Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

Scientific Name: *Didemnum vexillum*

Common Name *carpet sea squirt*

Phylum	Chordata
Class	Ascidiacea
Order	Aplousobranchia
Family	Didemnidae

Final Rank 65.64

Data Deficiency: 2.50

Species Occurrence by Ecoregion

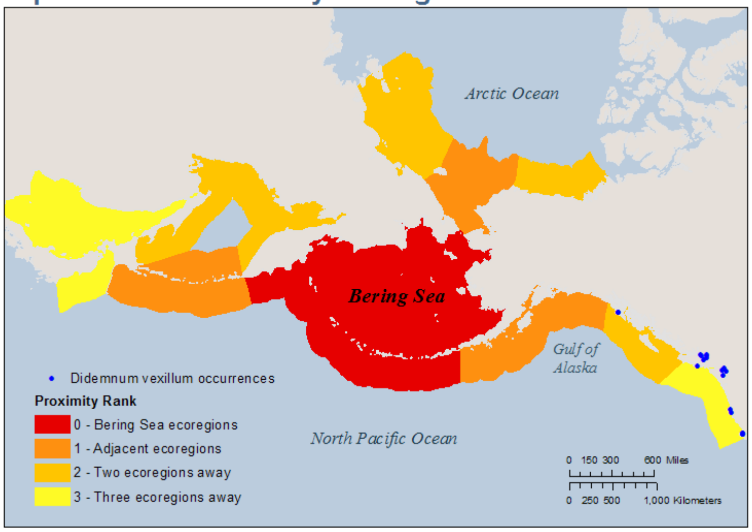

Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

Category Scores and Data Deficiencies

Category	Score	Total Possible	Data Deficient Points
Distribution and Habitat:	23.75	30	0
Anthropogenic Influence:	8	10	0
Biological Characteristics:	21.75	30	0
Impacts:	10.5	28	2.50
Totals:	64.00	97.50	2.50

General Biological Information

Tolerances and Thresholds

Minimum Temperature (°C)	-2	Minimum Salinity (ppt)	10
Maximum Temperature (°C)	24	Maximum Salinity (ppt)	35
Minimum Reproductive Temperature (°C)	14	Minimum Reproductive Salinity (ppt)	31*
Maximum Reproductive Temperature (°C)	20	Maximum Reproductive Salinity (ppt)	35*

Additional Notes

Spreading colonial tunicate consisting of many zooids. Yellow-cream in colour. Grows on rocks, shellfish, and other marine organisms such as sponges and algae.

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

Score: 3.75 of 3.75

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

Background Information:
Temperature range for survival is between -2°C and 24°C.

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:
Salinity range required for survival is between 10 ppt and 35 ppt.

Sources:
NIMPIS 2016

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 occur in a limited area (<25%) of the Bering Sea.

Background Information:
Requires temperatures between 14°C and 20°C for reproduction.

Sources:
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

Score: 3.75 of 3.75

High uncertainty? ☑

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

Background Information:
No information available in the literature.

Sources:
None listed

1.5 Local ecoregional distribution

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

Score: 2.5 **of** 5

Ranking Rationale:

Background Information:
Found in Sitka, Alaska. Native to Japan.

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

1.6 Global ecoregional distribution

Choice: A — In many ecoregions globally

Score: 5 **of** 5

Ranking Rationale:
Wide global distribution

Background Information:
Native to the northwest Pacific (Japan). Invasive to southeast AK, BC, south to CA and Mexico. On the east coast of North America, present in Nova Scotia and throughout New England. In Europe, present in Ireland, the Netherlands, France, and the Mediterranean Sea (Italy and Spain). This invasion suggests that D. vexillum has greater capacity to invade warm waters than previously thought (Ordonez et al. 2015). Discovered in New Zealand in 2001.

Sources:
NEMESIS; Fofonoff et al. 2003   Ordonez et al. 2015

1.7 Current distribution trends

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

Score: 5 **of** 5

Ranking Rationale:
Recent documentation of range expansion.

