Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

Scientific Name: *Styela clava*

Common Name *club sea squirt*

Phylum	Chordata
Class	Ascidiacea
Order	Stolidobranchia
Family	Styelidae

Final Rank 55.25

Data Deficiency: 0.00

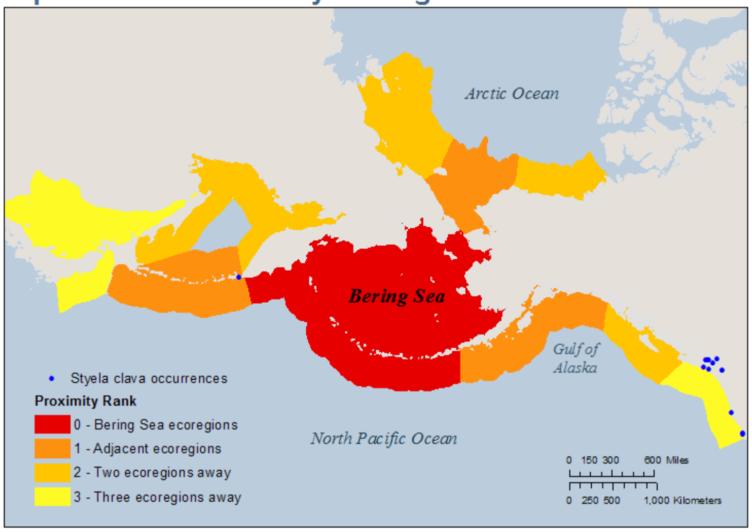

Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

Category Scores and Data Deficiencies

Category	Score	Total Possible	Data Deficient Points
Distribution and Habitat:	21.75	30	0
Anthropogenic Influence:	6.75	10	0
Biological Characteristics:	23	30	0
Impacts:	3.75	30	0
Totals:	55.25	100.00	0.00

General Biological Information

Tolerances and Thresholds

Minimum Temperature (°C)	-2	Minimum Salinity (ppt)	18
Maximum Temperature (°C)	27	Maximum Salinity (ppt)	35
Minimum Reproductive Temperature (°C)	15	Minimum Reproductive Salinity (ppt)	20
Maximum Reproductive Temperature (°C)	NA	Maximum Reproductive Salinity (ppt)	35*

Additional Notes

Styela clava is a small, solitary tunicate whose colors range from yellow to red to brown. It can attain a maximum length of 90 mm. It is native to the Northwest Pacific, from China to the southern Russia. It has become widely distributed in coastal waters through ship fouling, sea chests, and accidental transport with oysters.

Reviewed by Christina Simkanin, Marine Invasions Lab, Smithsonian Environmental Research Center, Edgewater MD

Review Date: 9/15/2017

1. Distribution and Habitat

1.1 Survival requirements - Water temperature

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

Score: 3.75 of 3.75

High uncertainty? ☑

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

Background Information:
Temperature range for this species is between -2°C and 26.6°C (based on geographic distribution).

Sources:
NEMESIS; Fofonoff et al. 2003

1.2 Survival requirements - Water salinity

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

Score: 3.75 of 3.75

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

Background Information:
The salinity range for this species is from 18 to 35 ppt (based on experimental data).

Sources:
NEMESIS; Fofonoff et al. 2003

1.3 Establishment requirements - Water temperature

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

Score: 0 of 3.75

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

Background Information:
In a survey of 260 European harbours, no specimens were found in sites where water temperatures do not exceed 16°C during the summer months, which is the temperature at which development of the gonad is thought to occur (Holmes 1968, qtd. in Davis and Davis 2007). Similarly, in PEI, Canada, S. clava began spawning when water temperatures reached 15°C. Larvae can tolerate colder temperatures as some were found in water samples with temperatures as low as ~11°C (Bourque et al. 2007).

Sources:
Bourque et al. 2007 Davis and Davis 2007

1.4 Establishment requirements - Water salinity

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

Score: 3.75 of 3.75

High uncertainty? ☑

Ranking Rationale:
We assume that this species can tolerate sea water up to 35 ppt. These salinities are found in a large (>75%) area of the Bering Sea.

Background Information:
In a survey of 260 European harbours, no specimens were found in water with salinity <20 PSU or >35 PSU (Davis and Davis 2007). A previous study suggested that larvae metamorphose at salinities between 20 and 32 (Kashenko 1996, qtd. in Davis and Davis 2007).

