Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

Scientific Name: *Ciona savignyi*

Common Name *Pacific transparent sea squirt*

Phylum	Chordata
Class	Ascidiacea
Order	Enterogona
Family	Cionidae

Final Rank 52.25

Data Deficiency: 0.00

Species Occurrence by Ecoregion

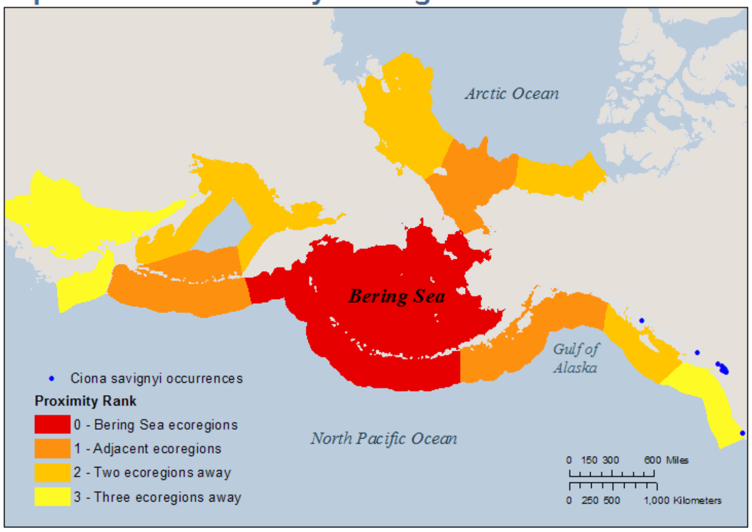

Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

Category Scores and Data Deficiencies

Category	Score	Total Possible	Data Deficient Points
Distribution and Habitat:	20.5	30	0
Anthropogenic Influence:	6	10	0
Biological Characteristics:	21.25	30	0
Impacts:	4.5	30	0
Totals:	52.25	100.00	0.00

General Biological Information

Tolerances and Thresholds

Minimum Temperature (°C)	-1.7	Minimum Salinity (ppt)	24
Maximum Temperature (°C)	27	Maximum Salinity (ppt)	37
Minimum Reproductive Temperature (°C)	12	Minimum Reproductive Salinity (ppt)	31*
Maximum Reproductive Temperature (°C)	25	Maximum Reproductive Salinity (ppt)	35*

Additional Notes

Ciona savignyi is a solitary, tube-shaped tunicate that is white to almost clear in colour. It has two siphons of unequal length, with small yellow or orange flecks on the siphons' rim. Although C. savignyi is considered solitary, individuals are most often found in groups, and can form dense aggregations (Jiang and Smith 2005).

1. Distribution and Habitat

1.1 Survival requirements - Water temperature

Choice: **B** — Moderate overlap – A moderate area (≥25%) of the Bering Sea has temperatures suitable for year-round survival

Score: 2.5 of 3.75

Ranking Rationale:
Temperatures required for year-round survival occur in a moderate area (≥25%) of the Bering Sea.

Background Information:
Based on this species' geographic distribution, it is estimated to tolerate water temperatures between -1.7°C and +27°C.

Sources:
NEMESIS; Fofonoff et al. 2003   CABI 2017

1.2 Survival requirements - Water salinity

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

Score: 3.75 of 3.75

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

Background Information:
This species' salinity tolerance ranges from 24 to 37 ppt.

Sources:
CABI 2017

1.3 Establishment requirements - Water temperature

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

Score: 1.25 of 3.75

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

Background Information:
A study by Nomaguchi et al. (1997) found that optimal temperatures for reproduction and larval growth varied between "warm-" and "cold-water" populations. Cold water groups produced gamete between 12 and 17°C, and optimal temperatures for larval development was between 12°C and 20°C. While embryos developed normally at 11°C, larvae could not metamorphose. In contrast, the warm-water group produced gametes between 22 and 26°C, and optimal development occurred between 15 and 25°C (Nomaguchi et al. 1997).

Sources:
Nomaguchi et al. 1997

1.4 *Establishment requirements - Water salinity*

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

Score: 3.75 of 3.75

High uncertainty? ✔

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

Background Information:
No information found.

Sources:
None listed

1.5 *Local ecoregional distribution*

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

Score: 2.5 of 5

Ranking Rationale:
This species has been reported from southeastern Alaska and to the west in southern Russia.

