INVASIVE TUNICATES

THE WESTERN REGIONAL PANEL ON AQUATIC NUISANCE SPECIES

This report summarizes the activities and outcomes of an invasive tunicate workshop hosted by the Western Regional Panel on Aquatic Nuisance Species August 6–7, 2014 in Seattle, Washington.

Cover photo: *Didemnum vexillum* from the State of Washington. Photo credit: Gretchen Lambert.

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THE WESTERN REGIONAL PANEL ON AQUATIC NUISANCE SPECIES

On August 6–7, 2014, 28 individuals convened in Seattle, Washington to participate in the Western Regional Panel on Aquatic Nuisance Species Invasive Tunicate workshop. The goals of the workshop:

- Discuss the environmental and economic risks (actual or potential) posed by non-native tunicates.
- Share information, efforts, issues, successes and challenges.
- Identify management options, research needs and funding priorities.
- Determine if a regional management plan is needed, and if so, create an action plan to inform scoping and development.

Attendees included:

Jeff Adams – Washington Sea Grant
Kevin Anderson – Puget Sound Partnership
Sam Chan – Oregon Sea Grant
Sara Cohen – San Francisco State University
Diane Cooper – Taylor Shellfish Farms
Tammy Davis – Alaska Department of Fish and Game
Lisa DeBruyckere – Creative Resource Strategies, LLC
Cat deRivera, Portland State University
Glenn Dolphin – Oregon State Marine Board
Robyn Draheim – US Fish and Wildlife Service
Anya Dunham – Fisheries and Ocean Canada
Leah Elwell – Western Regional Panel on Aquatic Nuisance Species
Gary Freitag – Alaska Sea Grant
Sonia Gorgula – Hawaii Department of Land and Natural Resources
Bruce Hansen – US Forest Service
Gordon King – Taylor Shellfish Farms
Gretchen Lambert – University of Washington
Joel Moribe – National Oceanic and Atmospheric Administration
Steve Murschel – Portland State University
Adam Obaza, National Oceanic and Atmospheric Administration
Susan Pasko – National Oceanic and Atmospheric Administration
Stephen Phillips – Pacific States Marine Fisheries Commission
Greg Ruiz – Smithsonian Environmental Research Center
Steve Rumrill – Oregon Department of Fish and Wildlife
Jesse Schultz – Washington Department Fish and Wildlife
Linda Shaw – National Oceanic and Atmospheric Administration
Ronald Smith – US Fish and Wildlife Service
Mark Sytsma – Portland State University

WORKSHOP SPONSORS

EXECUTIVE SUMMARY

A total of 28 individual convened August 6–7, 2014, in Seattle, Washington to discuss the environmental and economic risks (actual or potential) posed by non-native tunicates; share information, efforts, issues, successes and challenges; identify management options, research needs and funding priorities; and determine if a regional management plan is needed, and if so, decide key next steps to realize that vision.

The group received presentations on:

- The state of the science—tunicate biology and ecology, distribution, vectors, impacts, and current research.
- The impacts of invasive tunicates on mariculture operations.
- Tunicate eradication successes and failures in Washington.
- State/Province (Alaska, British Columbia, California, Hawaii, Oregon, and Washington), management of tunicates, including history, status, future plans, successes, level of risk assessments, and risk assessment methodology.
- The elements of a proposed Pacific Northwest fouling management plan.

The group formed breakout sessions to discuss risk assessments, funding, management options, research needs, collaboration and regional plans.

Case studies from Washington, Oregon, and British Columbia were reviewed to discuss the key management elements, with a focus on lessons learned to inform future management scenarios.

Attendees discussed whether or not a regional plan for tunicates and/or marine invasives/biofouling should be developed, and if so, what elements would be included in such a plan.

The group decided the Western Regional Panel on Aquatic Nuisance Species would request that Pacific States Marine Fisheries Commission take the lead in convening relevant entities to scope the development of a regional plan within the next 90 days. Fundamental versus means objectives should be defined with this request. Included in the scoping would be a timeline expectation for the development of a regional plan.

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WORKSHOP SUMMARY

Attendees were asked to describe their goals for attending the meeting:

- Venue to share industry perspectives
- Methods to practice aquaculture without introducing invasives
- Risks invasive tunicates pose
- Prioritizing investments in tunicate control in the context of other pressing natural resource issues
- Opportunities for regional and international collaboration
- Biology and genetics of tunicates
- Current tunicate activities (control, monitoring, research, genetics)
- Lessons learned
- Research needs and techniques
- Overcoming complacency – dealing with impacts
- How tunicates interact with other organisms
- Opportunities to integrate structured decision making

A. *State of the Science* Presentations

Three presenters, Gretchen Lambert of the University of Washington, Sarah Cohen of San Francisco State University, and Greg Ruiz of the Smithsonian Environmental Research Center, gave presentations on tunicate biology and ecology, the genetics of tunicates, and invasion history and vector dynamics in coastal marine ecosystems, respectively. The following are some of the key discussion points from these presentations:

GRETCHEN LAMBERT, UNIVERSITY OF WASHINGTON

- Not all tunicates are ascidians.
- They are in the Phylum Chordata, Sub-phylum Tunicata (all are marine and most cannot tolerate salinities below 25 parts per thousand), and Class Ascidiacea (sessile filter feeding adults; swimming, short-lived, non-feeding, tadpole larvae)
- The three orders of ascidians:
    - Phlebobranchia (phlebo=vessel)— most are solitary, thin tunics, that live only a few months, are killed by drying out, are sensitive to low salinity, and exhibit easily torn tunics. Examples include *Ciona*, *Ascidia*, and *Phallusia*.
    - Stolidobranchia (stolido=folded, pleated) — most are solitary with thick leathery tunics. Examples include *Styela* and *Molgula*. A few, such as *Botryllus* and *Botrylloides*, are colonial.
    - Aplousobranchia (aplouso=simple) — all are colonial. Examples include *Aplidium* and *Didemnum*.
- Non-colonial tunicates and colonial stolidobranchs (such as botyllids) have one body part, whereas colonial aplousobranchs have two forms (either two or three body parts).
- Didemnid colonies have two body parts, but because of their small size, they work together to create a larger current that can release their tadpoles and waste. Their embryos are nested in the base of the tunic – managers should consider this when undertaking control/management actions (ensure the embryos are not left behind).
- Nearly all tunicates have tadpoles. *Didemnum vexillum* has a particularly unique tadpole phase, which makes it very easy to identify. Colonial tunicates have a short tadpole phase, which settles quickly (and thus grows fast).

