Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

Scientific Name: *Botryllus schlosseri*

Common Name *golden star tunicate*

Phylum	Chordata
Class	Ascidiacea
Order	Stolidobranchia
Family	Styelidae

Final Rank 57.95

Data Deficiency: 2.50

Species Occurrence by Ecoregion

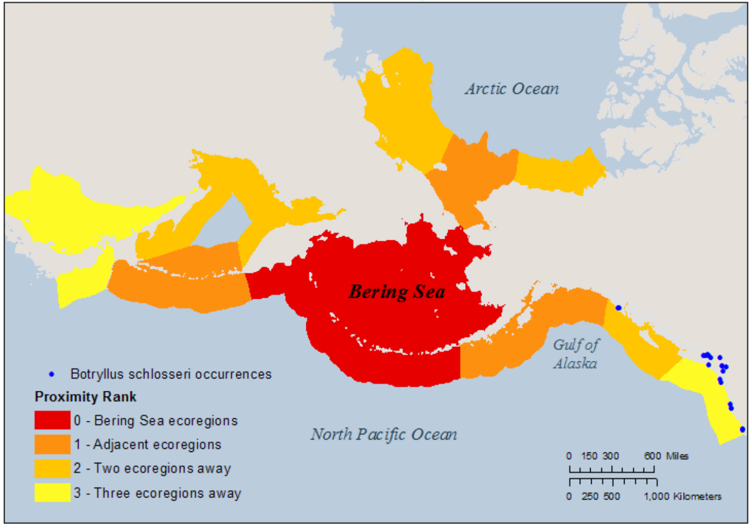

Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

Category Scores and Data Deficiencies

Category	Score	Total Possible	Data Deficient Points
Distribution and Habitat:	20.5	30	0
Anthropogenic Influence:	4.75	10	0
Biological Characteristics:	21.75	30	0
Impacts:	9.5	28	2.50
Totals:	56.50	97.50	2.50

General Biological Information

Tolerances and Thresholds

Minimum Temperature (°C)	-1	Minimum Salinity (ppt)	14
Maximum Temperature (°C)	30	Maximum Salinity (ppt)	44
Minimum Reproductive Temperature (°C)	11	Minimum Reproductive Salinity (ppt)	25
Maximum Reproductive Temperature (°C)	NA	Maximum Reproductive Salinity (ppt)	35*

Additional Notes

B. schlosseri is a colonial tunicate that grows in a flower- or star-shaped pattern. Its native range is unknown, but it is globally widespread and found in temperate waters in Europe, Asia, both coasts of North America, South America, South Africa, and Australia. In some areas of its introduced range, there is concern that B. schlosseri competes for space with native species, especially on artificial substrates where it can grow rapidly.

Reviewed by Linda Shaw, NOAA Fisheries Alaska Regional Office, Juneau AK

Review Date: 8/31/2017

1. Distribution and Habitat

1.1 Survival requirements - Water temperature

Choice: **B**

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

Score: 2.5 **of** 3.75

Ranking Rationale:

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

Background Information:

The temperature required for survival of B. schlosseri is -1°C to 30°C. Temperature tolerance varies with geographical location.

Sources:

Masterson 2007   NEMESIS; Fofonoff et al. 2003

1.2 Survival requirements - Water salinity

Choice: **A**

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

Score: 3.75 **of** 3.75

Ranking Rationale:

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

Background Information:

The salinity range required for survival of B. schlosseri is 14 ppt to 44 ppt.

Sources:

NEMESIS; Fofonoff et al. 2003   NIMPIS 2016

1.3 Establishment requirements - Water temperature

Choice: **C**

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

Score: 1.25 **of** 3.75

Ranking Rationale:

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

Background Information:

Reproduction of B. schlosseri has a lower temperature limit of 11°C (Brunetti et al. 1980).

Sources:

Brunetti et al. 1980   Masterson 2007   NEMESIS; Fofonoff et al. 2003

1.4 Establishment requirements - Water salinity

Choice: **A**

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

High uncertainty? ☑

Score: 3.75 **of** 3.75

Ranking Rationale:

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

Background Information:

Requires a minimum salinity of 25 ppt for reproduction (NIMPIS 2016). Upper reproductive salinity requirements are unknown.