Background Information:
D. vexillum has the potential for rapid colonization (Valentine et al. 2016) and is currently expanding its range in the Mediterranean Sea (Ordóñez et al. 2015). Documented instances of long-distance dispersal were likely assisted by anthropogenic vectors; however, fragments may be able to disperse naturally for up to 20 km depending on water currents (Lengyel et al. 2009). It has not spread since being discovered in 2010 in Sitka, AK (McCann et al. 2013).

Sources:
McCann et al. 2013   Ordonez et al. 2015   Valentine et al. 2016   Lengyel et al. 2009

Section Total - Scored Points:	23.75
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: A Has been observed using anthropogenic vectors for transport and transports independent of any anthropogenic vector once introduced

Score: 4 of 4

Ranking Rationale:
D. vexillum can be transported by both natural and anthropogenic vectors.

Background Information:
Anthropogenic vectors of dispersal include: hitchhiking on bivalves, ballast water and bilge water, and fouling of ships and gear (Dijkstra 2009). D. vexillum can also disperse naturally by larval dispersal and by fragmentation of adult colonies (Herborg et al. 2009; Lengyel et al. 2009). The impressive spread of D. vexillum on Georges Bank is likely due to such fragmentation (Valentine et al. 2007a). In a risk assessment study for British Columbia, Herborg et al. (2009) ranked natural dispersal methods as "moderately important" vectors, based on results from an expert survey.

Sources:
Dijkstra 2009 Lengyel et al. 2009 Herborg et al. 2009 Valentine et al. 2007a

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

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

Score: 4 of 4

Ranking Rationale:
D. vexillum establishes on anthropogenic surfaces and can spread to natural areas once introduced.

Background Information:
In addition to growing on anthropogenic substrates, D. vexillum can colonize and overgrow healthy natural subtidal surfaces including rocky reefs, gravel bottoms, bivalve colonies, seaweeds, and eelgrass (Valentine et al. 2007b; Dijkstra 2009). Spread to natural substrates following introduction has been observed in several areas including Georges Bank (Valentine et al. 2007b) and in Sitka, AK (L. Shaw, pers. comm., 31 August 2017).

Sources:
Valentine et al. 2007b Dijkstra 2009

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

Choice: B No

Score: 0 of 2

Ranking Rationale:
D. vexillum is not currently farmed or intentionally cultivated.

Background Information:

Sources:
None listed

Section Total - Scored Points:	8
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:
Prey taxa are readily available in the Bering Sea.

Background Information:
Suspension feeder. Feeds on phytoplankton, bacteria, and detritus. Larvae are non-feeding.

Sources:
NEMESIS; Fofonoff et al. 2003   NIMPIS 2016

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:
Tolerant of a wide range of temperatures and salinities and found in numerous habitats.

Background Information:
Can tolerate a wide range of temperature, salinity, and water quality conditions (Herborg et al. 2009; Dijkstra 2009). Common in marine water, though it has also been found in estuaries. Not only common in confined, disturbed, and polluted harbors and estuaries, but is also common in the more ‘pristine’ waters of Georges Bank (Massachusetts), British Columbia and New Zealand (Fofonoff et al. 2003). Appears to have a highly plastic life-cycle that responds to thermal conditions, with winter regression in colder environments and summer regression in warmer environments such as the Mediterranean (Ordóñez et al. 2015).

A popular science article by Tammy Davis (Invasive Species Program Coordinator at ADF&G) says that D. vexillum is not known to establish on sandy or muddy seabed. However, D. vexillum is found on a variety of substrates including bivalves, algae, wood, and rocks, and its potential for establishment on unusual substrates has been noted: “In addition to the establishment of populations in more protected shallow water habitats, in 2002 we discovered that portions of deeper water (~30 m) pebble-cobble habitats in eastern Long Island Sound were heavily colonized by Didemnum [vexillum]. […] The ability of Didemnum to colonize and form mats on the pebble-cobble seafloor habitats is unlike any of the other recent ascidian invaders or native and long-term resident colonial ascidians found in Long Island Sound” (Mercer et al. 2009).