Background Information:
Old records report this species in southeastern Alaska (Behm Canal, Alexander Archipelago, 1903) and northern British Columbia (Stuart Island, 1937). This species is also found in Peter the Great Bay in southern Russia.

Sources:
NEMESIS; Fofonoff et al. 2003

1.6 *Global ecoregional distribution*

Choice: C In few ecoregions globally

Score: 1.75 of 5

Ranking Rationale:
This species has a restricted global distribution. It is native to the northwest Pacific, and has been introduced to the west coast of North America, where it has a discontinuous distribution. In 2010, it was recorded for the first time in New Zealand. With the exception of an unverified report in Argentina, this species has not been found elsewhere.

Background Information:
This species is native to Japan, where it has spread as far north as Peter the Great Bay in southern Russia, Sea of Japan. In the early 20th century, it was collected in northern BC and southeastern Alaska. It occurs sporadically along the West Coast: in CA, it is found from Bodega Bay to San Diego, and in Puget Sound (WA), but it has not been recorded OR. In 2010, it was found in New Zealand, which the authors claim is the first report of this species' occurrence in the Southern Hemisphere (Smith et al. 2010). There are unverified reports of its occurrence in Argentina (Fofonoff et al. 2003).

Sources:
NEMESIS; Fofonoff et al. 2003

1.7 Current distribution trends

Choice:		Score:
A	Recent rapid range expansion and/or long-distance dispersal (within the last ten years)	**5** of **5**

Ranking Rationale:
This species is currently expanding its range in Washington.

Background Information:
This species is currently spreading in WA (Anderson et al. 2007). It can grow rapidly and form dense aggregations (Lambert and Lambert 2003). This species likely has limited natural dispersal abilities because adults are sessile and the larval stage is short-lived.

Sources:
CABI 2017 Lambert and Lambert 2003 Anderson et al. 2007

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

2. Anthropogenic Transportation and Establishment

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

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

Score: 2 of 4

High uncertainty? ✔

Ranking Rationale:
This species can be transported by fouling. Although it has limited natural dispersal abilities, it has been found in natural areas away from shipping traffic. Although further studies are needed, this information suggests that C. savignyi might be able to disperse without the assistance of anthropogenic vectors.

Background Information:
This species is likely dispersed by fouling ships and fishing gear. This species has limited potential for natural, long-distance dispersal, but divers in WA have found C. savignyi in areas several miles from the nearest marina (AISU 2011).

Sources:
AISU 2011

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

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

Score: 4 of 4

Ranking Rationale:
This species can establish on natural substrates in its introduced range.

Background Information:
In Washington, C. savignyi has been found growing on natural substrates such as rock, sand, and gravel. These populations were well-established and some occurred at high densities (Anderson et al. 2007). This species is an abundant fouling organism on ships and in harbors (Fofonoff et al. 2003).

Sources:
Anderson et al. 2007 NEMESIS; Fofonoff et al. 2003

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

Choice: B No

Score: 0 of 2

Ranking Rationale:
This species is not currently farmed.

Background Information:

Sources:
NEMESIS; Fofonoff et al. 2003

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

3. Biological Characteristics

3.1 Dietary specialization

Choice: **A**

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

Score: 5 of 5

Ranking Rationale:

This species is a generalist and its prey items are readily available in the Bering Sea.

Background Information:

C. savignyi is a filter feeder. It feeds primarily on phytoplankton, but also on zooplankton, bivalve larvae, and other suspended organic materials.

Sources:

NEMESIS; Fofonoff et al. 2003

3.2 Habitat specialization and water tolerances

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

Choice: **A**

Generalist; wide range of habitat tolerances at all life stages

Score: 5 of 5

Ranking Rationale:

This species has broad environmental tolerances at all life stages.

Background Information:

Adults can tolerate a wide range of temperatures and salinities. It is most commonly found at depths from 12 to 23 meters, but has been found at depths up to 100 m. This species grows on hard substrates, and prefers shaded areas in coastal, protected waters. It can tolerate polluted waters found near ports and marinas.

Sources:

CABI 2017   NEMESIS; Fofonoff et al. 2003

3.3 Desiccation tolerance

Choice: **C**

Little to no tolerance (<1 day) of desiccation during its life cycle

Score: 1.75 of 5

Ranking Rationale:

Both adults and juveniles have a low tolerance to desiccation. In laboratory and field experiments, no individual survived longer than 24 hours when exposed to air.