- Solitary tunicates are easier to manage because they reproduce only sexually, do not bud, and species such as *Styela clava* which have a stalk can be removed by chopping off the stalk (there's no need to detach).
- Colonial tunicates reproduce both sexually and asexually, exhibit internal brooding, the tadpole that is released is prepared to metamorph, and it settles almost instantly compared to solitary tunicate tadpoles.
- Identification of invasive tunicates is based on five characteristics (a refinement of the Chapman and Carlton, 1994 criteria):
    1. They have a disjunct distribution – they suddenly appear in an area far from known sites.
    2. They prefer artificial substrates, at least during the initial period of invasion.
    3. They exhibit rapid growth.
    4. They have a long breeding season and quick to sexually mature.
    5. They have a wide tolerance of environmental variables, such as temperature and salinity.
- Their distribution and abundance is a result of environmental tolerances (e.g., salinity, temperature, desiccation, wave action, and light), dispersal, food, competition, and predation.
- Ascidians prefer protected areas and preferentially colonize man-made structures. They appear to be pre-adapted to harbors or mariculture environments and tolerate heavy metals but not high sediment loads.
- It is challenging to predict their likelihood to be invasive.

SARAH COHEN, SAN FRANCISCO STATE UNIVERSITY

The role of genetics in tunicate management was discussed.

- Population connectivity will influence the type of population structure and dynamics that occur across space. Population connectivity is influenced by life history features of organisms and by anthropogenic vectors.
- Coastal waters are especially susceptible to invasion—ballast water, fouling of ship hulls and aquaculture activities are the three most important vectors of inoculation. Ballast water is not the most likely invasion vector of species with extremely limited natural dispersal, such as tunicates and other taxa with limited larval stages. Movement of fouled structures other than boats is an important vector pathway that should receive increased management attention.
- San Francisco estuary is one of the most highly invaded estuaries in the world and includes invasive taxa with varied life histories including many tunicates.
- The source regions often contain the most diversity - *Didemnum vexillum* genetics demonstrates the most different types are found in Japan. Age of introduction does not necessarily correlate to diversity, nor is diversity always correlated with the size of the population or rate of spread. For example, Alaskan *D. vex.* has a higher diversity than expected using higher resolution microsatellite DNA analysis. The Alaskan population is small, but diverse, which could suggest repetitive introductions or a longer history of introduction than previously supposed. However, there is a significant lack of comparative high-resolution genetic data that would allow useful inference of vector pathways.

- Areas surrounding the oldest port in the Americas (Lima, Peru) do not have a large biomass of invasive hull-fouling tunicate species. There are relatively few marinas, in comparison to California (USA), and few potential surfaces for inoculation, and the boats are often kept free of hull organisms. There are genetic differences among invasive tunicate populations across relatively shorter distances in Peru than on the Pacific coast of North America in California, where potential vectors have a much greater presence. Individual locations in Peru show strong differences in amounts of genetic diversity in a common invasive tunicate (*Ciona*) while locations in California are relatively similar in diversity, consistent with greater connectivity among California sites in comparison to Peruvian sites.
- Additional genetic analysis using functional genes, rather than the standard barcoding and occasional microsatellite DNA analysis, would allow more sophisticated testing of hypotheses on potential adaptation of invasive species to new areas. This information would allow us to assess the real threats of invasive species to novel areas such as Alaska, where relatively few marine invaders are currently found, though some species of high concern have begun to show up increasingly.

GREG RUIZ – SMITHSONIAN ENVIRONMENTAL RESEARCH CENTER

- The National Exotic Marine and Estuarine Species Information System (NEMESIS) (http://invasions.si.edu/nemesis/) is a database that consists of literature, monitoring, collection records, and reporting systems that inform invasion patterns, predictions, management/policy, early detection rapid response, and management efficacy for North America. It is a collection of various data sources not a standardized monitoring dataset.
- NEMESIS includes taxonomy, descriptions and images of species, occurrence records, maps, invasion and population status, vectors of introduction, reported impacts, and attributes (e.g. life history).
- As of 2013, the number of non-native invertebrates and algae reported in coastal waters of North America totaled 450, of which the top five were crustaceans, molluscs, algae, annelids, and insects. Tunicates comprise six percent of the total.
- The rate of detection of non-natives has increased 51% from 1999 to 2010. Eight percent of all detections of non-native species occurred from 1981-2010.
- More introductions of non-native species have occurred on the West Coast, compared to the East and Gulf Coasts. Tunicates comprise 6-10% of all non-native species on each coast.
- On the West Coast, most of the first records are in California; there has been a northward spread of those species. This could be a function of vector strength and historical anthropogenic activity.
- There is a latitudinal decline in tunicate species richness on the West Coast (i.e., there are more introduced tunicates in California than any other western coastal state; Alaska has the fewest introduced tunicates; British Columbia has fewer introduced tunicates than Oregon and Washington, but more than Alaska).
- Ballast water and hull fouling are the two most significant vectors for non-native tunicate introduction, followed by accidental introductions from the oyster industry, and non-oyster industry accidental introductions.
- The number of introduced species is correlated with vector type, with shipping being responsible for the greatest number of introductions. Of the 200 non-native species introduced to North American coasts, the majority were introduced via hull fouling and

ballast water (not surprising given the number of ship arrivals to U.S. ports annually - ~100,000).

- The number of non-native species in bays and estuaries is correlated to salinity zones – fresh and oligohaline waters have fewer non-native species than polyhaline and euhaline waters.
- Smaller boat traffic may serve as "conveyor belts," allowing regional spread, which enables even greater spread over time.
- To prevent the spread, we need to start focusing on managing hull fouling of all vessel types.
- Salinity could potentially be having an impact on the latitude gradient of invasive tunicates on the West Coast.

