Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

Scientific Name: *Botrylloides violaceus*

Common Name *chain tunicate*

Phylum	Chordata
Class	Ascidiacea
Order	Stolidobranchia
Family	Styelidae

Final Rank 56.25

Data Deficiency: 0.00

Species Occurrence by Ecoregion

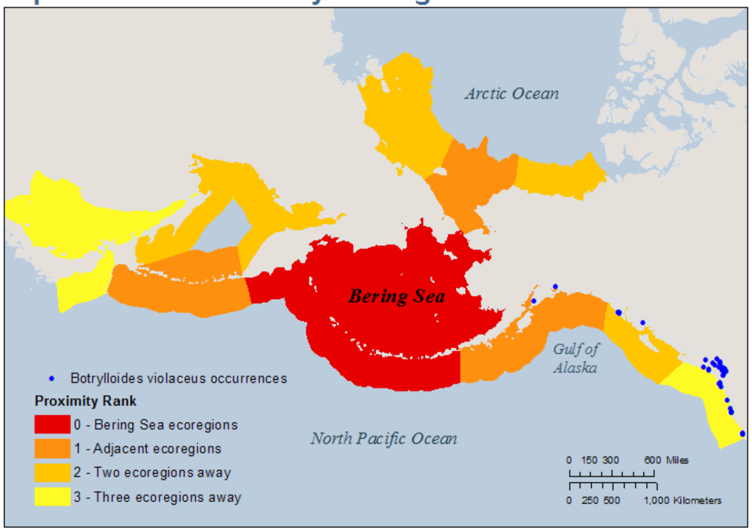

Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

Category Scores and Data Deficiencies

Category	Score	Total Possible	Data Deficient Points
Distribution and Habitat:	22	30	0
Anthropogenic Influence:	4.75	10	0
Biological Characteristics:	20.5	30	0
Impacts:	9	30	0
Totals:	56.25	100.00	0.00

General Biological Information

Tolerances and Thresholds

Minimum Temperature (°C)	-1	Minimum Salinity (ppt)	20
Maximum Temperature (°C)	29	Maximum Salinity (ppt)	38
Minimum Reproductive Temperature (°C)	15	Minimum Reproductive Salinity (ppt)	26
Maximum Reproductive Temperature (°C)	25	Maximum Reproductive Salinity (ppt)	38

Additional Notes

B. violaceus is a thinly encrusting, colonial tunicate. Colonies are uniformly colored, but can vary from purple, red, yellow, orange and brown. It species is native to the Northwest Pacific, but has been introduced on both coasts of North America, and parts of Atlantic Europe. It is a common fouling organism throughout much of its introduced range, where it often displaces and competes with other native and non-native fouling organisms, including tunicates, bryozoans, barnacles, and mussels.

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

High uncertainty? ✔

Ranking Rationale:
Temperatures required for year-round survival occur in a moderate area (≥25%) of the Bering Sea. We ranked this question with "High Uncertainty" to indicate disagreements in model estimates.

Background Information:
Based on B. violaceus' geographic range from AK to Palau (Micronesia), Zerebecki and Sorte (2011) estimated the upper and lower temperature tolerances at -0.6 ºC and 29.3 ºC, respectively. Sorte et al. (2011) evaluated temperature tolerances in several marine invertebrate taxa in a laboratory setting, by allowing acclimation for 24 h (at ~17°C) and then raising water temperature at a rate of 1°C per 5 min until the treatment temperature was reached (21, 25, 29, and 34°C). Mortality was assessed following temperature exposure for 24 h. They report LT50 values of 27.4°C and 25.3°C for west coast and east coast populations, respectively.

