Known Distribution

Violet Tunicate is believed to have originated from the northwest Pacific Ocean. It has been reported in Australia, Italy and the Netherlands as well as on both the east and west coasts of North America. It has been established in Savage Harbour, PEI since the summer 2004 (Figure 7) and was sighted for the first time on the Canadian Atlantic coast in 2001 in the Lunenburg and Mahone Bay area of Nova Scotia. A 2005 survey of nautical marks in Nova Scotia (Figure 5) shows a patchy distribution in the area. To date, there have been no reported sightings of this species in New Brunswick or the Gulf of St. Lawrence north of Prince Edward Island. On the west coast Violet Tunicate is considered a major fouling concern for shellfish and finfish growers in southern British Columbia (Figure 8).

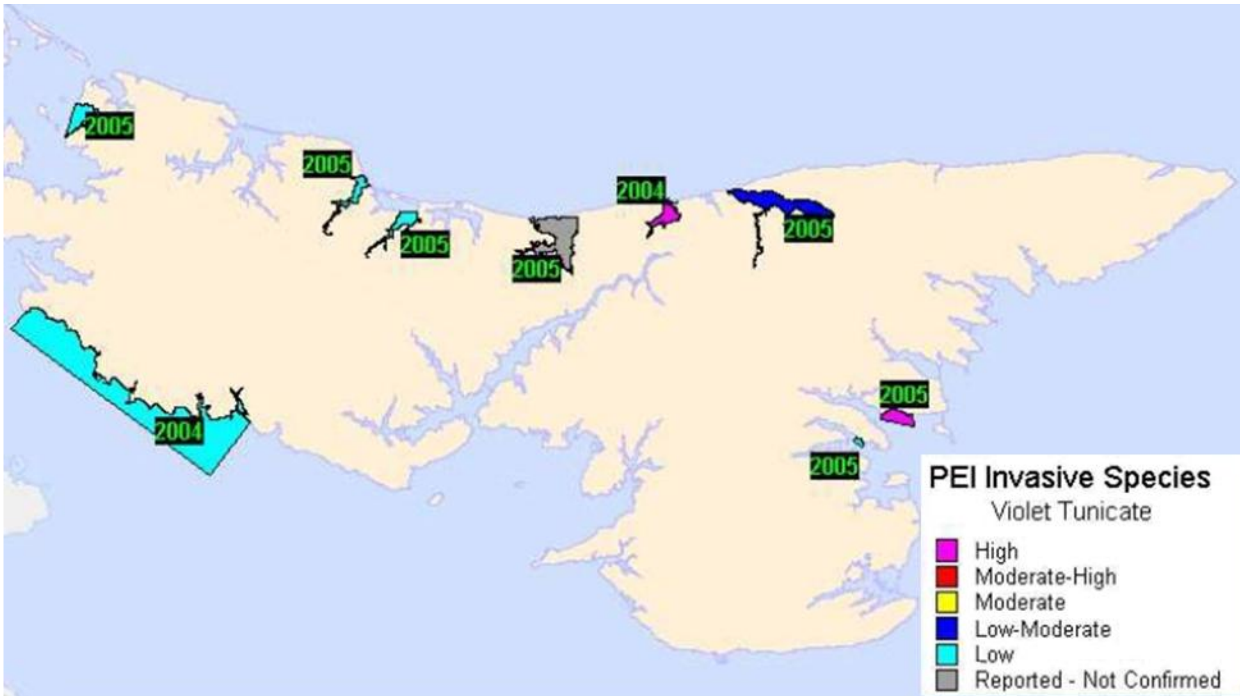


Figure 7. Distribution of Violet Tunicate in P.E.I. as of February 2006 (from Carver et al. 2006b).

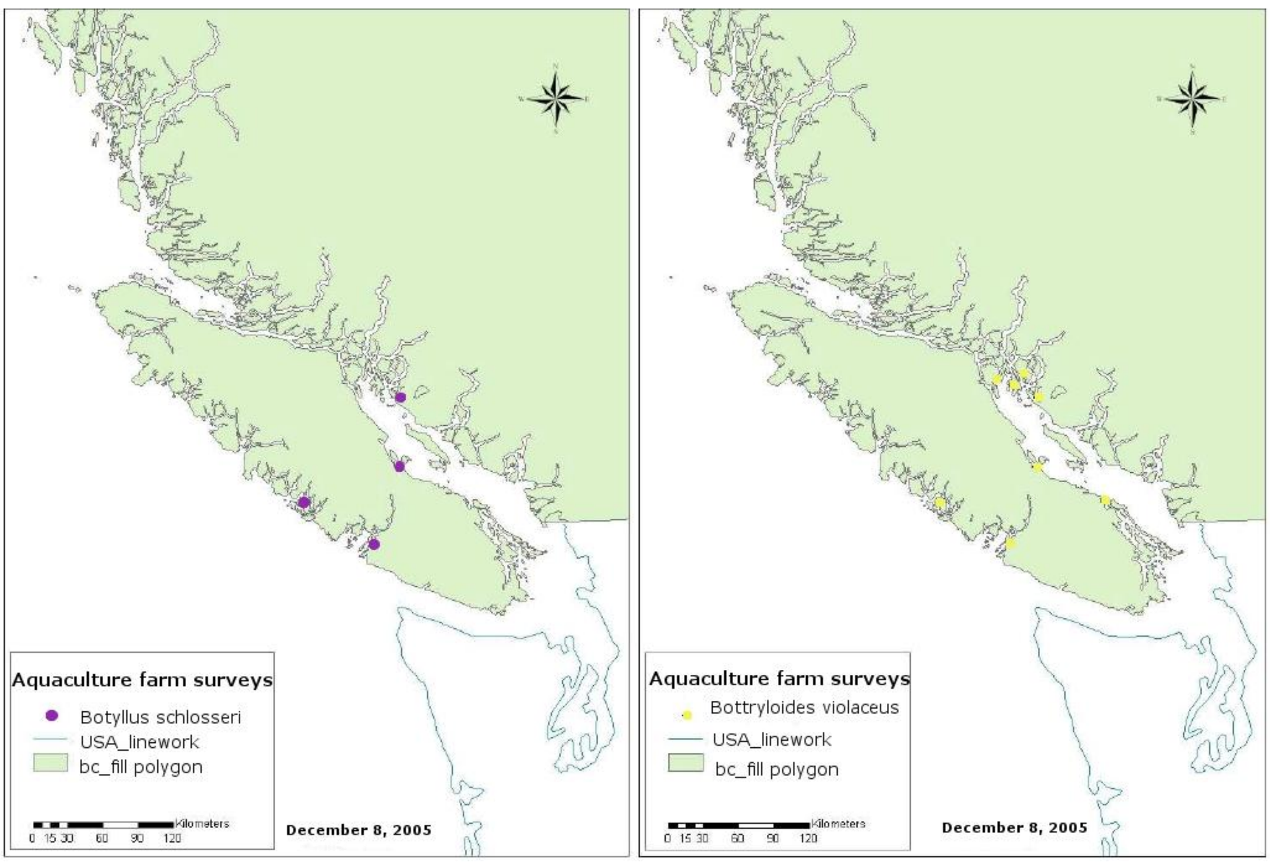


Figure 8. Results of the October 2005 aquaculture farm surveys in southern British Columbia. (from Carver et al. 2006b).

Didemnum sp.

The family Didemnidae remains taxonomically complex and controversial so that no consensus has been reached on the species of *Didemnum* that is invading coastal waters worldwide. The view that *Didemnum* sp. is native to Japan has been adopted for this assessment.

Biology

Didemnum sp. is a sessile, colonial, filter feeding tunicate characterized by small (1 to 2 mm) zooids embedded in a gelatinous matrix. *Didemnum* sp. forms thin encrusting sheets or lobed mounds depending on colony age and location. Colonies vary in colour from tan, cream, yellow, orange, or pinkish but all have white calcareous stellate spicules embedded in the matrix which give the colony a white dot appearance. *Didemnum* sp. reproduces both sexually and asexually. Eggs are fertilized internally by sperm released into the water column and drawn in through the oral siphon. Spawning is controlled by several factors of which light and temperature are the most important. Larvae are brooded in the tunic until fully developed and are released into the water column. Larvae swim for minutes to hours before settling in shaded areas and metamorphosing into the non motile adult form. Unlike other ascidians, didemnids can bud (asexual reproduction) while the gonads are maturing and can undergo precocious budding where blastozooids are produced in the larvae within the tunic.