B. Industry Presentation

Gordon King of Taylor Shellfish Farms gave a presentation on invasive tunicates and implications for production and response.

GORDON KING, TAYLOR SHELLFISH FARMS

- Taylor Shellfish Farms are the largest shellfish producer on the West Coast.
- Washington is unique because tidelands can be privately owned and the majority of shellfish production 98% is in the intertidal zone. Tunicate issues are minimal because of the location of aquaculture in the intertidal zone.
- There is strict control over shellfish transfers, which allows for cleaner farming and fewer invasives issues. State transfer permits help avoid invasions from spreading.
- *Didemnum vexillum* was discovered in New Zealand about the same time as it was discovered in the Northwest and in New England. A great deal of money was spent to prevent the invasion from spreading in New Zealand, but *Didemnum* continued to spread.
- Introductions are documented in aquaculture farms because aquaculture managers are constantly surveying – they quickly identify invasions when they occur.
- This is a highly regulated industry.
- Taylor's grow their own seed and transfers are highly regulated. This has led to industry led development of BMPs and includes practices including chlorination.

C. Management Presentations

JESSE SCHULTZ, WASHINGTON DEPARTMENT OF FISH AND WILDLIFE—TUNICATE ERADICATION SUCCESSES AND FAILURES IN WASHINGTON

Dockton Park is in King County on Maury Island. Facilities include 934 square meters of concrete elevated docks. Macrofaunal quadrat surveys were conducted on 10 randomly selected portions of the dock (three one-meter quadrats per section); all 30 quadrats had presence of *D. vexillum*. In January 2008, of the 52 wood pilings, 21 had *D. vexillum.*

At Dockton Park, they focused on areas at the main dock outside of the intertidal zone and used a grid to section off the dock, analyzing presence/absence per quadrat. They learned there is a relationship between *D. vexillum* and the feather worm, and that *D. vexillum* was present on creosote pilings. To treat the tunicates, *D. vexillum* was:

- scraped (labor intensive)
- wrapped with acetic acid (20% at 24 hours) (eradicated and killed everything, including native organisms; when the wrap was removed, all dead organisms fell to the bottom)
- wrapped and left alone for 14 days (eradicated and killed everything, including native organisms; when the wrap was removed, all dead organisms fell to the bottom)

- wrapped with freshwater (945 liters of water was pumped into each finger dock) and checked after 2 weeks (*D. vexillum* and most everything else survived, but their error was that they did not measure salinity)
- Sprayed with acetic acid (this was unsuccessful in killing *D.vexillum*)

Monitoring occurred in the winter and summer, with no seasonal difference documented. There is one location where *D. vexillum* frequently returns – there is a significant crack in the dock material that may be hard to reach – acid spray may be the best solution for this particular location.

In March of 2013, of the 52 wood pilings, 6 had *D. vexillum*. September 2013 was the last survey—5 pilings and 2 quadrats had *D. vexillum*.

D. Management Presentations

Representatives from Alaska, British Columbia, Washington, Oregon, and Hawaii gave presentations on tunicate issues in their region, including history and status, activities, future plans, successes, level of risk, and methodology.

TAMMY DAVIS, ALASKA DEPARTMENT OF FISH AND GAME

- 1997–2000 and 2006–2008 studies conducted analyzing invasive spreading and biodiversity
- 2006–2008: tunicates found in Sitka (*Botrylloides*)
- 2007 to present: Monitoring has increased
- 2008: Tunicate ID workshop for Homer stakeholders
- 2010: Bioblitz occurs in Sitka
- 2011: Models are developed to project ecosystem relations to vectors
- Defouling of mariculture gear leads to more spread of *D. vexillum* with outlier populations
- 2010–2014: Rapid response to *D. vexillum*; no environmental impact statement; good outreach to stakeholders; area closed to vessels; provided outreach to farmers.
- In Whiting Harbor, *D. vexillum* is established at the head of the bay, and there are distinct populations on the western shoreline. Actions including placing buoys and removing substrate (buoys were not effective in deterring boat presence). *D. vexillum* was not detected outside of the harbor.
- Challenges:
    - Intertidal zone issues: survives air exposure
    - Attaches easily to seaweed present
    - Unrealistic goals due to funding challenges and expectations
    - Limited engagement by stakeholders—Lack of intra- and inter-agency collaboration
    - Financial support for action, not research
    - Very real challenges needing to be addressed
    - Confirmation is important in species ID— we need funding for geneticist work
    - Benthic substrate is hard boulders; presenting a complex 3D challenge for treatment.

ANYA DUNHAM, BRITISH COLUMBIA, FISHERIES AND OCEANS CANADA

- Four species present in BC: *Botryllus schlosseri, Botrylloides violaceus, Styela clava, and Didemnum vexillum*.
- Determining what species are causing issues
    - Aquaculture not currently experiencing major issues due to tunicate invasion

    - Heavy infestations, however, in some marinas (most likely introductions from recreational use)
- Focus on research in support of management: environmental tolerances, predation pressure, and mechanical, biological, and chemical control options (lab and field studies).
- Environmental tolerance of tunicates
    - Wide range, but best growth in narrow window
    - Predation pressure: tested 13 common predators known to eat similar species x 4 tunicate species. Most successful predator-prey combinations: green and red sea urchins. Predation rates: green urchins: 12.7 cm^2 over two days. However, all predators preferred other food items over tunicates if given a choice.
- Control/mgmt. options for aquaculture
    - Must be safe for farmed animals, the environment, and people, and time- and cost-effective.
        - Mechanical and chemical treatments work well (reduced *D. vexillum* fouling by 85 to 96%), but mechanical efforts were time intensive and chemical treatments affected oyster survival rates. Chemical treatments were investigated further in field and lab experiments. Exposure to 3 and 4% hydrated lime for 5 min was extremely effective at reducing biofouling, including *D. vexillum*, while maintaining high oyster survival, growth and condition.
- Modeling and region-scale risk assessment work completed for 5 non-indigenous tunicate species found on the west and east coasts of Canada. Risk assessment methodology was adapted from the process outlined in the Canadian National Code on Introductions and Transfers of Aquatic Organisms and included scoring the probability and consequences of establishment based on GARP modelling and expert surveys. Risk potential was assessed in terms of ecological, industrial, and genetic consequences for 5 species for both coasts.
- Outreach is important; DFO created invasive species guides in 2006 in collaboration with the BC Shellfish Growers Association. Royal BC Museum developed an online taxonomic key for identifying tunicates.
- Future research:
    - Application of genetic markers to resolve invasion patterns
    - Enhanced environmental niche modeling to understand potential climate change implications
    - Evaluation of potential management options to limit the spread
    - Integrating invasive species management into marine conservation and spatial planning (*e.g.* exploring lesser known/monitored vectors of spread such as floating docks and similar structures – and their potential role in secondary spread from invasion hotspots to ecologically significant areas).