Sources:
Zerebecki and Sorte 2011   Sorte et al. 2011

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:
Epelbaum et al. (2009) evaluated temperature and salinity limits of two Botrylloides species, using laboratory colonies grown under five levels of salinity (14, 20, 26, 32, 38‰). B. violaceus colonies continued to grow under the most saline (38‰) conditions. Dijkstra and Harris (2007) used heart rate was used as a proxy for health to assess the condition of colonies subjected to variable salinity conditions, and found declining heart rates with decreasing salinity; specifically, that of B. violaceus remained constant between 20 psu and 30 psu, but slowed at 15 psu. B. violaceus suffered 100% mortality after 1 day at 5 psu (Dijkstra and Harris 2007).

Sources:
Dijkstra and Harris 2007   Epelbaum et al. 2009

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:
Although temperatures in parts of the Bering Sea can support the survival of juvenile colonies, temperatures are not high enough to support growth.

Background Information:
Juvenile colonies grown under laboratory conditions required temperatures between 15-25ºC to grow, but tolerated temperatures as low as 5ºC (Epelbaum et al. 2009).

Sources:
Epelbaum et al. 2009

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

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

Background Information:
Botrylloides violaceus is a marine species throughout its entire life cycle. Juvenile colonies grown under laboratory conditions demonstrated positive (and optimal) growth at salinities between 26 and 38 ppt (Epelbaum et al. 2009).

Sources:
Epelbaum et al. 2009

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 has been reported in Tatilek and Kachemak Bay.

Background Information:
This species is considered well-established in Tatitlek because of the detection of several newly-settled, healthy zooids, which suggests that mature, reproductively active colonies were nearby. B. violaceus has been reported from Kachemak Bay, AK but is not presumed to be established there.

Sources:
Dijkstra and Harris 2007   Epelbaum et al. 2009

1.6 Global ecoregional distribution

Choice: B In a moderate number of ecoregions globally

Score: 3.25 **of** 5

Ranking Rationale:
This species is found in cold and temperate waters in the northern hemisphere.

Background Information:
Native to the Northwest Pacific, where it is found in Japan, China, and South Korea. It is widely distributed on the west coast of North America, where it occurs from Mexico to southern Alaska. Although it has been reported in Kachemak Bay, it is not thought to be established there. Its distribution on the East Coast extends from Newfoundland to Virginia. In Europe, it occurs along the Atlantic coast from Scotland, south to Portugal and Italy.

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 has undergone a recent and rapid range expansion on North America's east coast.

Background Information:

This species was first detected in Santa Barbara, CA in 1966, and spread north to WA by 1980 and to AK by 1999 (Fofonoff et al. 2003). In eastern North America, it has spread rapidly along the coast of Prince Edward Island since its discovery in 2004 (Carver et al. 2006).

Sources:

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

Section Total - Scored Points:	22
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:
This species is known to use anthropogenic vectors for transport, but it is unlikely to undergo natural, long-distance dispersal once introduced.

Background Information:
Rafting on floating eelgrass and other debris can serve to transport colonies (Dijkstra 2011), but evidence from genetic analyses indicates that natural dispersal is not a major contributor to the spread B. violaceus on either coasts of North America (Bock et al. 2011). The most likely vectors for transport are hull fouling and hitchhiking on aquaculture species.

Sources:
Bock et al. 2011 Dijkstra 2011

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 is can establish on both anthropogenic substrates and natural habitats, but is more frequently found on the former.

Background Information:
Although this species can colonize natural habitats such as eelgrass and rocky shores, it is better able to colonize anthropogenic substrates (Simkanin et al. 2017; Wagstaff 2017).

Sources:
NEMESIS; Fofonoff et al. 2003 Simkanin et al. 2012 Wagstaff 2017

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 farmed or cultivated.

Background Information:

Sources:
NEMESIS; Fofonoff et al. 2003

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:
This species consumes foods that are readily available in the Bering Sea.

Background Information:
Filter feeder on phytoplankton and detritus.

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.

Background Information:
B. violaceus can tolerate a wide range of temperatures, salinities and nutrients including high sewage and heavy metal concentrations (Carver et al. 2006; Dijkstra 2011). It is intolerant of turbid environments.