Sources:
Davis and Davis 2007

1.5 Local ecoregional distribution

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

Score: 3.75 of 5

Ranking Rationale:
This species is found in the Sea of Okhotsk (to the west) and on Vancouver Island.

Background Information:
This species is found on the west coast of North America from Baja California to Vancouver Island. Its native range is in Asia, from southern Russia (Kurile Island) to the East China Sea.

Sources:
NEMESIS; Fofonoff et al. 2003

1.6 Global ecoregional distribution

Choice: A In many ecoregions globally

Score: 5 of 5

Ranking Rationale:
This species is currently found in several cold- and warm-temperate regions of the southern and northern hemisphere.

Background Information:
Native to the Sea of Okhotsk, potentially as far north as 51°N. Along the western North American coast, it is found from Mexico north to Vancouver Island. Its distribution on the east coast extends from Prince Edward Island to Virginia. Introduced to southern temperate regions of Patagonia, Australia and New Zealand. In Europe, it was first introduced to England, and it now extends as far south as Spain and Portugal. It has made its way along the North Sea as far north as Limfjord and Kattegat in Denmark (57°N).

Sources:
NEMESIS; Fofonoff et al. 2003

1.7 Current distribution trends

Choice:		Score:
C	Established outside of native range, but no evidence of rapid expansion or long-distance dispersal	1.75 of 5

Ranking Rationale:

In PEI, where it reached high densities in just a few years, S. clava expanded its range by 12 km in 3 years. Its spread is thought to be facilitated by anthropogenic vectors, as natural dispersal is limited in this species.

Background Information:

In PEI, this species expanded its range rapidly since it was first reported in 2002. By 2006, it was found 12 km from the area where it was first detected. Its population increased to such a level that it became a nuisance species for the mussel industry within three years of detection.

Sources:

Arsenault et al. 2009

Section Total - Scored Points:	21.75
Section Total - Possible Points:	30
Section Total -Data Deficient Points:	0

2. Anthropogenic Transportation and Establishment

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

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

Score: 2 of 4

Ranking Rationale:
Once introduced, S. clava can be transported passively by water currents, or by rafting on vegetation. However, its patchy distribution in areas where it has been introduced suggests that this species has limited potential for natural dispersal.

Background Information:
The patchy distribution observed in Britain, in the eastern US, and in PEI suggests that natural larval dispersal is sporadic and does not necessarily lead to the colonization of neighbouring sites (Clarke and Therriault 2007; Darbyson et al. 2009). However, colonization of natural areas was observed recently in Argentina, where individuals of S. clava were found on mollusk beds several kilometers away from the presumed point of introduction (Pereyra et al. 2015).

Sources:
Clarke and Therriault 2007   Darbyson et al. 2009   Pereyra et al. 2015

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

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

Score: 2.75 of 4

Ranking Rationale:
This species can establish on natural substrates, but is found most often on anthropogenic infrastructure.

Background Information:
In both its native and introduced range, S. clava is more frequently reported from anthropogenic structures than from natural surfaces (Simkanin et al. 2012). For example, the successful establishment of S. clava in Malpeque Bay, PEI was largely dependent on the availability of hard substrate associated with anthropogenic infrastructure (Bourque et al. 2007). However, S. clava can also establish on rocks, and can grow epiphytically on bivalves and seaweed. In Argentina, where S. clava has been recently introduced, populations were found growing on bivalve beds, and high-density populations have established on rocky shorelines away from anthropogenic structures (Pereyra et al. 2015; Pereyra et al. 2017).

Sources:
Bourque et al. 2007   Simkanin et al. 2012   Pereyra et al. 2015   Pereyra et al. 2017

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

Choice: **A** Yes

Score: 2 of 2

Ranking Rationale:
This species is farmed for food in Asia.

Background Information:
S. clava is a popular food item in Korea and is extensively cultured on long lines in Korea and Japan.

Sources:
NEMESIS; Fofonoff et al. 2003

Section Total - Scored Points:	6.75
Section Total - Possible Points:	10
Section Total -Data Deficient Points:	0

3. Biological Characteristics

3.1 Dietary specialization

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

Score: 5 of 5

Ranking Rationale:
Food items are readily available in the Bering Sea.