SONIA GORGULA, HAWAII DEPARTMENT OF LAND AND NATURAL RESOURCES

- Ascidian invasions in Hawaii over time has resulted in a great deal of information, but ongoing monitoring is not consistent
- In 2007, DLNR began to regulate ballast water discharges. Management of hull fouling remains a biosecurity gap

- The Northwestern Hawaiian Islands are part of the Papahanaumokuakea Marine National Monument and all activity is permitted. E.g. Permit conditions require ships to be 100% clean of biofouling
- Issues with introductions include 7 million annual visitors, military activity, and the volume of imports
- Hawaii has good data published by the Bishop Museum — long-term records with dates of introduction
    - Taking that whole dataset and relating the vector shows vessel fouling likely
- Need more incentives to keep boat hulls clean
- A total of 30 non-native ascidians are found in Hawaii—only one is cryptogenic; the rest are introduced, and all are believed to be introduced via ship fouling
- Analysis of source region: board range of potential source regions
- Recent example of a native ascidian potentially killing coral
- Response and preparedness requires a field team to detect and respond quickly, an AIS program, local citizens and community partners, and preparation consisting of a risk assessment tool and AIS management plan
- Gaps including understanding impacts, creating an AIS program with staff and building a more rapid response network and protocols

JESSE SCHULTZ, WASHINGTON DEPARTMENT OF FISH AND WILDLIFE

The Washington Department of Fish and Wildlife is the lead regulatory agency to prevent the introduction or distribution of aquatic invasive animals in Washington. The recent passage of Senate Bill 6040 will reclassify invasive tunicates, currently listed as "Unlisted Aquatic Animal Species." RCW 77.135.040 has three prohibited levels of species (level 1, level 2 and level 3), and three regulatory types (type A, type B, and type C). Tunicates will default to the regulated type B or C.

From 2006–2011, an invasive tunicate management program was funded in consultation with a stakeholder Tunicate Response Advisory Committee (TRAC), a group established by the Puget Sound Partnership (PSP) and comprised of representatives from agencies, tribes, NOGs and industry stakeholders.

At the 2009 Sixth International Conference on Marine Bioinvasions, WDW and PSP surveyed ascidian experts worldwide to assess the risks of invasive tunicates to Puget Sound. It was determined that *D. vexillum*, *S. clava*, and *C. intestinalis* pose the greatest risks to Puget Sound based on threats to ecosystem health, aquaculture industries, wild-stock harvests, and infrastructure. *C. intes*tinalis was identified as the highest priority for eradication.

One outcome of these discussions was the decision to develop an invasive tunicate management plan to:

1. Prevent the introduction of new invasive tunicates (a field-ready rapid response team was created)
2. Control, contain, or eradicate established invasive tunicate sites (Dockton Park was chosen as a site for removal of tunicates from vessel hulls at marinas)
3. Predict and detect new or recurring invasive tunicate sites (presence/absence surveys)
4. Coordinate/collaborate in state, regional, national, and international invasive tunicate processes (a tunicate management plan was developed)

5. Promote public education and volunteer opportunities (an education campaign was created and the Washington Dept. Fish and Wildlife website was used as a resource tool)
6. Promote biodiversity and restoration (research was compiled on the effects of control on native species at Dockton Park)

Note: See Section C of this report for more details on Dockton Park.

Current and future management activities include continuing the Dockton Park surveys (and removing any *D. vexillum* present), confirming and documenting new sightings, updating WDFW's website, and addressing emergency situations.

GLENN DOLPHIN, OREGON STATE MARINE BOARD

- No state management plan for tunicates—Committee has formed to develop an action plan for tunicates:

  Steve Rumrill – ODFW
  Glenn Dolphin – OSMB
  Bruce Hansen – USFS
  Robyn Draheim – USFWS
  Mark Sytsma – PSU
  Catherine de Rivera - PSU
  Sam Chan – OSU
  Jamie Doyle – OSU
  Richard Emlet – U of O - OIMB
  Lanelle Comstock – Port of Coos Bay
  Mike Dunning – Port of Coos Bay
  Lorne Curran – Oregon Coast Aquarium – Volunteer Scientific Diver
- A risk assessment was completed for *D. vexillum* by the Oregon Department of Fish and Wildlife in 2010 and updated in 2014. The assessment was based on the format used by the Exotic Forest Pest Information System for North America. The assessment determined *D. vexillum* was a high risk (83% rating), with a numerical risk factor of 12.5 (on a scale from 1–15).
- *D. vexillum* was first discovered in Charleston Marina in Coos Bay and the "Triangle Area" at mouth of Umpqua River (Winchester Bay) in 2010 by recreational/scientific divers.
  - Diver monitoring of both populations has been ongoing, 1-2 dives per year from 2010 – 2014 (most dives have been at the triangle area).
  - Dock surveys and in-water dives completed at six estuaries (Nehalem, Tillamook, Depoe Bay, Yaquina, Winchester and Coos) in Oregon during 2010 + 2011 with no new detections of *D. vexillum* found.
  - Follow-up surveys were scheduled for 2013 but were cancelled due to Federal Government shut-down when surveys were scheduled to occur.
  - Monitoring for tunicates continues, 1–2 dives per year
- Many boats remain moored in marinas and become breeding grounds for biofouling
- Jetty and survey work shows tunicate populations are increasing
- There are plans to conduct dock wrapping in Charleston marina – this was conducted in 2012 at three finger docks; after two weeks, it seemed as though everything was dead. Docks towed to freshwater had similar results.
- Tunicates may be able to grow back from just a few cells of specific tissue.
- Current management/action plan is aimed at suppressing and controlling populations, and includes steps to engage more with the oyster facility in the Winchester Triangle to help control waste water processing
- *D. vexillum* is not on the invasive species list for Oregon.