Background Information:

In laboratory experiments under controlled conditions, adults exposed to air died within the first hour, and all specimens died within 24 h (Hopkins et al. 2016). In outdoor trials, mortality occurred within 6 to 24 h. Individuals facing upwards died significantly faster (range 6–12 h) than those facing downwards (range 8–24 h). Sea spray and the presence of other fouling organisms did not have significant effects. Mortality of early life stages was greatest in the first 2 h (83%), with 100% mortality achieved after 8 h for all treatments (Hopkins et al. 2016).

Sources:

Hopkins et al. 2016

3.4 Likelihood of success for reproductive strategy

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

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

Score: 5 **of** 5

Ranking Rationale:

C. savignyi is hermaphroditic, and exhibits low parental investment, external fertilization, and a short generation time.

Background Information:

This species is hermaphroditic and can self-fertilize, but experiments have shown that "self" sperm is greatly outcompeted by "non-self" sperm (Jiang and Smith 2005). Fertilization is external, and gametes can persist for 1-2 days in the water column. C. savignyi is typically found in groups of several individuals. Individuals in a group simultaneously release gametes in response to an environmental cue (i.e., sunrise) (Jiang and Smith 2005). Planktonic, free-swimming larvae can survive 2-10 days in the water column. When a suitable substrate is found, larvae settle, undergo metamorphosis, and become sessile. Near Tokyo, Japan, C. savignyi reproduces year-round. Its lifespan varies from 2 to 6 months, and sexual maturity occurs in 2 to 3 months. Embryo development and hatching time decreases with increasing temperatures (Nomaguchi et al. 1997).

Fecundity estimates are not available for C. savignyi. However, there are estimates for a closely related species, Ciona intestinalis. Based on length and mass of oviducts and eggs, Petersen and Svane (1995) estimated that C. intestinalis produces between 2500 to 12000 eggs per oviduct, and used a conservative estimate of 10 000 eggs/individual in their modelling exercise.

Sources:

Jiang and Smith 2005 Nomaguchi et al. 1997 Petersen and Svane 1995

3.5 Likelihood of long-distance dispersal or movements

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

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

High uncertainty? ☑

Score: 0.75 **of** 2.5

Ranking Rationale:

Adults are sessile, but eggs and larvae can be dispersed passively. Although we did not find information on the dispersal distance of C. savignyi, studies on the closely related Ciona intestinalis suggest that natural dispersal is very limited.

Background Information:

Adults are sessile, but may disperse naturally by rafting on floating vegetation. Eggs and larvae can be dispersed passively by water currents. Larvae are also capable of active swimming.

Information on Ciona intestinalis, a closely related species: Natural dispersal is very short (0-3 m) and occurs primarily by drifting eggs and swimming larvae. Petersen and Svane (1995) found that their study population in Scandinavia was patchily distributed and highly localized within the cove. Dispersal to the outside was very limited (Petersen and Svane 1995). Similarly, a study in Nova Scotia found that larvae settled very close to adults (Howes et al. 2007).

Sources:

Petersen and Svane 1995 Howes et al. 2007 NEMESIS; Fofonoff et al. 2003

3.6 Likelihood of dispersal or movement events during multiple life stages

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

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

Score: 2.5 of 2.5

Ranking Rationale:
Adults are sessile, but eggs and larvae can disperse by drifting and/or swimming. Both gametes and larvae can remain viable in the water column for several days.

Background Information:
Fertilization is external, and gametes can persist for 1-2 days in the water column (Jiang and Smith 2005). When a suitable substrate is found, larvae settle, undergo metamorphosis, and become sessile. Larvae can exist in the water column for 2 to 10 days before settling.

Sources:
CABI 2017 Jiang and Smith 2005

3.7 Vulnerability to predators

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

Score: 1.25 of 5

Ranking Rationale:
Based on information from a closely related species, there are several taxa in the Bering Sea that are expected to predate upon Ciona savignyi.

Background Information:
No information was found for C. savignyi. However, eggs and larvae of Ciona intestinalis (a closely related species) were consumed by jellyfish. Adult predators include sea stars, fishes, crabs, and small snails (Petersen and Svane 1995; CABI 2017).