Background Information:
Larval stage is non-feeding. Adults are sessile and filter feed on phytoplankton and oyster larvae.

Sources:
NEMESIS; Fofonoff et al. 2003

3.2 Habitat specialization and water tolerances

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

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

Score: 5 of 5

Ranking Rationale:
This species does not require specialized habitat for survival or reproduction. It can tolerate a broad range of temperatures and salinities, and has been found on a variety of substrates.

Background Information:
S. clava is most common in sheltered habitats with low wave action, such as inlets, bays, harbours and marinas (Lutzen 1999). In a survey of 260 European harbours, no specimens of S. clava were found in shallow exposed sites, supporting the observation that S. clava is intolerant of wave exposure (Davis and Davis 2007). Adults establish on a variety of anthropogenic and hard substrates, including docks, pilings, boat hulls, rocks, bivalves, and seaweed, but are more frequently reported from anthropogenic structures than from natural surfaces (Simkanin et al. 2012). It is often a secondary settler, settling on substrates already fouled by other species. S. clava was abundant in harbors with poor, fair, or good water quality (Carman et al. 2007). It can tolerate a wide range of temperatures and salinities (Clarke and Therriault 2007), although minimum temperatures and marine waters are required for reproduction and larval development.

Sources:
Lutzen 1999   Davis and Davis 2007   Carman et al. 2016   Simkanin et al. 2012   Clarke and Therriault 2007

3.3 Desiccation tolerance

Choice: B Moderately tolerant (1-7 days) during one or more stages during its life cycle

Score: 3.25 of 5

Ranking Rationale:

Depending on air temperature and sun exposure, S. clava can survive outside of water from < 24 hours to > 48 hours.

Background Information:

Aluminum and fiberglass hull material that had one-year-old [adult] tunicates growing on them were exposed to open air for 48 h during September (mean daytime high temperature 29.7˚C, night-time low 8.5˚C) (Darbyson et al. 2009). Nearly all tunicates were alive after 8 hours, and only 10 to 11 % mortality was observed after 48 h. High desiccation tolerance suggests that S. clava could survive overland transport (e.g. on a trailered boat), facilitating spread and increasing dispersal potential (Darbyson et al. 2009).

An experiment by Hillock and Costello (2013) considered three different treatments to test for desiccation tolerance in S. clava adults: 1) constant 10°C, 2) sun (25-27°C), and 3) shade (range: 15-27°C). Only the group held at 10 °C had any individuals surviving after 48 h. There was > 50% mortality amongst S. clava exposed to shade after 24 h, with 100% mortality after 48 h. In the group that was exposed to sun, no individuals survived after 24 h. A modelling exercise found that it would take 11 days for 99% of an S. clava population to die at 10°C. The authors suggest air exposure for at least two weeks to ensure complete mortality (Hillock and Costello 2013).

Sources:

Darbyson et al. 2009   Hillock et al. 2013

3.4 Likelihood of success for reproductive strategy

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

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

Score: 5 of 5

Ranking Rationale:

This species is hermaphroditic and highly fecund. Eggs are fertilized externally. S. clava has a short generation time.

Background Information:

Solitary tunicates cannot reproduce asexually (i.e. through budding; O'Clair and O'Clair 1998). This species is hermaphroditic, but not self-fertile. It exhibits external fertilization and low parental investment (Clarke and Therriault 2007). In PEI, S. clava exhibited seasonal reproduction brought about by warming water temperatures in early summer (Bourque et al. 2007). Davis (1997) estimated a production of ~ 5000 eggs per individual, which hatched after 12 to 15 h (qtd. in Davis and Davis 2007). S. clava reaches maturity around 10 months and can live 2 to 3 years (JNCC 1997, NIMPIS, 2002, Parker et al. 1999; qtd. in Global Species Invasive Data 2006). Upon maturity, this species has the ability to spawn every 24 hours (Biosecurity New Zealand 2005, qtd. in Clarke and Therriault 2007).

Sources:

O'Clair and O'Clair 1998   Davis and Davis 2007   Clarke and Therriault 2007   GISD 2016

3.5 *Likelihood of long-distance dispersal or movements*

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

Choice: **B** Disperses moderate (1-10 km) distances

Score: 1.75 **of** 2.5

High uncertainty? ☑

Ranking Rationale:

The dispersal distance of S. clava is unknown, but its distributional pattern suggests that natural dispersal is limited. In PEI, this species spread at a rate of 4 km/year, but anthropogenic vectors likely facilitated this expansion. In Argentina, S. clava has been found growing on bivalve beds several kilometers away from its presumed point of introduction.