MARTHA VOLKOFF, CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE

Status of invasion: Widespread and many species. The following species have been documented in California:

Species	CA Discovery Year
Ciona intestinalis	1897
Styela plicata	1915
Diplosoma listerianum	1917
Styela clava	1932
Botryllus schlosseri	1947
Molgula manhattensis	1949
Botrylloides violaceus	1966
Styela canopus	1972
Botryllus sp. A Lambert	1980
Ascidia sp. A Lambert	1983
Ascidia zara	1984
Ciona savignyi	1985
Microcosmus squamiger	1986
Symplegma reptans	1991
Bostrichobranchus pilularis	1992
Didemnum vexillum	1993
Molgula ficus	1994
Polyandrocarpa zorritensis	1994
Botrylloides perspicuum	1997
Perophora japonica	2003
Molgula citrina	2011
Botrylloides sp. A Lambert	unk

A non-native tunicate, Molgula citrina, was found at 2 sites in Humboldt Bay during the Marine Invasive Species Program 2011 survey. Native to the North Atlantic, it was previously recorded in the Pacific in Alaska in 2008 (Lambert et al. 2010) and Oregon in 2010 (Chapman et al. 2011), but is new to California. Its Atlantic distribution ranges from northeast North America to Great Britain and northern Europe. The most likely vector of introduction is via ship sea chests (Lambert et al. 2010).

Management activities:

The State's greatest efforts have focused on vector management and monitoring:

California Ballast Water Management Act (1999) - Three state agencies share responsibility for managing ballast water: Fish and Wildlife, State Water Resources Control Board, and State Lands Commission. Fish and Wildlife was required to conduct a study to determine the location and geographic range of introduced species populations along the California coast. The Department's Marine Invasive Species Program receives funds from the Marne Invasive Species Control Fund to continue conducting biological surveys at major ports to determine the level of invasion by non-native species via ballast water.

Marine Invasive Species Act (2004) – Extended the Marine Invasive Species Program and expanded scope to include coastwise traffic and a baseline survey of outer coast habitats to supplement prior data collected up to 2002. Extended monitoring to determine whether new introductions have occurred since the original baseline.

Coastal Ecosystem Protection Act (2006) – Extended the Marine Invasive Species Program again (making it ongoing), and expanded its scope further to include hull-fouling introductions, annual posting of database online, reporting results to the Legislature, and an assessment of the effectiveness of the Program at controlling introductions from ship-related vectors.

California Aquatic Invasive Species Management Plan (2008) - Developed a framework for agency coordination and identifies actions to prevent and manage invasive species.

Future plans:

Given the prevalence of non-native tunicates management efforts will likely continue to be focused on vector management (trans-oceanic and coastal movement) and monitoring.

Upcoming monitoring for tunicates will include sampling in ten major California estuaries over the next 4 years using PVC settling plates. Up to ten replicate plates each will be set at ten sites per estuary. For San Francisco Bay, there is continuous quarterly sampling. All plates are deployed for a three-month period. Samples also are analyzed using state-of-the-art genetic tools to assure consistent taxonomic assignment, identify cryptic and unresolved taxa, and build a robust molecular voucher database for rapid, high-throughput, and high-sensitivity NIS detection.

E. CAT DE RIVERA, PORTLAND STATE UNIVERSITY—ELEMENTS OF A WASHINGTON/OREGON TUNICATE MANAGEMENT PLAN

Marine biofouling invasions in the Pacific NW: assessing and managing potential pest species and vectors

Background and Aims:

Biofouling is a major vector (transfer mechanism) for marine nonindigenous species (NIS) introductions to West Coast bays and estuaries. Biofouling species are transferred unintentionally into and within the Pacific Northwest on the hulls and submerged surfaces of ships, recreational boats, fishing vessels, and maritime equipment as well as in association with other vectors (e.g. possibly aquaculture). There has been no comprehensive evaluation of the vector or the impacts and potential impacts of biofouling species in the region. The goal of this project is to create a framework (report) for assessing biofouling vectors and species in the region under the following headings: (a) an overview of current knowledge regarding biofouling invaders, (b) an assessment of vector operations in the region, (c) an account of information gaps and research needs (d) control and management plans and (e) outreach options.

Overview of Current Knowledge on biofouling invaders

This component will frame the issue of marine biofouling invasions in the Pacific Northwest. It will provide a brief summary of invasion history (a task already underway for a separate report) and specific case-study examples of potential biofouling pests in the region (e.g. *Didemnum vexillum*).

An assessment of vector operations in the states

This will comprise reviews and new data generation across several biofouling vector sources:

- **Commercial Shipping** – a summary of contemporary arrival patterns and state management (DEQ) of commercial vessel biofouling
- **Fishing Boats** – an analysis of port connectivity using a dataset already acquired
- **Recreational boats** – a pilot scale survey of Coos Bay marina to evaluate boater maintenance and voyage patterns; interaction with Oregon State Marine Board and the Clean Marina program; an assessment of state boating infrastructure; data mining of marina transient visitor arrivals
- **Other vessel vectors** – an assessment of maritime infrastructure, stochastic vessel movements, work barges, etc.
- **Aquaculture vectors** – an evaluation of historical and contemporary aquaculture vector practices
- **Other biofouling** – a brief assessment of biofouling associated with bait shipments, seafood or any other mechanism.

An account of information gaps and research needs

Using information from the components above, identify important gaps in knowledge about biofouling species, vectors, and locations:

- Statewide boater movements on the coast and hull sampling.
- What monitoring is a priority at community and population levels?
- Evaluate impacts of species established in the region.
- How effective and feasible are eradication attempts (e.g. for *D. vexillum*)?

Control and management plans

Evaluate the need and utility of policy plans to cover pre-border (vector), post-border (spread) and post- establishment (control/eradication) of biofouling invasions?