Sources:
CABI 2017 Petersen and Svane 1995

Section Total - Scored Points:	21.25
Section Total - Possible Points:	30
Section Total -Data Deficient Points:	0

4. Ecological and Socioeconomic Impacts

4.1 Impact on community composition

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

Score: 0.75 of 2.5

High uncertainty? ✔

Ranking Rationale:
C. savignyi is not as well-studied as its congener C. intestinalis, which has had significant impacts on the benthic community. However, the effects of C. intestinalis cannot be generalized to C. savignyi. For now, there is limited evidence that C. savignyi negatively impacts other marine organisms.

Background Information:
In southern California, C. savignyi may compete with C. intestinalis, another invasive tunicate. Frequent die-offs of both species make it difficult to determine the extent of competition, and environmental change seems to equalize their populations (Fofonoff et al. 2003). A study by Cordell et al. (2013) in Puget Sound found that C. savignyi, along with two other non-native tunicate species, did not have significant effects on the non-fouling community. Two species, the native solitary tunicate Corella inflata and the amphipod Monocorophium insidiosum, were more abundant at sites without C. savignyi (Cordell et al. 2013).

Sources:
NEMESIS; Fofonoff et al. 2003   Cordell et al. 2013

4.2 Impact on habitat for other species

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

Score: 0.75 of 2.5

Ranking Rationale:
By fouling substrates, this species may reduce available habitat for some organisms. Conversely, it may create secondary settlement habitat for others.

Background Information:
C. savignyi can form dense aggregations that can provide new habitat for fouling organisms. No specific impacts have been reported.

Sources:
NEMESIS; Fofonoff et al. 2003

4.3 Impact on ecosystem function and processes

Choice: **D** No impact

Score: 0 of 2.5

Ranking Rationale:
Considering its limited ecological impacts in its introduced range, this species is not expected to affect ecosystem functions in the Bering Sea.

Background Information:
No impacts have been reported.

Sources:
NEMESIS; Fofonoff et al. 2003

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

Choice: **D** No impact

Score: 0 of 2.5

Ranking Rationale:
This species may establish on or near bivalve shells; however, no impacts of C. savignyi on native bivalves have been reported to date.

Background Information:
In Washington, large populations of C. savignyi were found in and around geoduck beds, sparking concern that C. savignyi might negatively impact the Pacific geoduck (Panopea generosa) and other bivalve species (Anderson et al. 2007). However, no impacts have been documented to date. Efforts to study interactions between C. savignyi and P. generosa were unsuccessful (AISU 2011).

Sources:
Anderson et al. 2007   AISU 2011

4.5 *Introduction of diseases, parasites, or travelers*

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

Choice: **D** No impact

Score: 0 of 2.5

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

Background Information:
No impacts have been reported.

Sources:
NEMESIS; Fofonoff et al. 2003

4.6 *Level of genetic impact on native species*

Can this invasive species hybridize with native species?

Choice: **D** No impact

Score: 0 of 2.5

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

Background Information:
No impacts have been reported.

Sources:
NEMESIS; Fofonoff et al. 2003

4.7 *Infrastructure*

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

Score: 1.5 of 3

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

Background Information:
Ciona savignyi is an abundant member of the fouling community in southern California and in Puget Sound.

Sources:
Lambert and Lambert 1998

4.8 Commercial fisheries and aquaculture

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

Score: 0.75 of 3

High uncertainty? ✔

Ranking Rationale:
No negative impacts have been reported, but there is concern that C. savignyi might affect bivalves. Shellfish aquaculture currently occurs only in a restricted area of the Bering Sea (Mathis et al. 2015).

Background Information:
There are concerns that Ciona savignyi might negatively affect the Pacific geoduck or other bivalves (Anderson et al. 2007). The closely related Ciona intestinalis has had negative effects on the commercial shellfish industry by fouling gear, and by overgrowing and competing with shellfish species.

Sources:
Mathis et al. 2015 Anderson et al. 2007 CABI 2017

4.9 Subsistence

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

Score: 0.75 of 3

High uncertainty? ✔

Ranking Rationale:
No negative impacts have been reported, but there is concern that C. savignyi might affect bivalves and, in so doing, affect subsistence resources.

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

Sources:
Mathis et al. 2015

4.101 Recreation

Choice: D No impact

Score: 0 of 3

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

Background Information:
No impacts have been reported.