Sources:

NIMPIS 2016

1.5 Local ecoregional distribution

Choice: C	Present in an ecoregion two regions away from the Bering Sea (i.e. adjacent to an adjacent ecoregion)	**Score:** 2.5 **of** 5

Ranking Rationale:

Background Information:
Found in Sitka, Alaska.

Sources:
NEMESIS; Fofonoff et al. 2003

1.6 Global ecoregional distribution

Choice: A	In many ecoregions globally	**Score:** 5 **of** 5

Ranking Rationale:
Wide global distribution.

Background Information:
In Europe, established in northern Norway, south to the Mediterranean. East to the Black and Red Seas. Found on oceanic islands including the Azores and Madeira (northwest Africa). Introduced to South Africa, India’s Bay of Bengal, and to Australia and New Zealand. Cryptogenic in Asia (China, Korea, Japan, southern Russia). In America, occurs on the West Coast from Sitka, AK to California, and in South America off the coasts of Chile and east to Argentina. On the east coast, found in Florida, north to Canada’s maritime provinces (Nova Scotia and Newfoundland).

Sources:
NEMESIS; Fofonoff et al. 2003

1.7 Current distribution trends

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

Ranking Rationale:
Can establish easily, but have limited natural dispersal abilities.

Background Information:
Once established, colonial tunicate species have the potential to reach sexual maturity within a few weeks and rapidly establish broodstock populations. Capable of reproducing asexually.

Was found in Sitka, Alaska in 2000, but does not seem to have spread anywhere else in Alaska (Davis 2010). However, a survey of non-indigenous species in British Columbia documented a northern range expansion of B. schlosseri (Gartner et al. 2016).

Sources:
Carver et al. 2006   Davis 2010   Gartner et al. 2016

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

2. Anthropogenic Transportation and Establishment

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

Choice: **B**	Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced	**Score:** **2** of **4**

Ranking Rationale:

Background Information:

Can be transported on ships due to hull fouling. Spread is likely due to the introduction of oyster culture. Found from California to Sitka, Alaska, and in the west from China to southern Russia.

Sources:

NEMESIS; Fofonoff et al. 2003

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

Choice: **B**	Readily establishes in areas with anthropogenic disturbance/infrastructure; occasionally establishes in undisturbed areas	**Score:** **2.75** of **4**

Ranking Rationale:

Can establish on both anthropogenic and natural substrates, but is more common on the former.

Background Information:

B. schlosseri is more commonly found on anthropogenic structures than natural surfaces, and is especially prevalent on dock floats (Simkanin et al. 2012).

Sources:

NEMESIS; Fofonoff et al. 2003 Simkanin et al. 2012

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

Choice: **B**	No	**Score:** **0** of **2**

Ranking Rationale:

Background Information:

B. schlosseri is not currently farmed or intentionally cultivated.

Sources:

None listed

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

3. Biological Characteristics

3.1 Dietary specialization

Choice: **A**

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

Score: 5 **of** 5

Ranking Rationale:
Filter feeder, phytoplankton.

Background Information:
B. schlosseri is a filter suspension feeder that primarily consumes phytoplankton.

Sources:
NEMESIS; Fofonoff et al. 2003

3.2 Habitat specialization and water tolerances

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

Choice: **A**

Generalist; wide range of habitat tolerances at all life stages

Score: 5 **of** 5

Ranking Rationale:
B. schlosseri has a wide range of temperature and salinity tolerances and has been reported in several different habitats.

Background Information:
B. schlosseri is a sessile organism as an adult being found on dock floats, pilings, piers, aquaculture structures, boat hulls, rocky reefs, bivalve colonies, seaweeds, and eelgrass (Glasby 2001; Carman et al. 2010; Davidson et al. 2010 qtd. in Fofonoff et al. 2003; Simkanin et al. 2012; White and Orr 2011 qtd. in Fofonoff et al. 2003; Wong and Vercaemer 2012; Carman et al. 2016).

Sources:
NEMESIS; Fofonoff et al. 2003   Glasby 2001   Carman et al. 2010   Simkanin et al. 2012   Wong and Vercaemer 2012   Carman et al. 2016

3.3 Desiccation tolerance

Choice: **C**

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

High uncertainty? ☑

Score: 1.75 **of** 5

Ranking Rationale:
Although exact desiccation tolerances are unknown, studies suggest that this species has a low tolerance to air exposure.