Didemnum sp. is capable of rapid growth (6-11 fold increase in area in 15 days) but growth slows as colonies age. Growth is affected by season, temperature and habitat type and is generally fastest in the summer. In winter colonies grow slowly, go dormant or die. *Didemnum* sp. is highly opportunistic and will colonize free space or grow over animals, substrate and plants. *Didemnum* sp. is reported to grow faster in open coastal habitats apparently due to competitive advantage over co-occurring species that become overgrown. Colonies can either fuse or reject each other when they meet. Colonies typically live from 1 to 3 years, but, age determination is difficult due to the periodic regeneration and reduction of colonies.

Didemnum sp. grows on hard substrates or surfaces, from the intertidal zone to 65 m, and does not grow on mud or sand bottoms where sediments shift. *Didemnum* sp. tolerates a wide range of environmental conditions including temperature (-2 to 24 °C), salinity, wave action and water quality. Four degrees Celcius may be the cut off temperature for winter dormancy as colonies in 4 to 15 °C water do not die off during the winter months. *Didemnum* sp. is rarely found in salinities less than 25‰ and close their siphons at less than 20‰ which leads to zooid death.

Didemnum sp. releases an acid (pH 1 to 2) from the tunic when injured. The acid and spicules in the tough tunic provide protection from predators for adults. Despite these defenses, Common Periwinkle (*Litorina littorea*), chiton, sea urchins, and sea stars have been observed preying upon *Didemnum* sp. Probable predators of *Didemnum* sp. include general ascidian predators such as fishes, flatworms, polychaete worms, echinoderms (mainly sea stars), gastropods, seals, and other cetaceans.

Known Distribution

Given the taxonomic debate about the species, the authors assumed that *Didemnum* sp. is native to Japan. It has been introduced to Ireland, France, the Netherlands, New Zealand, the United States and the west coast of Canada (Figure 9). There is an offshore colony on the American side of Georges Bank off the east coast of Maine and just south of Canadian waters.

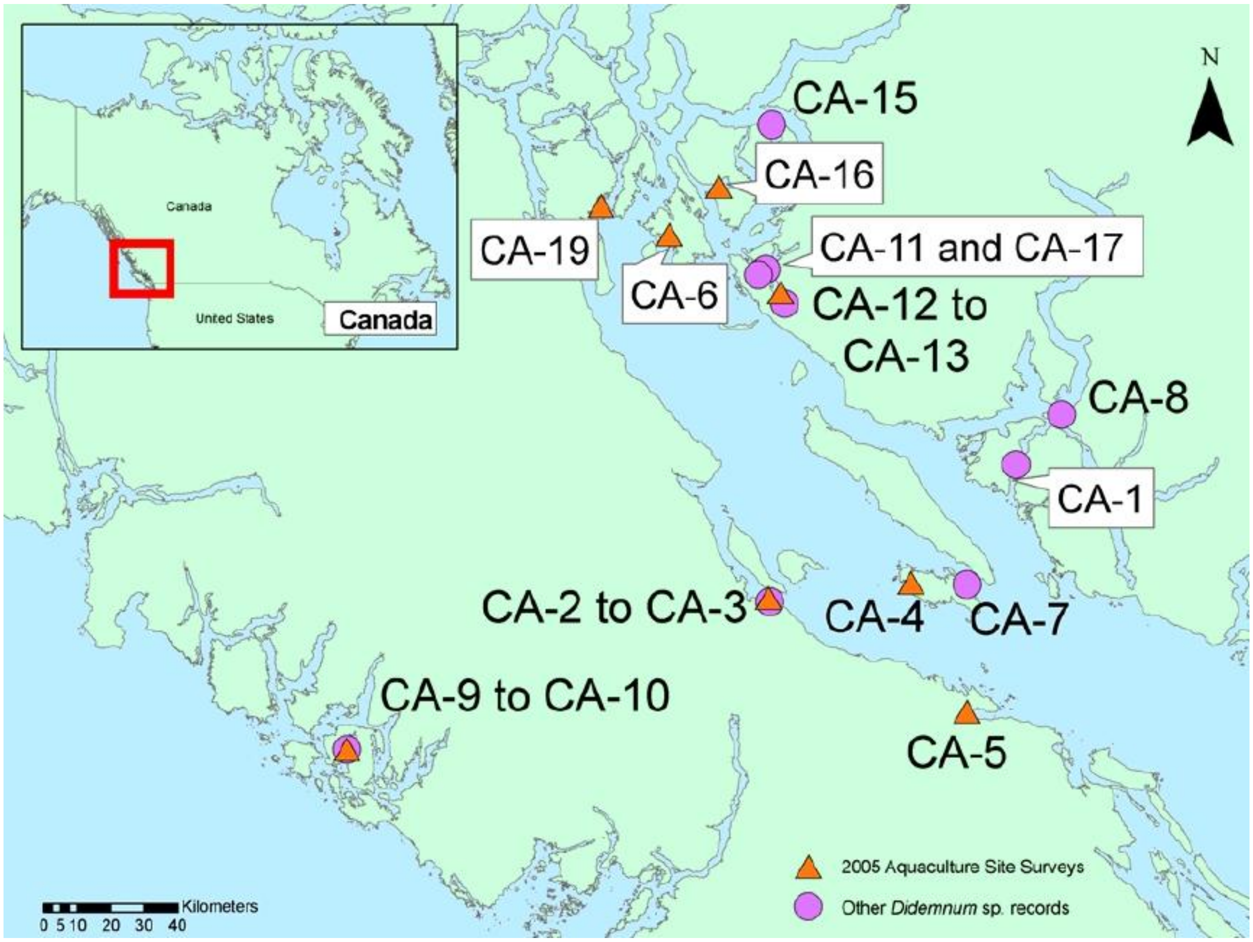


Figure 9. Didemnum *sp. records in British Columbia, Canada. The orange triangles represent the aquaculture survey records from October and November 2005. The purple circles are* Didemnum *sp. records from the USGS Nonindigenous Aquatic Species Database (from Daniel and Therriault 2007).*

RISK ASSESSMENT

Risk was determined by estimating the probability of the species arriving in the assessment area, surviving, establishing a reproducing population, and spreading to become widely established. The probability of widespread establishment was then multiplied by the magnitude of potential impact to the assessed area to determine the overall risk. Each variable in the assessment had an associated level of uncertainty that depended on the quantity and quality of data used to assess the risk.

Survival and reproduction were estimated using an environmental niche model called GARP (Genetic Algorithm for Rule-set Prediction) which used species presence and geo-referenced environmental data. Ten oceanographic environmental layers including salinity, temperature, annual chlorophyll, and annual oxygen where generated based on National Oceanographic and Atmospheric Administration's (NOAA) ocean database. A maximum depth of 200 m was used as this is the deepest recorded depth for tunicate species.

To determine potential spread, expert opinion survey of tunicate experts was undertaken to estimate the transport vectors moving tunicates. These vectors were mapped on both coasts to determine importance in particular areas.

The potential impact of tunicates was also evaluated using a tunicate expert opinion survey and a draft was presented at a peer review meeting.

Results of GARP modelling

The results of the GARP modeling for all five tunicate species are presented in Figures 10-19 for both the Atlantic and Pacific coasts.

Potential Distribution of Club Tunicate

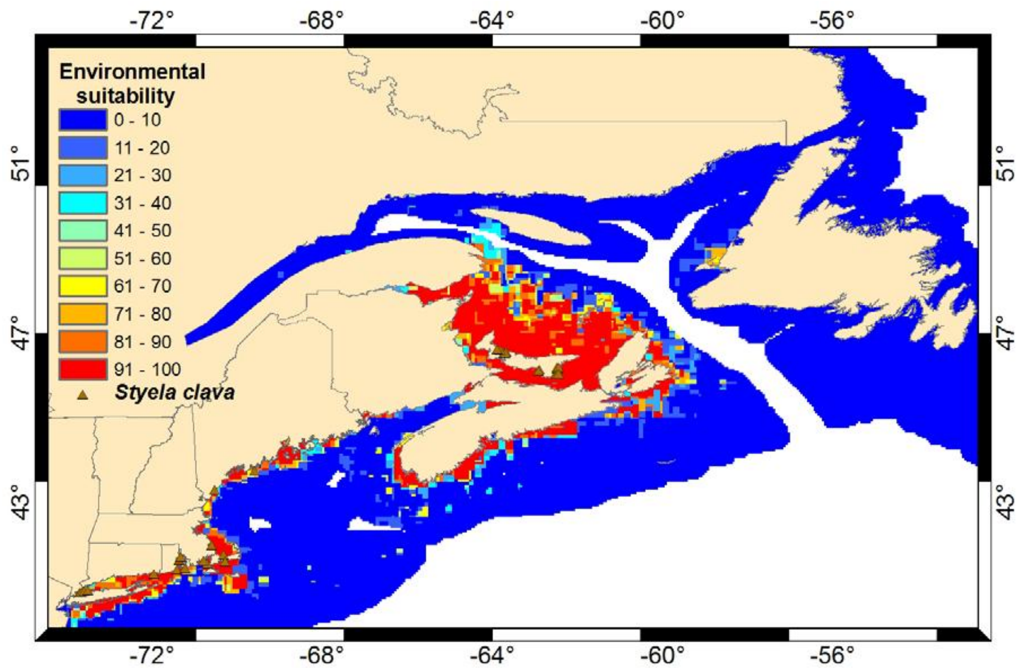


Figure 10. Potential distribution of S. clava *on the Atlantic coast based on temperature and salinity tolerances (from Therriault and Herborg 2007).*