Sources:
NEMESIS; Fofonoff et al. 2003

4.11 Human health and water quality

Choice: D No impact

Score: 0 of 3

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

Background Information:
No impacts have been reported.

Sources:
NEMESIS; Fofonoff et al. 2003

Section Total - Scored Points:	4.5
Section Total - Possible Points:	30
Section Total -Data Deficient Points:	0

5. Feasibility of prevention, detection and control

5.1 History of management, containment, and eradication

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

Score: of

Ranking Rationale:

Control of C. savignyi populations have been attempted. Methods to control or eradicate invasive solitary tunicates are being studied.

Background Information:

From 2006 to 2009, SCUBA divers in WA monitored C. savignyi populations and removed infestations by hand. In some cases, vessels were so severely infested that the divers could not feasibly remove them (AISU 2011). No removals were conducted after 2009 because the control and eradication of C. savignyi was determined to be low priority. Hand culling is expensive and time-consuming, and unlikely to eradicate the entire population, especially if it consists of small individuals.

Exposure to anoxic or very low oxygen conditions was shown to cause complete mortality in C. savignyi. Wrapping docks fouled by C. savignyi with polyethylene tarps may be an effective management option to locally-control and reduce the spread of this tunicate species from marina habitats (Pool et al. 2013).

Five allelochemicals were tested on C. savignyi to see if they prevented larval metamorphosis (i.e. prevent transition to adult stage; Cahill et al. 2012). Three chemicals (radicicol, polygodial, and ubiquinone-10) inhibited metamorphosis and increased mortality. The authors propose that these chemicals have potential for future development in antifoulant formulations targeted towards the inhibition of metamorphosis in ascidian larvae (Cahill et al. 2012).

Sources:

AISU 2011   Anderson et al. 2007   Cahill et al. 2012   Pool et al. 2013

5.2 Cost and methods of management, containment, and eradication

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

Score: of

Ranking Rationale:

The methods currently available to control C. savignyi require major short-term investments.

Background Information:

Hand culling is expensive and time-consuming, and is not feasible when C. savignyi is very abundant. Wrapping docks fouled by C. savignyi with polyethylene tarps may control and reduce the spread near marinas (Pool et al. 2013). Chemicals that inhibit the establishment of C. savignyi could be used in antifouling treatments (Cahill et al. 2012), but such products have not been developed yet.

Sources:

Pool et al. 2013   Cahill et al. 2012   CABI 2017

5.3 *Regulatory barriers to prevent introductions and transport*

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

Score: of

Ranking Rationale:
This species is primarily transported by fouling ship. Compliance with federal fouling regulations remains voluntary.

Background Information:
In the U.S., Coast Guard regulations require masters and ship owners to engage in practices that will reduce the spread of invasive species, including cleaning ballast tanks and removing fouling organisms from hulls, anchors, and other infrastructure on a "regular" basis (CFR 33 § 151.2050). However, the word "regular" is not defined, which makes the regulations hard to enforce. As a result of this technical ambiguity, compliance with ship fouling regulations remains largely voluntary (Hagan et al. 2014).

Sources:
CFR 2017 Hagan et al. 2014

5.4 *Presence and frequency of monitoring programs*

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

Score: of

Ranking Rationale:
C. savignyi is listed as a species of interest on the Invasive Tunicate Network website.

Background Information:
In Alaska, the Invasive Tunicate Network and KBNERR conduct monitoring for non-native tunicates and other invasive or harmful species. The programs involve teachers, students, outdoor enthusiasts, environmental groups and professional biologists to detect invasive species.

Sources:
iTunicate Plate Watch 2016

5.5 *Current efforts for outreach and education*

Choice: **D** Programs and materials exist and are readily available in the Bering Sea or adjacent regions

Score: of

Ranking Rationale:
C. savignyi is listed as a species of interest on the Invasive Tunicate Network website.

Background Information:
Alaska's Invasive Tunicate Network and the Kachemak Bay National Estuarine Research Reserve (KBNERR) provide training opportunities for identifying and detecting non-native tunicates, and public education events on coastal and marine ecosystems more generally. Southeast AK hosts an annual Marine Invasive Species Bioblitz, which engages the public through education and hands-on activities. Field identification guides for native and non-native tunicates, as well as common fouling organisms, are readily available.

Sources:
iTunicate Plate Watch 2016

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

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