Background Information:
Colonies are very susceptible to desiccation. They are rarely observed in intertidal areas and, when found there, only occur in damp shaded zones (Carver et al. 2016). Pleus (2008) suggests that tunicates as a group have a low tolerance to desiccation.

Sources:
Carver et al. 2006   Pleus 2008

3.4 Likelihood of success for reproductive strategy

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

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

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

Ranking Rationale:

Asexual, high fecundity, low parental investment.

Background Information:

B. schlosseri is a cyclical hermaphrodite. It reproduces asexually by budding with a sexual reproductive cycle after 5 to 10 asexual growth cycles.

In sexual reproduction, each zooid can produce up to 10 clutches of up to 5 eggs resulting in an average of 8000 eggs per colony. Eggs are internally fertilized and developed for approximately 1 week. The resulting larva is lecithotrophic and settles after 36 hours forming its first functional zooid within 3 days. Sexual maturity occurs within 49 days with an average lifespan of 12 to 18 months (Chadwick-Furman and Weissman 1995; Carver et al. 2006)

Sources:

Carver et al. 2006 Chadwick-Furman and Weissman 1995 NEMESIS; Fofonoff et al. 2003

3.5 Likelihood of long-distance dispersal or movements

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

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

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

Ranking Rationale:

Long-distance, natural dispersal may be possible under certain conditions; however, the short longevity of sperm and free-swimming larvae, and evidence of genetically distant subpopulations within a small spatial scale, suggest that realized dispersal is low.

Background Information:

During sexual reproduction, it was found that sperm effect declined rapidly at only 50 cm away from the colony despite it's long effective lifespan of 28 hours (Johnson and Yund 2003 qtd. in Carver et al. 2006; Johanson and Yund 2004; Grosberg 1991).

Planktonic larval stage lasts only 24 to 36 hours and they remain withing a few meters of the parental colony settling nearby another colony or fusing together to form a new colony (Rinkevich and Weissman 1987 qtd in Carver et al. 2006; Chadwick-Furman and Weissman 2003).

Several population genetic studies suggest that larval dispersal is limited. Sabbadin and Graziani (1967 qtd. in Carver et al. 2006) found that genetically-distinct sub-populations of B. schlosseri existed under similar ecological conditions within the Lagoon of Venice. Yund and O’Neil (2000) noted that genetic differentiation may occur over very short distances (8 to 21 m), and the patterns were consistent with inbreeding and genetic drift models.

Sources:

Carver et al. 2006 Masterson 2007 Johnson and Yund 2004 Grosberg 1991 Chadwick-Furman and Weissman 1995 Yund and O'Neil 2000

3.6 Likelihood of dispersal or movement events during multiple life stages

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

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

Score: 1.75 **of** 2.5

Ranking Rationale:
Can disperse at more than one life stage, but larvae are short-lived and adults are sessile.

Background Information:
Can disperse at multiple life stages as sperm, planktonic larvae, and by drifting, but none of these stages are successful at long-distance dispersal. Sperm have a short viability in seawater (Grosberg 1987). Larvae are short-lived and tend to settle nearby the sessile parent colony (Carver et al. 2016).

Sources:
Carver et al. 2006 Grosberg 1987

3.7 Vulnerability to predators

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

Score: 2.5 **of** 5

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

Background Information:
Early life stages are predated upon by crabs, snails, urchins, starfish, and fish. Adult colonial tunicates generally have few predators, but certain gastropods, flatworms, and nudibranchs can eat them.

Sources:
Carver et al. 2006 NEMESIS; Fofonoff et al. 2003

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

4. Ecological and Socioeconomic Impacts

4.1 *Impact on community composition*

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

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

Ranking Rationale:

B. schlosseri competes with other attached benthic filter feeders for space and possibly food. Fast-growing B. schlosseri colonies may overgrow neighboring organisms, including native tunicates and seagrass.

Background Information:

B. schlosseri is linked to lower recruitment rates of native Spirorbis spp in Long Isand New York (Osman and Whitlatch 1995). In Humboldt Bay, California, colonial tunicates were found to not decrease recruitment or species richness (Nelson 2009). B. schlosseri was also found to adversely affect the eelgrass Zostera marina in Nova Scotia by fouling the grass leaves, limiting the available sunlight (Wong and Vercaemer 2012).