- Design a biofouling vector management plan.
- Design a pro-active policy framework, or decision matrix, for managers (why control, why eradication, why do nothing).
- Design a re-active management framework for a vector event (e.g. a detection of a species on a vessel that has arrived)
- Design a re-active management framework for established recognized pests (using *D. vexillum* as an example), including biological information requirements, logistical considerations, and funding needs.

Outreach options

Evaluate previous and existing outreach to salt-water boaters in the state:

- "Have you seen this species" campaign
- Hull husbandry outreach to boater populations
- Interaction with existing groups – e.g., Coos Bay citizen science group, Clean Marina Program
- How could a citizen science network be established (piggy-back into the SERC plate watch project)

- Design an outreach campaign (e.g. promoting awareness of boats as vectors and solutions to prevent species transfers) with before-and-after polling (social science) to evaluate the effect of outreach.

F. Breakout Sessions

RISK ASSESSMENTS

Attendees participated in three breakout sessions to address the following questions to inform the potential development of a regional action plan:

- Risk Assessments—Have you used risk assessments – why/why not? If not, what was the basis to act and devote resources to response/control? If yes, what RA method was used, what worked and didn't work, and what gaps existed that would have made the RA process easier? Should RA be considered before response? What type of work needs to be done to better evaluate risk to the ecosystem and economy? What is the status of our understanding of impacts and how can we plug the gaps?
- Funding—What opportunities exist to generate revenue to support response efforts? What other funding needs exist (e.g., monitoring)?
- Management Options—What management options are effective and ineffective under various circumstances and why?
- Research—What major research gaps need to be filled, and in what priority order should these proceed? Identify the top 3–5 needs.
- Collaboration—In what specific ways can response agencies work together to combat new introductions and manage the spread of existing tunicate populations?
- Regional Plan—What are the pros and cons of developing a regional management plan, similar to *Spartina*? Would such an approach improve control and eradication success and increase opportunities for funding? What elements should be included in a regional plan?

The following is the input received from the three groups, as well as topics discussed during the follow-up information sharing session:

RISK ASSESSMENTS

Have you used to risk assessments? Why or why not?

- Washington never completed a risk assessment.
- There is interest in responding before numbers become overwhelming but it is difficult to determine when that would occur.
- There is concern risk assessments would slow down the process.
- Risk assessments are often necessary in demonstrating a priority to constituents.
- Risk assessments are required to release some emergency response funds.
- Risk assessments help determine strategic investments in priorities.
- Risk assessments help determine the most likely vectors and where to put your energy.

What methods of risk assessments were used, what worked and didn't work, and what gaps existed that would make the process easier?

- Gaps
    - Identifying the source of invasive tunicates.

- Research.
- Monitoring – it is easier to find funds for action than for monitoring.
- Work is needed to better evaluate risk to systems; highlights need for local data, platform for viewing climate change variables.

- Nasty invasions raise awareness to managers and the public, creating attention for subsequent invasions.

Should RA be considered before response? Why/why not?

- Couple data directly to vectors.
- Aquaculture development needs information for expansion.
- Showing economic impacts is important to bringing industry partners/stakeholders together.
- Yes - pulls all parts together into coherent assessment.
- Helps with funding and political will.

What type of work needs to be done to better evaluate risk to the ecosystem and economy?

- Research.
- ID vectors and their source.
- Define local impacts to economically important fish and wildlife species of concern.
- Need risk analysis (subsumes risk assessment, management, communication). If we don't have effective management, a risk assessment is not very useful. We need to know why, when, how will respond.
- Use multiple experts to review a risk assessment, then average the scores.
- Need consistent risk assessment model.

What is the status of our understanding of impacts, and how can we plug the gaps?

- Apply scenario impacts to other areas.
- Research on how invasive tunicates affects community structure.
- Are tunicates impacting ecosystems? Examples include *Didemnum vexillum* on Georges Bank, which is covering the bottom and creating barriers to groundfish feeding.
- Mary Carmen (WHOI) - Impacts of colonials on seagrass in New England.
- How to plug: funding, monitoring to have baseline about changes in population abundance and distribution as well as site vulnerabilities.

FUNDING

What opportunities exist to generate revenue to support response efforts?

- Federal Funding, or state Capitol improvement project $ from legislature.
- Governor emergency funds, PSWQAT
- National Sea Grant – citizen science
- Mitigation banking
- User fees
- Industry-based monitoring
- National movement to establish response fund (Schumer bill).
- Elevate awareness of issues as priorities to agencies/entities that fund projects.

- Add invasive species, AIS monitoring, risk assessment costs, and monitoring to requests for proposals.
- Proposed Funding model: user specific fees okay if users (boaters) see benefits and there is large corporate (shippers) match. Hunting and fishing licenses revenue increases require outreach and education with stakeholder groups.
- Mitigation often needed, but there's not always mitigation available. Can non-native species work qualify as mitigation work?
- Funding that helps clean the water (sewage treatment).
- Ballast water fees.
- Institute rules that key vectors (e.g., shipping) must pay for invasive species research, monitoring –publication should be mandatory.

What other funding needs exist (e.g., monitoring)? Please be as specific as possible (e.g., if monitoring, what types of monitoring, where, how frequent?).

- Taxonomic ID, genetics.
- Ecotourism (investment in "sustainability" etc.) Gary – tour company and green crab.
- High-risk vector inoculation areas.
- Outreach and education woven into monitoring (plus evaluation etc.) – community supplies support for project.

MANAGEMENT OPTIONS

What management options are effective under various circumstances and why?

- PREVENTION, PREVENTION, PREVENTION
- EDRR (including early ID)
- Target source populations, interception points/ find management boundaries.
- Develop fouling guidance BMPs (regulatory part is tricky).
- Watch overlap and evolution from ballast water to hull fouling.
- Use carrots and sticks.
- Ensure management and coordination plan in place *a priori*.
- Vector management, e.g., ballast water and biofouling of vessels & submerged structures.
- Enact clean water discharge requirements, which reduce the tunicate food supply.
- Prioritize.
- Engage the public/community to elevate cooperation and response.
- Focus on what is possible (scale).
- Add decreasing man-made habitat suitability/areas for early colonization of new invaders to a list of potential management actions (improve WQ, decrease disturbance, remove derelict pilings, etc.).
- **[GAP]ID rapid response authorities (needed organizational structure).**

What management options are ineffective under various circumstances and why?