Sources:
Carver et al. 2006 Dijkstra 2011

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 (< 24 h) tolerance to air exposure.

Background Information:
Air exposure has been proposed as a method to control tunicate fouling on aquaculture equipment and bivalves. A test of the OysterGro system, which routinely exposes oysters and oyster bags to air, concluded that 24 h air exposure was efficient at controlling tunicate species including Botrylloides violaceus (Gill et al. 2008). A literature review by Carver et al. (2006) reported that colonies are very susceptible to desiccation, and are rarely observed in intertidal areas. Pleus (2008) claims that tunicates as a group have low desiccation tolerance.

Sources:
Carver et al. 2006 Gill et al. 2008 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:
This species exhibits both asexual and sexual reproduction, and has a short generation time. Fertilization is internal. Individual zooids typically produce only one egg, but the reproductive output for a single colony is likely high.

Background Information:
Colonial tunicates are hermaphroditic and can reproduce both sexually and asexually. Individual zooids normally produce one egg (qtd. in Carver et al. 2006). Eggs are fertilized internally and embryos are incubated in a brood pouch for 1 month (Carver et al. 2006). Eggs hatch into non-feeding, planktonic larvae that swim briefly before settling. In its native range, zooids attained sexual maturity within a week of having settled, and then began producing buds asexually (Yamaguchi 1975, qtd. in Carver et al. 2006). During this time, colonies grew exponentially. Sexual reproduction was initiated 8 weeks after metamorphosis and continued for 3 weeks. After sexual reproduction, parent colonies regress and eventually die. Many generations can be achieved in a single year.

Sources:
Carver et al. 2006 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

High uncertainty? ☑

Score: 0.75 of 2.5

Ranking Rationale:
Genetic analyses and distributional patterns suggest that this species likely has limited dispersal ability.

Background Information:
Adults are sessile and eggs are fertilized internally. Larvae are short-lived, and usually settle within 4 to 10 hours (Carver et al. 2006). Several lines of evidence suggest that dispersal in this species is limited. In Washington and BC, the species exhibits patchy distributions even in suitable environments (Cahill et al. 2010). In addition, high genetic differentiation, even at nearby sites (< 1 km) indicates limited capacity for natural dispersal (Bock et al. 2011).

Sources:
Carver et al. 2006 Bock et al. 2011 Cahill et al. 2010

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:
This species can disperse either as free-swimming larvae or as adults by rafting.

Background Information:
Adults are sessile, but in some instances may be dispersed by rafting on drifting vegetation or woody debris (Worcester 1994; Thiel and Gutow 2005). Eggs are fertilized internally and brooded in a pouch. Free-swimming larvae are short-lived, and usually settle within 4 to 10 hours (Carver et al. 2006), though the duration of this stage may be longer at lower temperatures (Fofonoff et al. 2003).

Sources:
NEMESIS; Fofonoff et al. 2003   Carver et al. 2006   Worcester 1994   Thiel and Gutow 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:
This species is preyed upon by a variety of taxa that occur in the Bering Sea.

Background Information:
This species is preyed upon by fishes, snails, crabs, urchins, and starfish. Simkanin et al. (2013) proposed that native predators may limit or slow the spread of B. violaceus in British Columbia. On the east coast of North America, B. violaceus has provided a new source of prey for some species such as the blood star Henricia sanguinolenta (qtd. in Dijkstra 2011). B. violaceus was not predated upon by the snail Mitrella lunata, and was only rarely predated upon by Anachis lafrashnayi (Osman and Whitlatch 1995, Whitlatch and Osman 2009).

Sources:
Dijkstra 2011   NEMESIS; Fofonoff et al. 2003   Simkanin et al. 2013   Whitlatch and Osman 2009

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

4. Ecological and Socioeconomic Impacts

4.1 *Impact on community composition*

Choice: **B**

Moderate – More than one trophic level; may cause declines but not extirpation

Score: 1.75 **of** 2.5

Ranking Rationale:

This species can compete for space with other fouling organisms and can quickly become a dominant species.