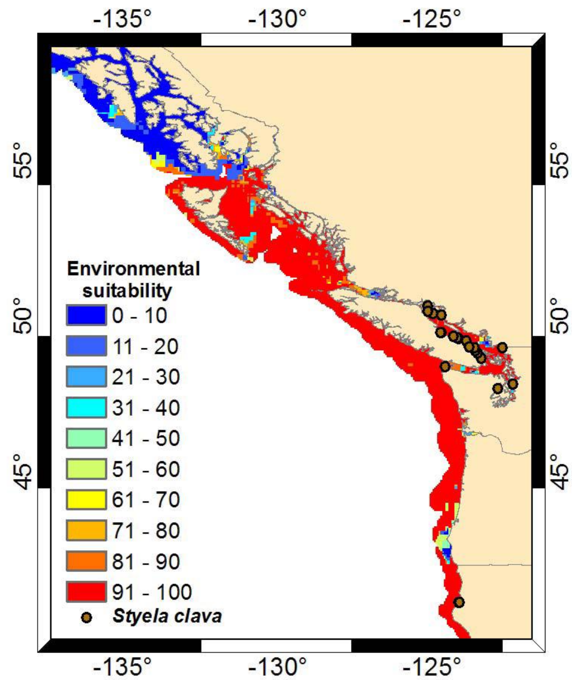


Figure 11. Potential distribution of S. clava *on the Pacific coast based on temperature and salinity tolerances (from Therriault and Herborg 2007).*

Potential Distribution of Vase Tunicate

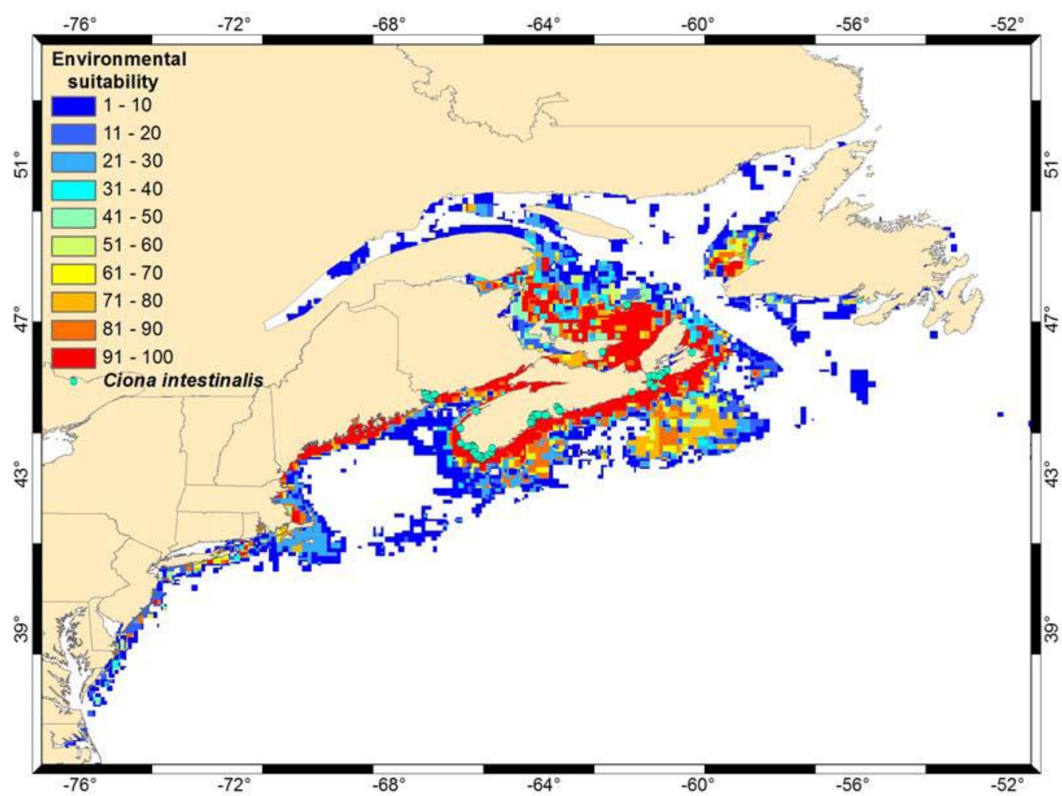


Figure 12. Potential distribution of C. intestinalis *on the Atlantic coast based on temperature and salinity tolerances (from Therriault and Herborg 2007).*

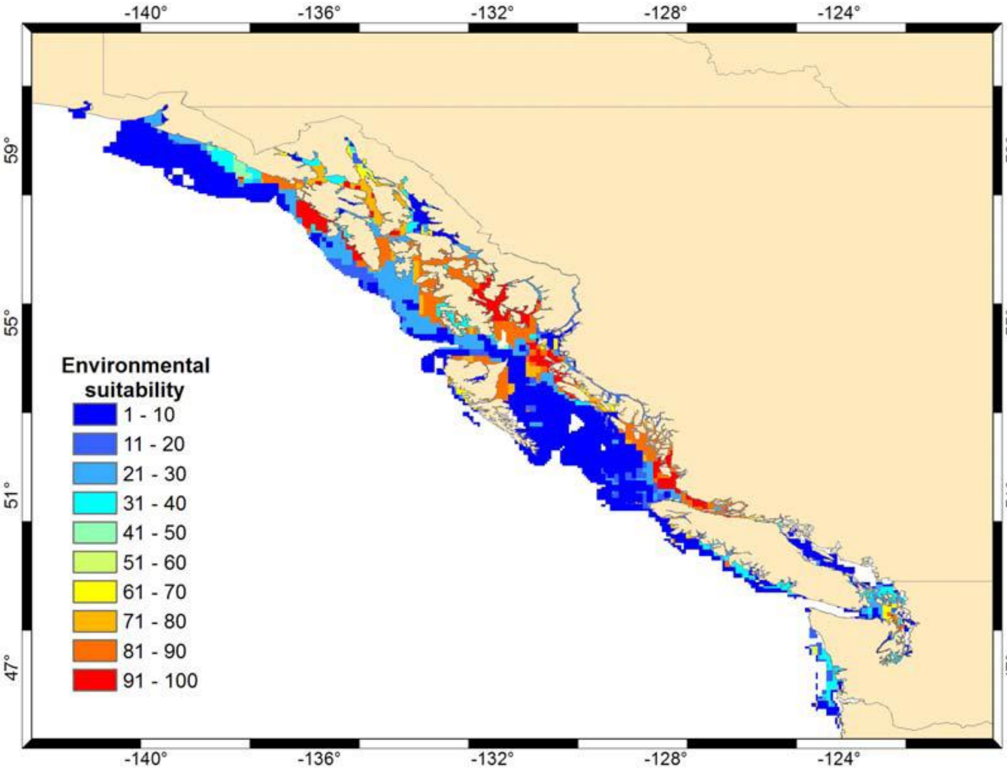


Figure 13. Potential distribution of C. intestinalis *on the Pacific coast based on temperature and salinity tolerances determined from Atlantic Canada populations (from Therriault and Herborg 2007).*