- Eradication of some species, e.g. *D. vexillum.*
- Scale response to infestation.
- Lack of monitoring post treatment.
- Enforcement and/or action not coupled to species identification.
- Management actions not tied to entire infestation area/vectors able to re-infest.

- In situ cleaning of hulls (e.g., for recreational and fishing vessels) – needs to be rule against this.
- Address the population, not the vector.

What major research gaps need to be filled, and in what priority order should these proceed? (Note: top 3 priorities identified in bold)

- Baseline monitoring.
- Understanding climate change and range expansion effects.
- Economic impacts to important species, priority fish and wildlife resources, ecosystem level impacts.
- Impacts of introduced filter feeders.
- **ID vector pressures (large scale introductions, secondary movement) and efficacy of management of vectors.**
- **ID source population.**
- Habitat suitability models.
- Basic ecology, genetics, physiology, other biology.
- Evaluation of need for/effectiveness of management options (including none).
- Secondary spread from infested 'hubs' (main pathways: recreational boating, towed docks, drilling rigs in AK, research buoys, fishing camps, etc.).
- In-water mechanical cleaning.
- Better understanding of AIS impacts - and articulating ecological, economic, and social effects.
- Early detection methods.
- Controlling invasions on natural substrates and developing methods of control.
- **Social marketing (especially for boaters – what are their core values?) and collaborations with social scientists.**

COLLABORATION

In what specific ways can response agencies work together to combat new introductions and manage the spread of existing tunicate populations?

- Involve recreational boating community via ports and marinas to prevent/minimize spread.
- Collaborate w/ social scientists to facilitate outreach and engage various segments of the community (social marketing).
- Involve commercial fisheries associations.
- Agreement between governments and industry on process to follow before management actions.
- Have contact network in place for emergency response including specific roles; e.g., incident command system.
- Establish cross border commitments and agreed upon reciprocal actions.
- Contact list for different taxa of novel species; '100 worst approach'.
- Roles for invasive species councils and task force; states (whichever one is deciding on an action) should lead the collaborations unless it's an instantaneously multi-state issue (e.g. w/ tsunami debris) in which case a good federal role is funding and a directive to take some action.

- West Coast Tunicate Working Group (coordinating body, bring people together, charismatic passionate leader, industry participation).
- Model legislation, adopt regional standards, follow BW and other regional successes.
- National Sea Grant Law Center.
- Poster child.

REGIONAL PLAN

What are the pros and cons of developing a regional management plan, similar to *Spartina*?

- PROS: Captures country, State/Province, individual bay scales.
  - Goals: addresses broader vectors (connectivity); enhances communication; may provide basis for individual action plans.
- CONS: may become large and cumbersome.

Would such an approach improve control and eradication success and increase opportunities for funding?

- Would increase opportunities for state and federal funding.
- Could approach the Western Governors Association/PNWER for endorsement.
- IUCN conference in HI in 2016.

What elements should be included in a regional plan?

- **Important to consider what the plan is to be used for.**
- Multi-species focus; need to prioritize species.
- Include the recreational boating sector.

G. Case studies

Breakout groups then walked through individual case studies in Washington, Oregon, and British Columbia to identify key strengths and weaknesses of existing protocols and response/control structures to address invasive tunicates.

H. Elements of a Regional Marine Invasive Species Plan

Attendees then discussed the core elements of three plans:

- WCGA Regional *Spartina* Eradication ACT Work Plan (2010)
- Washington State Tunicate Plan (2007-2009)
- Western Australia Eradication and Control Methods Document (2014)

Using the framework provided by Cat deRivera in an earlier presentation, the group proposed the first key step in the development of a regional plan would be to articulate the plan purpose.

The core elements of such a regional marine invasive species plan would include:

A. OVERVIEW OF CURRENT KNOWLEDGE ON VECTOR-RELATED BIOFOULING IN REGION

- Commercial shipping
- Commercial and recreational boats
- Other vessel vectors

- Aquaculture vectors
- Other (bait, seafood, other)
- Floating docks, barges, and other floating structures
- Dept of Defense
- Marine-based alternative energy
- Oil and Gas guidelines exist without enforcement

B. ASSESSMENT OF REGIONAL VECTORS

Conduct risk assessments to identify likelihood of establishment, impact, spread, and to inform priorities and strategic investments

- Use multiple experts to review, then average the scores.
- Develop consistent risk assessment model.
- Existing laws and regulations should be analyzed (possibly in Policy section).
- Cross-walk significant differences within the region on regulation.
- Rapid response with tiers of assessments.

C. INFORMATION GAPS AND RESEARCH NEEDS (NOTE: THE TOP THREE PRIORITIES ARE BOLDED).

- Biology of native predators as a tool for control.
- Library of case studies.
- Habitat suitability (environmental niche modeling) feed into a risk assessment, biotic resistance into RA monitoring.
- Eradication successes and failures for each species.
- Identification of most important vectors in the region.
- Monitoring procedures – pre and post detection, early detection vs measurement of changes.
- Basic research on biology, tolerances of invasives, ecology.
- Impacts.
- Areas less likely for colonization; natural barriers to spread.
- Mandatory publication and sharing of research.
- **Taxonomic ID, genetics.**
- Understanding climate change and range expansion effects.
- **Impacts of introduced filter feeders.**
- In-water mechanical cleaning.
- Early detection methodology.
- Developing methods of control.
- **Collaboration with social scientists.**
- Education on basic biology to general public.

D. MANAGEMENT

- Communication network among managers.
- Look at other examples for strategies of protocols (snails, e.g.).
- Review of current management plans in and beyond the region.
- Management tools
    - Vector management plan.
    - Proactive decision matrix for managers.