Background Information:

S. clava is not able to spread long distances by most natural vectors because it has a relatively short planktonic larval phase of 12 to 36 hours (Stachowicz et al. 2002, qtd. in Darbyson et al. 2009). Pre-settlement metamorphosed juveniles do not actively swim, but may be passively dispersed short distances by water currents or rafting (Darbyson et al. 2009). Adults are sessile, but may be able to naturally disperse by rafting on floating vegetation. The patchy distribution observed in Britain, in the eastern US, and in PEI suggests that natural larval dispersal is sporadic and does not necessarily lead to the colonization of neighbouring sites (Clarke and Therriault 2007; Darbyson et al. 2009). A study by Darbyson et al. (2009) found that S. clava spread 12 km within 3 years, but the authors hesitate to attribute this spread entirely to natural dispersal. In Argentina, where this species likely established after 2012, S. clava was found growing on bivalve beds several kilometers away from its presumed point of introduction (Pereyra et al. 2015).

Sources:

Darbyson et al. 2009   Clarke and Therriault 2007   Pereyra et al. 2015

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

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

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

Score: 1.75 **of** 2.5

Ranking Rationale:

Both adults and larvae may be capable of passive dispersal. The larval stage is relatively short-lived, and usually lasts less than 1 day before undergoing metamorphosis.

Background Information:

The larval stage lasts between ~12 to 36 hours (Clarke and Therriault 2007; Darbyson et al. 2009). Natural dispersal is limited at all life stages. Larvae can disperse passively by water currents. Adults are sessile but may disperse by rafting on floating vegetation or debris.

Sources:

Clarke and Therriault 2007   Darbyson et al. 2009

3.7 Vulnerability to predators

Choice:		Score:
D	Multiple predators present in the Bering Sea or neighboring regions	1.25 of 5

Ranking Rationale:

This species is predated upon by several taxa which occur in the Bering Sea, including urchins, crabs, snails, and fishes.

Background Information:

An experimental study exposing S. clava to predators in BC found that S. clava experienced 100% mortality in treatments with the green sea urchin Strongylocentrotus droebachiensis, the red sea urchin Strongylocentrotus franciscanus, the red rock crab Cancer productus, and the European green crab Carcinus maenas (Epelbaum et al. 2009). It experienced 30% mortality with the sea star Evasterias troschelii. Two other species of sea stars were unable to kill S. clava (Epelbaum et al. 2009). The authors suggest that predation alone will not be sufficient to limit the establishment and spread of S. clava and other invasive tunicates in BC. Other predators include snails and fishes (Fofonoff et al. 2003).

Sources:

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

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

4. Ecological and Socioeconomic Impacts

4.1 Impact on community composition

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

Score: 0.75 of 2.5

Ranking Rationale:
Through competition and overgrowth, this species may lead to the decline of other fouling organisms. It may also have a negative impact on oyster populations by predating upon oyster larvae. Field studies have reported moderate to mild community effects.

Background Information:
In southern California harbors, it often forms dense patches with 100% cover, where it and other introduced ascidians have replaced native species (Lambert and Lambert 1998; Lambert and Lambert 2003). In English waters, the population growth of S. clava was paralleled by a decrease in Ciona intestinalis (Lutzen 1999). An experimental study showed that predation on oyster larvae by S. clava can greatly reduce settlement rate of oysters (Osman et al. 1989 qtd. in Clarke and Therriault 2007). In Argentina, it is believed to have facilitated the invasion of the seaweed Undaria pinnatifida by providing attachment sites for spores (Pereyra et al. 2015).

A field-based experiment by Ross et al. (2007) found a significant negative relationship between Styela density and the abundance of lumbrinerids, tanaids, crustaceans, and the bivalve Laternula rostrata. Nonetheless, these taxa only represent a small proportion of those present, and the effects emerged at Styela densities greater than what was typically recorded in the wild (>1 to 2 ind./m2). As a result, Ross et al. (2007) concluded that the effects of Styela on soft sediment assemblages in Port Phillip Bay were likely to be negligible (Ross et al. 2007).