Sources:
Davis 2016   Dijkstra 2009   Herborg et al. 2009   Mercer et al. 2009   NEMESIS; Fofonoff et al. 2003   Ordonez et al. 2015

3.3 Desiccation tolerance

Choice: **C** Little to no tolerance (<1 day) of desiccation during its life cycle

Score: 1.75 of 5

High uncertainty? ✔

Ranking Rationale:

Colonies died when exposed to air for 2-3 hours per days for 30 days.

Background Information:

Carman et al. (2009) exposed D. vexillum to 3 treatments, ranging from 1.5 to 3.5 hours of air exposure. Senescence was observed only when exposing D. vexillum to both air and freshwater. Colonies in tide pools were able to survive exposure to air for short periods of time, probably not exceeding 2 hours (Valentine et al. 2007a). Colonies died when exposed to air for extended period of time (2-3 hours per day for 30 days; Valentine et al. 2007a). In general, tunicates have low tolerance to desiccation (Daniel and Therriault 2007; Pleus 2008).

Sources:

Carman et al. 2009   Daniel and Therriault 2007   Valentine et al. 2007a   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: **B** Moderate – Exhibits one or two of the above characteristics

Score: 3.25 of 5

Ranking Rationale:

Hermaphroditic, low fecundity, low parental investment.

Background Information:

Hermaphroditic and internal fertilization. Sperm are released in the water column, and travel to another zooid in the colony, where fertilization occurs. A typical zooid can produce 1-20 eggs, and eggs develop in the ovary one at a time (Berrill 1950, Lambert and Lambert 2005; qtd. in Daniel and Therriault 2007). Eggs mature within several weeks and are released as non-feeding, free-swimming larvae.

Under control treatment conditions, Didemnum vexillum reached sexual maturity 62 days after recruitment (Stefaniak and Whitlatch 2014). Length of reproductive cycle is variable: In New England, recruitment in coastal sites occurred over 3.5–5 months in the range of 14–20°C and ceased at 9–11°C (Valentine et al. 2009). In New Zealand, recruitment occurred over a longer period of time (at least 9 months) (Fletcher et al. 2013b). Recruitment stopped during the winter when temperatures dipped below 12°C (Fletcher et al. 2013b).

Sources:

Daniel and Therriault 2007   Fletcher et al. 2013b   NIMPIS 2016   Ordonez et al. 2015   Stefaniak and Whitlatch 2014

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

Ranking Rationale:

Primary transport is due to anthropogenic means. Can disperse naturally hundreds of meters to a few kilometers.

Background Information:

Limited ability for natural dispersal. Pelagic larvae only remain in the water column for a short time (≤1 day; Osman and Whitlatch 2007). Once the larva has settled and metamorphosed, individuals are sessile for the rest of their life. Unlike some other colonial tunicate invaders, there is no information about this species' ability to spread naturally by drifting on floating debris.

A field-based study consistently recorded larval dispersal on settlement plates 250 m away from source populations (Fletcher et al. 2013a). Exponential decay models suggested that dispersal greater than 250 m was theoretically possible (>1 km in some situations) (Fletcher et al. 2013a). Monitoring of settlement plates revealed dispersal distances up to 350 m from known source populations (Fletcher et al. 2013a). Small fragments can detach from D. vexillum and form new colonies by drifting within the water column. Fletcher et al. (2013a) estimated (based on rates of sinking) that fragments could spread ~100 m from their release point. Longer dispersal distances from larvae or fragmentation may be possible depending on hydrological conditions.

Human-mediated transport is the most important vector for long-distance dispersal. The most likely transport scenarios are either the direct transport of colonies fouled on aquaculture equipment, boat hulls or other mobile structures or the indirect transport of colony fragments where small parts of a colony break off during transport or disturbance (e.g. dredging, trawling) and subsequently find suitable conditions for establishment and growth.