Tunicates grow more rapidly than oyster spat and can interfere with them inhibiting growth and in some cases, causing death (Arakawa 1990 qtd. in Carver et al. 2006). However, fouling by tunicates on oysters does not always have a negative or even neutral effect.

Sources:

Arens et al. 2011 Carver et al. 2006 NEMESIS; Fofonoff et al. 2003 Masterson 2007 Wong and Vercaemer 2012 Osman and Whitlatch 1995 Nelson 2009

4.2 *Impact on habitat for other species*

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

Score: **1.75** **of** **2.5**

Ranking Rationale:

By fouling eelgrass leaves and reducing their access to light, B. schlosseri may negatively affect eelgrass and the species that depend on it for habitat. To our knowledge, no infestations of eelgrass beds by B. schlosseri have been reported in Alaska so far (L. Shaw, pers. comm., 31 August 2017).

Background Information:

Through establishment and colonization, competes for space with other fouling organisms (Masterson 2007; Wong and Vercaemer 2012). On the east coast of North America, B. schlosseri and other fouling organisms were found to adversely affect native eelgrass Zostera marina by fouling the leaves and reducing light availability; fouling increased the mortality of Z. marina (Wong and Vercaemer 2012). Eelgrass are highly productive habitats that serve as refuges and nurseries for several species. In Alaska, eelgrass ranging almost continuously from southeast Alaska and north into the Bering Sea up to about 67°N (qtd. in Hogrefe et al. 2014).

Sources:

Wong and Vercaemer 2012 Masterson 2007 Hogrefe et al. 2014

4.3 Impact on ecosystem function and processes

Choice: **C**

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

Score: 0.75 **of** 2.5

High uncertainty? ☑

Ranking Rationale:

Through its effects on eelgrass, B. schlosseri may affect ecosystem functions. Impacts on water quality are speculative based on its biology, but have not yet been substantiated by evidence.

Background Information:

On the east coast of North America, B. schlosseri and other fouling organisms were found to adversely affect native eelgrass Zostera marina by fouling the leaves and reducing light availability; fouling increased the mortality of Z. marina (Wong and Vercaemer 2012). Eelgrass support a variety of ecosystem functions by affecting water flow, stabilizing sediments, assimilating nutrients, supporting a high diversity of plants and animals, and through their role as primary producers (qtd. in Winfree 2005; Orth et al. 2006). As a filter feeder, B. schlosseri may also impact water quality e.g. improve water clarity, production of waste (Carver et al. 2006).

Sources:

Carver et al. 2006   Winfree 2005   Orth et al. 2006   Wong and Vercaemer 2012

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

Choice: **B**

Moderate – Causes or has potential to cause degradation of one or more species or communities, with moderate impact

Score: 1.75 **of** 2.5

High uncertainty? ☑

Ranking Rationale:

Through fouling, can have a negative impact on the eelgrass Zostera marina, which provides valuable ecosystem services and coastal habitat for several species. To our knowledge, no infestations of eelgrass beds by B. schlosseri have been reported in Alaska so far (L. Shaw, pers. comm., 31 August 2017).

Background Information:

A study by Wong and Vercaemer (2012) found that B. violaceus, along with other fouling organisms, reduced light availability of eelgrass, which led to reduced growth and increased mortality of eelgrass. Eelgrass is a valuable species that provides numerous ecosystem services to the marine environment, including water regulation, nutrient cycling, refuge, and food (Costanza et al. 1997).

Sources:

Wong and Vercaemer 2012   Costanza et al. 1997

4.5 Introduction of diseases, parasites, or travelers

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

Choice: **C**

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

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

Ranking Rationale:

Is host to a protist and several parasites. The effect of these parasites on other species is unknown.

Background Information:

Moiseeva et al. (2004) described a progressive fatal disease called ‘cup cell disease’ that caused mortality from 30 to 45 days in B. schlosseri colonies grown in the lab. The disease-causing protist was transferred between colonies through seawater without direct contact between infected colonies. The authors suggest that this disease may be a serious problem in stocks of inbred lines or other important Botryllus spp. genotypes raised for scientific needs (Moiseeva et al. 2004), but this disease has not been reported in nature or in other species.

B. schlosseri hosts other ectoparasites, including Lankesteria botrylii (Ormières 1965, qtd. in Moiseeva et al. 2004), Botryllophilus ruber, Mycophilus roseus, and Zygomolgus poucheti. Although M. roseus has also been recorded in Botrylloides leachii, Gotto (1954) found morphological differences between adult females inhabiting the two ascidians, and suggests that M. roseus exists in two host-specific forms. No impacts have been reported for any of these parasites.