Sources:
Ross et al. 2007   Clarke and Therriault 2007   Pereyra et al. 2015   Lutzen 1999   Lambert 2003   Lambert and Lambert 1998

4.2 Impact on habitat for other species

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

Score: 0.75 of 2.5

Ranking Rationale:
This species may simultaneously reduce habitat and create secondary habitat for fouling organisms. No specific impacts on habitat have been reported.

Background Information:
Dense aggregations provide secondary settlement substrates for other fouling organisms. At the same time, S. clava may compete for habitat (Clarke and Therriault 2007).

Sources:
NEMESIS; Fofonoff et al. 2003   Clarke and Therriault 2007

4.3 Impact on ecosystem function and processes

Choice: **D** No impact

Score: 0 of 2.5

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

Background Information:
No species-specific information found. Ascidians can play a positive role in some areas by filtering and sequestering heavy metals and other pollutants from the water (Lambert and Lambert 1998).

Sources:
Lambert and Lambert 1998

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

Choice: D No impact

Score: 0 of 2.5

Ranking Rationale:
This species is not expected to affect high-value species or communities in the Bering Sea.

Background Information:
No impacts reported.

Sources:
NEMESIS; Fofonoff et al. 2003 Clarke and Therriault 2007

4.5 Introduction of diseases, parasites, or travelers

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

Choice: D No impact

Score: 0 of 2.5

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

Background Information:
No impacts reported.

Sources:
NEMESIS; Fofonoff et al. 2003 Clarke and Therriault 2007

4.6 Level of genetic impact on native species

Can this invasive species hybridize with native species?

Choice: D No impact

Score: 0 of 2.5

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

Background Information:
No impacts reported.

Sources:
NEMESIS; Fofonoff et al. 2003 Clarke and Therriault 2007

4.7 Infrastructure

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

Score: 1.5 of 3

Ranking Rationale:
This species can severely foul and impact aquaculture and marine infrastructure.

Background Information:
Styela clava can grow in very dense populations, fouling boat hulls, docks, fishing gear, and aquaculture equipment. Densities as high as 500-1000/m2 have been recorded, especially on artificial substrates (Lützen 1999). In Denmark, S. clava is a major gear fouling problem for the cod, flounder and eel fisheries. In Prince Edward Island, mussel lines and floating docks have been weighed down by heavy growth of S. clava.

Sources:
Lutzen 1999   Clarke and Therriault 2007   NEMESIS; Fofonoff et al. 2003

4.8 Commercial fisheries and aquaculture

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

Score: 0.75 of 3

Ranking Rationale:
The shellfish industry in Alaska is estimated at $1 million (PSI Alaska 2017), but only occurs in a limited area in the Bering Sea. Revenues from shellfish are most important in the Gulf of Alaska and in southwest Alaska (Aleutians East through Lake and Peninsula; Mathis et al. 2015).

Background Information:
The largest economic impacts of Styela clava have been seen in Prince Edward Island, Canada. Dense populations foul cages ropes, and other gear used in fish aquaculture and mussel culture (Locke et al. 2007; Arsenault et al. 2009). S. clava also competes with cultured mussels, reducing mussel harvests by ~50%. This species is considered a serious threat to the long-term economic viability of the shellfish industry in PEI (Clarke and Therriault 2007). The estimated economic impact is CAN $34-88 million per year (Coulatti et al. 2006).

Sources:
Clarke and Therriault 2007   Mathis et al. 2015   PSI Alaska 2017

4.9 Subsistence

Choice: D — No impact

Score: 0 of 3

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

Background Information:
The impacts of Styela clava on shellfish result from S. clava fouling aquaculture infrastructure such as cages and mussel socks. No impacts on wild populations have been reported.

Sources:
Clarke and Therriault 2007

4.101 Recreation

Choice: D No impact

Score: 0 of 3

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

Background Information:
No impacts have been reported.

Sources:
NEMESIS; Fofonoff et al. 2003

4.11 Human health and water quality

Choice: D No impact

Score: 0 of 3

Ranking Rationale:
S. clava is not expected to have any impacts on human health or water quality in the Bering Sea.

Background Information:
In Japan, where this species is cultivated, it is responsible for an asthmatic-like condition in workers exposed to their fluids when detaching them from oysters (NIMPIS 2009; Cohen 2005 qtd. in Clarke and Therriault 2007). This effect is more likely to happen in poorly-ventilated work environments (Minchin 2008).