Potential Distribution of Golden Star Tunicate

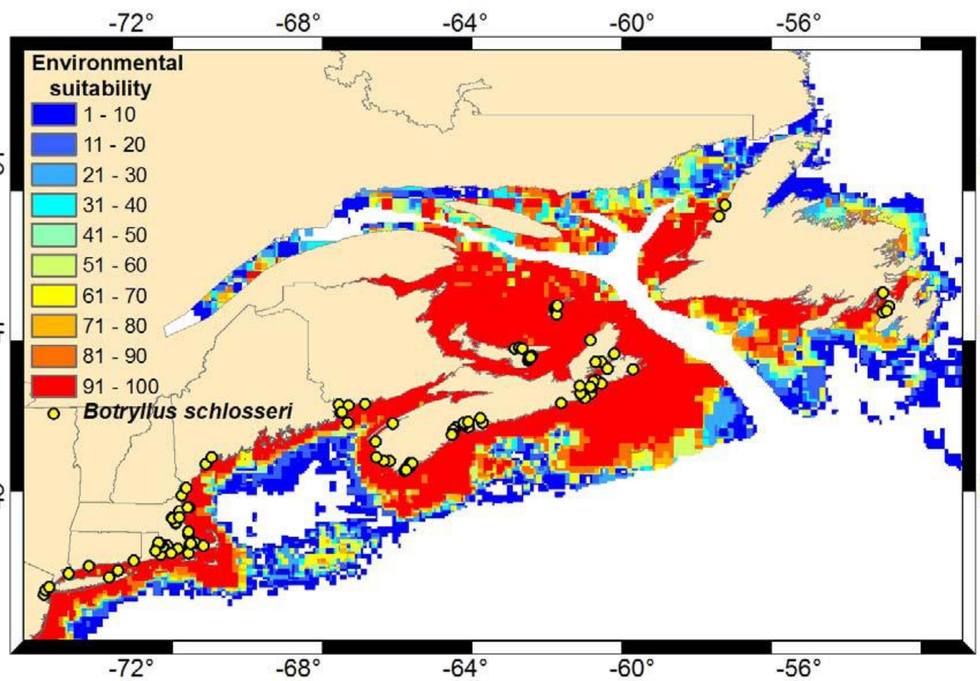


Figure 14. Potential distribution of B. schlosseri *on the Atlantic coast based on temperature and salinity tolerances (from Therriault and Herborg 2007).*

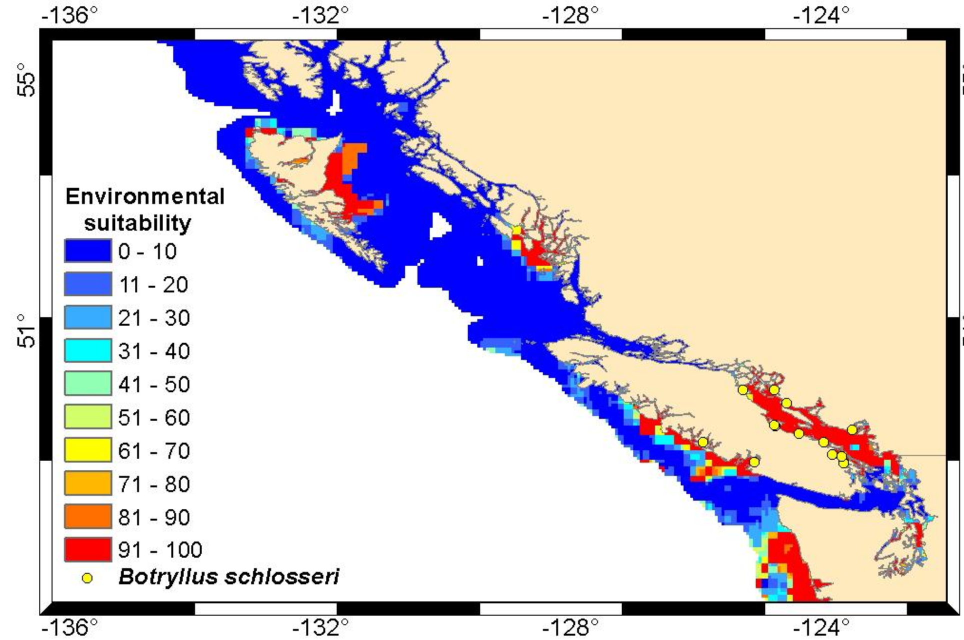


Figure 15. Potential distribution of B. schlosseri *on the Pacific coast based on temperature and salinity tolerances (from Therriault and Herborg 2007).*

Potential Distribution of Violet Tunicate

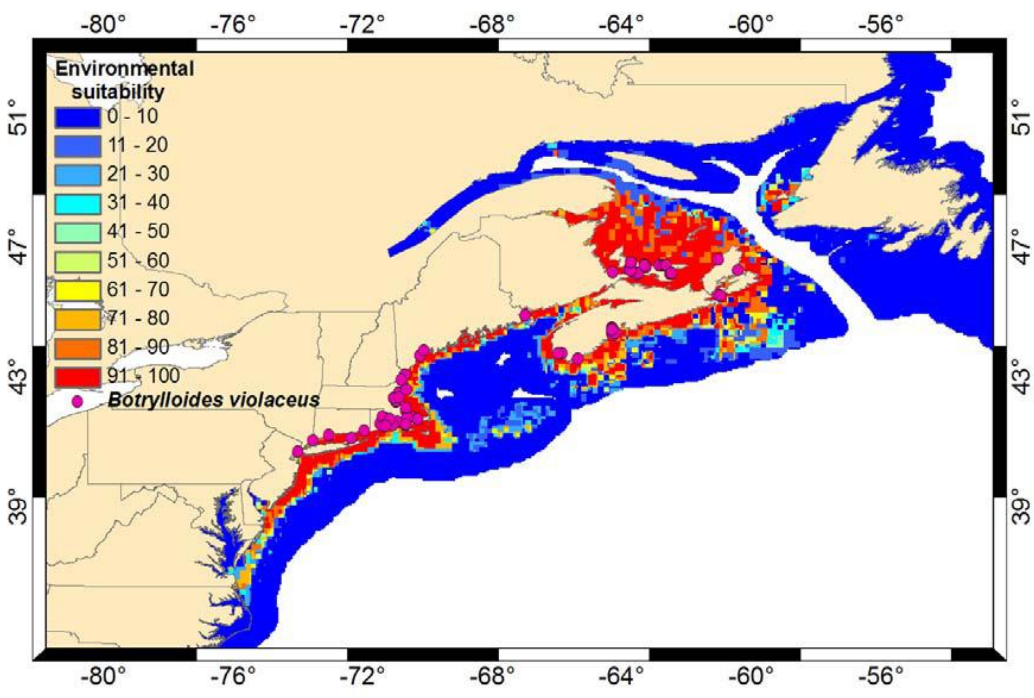


Figure 16. Potential distribution of B. violaceus *on the Atlantic coast based on temperature and salinity tolerances (from Therriault and Herborg 2007).*

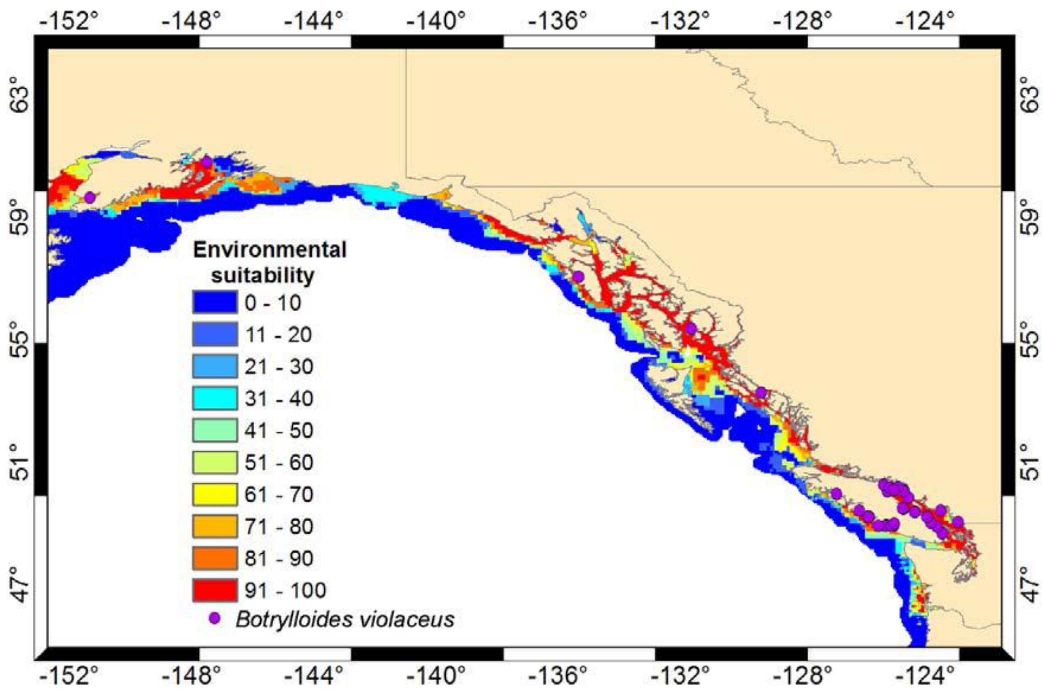


Figure 17. Potential distribution of B. violaceus *on the Pacific coast based on temperature and salinity tolerances (from Therriault and Herborg 2007).*

Potential Distribution of *Didemnum* sp.