Sources:

Dijkstra 2009   Fletcher et al. 2013a   Herborg et al. 2009   Osman and Whitlatch 2007

3.6 Likelihood of dispersal or movement events during multiple life stages

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

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

Score: 2.5 of 2.5

Ranking Rationale:

Larval viability window is < 36 hours. Can disperse as larvae (by swimming or passive dispersal) and asexually as adults via fragmentation.

Background Information:

The larval stage can disperse by swimming or passively by water currents. The larval stage is likely short-lived (minutes to hours, < 1 day) (Bullard et al. 2007). Under experimental conditions, most larvae (>70%) were able to undergo successful metamorphosis following an artificial delay of 2 h (Fletcher et al. 2013a). Larval viability decreased with increasing delay duration, but 10% of larvae did remain viable after a 36 h delay (Fletcher et al. 2013a). Although adults are sessile, colonies can disperse asexually by fragmentation and rafting (Thiel and Gutow 2005; Bullard et al. 2007; Lengyel et al. 2009).

Sources:

Bullard et al. 2007   Fletcher et al. 2013a   Lengyel et al. 2009   Thiel and Gutow 2005

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

High uncertainty? ☑

Ranking Rationale:

It is believed that D. vexillum has few predators, but a recent study suggests that predation in its introduced range may be strong enough to limit growth and establishment.

Background Information:

D. vexillum is eaten by fish (perhaps accidentally), periwinkles, snails, starfish, and urchins (Fofonoff et al. 2003; Gittenberger 2007; Valentine et al. 2007a,b). Some authors believe that predation on D. vexillum is low because it is a poor source of nutrition and contains chemicals to deter predators (Daniel and Therriault 2007; Valentine et al. 2007a; Valentine et al. 2007b; Carman et al. 2009). However, a study in New Zealand by Forrest et al. (2013) found that predation on D. vexillum was strong enough to limit population growth and prevent establishment. Furthermore, the authors of this study point out that D. vexillum does not have secondary metabolites that would reduce predation (Forrest et al. 2013).

Sources:

Carman et al. 2009 Daniel and Therriault 2007 NEMESIS; Fofonoff et al. 2003 Forrest et al. 2013 Gittenberger 2007 Valentine et al. 2007a Valentine et al. 2007b

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: **B**

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

Score: 1.75 **of** 2.5

Ranking Rationale:

May outcompete similar organisms for habitat. Affects the composition and diversity of taxa that span multiple trophic levels i.e. worms, crustaceans, and fish. To our knowledge, extirpation caused by D. vexillum has not been documented.

Background Information:

Effects of D. vexillum are context-dependent: some sites such as Georges Bank report very large invasions, whereas at other sites, D. vexillum has not spread much from where it was initially discovered (e.g. Whiting Harbour, Sitka, AK). While D. vexillum does not seem to have negative effects on mobile species, it does overgrow several sessile marine organisms (e.g., hydroids, shellfish, anemones). Moreover, studies have found that it alters the composition of marine communities, notably by increasing the abundance and diversity of certain taxa (polychaete worms, tanaids, crabs, and fish) (Daniel and Therriault 2007; Smith et al. 2014).

Sources:

NEMESIS; Fofonoff et al. 2003   Daniel and Therriault 2007   Smith et al. 2014

4.2 Impact on habitat for other species

Choice:		Score:
B	Moderate – Causes or has potential to cause changes to one or more habitats	**1.75** of **2.5**

Ranking Rationale:

Through competition and rapid expansion, has been shown to alter mussel bed habitat and pebble-gravel habitat, with potential implications for the communities that rely on those habitats.

Background Information:

By 2003-2006, colonial tunicates, including D. vexillum, replaced mussels (M. edulis) as the dominant species in fouling communities in Portsmouth Harbor, NH. (Dijkstra and Harris 2009). A comparison of pre- and post-invasion species richness found that species richness increased in post-invasion communities; however, the authors attribute this result to differences in life history between mussels and tunicates. While mussels provided a year-round substrate available to other organisms for settlement, tunicates, such as D. vexillum, are more resistant to secondary settlement by these other organisms because they possess a chemical defense that deters secondary settlement. However, D. vexillum dies off seasonally and creates large areas of bare substrate available for colonization by other organisms (Dijkstra and Harris 2009). Senescence of colonies or individuals from a single species eliminates them from an area and opens that area to recolonization, thereby preventing competitive exclusion of species.
The life-history cycle, e.g. senescence of invasive colonial ascidians, in this system created a community that is susceptible to colonization and can support regional increases in species richness (Dijkstra and Harris 2009).