Background Information:

By competing for space and food, B. violaceus frequently displaces other fouling organisms, including native and introduced tunicates, bryozoans, barnacles, and mussels. At two locations in California, it has formed extensive areas of 100% cover, indicating strong competitive ability (Lambert and Lambert 2003). In Portsmouth Harbor, B. violaceus was the most abundant colonial tunicate on fouling plates in 1984-1985 (Berman et al. 1992) and in 2003-2005, partially replacing B. schlosseri, the previous dominant colonial ascidian (Dijkstra et al. 2007). By 2003-2006, B. violaceus, along with Didemnum vexillum, replaced the mussel M. edulis as dominant species in fouling communities (Dijkstra and Harris 2009).

In fouling plate experiments in Humboldt Bay, Nelson (2009) found that colonial tunicates (Botryllus schlosseri and Botrylloides violaceus) quickly occupied space on fouling plates, but did not decrease recruitment or species richness. Dijkstra (2011) suggests that, while B. violaceus may become a permanent member of the community, it is unlikely to replace native species.

Sources:

Dijkstra 2011   NEMESIS; Fofonoff et al. 2003   Lambert and Lambert 2003   Dijkstra and Harris 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. violaceus may negatively affect eelgrass and the species that depend on it for habitat. To our knowledge, no infestations of eelgrass beds by B. violaceus have been reported in Alaska so far (L. Shaw, pers. comm., 31 August 2017). B. violaceus may also affect habitat by reducing available habitat for some organisms, and by creating secondary settlement habitat for others.

Background Information:

On the east coast of North America, Botrylloides violaceus and other fouling organisms were found to adversely affect native eelgrass Zostera marina by fouling leaves and reducing light availability, which increased the mortality of Z. marina (Wong and Vercaemer 2012). The violet morph of B. violaceus had a more negative effect than lighter-colored tunicates, which allowed more light to reach the eelgrass (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).

In fouling communities of Portsmouth Harbor, New Hampshire, tunicates including B. violaceus had competitvely displaced the mussel Mytilus edulis as the dominant species (Dijkstra and Harris 2009). A major functional habitat change occurred, because mussels provided a year-round substrate for other organisms, but B. violaceus dies off seasonally. At the same time, this seasonal die-off created large areas of bare substrate for new organisms to colonize (Dijkstra and Harris 2009).

Sources:

Wong and Vercaemer 2012   Dijkstra and Harris 2009   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. violaceus might affect ecosystem functions.

Background Information:
On the east coast of North America, Botrylloides violaceus and other fouling organisms were found to adversely affect native eelgrass Zostera marina by fouling leaves and reducing light availability, which 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).

Sources:
Wong and Vercaemer 2012 Winfree 2005 Orth et al. 2006

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. violaceus 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: D No impact

Score: 0 of 2.5

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

Background Information:
Ascidians are commensal hosts to notodelphid copepods, amphipods, and host to some specific parasitic copepods (Miller 1971, qtd. in Rudy et al. 2013).

Sources:
Rudy et al. 2013

4.6 *Level of genetic impact on native species*

Can this invasive species hybridize with native species?

Choice:		Score:
D	No impact	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

4.7 *Infrastructure*

Choice:		Score:
B	Moderate – Causes or has the potential to cause degradation to infrastructure, with moderate impact and/or within only a portion of the region	1.5 of 3

Ranking Rationale:
This species is known to foul shellfish farming equipment, which is practiced in a small region of the Bering Sea. This species also fouls ship hulls and marine infrastructure.