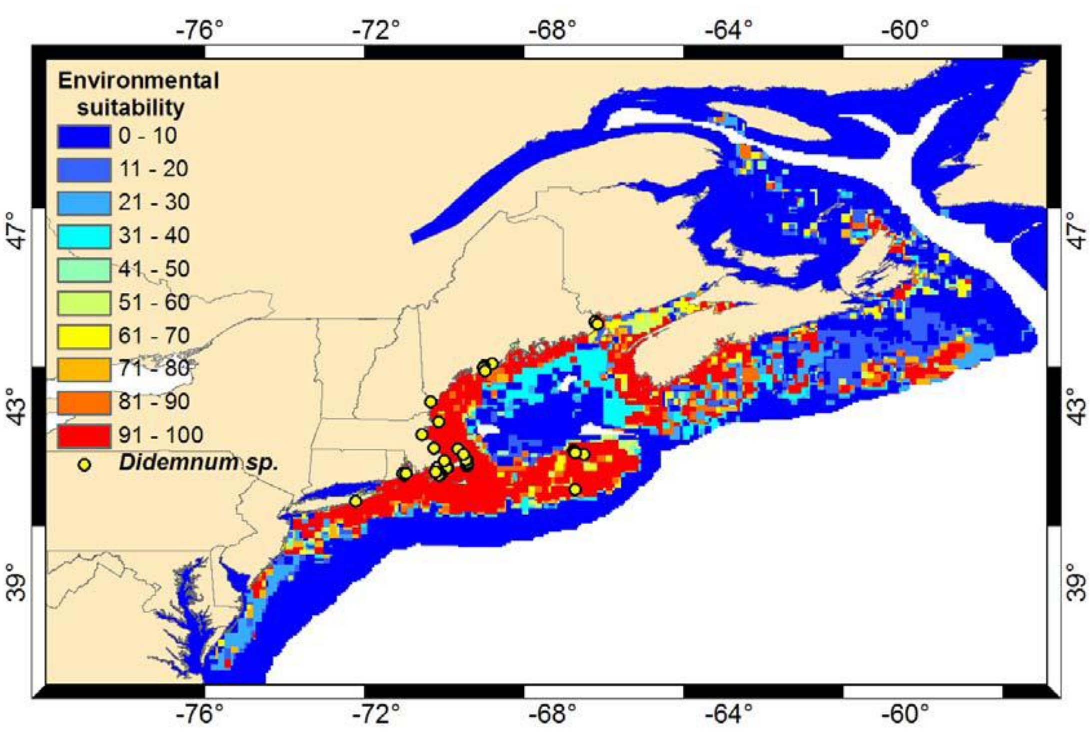


Figure 18. Potential distribution of Didemnum *sp. on the Atlantic coast based on temperature and salinity tolerances (from Therriault and Herborg 2007).*

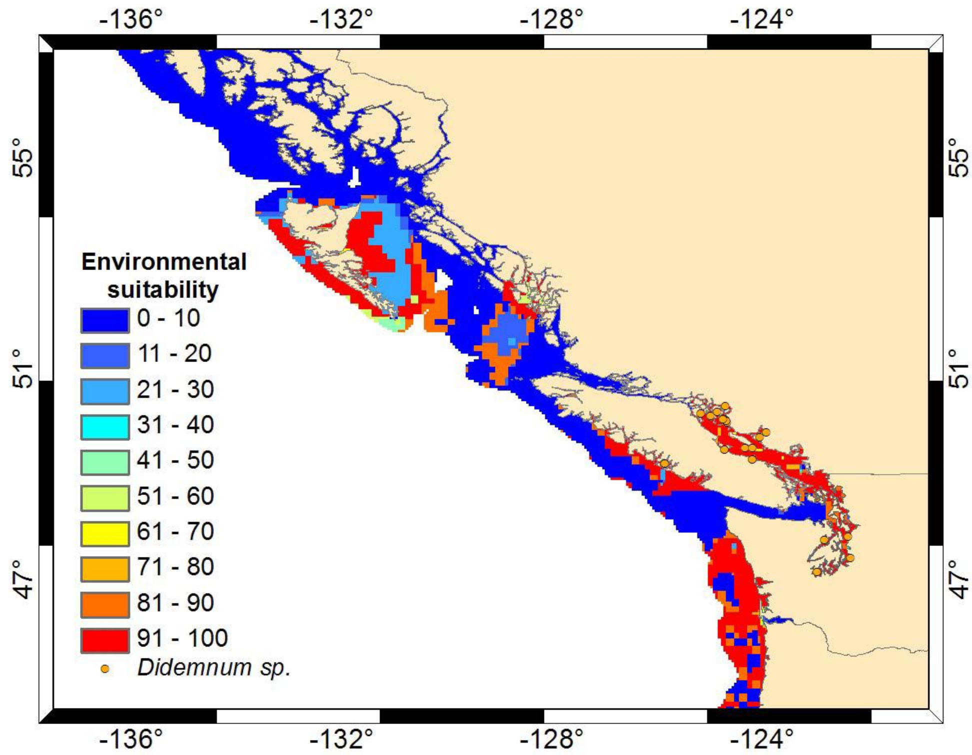


Figure 19. Potential distribution of Didemnum *sp. on the Pacific coast based on temperature and salinity tolerances (from Therriault and Herborg 2007).*

Vectors of Spread

Ascidian larvae swim for a short time after release and this limited dispersal is affected by angle of the sun, currents, water temperature, wave action, and wind exposure. Adult dispersal is limited to the movement of the substrate they inhabit. Rafting on eelgrass and other types of floating debris would distribute colonies further afield. Fouling of aquaculture equipment, boat hulls, fishing gear, oyster and shellfish stock as well as colony fragments in ballast, dredges, and fishing trawls are other potential vectors of spread.

Vectors of Spread: West Coast

The density and distribution of potential vectors were used to estimate potential for introduction:

- Densities of aquaculture facilities are given in Figure 20.
- Densities of small craft marinas, moorings, and anchorage are given in Figure 21.
- Densities of shipping activity for container ships, tanker ships, fishing vessels, and tugs and barges are given in Figures 22 to 25.

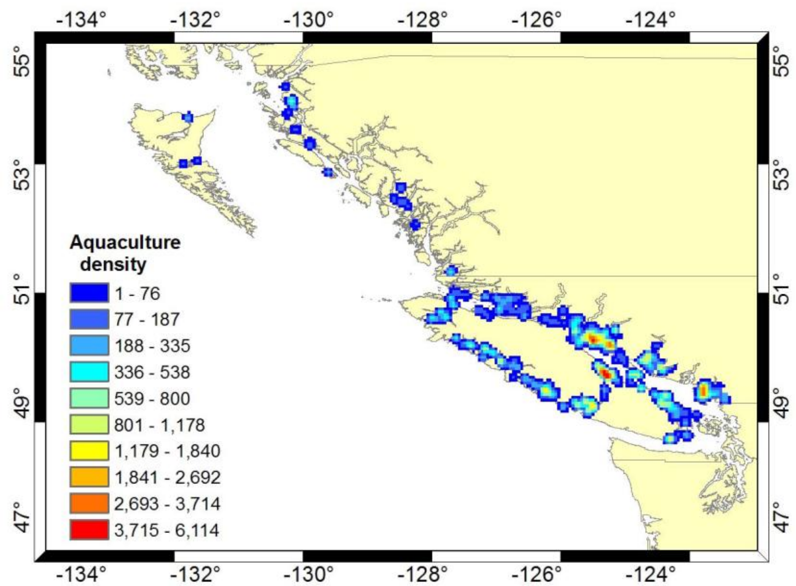


Figure 20. Density of aquaculture facilities in BC waters (from Therriault and Herborg 2007).