Sources:

Carver et al. 2006   Gotto 1954   Moiseeva et al. 2004   Sanamyan and Monniot 2007

4.6 Level of genetic impact on native species

Can this invasive species hybridize with native species?

Choice: **U**

Unknown

Score: **of**

Ranking Rationale:

Background Information:

No information available in the literature.

Sources:

None listed

4.7 Infrastructure

Choice: **B**

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

Score: **1.5** **of** **3**

Ranking Rationale:

Is an abundant fouling organism.

Background Information:

In Bodega Harbor, California, Botryllus schlosseri was one of the eight most abundant fouling organisms both in 1969-1971 and in 2005-2009 (Sorte and Stachowicz 2011). Because of its abundance, B. schlosseri is a nuisance species that fouls boat hulls, marine equipment, aquaculture gear, and other submerged structures.

Sources:

Masterson 2007   NEMESIS; Fofonoff et al. 2003   Sorte and Stachowicz 2011

4.8 *Commercial fisheries and aquaculture*

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

Score: **0.75** **of** **3**

Ranking Rationale:

B. schlosseri can negatively impact cultured molluscs and finfish nets by fouling aquaculture gear. However, only limited effects were observed even when B. schlosseri grew to high densities.

Background Information:

By fouling bivalves and aquaculture gear, B. schlosseri can compete with commercial species, and may prevent the flow of nutrients through nets and cages (Carver et al. 2006; Masterson 2007). However, several studies have found that B. schlosseri had little impact on mussels (Lesser et al. 1992; Gittenberger 2009; Arens et al. 2011; Paetzold et al. 2012). Paetzold et al. (2012) found high levels of fouling on mussel socks in 2010 (average biomass of 600-800 g per mussel sock), but still did not observe any impacts on mussel productivity.

Sources:

Arens et al. 2011 Carver et al. 2006 Gittenberger 2009 Masterson 2007 Paetzold et al. 2012 Lesser et al. 1992

4.9 *Subsistence*

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

Score: **0.75** **of** **3**

Ranking Rationale:

B. schlosseri may impact bivalve species by fouling shells. By fouling eelgrass, this species may affect nursery habitats for subsistence fish species.

Background Information:

No information found. B. schlosseri is absent or rare on natural oyster beds, presumably because of siltation (Andrews 1973).

Sources:

Andrews 1973 NEMESIS; Fofonoff et al. 2003

4.101 *Recreation*

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

Score: **0.75** **of** **3**

High uncertainty? ☑

Ranking Rationale:

Background Information:

No information available in the literature.

Sources:

None listed

4.11 *Human health and water quality*

Choice: **D** No impact

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

Ranking Rationale:

To date, no impacts on human health and water quality have been reported for B. schlosseri.

Background Information:

No information available in the literature.

Sources:

None listed

Section Total - Scored Points:	9.5
Section Total - Possible Points:	27.5
Section Total -Data Deficient Points:	2.5

5. Feasibility of prevention, detection and control

5.1 History of management, containment, and eradication

Choice: **C**

Attempted; control methods are currently in development/being studied

Score:

of

Ranking Rationale:

Control methods were attempted and were only effective for a short while.

Background Information:

In Atlantic Canada, efforts to minimize the impact of tunicate invasions on mussel aquaculture operations are ongoing. Mussel farmers currently use pressurized seawater to remove colonial tunicates. In St. Peters Bay, PEI, high-pressure spraying was effective at reducing the biomass of the colonial tunicates Botryllus schlosseri and Botrylloides violaceus on mussel socks (Arens et al. 2011). However, results were effective only in the short term, as tunicates re-established over time. In addition, the use of pressurized seawater could increase the spread of these species through fragmentation, and can reduce mussel productivity if applied too often (Arens et al. 2011; Paetzold et al. 2012).

Alternative treatments for controlling Botryllus schlosseri and Botrylloides violaceus include the use of freshwater, brine, lime, and acetic acid immersion, with exposure to ~5% acetic acid for >15 s proving the most effective (Carver et al. 2006).