Background Information:
Various surveys have listed its occurrence as a nuisance fouling organism on the hulls of ships, floating docks and nautical buoys. On Vancouver Island, B. violaceus is considered a major fouling concern for both shellfish and finfish growers who rely on nets as part of their culture technique. Finfish nets and shellfish cages may become infested with a mat of colonial tunicates that effectively eliminates the flow of oxygen and particles through the mesh. Active research on methods to control fouling by B. violaceus in eastern Canada (Gill et al. 2008; Arens et al. 2011) suggests that this species is having negative impacts on aquaculture infrastructure.

Sources:
Carver et al. 2006   Gill et al. 2008   Arens et al. 2011

4.8 *Commercial fisheries and aquaculture*

Choice:		Score:
C	Limited – Has limited potential to cause degradation to fisheries and aquaculture, and/or is restricted to a limited region	0.75 of 3

Ranking Rationale:
Studies suggest that Botrylloides violaceus has mild effects on mussel aquaculture.

Background Information:
Although B. violaceus may compete with bivalves for food and space, Arens et al. (2011) found that Botrylloides violaceus and Botryllus schlosseri had little impact on mussel productivity over the course of their study. In comparative trials in PEI where B. violaceus was actively cleaned from the surface of cultured mussels, there was no significant positive impact on growth, meat yield or survival relative to heavily fouled mussels (qtd. in Carver et al. 2006). Compared to Botryllus schlosseri, B. violaceus was only present in small amounts on mussel socks, and therefore did not substantially increase the weight of mussel socks (< 50 g; Paetzold et al. 2012). Gittenberger (2009) also asserts that B. violaceus does not add significant weight to mussel socks and only causes minimal loss during harvesting.

Sources:
Carver et al. 2006   Arens et al. 2011   Gittenberger 2009   Paetzold 2012

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:
Botrylloides violaceus appears to be a stronger competitor on anthropogenic than natural substrates. Fouling of other organisms in natural settings seems very limited, and no negative impacts have been reported so far. However, through competition or overgrowth, this species may affect subsistence resources such as the blue mussel. By fouling eelgrass, this species may affect nursery habitats for subsistence fish species.

Background Information:
In PEI, B. violaceus was rarely found on the shells of rock crabs (5 of 275 crabs), and only occurred at low densities (Bernier et al. 2009). Studies on mussel farms found that B. violaceus had little to no impact on mussel productivity (Arens et al. 2011).

Sources:
NEMESIS; Fofonoff et al. 2003   Arens et al. 2011   Bernier et al. 2009

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 reported.

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

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 or water quality in the Bering Sea.

Background Information:
No impacts reported.

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

Section Total - Scored Points:	9
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:
Methods to control tunicates, especially on aquaculture operations, are currently being studied.

Background Information:
In Atlantic Canada, 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:
Carver et al. 2006   Arens et al. 2011   Paetzold 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 treatment methods need to be repeated to be successful, and require moderate, but long-term investment.

Background Information:
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). Davidson et al. (2017) estimated the cost of equipment at $156 000 for this type of treatment. The cost of labor and fuel was estimated at $54 per treatment per line (Davidson et al. 2017). Farms in their study had an average of 134 lines and applied 3 treatments per year (Davidson et al. 2017). The use of pressurized seawater as a control method is only effective only in the short term, as tunicates re-establish over time (Paetzold et al. 2012). 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:
Carver et al. 2006   Arens et al. 2011   Davidson et al. 2017

5.3 *Regulatory barriers to prevent introductions and transport*

Choice: B Regulatory oversight, but compliance is voluntary

Score: of

Ranking Rationale:

Botrylloides violaceus is thought to have been accidentally transported with aquaculture species (e.g., mussels and bivalves), and by hull fouling. Although regulations exist to reduce fouling organisms on ships, compliance is largely 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:

Botrylloides violaceus is listed as a species of interest on the Invasive Tunicate Network website.

Background Information:

In Alaska, the Invasive Tunicate Network conducts monitoring for non-native tunicates and other invasive species. The network is comprised of teachers, students, outdoor enthusiasts, environmental groups and state and federal biologists.

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. Botrylloides violaceus 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. "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:

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