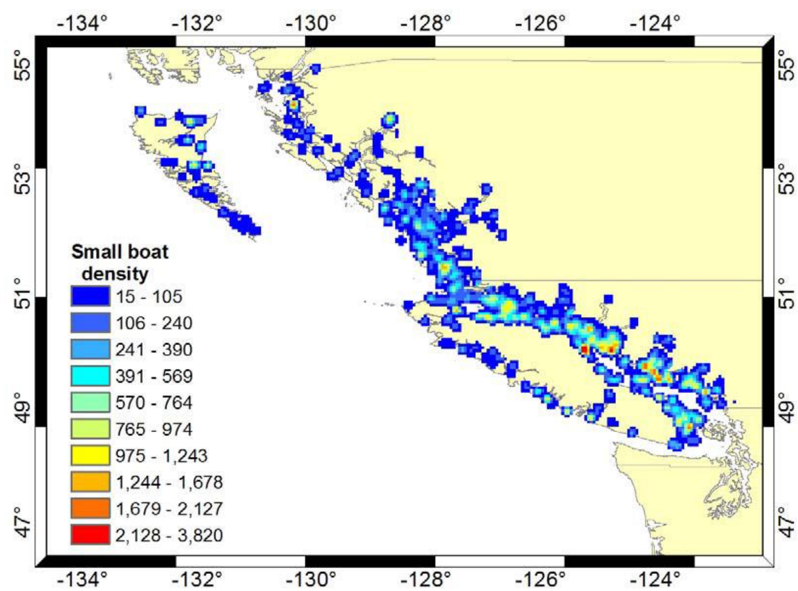


Figure 21. Density of small craft marinas, moorings, and anchorages in BC waters (from Therriault and Herborg 2007).

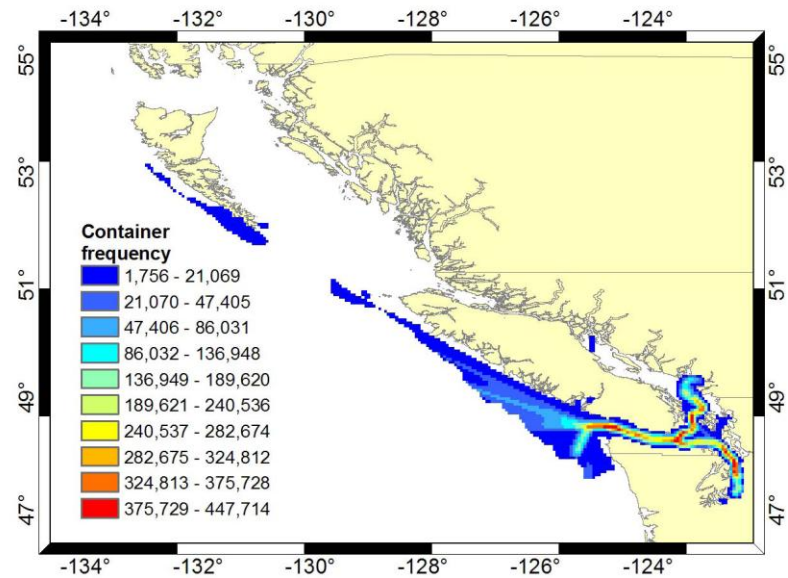


Figure 22. Density of container ship activity in BC waters (from Therriault and Herborg 2007).

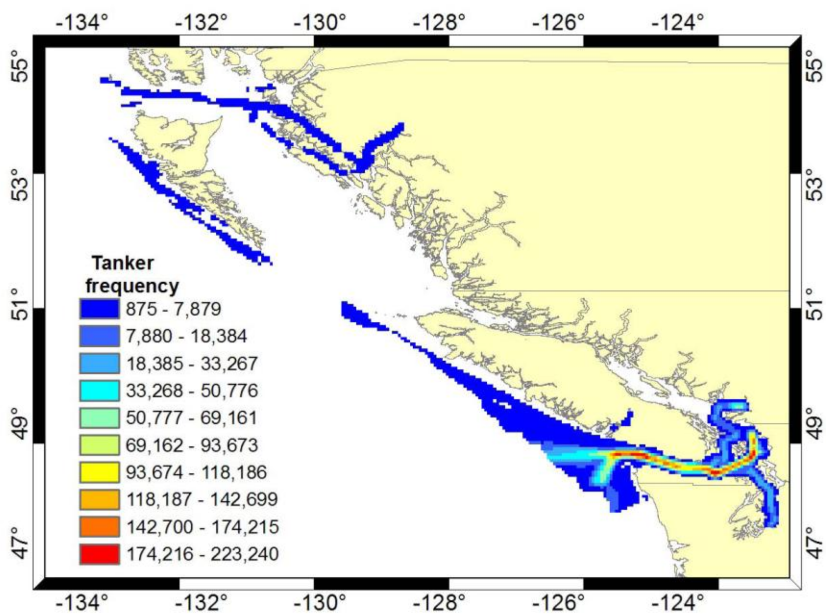


Figure 23. Density of tanker ship activity in BC waters (from Therriault and Herborg 2007).

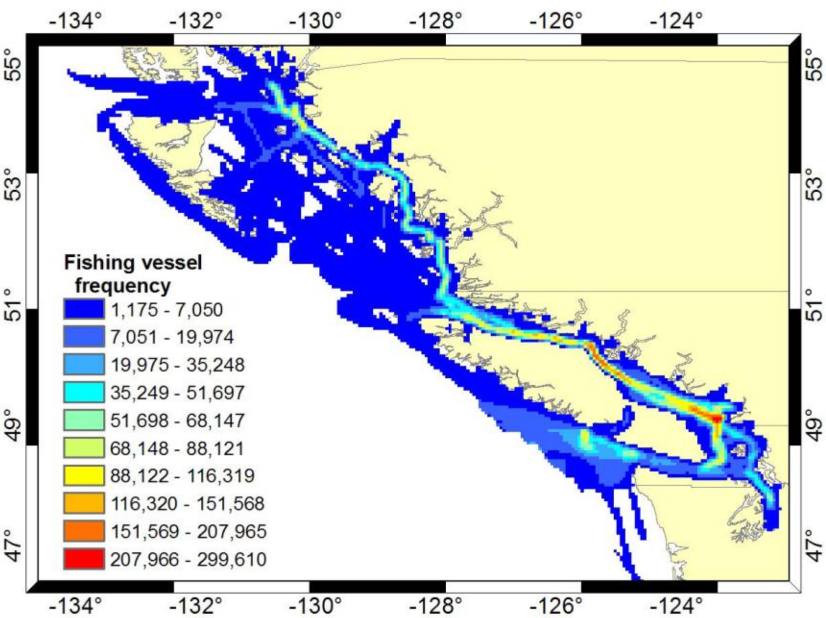


Figure 24. Density of fishing vessel activity in BC waters (from Therriault and Herborg 2007).

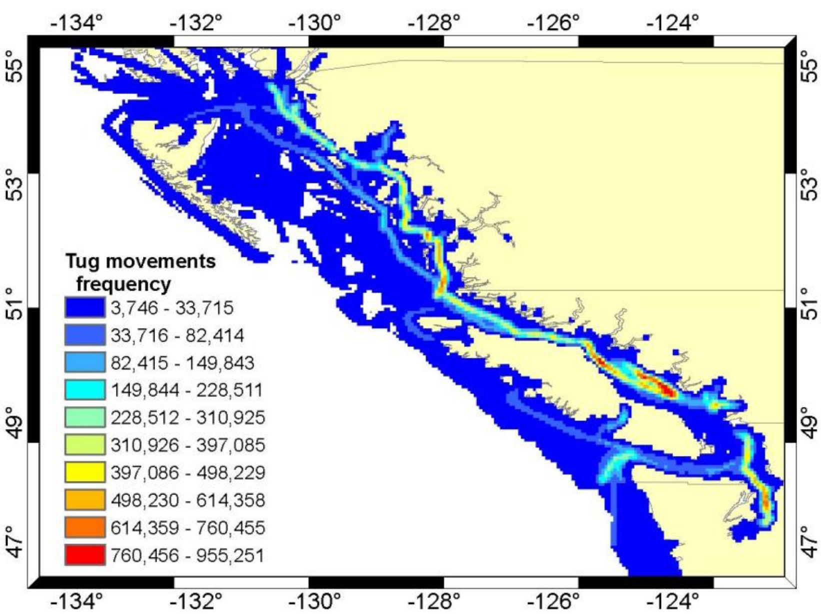


Figure 25. Density of tug/barge activity in BC waters (from Therriault and Herborg 2007).

Vectors of Spread: East Coast

Densities of aquaculture facilities on the east coast (Figure 26) and densities of small craft harbours (Figure 27) were mapped. Information on shipping vectors was not available for the east coast.