    - Reactive management framework for a vector event.
    - Reactive management framework for established recognized pests.
- Management BMPs
    - Prevention.
    - EDRR.
    - Target and manage source vectors.
    - Fouling guidance.
    - Establish priorities.
    - Potential management actions – reduce man-made habitat suitability/areas for early colonization of new invaders.
    - Rapid Response authorities, roles and responsibilities.
    - Monitoring protocols.
    - Improving permitting process to improve reaction time.
    - Permitting to collect is a hurdle.

E. OUTREACH AND "INREACH" STRATEGIES

- Identify affected users and their motivations (boaters, divers, etc.).
- Outreach to salt water boaters
    - "Have you seen this species?" campaign
    - Hull husbandry outreach
    - Interaction with existing groups/programs, e.g. Clean Marina
    - Citizen science network
    - Conduct outreach campaign with polling to evaluate effectiveness
- Inreach (e.g., key messages) to agencies that fund projects.
- Use examples (e.g., Caulerpa, polychaete) to tell the story and create attention for subsequent invasions – "poster child" approach.
- Weave outreach into monitoring to raise awareness/gain community support.

F. POLICY AND REGULATORY FRAMEWORKS

- Evaluate the utility of policy for vector, spread, and control of non-native species.
- Model legislation, adopt regional standards, follow BW and other regional successes - National Sea Grant Law Center.
- Crosswalk of regulations across states.
- Identify who has responsibility or authority for what.
- Identify policy gaps and take steps to fill them.
- Recreational boat permit to generate funds for invasive species prevention and management.

G. IMPACTS OF MARINE INVASIVES (ECONOMIC, ENVIRONMENTAL, SOCIAL)

- Economic
    - Every and all costs; ecosystem costs
    - Aquaculture industry effects/costs
- Environmental
    - Restoration projects
    - How are they impacting ecosystems, ecosystem function, native species?

- Social/Cultural
    - Impacts to recreation and cultural practices
    - Human health
- Ecosystems connections and their functions
- Developing the tools to make those assessments on impacts
- Apply scenario outcomes to other areas – e.g., infectious polychaete

H. FUNDING/BUDGET

- Vector fees (ballast water, e.g.)
- Governor Emergency funds
- Federal funds
- Mitigation funds (tied to net loss of wetlands, waters of the United States)
- Sewage treatment funds
- Mooring tax
- Identify existing or potential funds to implement a plan
- Create agreements with possible funding sources to be ready to implement portions of plan
- Marine fuel taxes separate from other transportation taxes
- Tourism fee or tax
- Develop a budget for a regional plan
    - Possibly for the first tier of priorities

I. MONITORING

It was acknowledged that the scope of "monitoring" should be articulated before entities could move forward with describing what elements of monitoring would be emphasized in a regional plan. The following elements could be considered.

- BMP protocols.
- Monitoring will be goal based; scope with priorities.
- Capitalize on working with the public and citizen scientists with good guidance on id and recording useful date and help fill gaps.
- Communicating a new species discovery within WRP Coastal Committee.
- Ancillary permitting requirements for other species ID.
- Utilize industry as citizen monitoring.
    - Survey frequency
    - Vector-based (aquaculture, marinas)

J. COLLABORATION OPPORTUNITIES

- Involve stakeholders in the decision making (a more diverse set of interest groups that were not represented need to be included moving forward).
- Involve recreational boating community.
- Evaluate the outreach value.
- Collaborate w/ social scientists to facilitate outreach.
- Involve commercial fisher associations.
- Agreement between governments and industry on process to follow before actions.

- Have contact network, roles and responsibilities in place.
- Establish cross border commitments/reciprocity.
- Contact list for different taxa of novel species; '100 worst approach'.
- West Coast Marine Invasives Working Group (coordinating body, bring people together, charismatic passionate leader, industry participation).
- Embrace a poster child.

I. Development of a Regional Plan

Discussion about whether or not a regional plan should be developed included:

- It is very important to determine and agree upon what the plan will be used for.
- There has to be "power" behind the plan if the effort will be made to create it.
- Use ballast as a model for biofouling management efforts.
- Identify gaps and use a regional plan to increase communications among entities, enlarge the Washington tunicate plan.
- A regional plan would give assurance that various states have a program in place for reduction of propagules.
- Pacific Ballast Water group functions as coordination for rules, BMPs; could hull fouling be addressed by the Western Governors group using that same level of coordination?
- There needs to be a regional commitment to move forward to improve communication and relationships.
- The decision needs to be made re: whether or not the plan is vector- or species-based.
- A plan would justify the funding of the implementation of the plan.
- A plan could initiate more partnership and funding.
- Perhaps the Coastal Committee (CC) with the WRP could be the vehicle to bring interested people together, but will need people to participate and give time.
- A regional approach is needed prior to the funding so that we invest in something that our neighbors can agree to.
- The WRP Quagga Zebra Action Plan plan does have budgets in it, but there was no initial funding – because of pressure, some funding now exists.
- A USFWS intern will be fleshing out all of the information on a regional *Didemnum* plan, but will also discuss other biofouling issues, general response plan and areas that may not have been addressed.
- A species approach for a plan lends itself to the control/eradication plan, whereas the vector approach for a plan addresses the prevention aspect, how should we prioritize.
- General purpose to improve coordination and communication for existing and new infestations in the first step of this would be to identify a lead for this. Would PSMFC be willing to lead this effort?
- WGA or WCGA, PNWER could support and fund to advance the development of a plan, tie this with Cat/Robyn intern effort? WRP Coastal Committee should play a critical role in communication and could play a coordination role.
- Scoping of this plan - what will have more traction in terms of possible groups support and move it forward, what is a good fit for approaching others? This could be defined by this group or PSMFC - scoping issue is critical.

- Southern California needs to be included. CALState University system has an organization called COAST to create cross communication across campus and funding; they could be addressed for getting them to take on the banner of IS.
- Industry participation is critical for a plan that others will buy into.
- How does BC fit into this, would they be captured somehow? Yes, via PNWER.
- 2014 WRP CC informal polling in setting priorities for 2015 - the group was very keen on working on vectors.
- The PSGA covers the entire West Coast growers and some in HI - any regional plan should consider the shellfish growers

Coming together is a beginning;

Keeping together is progress;

Working together is success.

~ Henry Ford