Sources:
Clarke and Therriault 2007 Minchin 2008 NIMPIS 2009

Section Total - Scored Points:	3.75
Section Total - Possible Points:	30
Section Total -Data Deficient Points:	0

5. Feasibility of prevention, detection and control

5.1 History of management, containment, and eradication

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

Score: of

Ranking Rationale:
Efforts to control S. clava are ongoing.

Background Information:
Control and eradication have been attempted in several regions, including Australia, PEI, and Washington. The success of management methods is context-dependent. Lowering water levels in power plants has been successful in controlling S. clava in Australia. In aquaculture settings, various combinations of salinity, temperature and exposure to air have proved successful in killing S. clava on oyster farms, without harming the oysters (NIMPIS 2009). Dipping of oysters or mussels in a brine solution is extremely effective at killing ascidians without harming oysters, but some treatments cause high mortality rates when applied to mussels (Carman et al. 2016). In PEI growers are using an acetic acid solution to treat mussel lines, but this method has limited success (Clarke and Therriault 2007).

Sources:
Carman et al. 2016   Darbyson et al. 2009   Clarke and Therriault 2007   NIMPIS 2009

5.2 Cost and methods of management, containment, and eradication

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

Score: of

Ranking Rationale:
The methods that are currently used need to be repeated for sustained population control to be achieved. With respect to aquaculture fouling, these methods may also cause mussel mortality.

Background Information:
Control methods include: exposing S. clava to air, or to brine or acid solutions, applying antifouling paints on ships and marine infrastructure, hand removal, and biocides. These methods have had various degrees of efficacy depending on the context of the study. Dipping of oysters or mussels in a brine solution is extremely effective at killing ascidians without harming oysters, but some treatments cause high mortality rates when applied to mussels (Carman et al. 2016). In PEI growers are using an acetic acid solution to treat mussel lines, but this method has limited success (Clarke and Therriault 2007).

Sources:
Clarke and Therriault 2007   Carman et al. 2016   Darbyson et al. 2009

5.3 Regulatory barriers to prevent introductions and transport

Choice: B Regulatory oversight, but compliance is voluntary

Score: of

Ranking Rationale:

This species is likely transported by fouling ship hulls and sea chests. Regulations to prevent the spread of species by fouling do exist, but compliance is voluntary.

Background Information:

According to Davis and Davis (2007), this species is more likely to have been transported to new areas by fouling protected areas in ships such as sea chests and bow thruster tubes. Transport of larvae by ballast water is unlikely, given that this species has a short-lived larval stage. In the U.S., Coast Guard regulations require masters and ship owners to clean vessels and related infrastructure on a regular basis (CFR 33 § 151.2050). However, because the word “regular” is not defined, regulations are hard to enforce and compliance remains largely voluntary (Hagan et al. 2014).

Sources:

Davis and Davis 2007   Hagan et al. 2014   CFR 2017

5.4 Presence and frequency of monitoring programs

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

Score: of

Ranking Rationale:

Styela clava is listed as a species of interest on the Invasive Tunicate Network website.

Background Information:

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

Sources:

iTunicate Plate Watch 2016

5.5 Current efforts for outreach and education

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

Score: of

Ranking Rationale:

Outreach and education programs are in place in Alaska to educate people on invasive tunicates. Styela clava is listed as a species of interest on the Invasive Tunicate Network website.

Background Information:

The Invasive Tunicate Network and the Kachemak Bay National Estuarine Research Reserve (KBNERR) provide training opportunities for identifying and detecting non-native fouling organisms, and public education events on coastal and marine ecosystems more generally. "Bioblitzes" were held in Southeast AK in 2010 and 2012; these events engage and educate the public on marine invasive species. Field identification guides for native and non-native tunicates, as well as common fouling organisms, are readily available.

Sources:

iTunicate Plate Watch 2016

Section Total - Scored Points:

Section Total - Possible Points:

Section Total -Data Deficient Points:

Literature Cited for *Styela clava*

- Arsenault, G., Davidson, J., and A. Ramsay. 2009. Temporal and spatial development of an infestation of Styela clava on mussel farms in Malpeque Bay, Prince Edward Island, Canada. Aquatic Invasions 4(1):189-194.

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