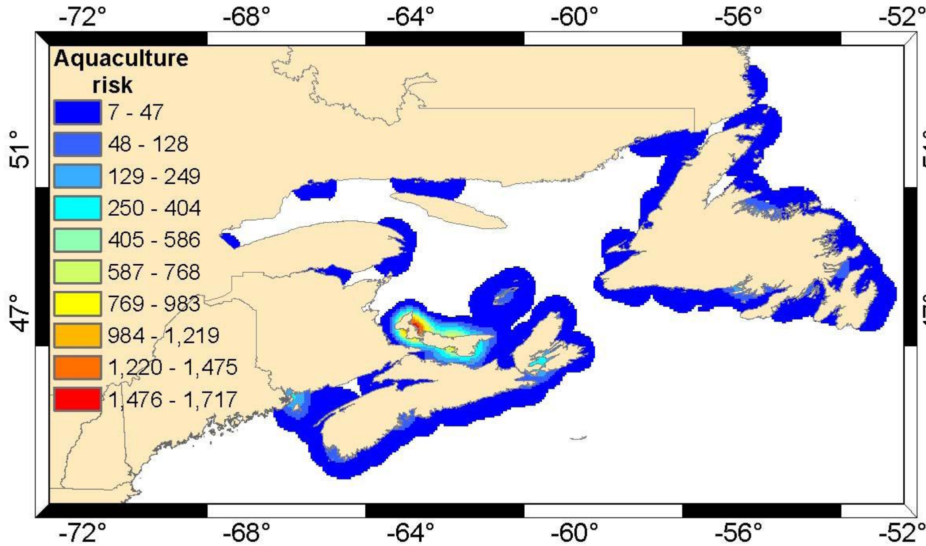


Figure 26. Density of aquaculture facilities around Atlantic Canada (from Therriault and Herborg 2007).

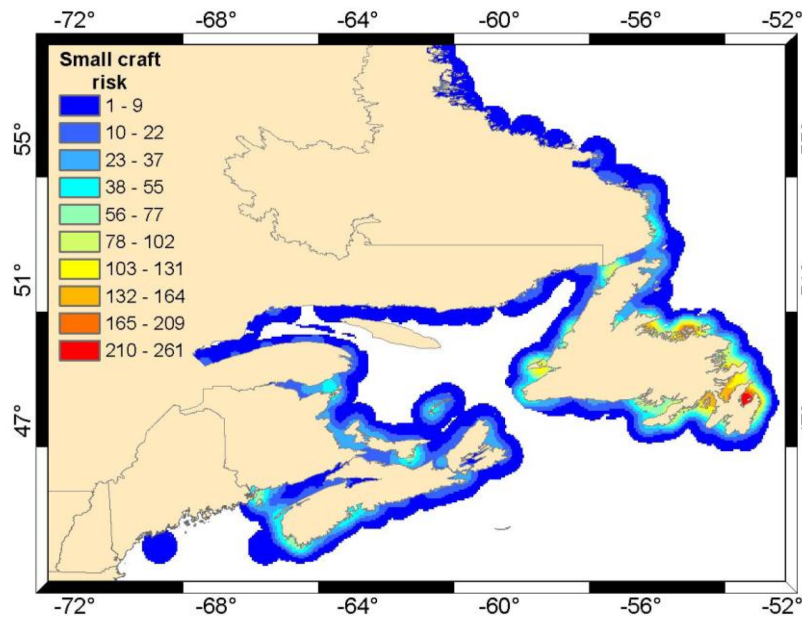


Figure 27. Density of small craft harbours around Atlantic Canada (from Therriault and Herborg 2007).

Potential Impacts

All tunicates are filter-feeding members of the biofouling community and, as such, compete for food with other filtering species and for space with other biofouling and benthic organisms. Tunicates can cause negative impacts on habitat structure and potentially food web and trophic structure through changes to plant and invertebrate communities. Although larval forms are preyed upon by multiple species, the adults are not considered a high quality prey item.

Impacts of these invasive tunicates are more apparent on floating structures that are often a new habitat free of competitors and where predators are absent or have less impact on the biofouling community.

The expert opinion survey identified several potentially important impacts for each of the five species. Impacts were considered to be moderate by most respondents, impacts on shellfish species used in aquaculture were considered to be high. The survey also indicated that impacts would be highest for *Didemnum* sp. and lowest for Golden Star Tunicate.

Overall Risk Rating

Overall ecological risk posed by each of these species was classified as 'high', generally with 'moderate' uncertainty. The exception was Vase Tunicate on the west coast where the risk was moderate with high uncertainty (Table 1).

Table 1. Summary of the overall risk for each of the five nonindigenous tunicate species.

	Atlantic Coast		**Pacific Coast**	
Species	**Rating**	**Uncertainty**	**Rating**	**Uncertainty**
	Ecological Risk			
Club Tunicate	High	Moderate	High	Moderate
Vase Tunicate	High	Moderate	Moderate	High
Golden Star Tunicate	High	Moderate	High	Moderate
Violet Tunicate	High	Moderate	High	Moderate
Didemnum sp.	High	Low	High	Low
	Genetic Risk			
Club Tunicate	Moderate	Low	Moderate	Low
Vase Tunicate	Moderate	Low	Moderate	High
Golden Star Tunicate	Moderate	Low	Moderate	Low
Violet Tunicate	Moderate	Low	Moderate	Low
Didemnum sp.	Moderate	Low	Moderate	Low

For tunicates that are transported as fouling organisms, it is usually the progeny of these organisms that become established at new locations rather than dislodgement of the individual or colony. This dramatically reduces the probability that a pathogen, parasite or fellow traveler will be introduced at the same time as larval stages often are assumed to be relatively insusceptible to these agents.

Overall risk posed by parasites, pathogens or fellow travelers of the evaluated tunicates was found to be low with high or very high uncertainty with the exception of the Club Tunicate which is known to carry a large variety of epibiont fauna, including the other tunicate species evaluated in this risk assessment. As the evaluated tunicates were found to pose a high risk, the Club Tunicate poses a high risk for its fellow travelers as well as itself.

Table 2. Summary of the parasite, pathogen or fellow traveler overall risk for each of the five nonindigenous tunicate species.

Species	Atlantic Coast		Pacific Coast	
	Rating	Uncertainty	Rating	Uncertainty
	Ecological Risk			
Club Tunicate	High	Very High	High	Very High
Vase Tunicate	Moderate	High	Moderate	High
Golden Star Tunicate	Low	High	Low	High
Violet Tunicate	Low	Very High	Low	Very High
Didemnum sp.	Low	Very High	Low	Very High
	Genetic Risk			
Club Tunicate	Moderate	Very High	Moderate	Very High
Vase Tunicate	Low	High	Low	High
Golden Star Tunicate	Low	High	Low	High
Violet Tunicate	Low	Very High	Low	Very High
Didemnum sp.	Low	Very High	Low	Very High

Sources of Uncertainty

- This risk assessment focused the Canadian Atlantic and Pacific regions. Although the best available information was used for ecological niche modeling, it was at a large spatial scale (i.e., Pacific Ocean, Atlantic Ocean). Smaller-scale data would better identify micro-scale habitats and refine the environmental suitability estimate.

- This risk assessment was undertaken in 2007 and is based on the best available information at that time. If vector movement patterns or global climate conditions change significantly, a re-assessment may be required.

- Predictions of environmental suitability were based on the 2005 tunicate distributions. This approach can underestimate the potential habitat available if the 2005 invaded range is not fully representative of its potential range. As species spread to new areas, it is possible the predicted suitable habitats also will increase as the true habitat limitations become more apparent.

CONCLUSIONS AND ADVICE

- Since natural long distance dispersal appears very limited, increased management of human-mediated dispersal vectors could substantially reduce spread of these nonindigenous tunicate species.

- Best practice advice should be developed in collaboration with aquaculture groups, small craft operators and other stakeholders. These efforts should be aimed at educating marine users on these species, including how they can spread, to determine suitable practices to limit further spread and associated ecological and genetic consequences.

- Higher resolution data on environmental conditions and the patterns of human transport vectors (e.g., recreational boating, tug and barge, or aquaculture related activities) in nearshore waters is required as this is where most nonindigenous marine species first arrive.

- A central register is recommend for invasive species risk assessments, reports and monitoring findings. This would ensure up-to-date information, including recommendations, are readily available to all involved parties including scientists, managers, and stakeholders. This register could house marine use data that would allow more timely access to critical data for rapid risk assessments for future invaders.