On Georges Bank, where D. vexillum has invaded an area of 230km2, it has turned a heterogeneous pebble gravel habitat into a homogeneous tunicate mat (Lengyel et al. 2009). This may negatively effect Atlantic Cod (Gadus morhua), haddock (melanogrammus aeglefinus), and the sea scallop (Placopecten magellanicus) as pebble gravel habitat may be important to survival and success of these species (Lough et al. 1989; Thouzeau et al. 1991).

Based on results from their study, Mercer et al. (2009) suggested that mats of D. vexillum may serve as novel habitat for benthic species. Invertebrates capable of living beneath the mats may use the mats for shelter and protection from epibenthic predators. However, Mercer et al. (2009) did not explicitly test for these effects.

Sources:

Dijkstra and Harris 2009   NEMESIS; Fofonoff et al. 2003   Lengyel et al. 2009   Mercer et al. 2009   Lough et al. 1989   Thouzeau et al. 1991

4.3 Impact on ecosystem function and processes

Choice: B Moderate – Causes moderate changes to food webs or ecosystem functions in several areas, or causes severe effects in only one or a few areas (e.g., in areas where species occurs at high densities)

Score: 1.75 **of** 2.5

High uncertainty? ☑

Ranking Rationale:
While potential impacts have been discussed, the actual (or realized) impacts of D. vexillum on ecosystem functions and processes is unknown.

Background Information:
Mercer et al. (2009) suggested that Didemnum mats alter benthic-pelagic coupling and influence the biogeochemical cycling of many nutrients and elements by creating a physical barrier between the seafloor below the mats and the water column above. This physical barrier may influence dissolved oxygen exchange leading to hypoxic conditions in the sediment (Diaz and Rosenberg 1995).

Didemnum sp. could lower suspended organic particles in the water column while filter feeding (Lambert and Lambert 1998, qtd. in Daniel and Therriault 2007).

Sources:
Daniel and Therriault 2007 Diaz and Rosenberg 1995 Mercer et al. 2009

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

Choice: U Unknown

Score: **of**

Ranking Rationale:

Background Information:
No information available in the literature.

Sources:
None listed

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:
To date, no diseases, parasites, or travelers have been reported for D. vexillum, and given its ecology, none would be expected.

Background Information:
No information available in the literature.

Sources:
None listed

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

High uncertainty? ☑

Ranking Rationale:
To date, no impacts on genetic of native species have been reported for D. vexillum, and given its ecology, none would be expected.

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:
Abundant fouling species that can occur in large, thick mats.

Background Information:
Known to foul ships, fishing and diving gear, and infrastructure (docks, moorings). Reports of D. vexillum fouling are widespread, having been documented in New Zealand, both coasts of North America, and Europe (see Lambert 2009). Fouling by Didemnum spp. (likely D. vexillum) can be severe: in Ireland, colonies were frequently found as an overgrowing carpet that occupied up to several hundreds of square centimeters and extensive pendulous growths sometimes extended over 60 cm in length (Minchin and Sides 2006).

Sources:
Lambert 2009   Minchin and Sides 2006

4.8 Commercial fisheries and aquaculture

Choice: B Moderate – Causes or has the potential to cause degradation to fisheries and aquaculture, with moderate impact in the region

Score: 1.5 of 3

Ranking Rationale:
By fouling bivalve shells and aquaculture gear, D. vexillum may have negative impacts on the shellfish industry. A recent study on Georges Bank found that D. vexillum had an overall positive effect on cod species (Smith et al. 2014).