Sources:

Aquaculture Science Branch 2010   Arens et al. 2011   Carver et al. 2006   Paetzold et al. 2012

5.2 Cost and methods of management, containment, and eradication

Choice: **B**

Major short-term and/or moderate long-term investment

Score:

of

Ranking Rationale:

Current methods of control are only effective in the short term and require specialized equipment.

Background Information:

High-pressure spraying was only effective in the short term, as tunicates re-established over time. In addition, the use of pressurized seawater could increase the spread of these species through fragmentation, and can reduce mussel productivity if applied too often (Arens et al. 2011; Paetzold et al. 2012). Davidson et al. (2017) estimated a total equipment cost of $156 000 for this type of treatment. The cost of labor and fuel was estimated at $54 per treatment (Davidson et al. 2017).

Alternative treatments for controlling Botryllus schlosseri and Botrylloides violaceus include the use of freshwater, brine, lime, and acetic acid immersion, with exposure to ~5% acetic acid for >15 s proving the most effective (Carver et al. 2006).

Sources:

Arens et al. 2011   Carver et al. 2006   Davidson et al. 2017   Paetzold et al. 2012

5.3 Regulatory barriers to prevent introductions and transport

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

Ranking Rationale:

While a permit is required for shellfish transfers, hull fouling regulations are largely voluntary.

Background Information:

The most likely vectors for introductions of Botryllus schlosseri are via bivalve aquaculture and ship fouling. In Alaska, a Shellfish Spat Transport Permit is required for importing, exporting, and moving shellfish seed within the state. Suppliers must be approved by the Board of Fisheries.

Although regulations exist to minimize hull fouling, compliance is largely voluntary (Hagan et al. 2014). The U.S. Coast Guard requires rinsing of anchors and anchor chains, and removal of fouling from the hull, piping and tanks on a regular basis, and the EPA Vessel General Permit also requires inspection of hard-to-reach areas of vessels during drydock. At the same, the EPA recognizes that methods and technologies to manage vessel biofouling are in early stages of development.

Sources:

Hagan et al. 2014   EPA 2013

5.4 Presence and frequency of monitoring programs

Choice: **D**	State and/or federal monitoring programs exist, and monitoring is conducted frequently	**Score:** of

Ranking Rationale:

There are several programs that use volunteers to monitor for invasive tunicates.

Background Information:

Alaska has a tunicate monitoring program that conducts education and outreach. Tammy Davis (Invasive Species Program, Alaska Department of Fish and Game) gave a presentation on marine invasive species at the Alaska Shellfish Growers Association annual meeting in 2010. Botryllus schlosseri was one of the species she discussed. Alaska's Invasive Tunicate Network provides education opportunities by training volunteers to identify and collect non-native tunicates.
Material on identifying invasive tunicates, including B. schlosseri, is available on Canada's Department of Fisheries and Oceans website.

Sources:

Davis 2010   DFO 2016   Sephton et al. 2011   Washington Department of Fish and Wildlife 2013

5.5 *Current efforts for outreach and education*

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

Score: of

Ranking Rationale:

Several programs and educational materials are available in Alaska.

Background Information:

Alaska’s Invasive Tunicate Network and the Kachemak Bay National Estuarine Research Reserve (KBNERR) provide training opportunities for identifying and detecting non-native tunicates, and public education events on coastal and marine ecosystems more generally. "Bioblitzes" were held in Southeast AK in 2010 and 2012; these events engage and educate the public on marine invasive species. Field identification guides for native and non-native tunicates, as well as common fouling organisms, are readily available. In 2010, Tammy Davis (Invasive Species Program, Alaska Department of Fish and Game) gave a presentation on marine invasive species at the Alaska Shellfish Growers Association annual meeting; Botryllus schlosseri was one of the species she discussed.

Sources:

Davis 2010 iTunicate Plate Watch 2016

Section Total - Scored Points:

Section Total - Possible Points:

Section Total -Data Deficient Points:

Literature Cited for *Botryllus schlosseri*

- Carman, M. R., Lindell, S., Green-Beach, E., and V. R. Starczak. 2016. Treatments to eradicate invasive tunicate fouling from blue mussel seed and aquaculture socks. Management of Biological Invasions 7(1):101-110.
- Carver, C. E., Mallet, A. L., and B. Vercaemer. 2006. Biological synopsis of the colonial tunicates, Botryllus schlosseri and Botrylloides violaceus. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 2747, Fisheries and Oceans Canada, Darmo
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