OTHER CONSIDERATIONS

- More recent distribution maps available for these invasive species are given in the appendices that follow:
  - Club Tunicate (*Styela clava*): Appendix A,
  - Vase Tunicate (*Ciona intestinalis):* Appendix B,
  - Golden Star Tunicate (*Botryllus schlosseri*): Appendix C,
  - Violet Tunicate (*Botrylloides violaceus*): Appendix D; and
  - *Didemnum* spp.: Appendix E.

SOURCES OF INFORMATION

This Science Advisory Report is from the March 13-14, 2007 tunicate risk assessment. Additional publications from this process will be posted as they become available on the Fisheries and Oceans Canada Science Advisory Schedule at www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

Carver C.E., Mallet, A.L. and Vercaemer, B. 2006a. Biological synopsis of the solitary tunicate *Ciona intestinalis*. Can. Manusc. Rep. Fish. Aquat. Sci. 2746: v + 55 p.

Carver C.E., Mallet ,A.L., and Vercaemer, B. 2006b. Biological synopsis of the colonial tunicates, *Botryllus schlosseri* and *Botrylloides violaceus*. Can. Manuscr. Rep. Fish. Aquat. Sci. 2747: v + 42 p.

Cirino, P., Toscano, A. Caramiello, D., Macina, A., Miraglia, V., and Monte, A. 2002. Laboratory culture of the ascidian *Ciona intestinalis* (L.): a model system for molecular developmental biology research. Mar. Mod. Elec. Rec. [serial online]. Available: http://hermes.mbl.edu/BiologicalBulletin/MMER/cirino/CirTit.html, accessed July 2012).

Clarke C.L., and Therriault, T.W. 2007. Biological synopsis of the invasive tunicate *Styela clava* (Herdman 1881). Can. Manuscr. Rep. Fish. Aquat. Sci.2807: vi + 23 p.

Daniel K.S., and Therriault, T.W. 2007. Biological synopsis of the invasive tunicate *Didemnum*sp. Can. Manuscr. Rep. Fish. Aquat. Sci. 2788: vi + 53 p.

DFO. 2009. DFO GeoPortal — Aquatic Invasive Species Observations (http://public.geoportal-geoportail.gc.ca/dfoGeoPortal/, accessed July 2012).

DFO. 2010. Proceedings of the national peer review of the risk assessments of two solitary and three colonial invasive tunicates in both Atlantic and Pacific Canadian waters; March 13-14, 2007. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2009/045.

Therriault, T. and L.-M. Herborg, 2007. Risk assessment for two solitary and three colonial tunicates in both Atlantic and Pacific Canadian waters. DFO Can. Sci. Advis. Sec. Res. Doc. 2007/63. iv+64 p.

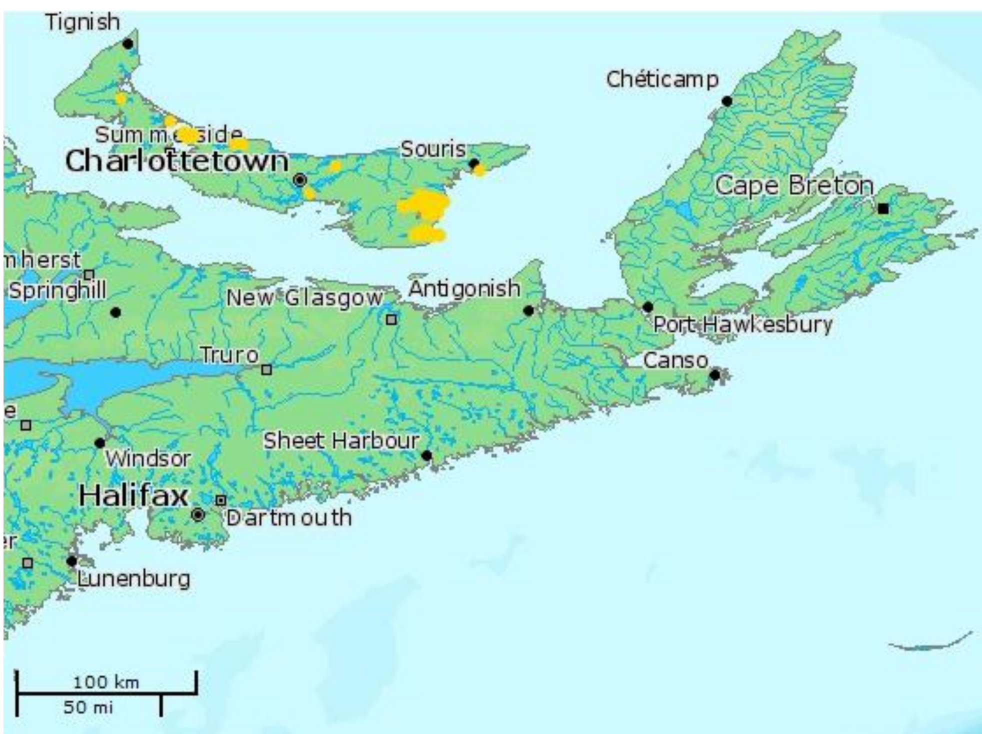
USGS. 2009. NAS — Nonindigenous Aquatic Species (http://nas.er.usgs.gov, accessed July 2012).

APPENDICES

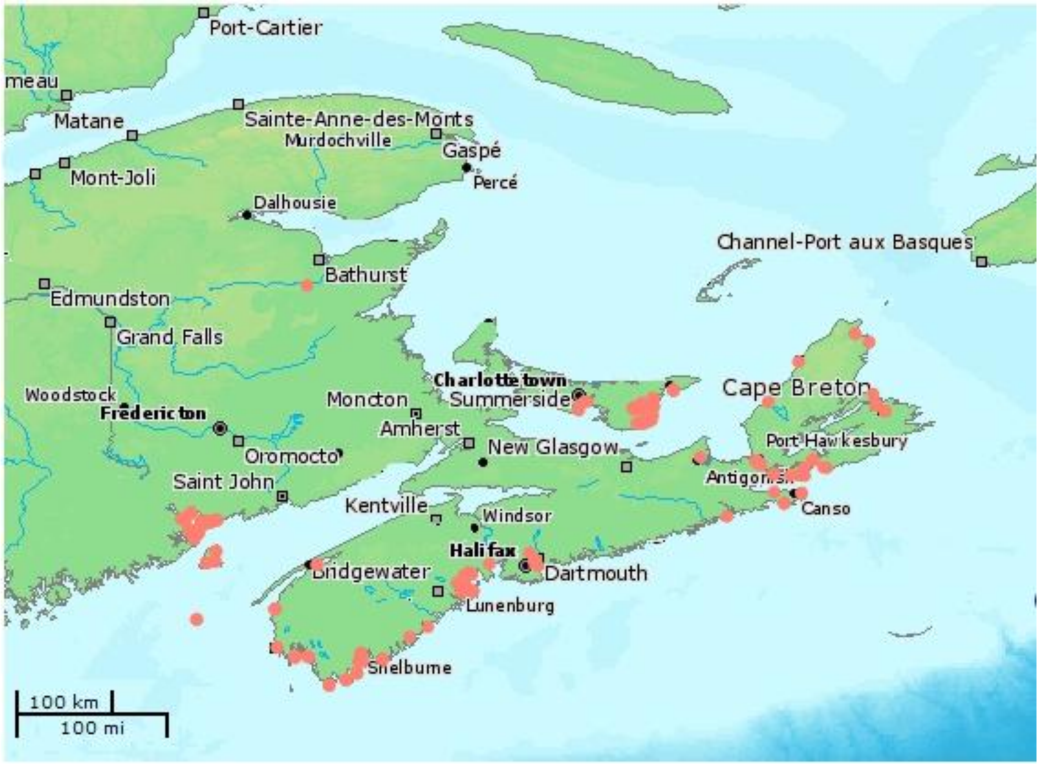
Appendix A. Distribution of the Club Tunicate (*Styela clava*) in Canada based on 2005-2009 reported observation for a) Pacific and b) Atlantic regions (DFO 2009).

a)

b)



Appendix B. Distribution of the Vase Tunicate (*Ciona intestinalis*) in Canada based on 2005-2009 reported observations (DFO 2009).



Appendix C. Distribution of the Golden Star Tunicate (*Botryllus schlosseri*) in Canada based on 2004-2009 reported observations for a) Pacific and b) Atlantic regions (DFO 2009).

a)

b)

Appendix D. Distribution of the Violet Tunicate (*Botrylloides violaceus*) in Canada based on 2004-2010 reported observations for a) Pacific and b) Atlantic regions (DFO 2009).

a)

b)

Appendix E. Distribution of the *Didemnum* sp. in Canada based on reported observations for a) Pacific and b) Atlantic regions (DFO 2009).

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