Background Information:
Fouling by D. vexillum has been linked with slower mussel growth (Auker 2010; Fletcher et al. 2013c). D. vexillum mats were avoided by bay scallop larvae looking for a settlement substrate; in large numbers, D. vexillum may impact scallop recruitment (Morris et al. 2009). Colonies also foul coastal shellfish aquaculture gear, which increases maintenance costs (Morris et al. 2009). Indeed, a cost-benefit analysis in New Zealand conducted by Coutts and Spinner (2004) estimated that, if D. vexillum were to spread throughout the Marlborough Sounds area, it would foul about 10% of mussel lines within five years. They estimated that the cost to treat or replace fouled lines would reach $574 000 per year (Coutts and Spinner 2004). Managers and biologists are worried about the impacts that D. vexillum might have on gadid species (including haddock and Atlantic cod) in Georges Bank, where D. vexillum has spread extensively (Smith et al. 2014). For now, the overall effect on fish species appears positive, as fish eat organisms which are positively associated with D. vexillum mats (Smith et al.

Sources:
Auker 2010   Morris et al. 2009   Coutts and Sinner 2004   Fletcher et al. 2013c   Smith et al. 2014

4.9 *Subsistence*

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

Score: 1.5 of 3

Ranking Rationale:
By fouling bivalve shells and gear, D. vexillum may have negative impacts on subsistence shellfish species.

Background Information:
Fouling by D. vexillum has been linked with slower mussel growth (Auker 2010; Fletcher et al. 2013c). D. vexillum mats were avoided by bay scallop larvae looking for a settlement substrate; in large numbers, D. vexillum may impact scallop recruitment (Morris et al. 2009).

Sources:
Morris et al. 2009 Auker 2010 Fletcher et al. 2013c

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

Ranking Rationale:
Although this species may have a negative effect on bivalves, recreational harvesting of shellfish in the Bering Sea is limited.

Background Information:
Fouling by D. vexillum has been linked with slower mussel growth (Auker 2010; Fletcher et al. 2013c). D. vexillum mats were avoided by bay scallop larvae looking for a settlement substrate; in large numbers, D. vexillum may impact scallop recruitment (Morris et al. 2009). This species is also known to foul ships, fishing and diving gear, and infrastructure (docks, moorings).

Sources:
Auker 2010 Morris et al. 2009 Fletcher et al. 2013c

4.11 *Human health and water quality*

Choice: D — No impact

High uncertainty? ☑

Score: 0 of 3

Ranking Rationale:
To date, no impacts on human health and water quality have been reported for D. vexillum, and given its ecology, none would be expected.

Background Information:
No information available in the literature.

Sources:
None listed

Section Total - Scored Points:	10.5
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: **A** Attempted; control methods are not successful

Score: of

Ranking Rationale:

All control efforts have met with limited success.

Background Information:

In New Zealand, local scale eradication of D. vexillum was attempted at Shakespeare Bay without success (Coutts and Forrest 2007). However, a sustained (2006–2008) intensive surveillance and eradication program was set up afterwards and obtained a substantial reduction or eradication of populations in the Marlborough Sounds area, together with an almost complete lack of vessel infestation (and thus potential for further spread) (Forrest and Hopkins 2013).

An eradication attempt in Holyhead Marina (Wales, UK) was not successful, as D. vexillum was found a few months over a much larger proportion of the marina than had been detected earlier (Holt and Cordingley 2011).

In Sitka, AK, initial treatments have not succeeded in eradicating D. vexillum from Whiting Harbour, but it is contained to the area where it was first discovered, and the northernmost discrete population was not detected during 2016 surveys. Monitoring and treatment experiments are ongoing.

Regional eradication is unlikely, but may be possible at smaller scales.

Sources:

Coutts and Forrest 2007   Davis 2016   Dijkstra 2009   Forrest and Hopkins 2013   Holt and Cordingley 2011   Ordonez et al. 2015

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:

Effective control methods are still in development.

Background Information:

Several methods of control have been tested. Chemical methods have been used to prevent infestation of D. vexillum on oyster and mussel lines. The two most effective treatments were dipping lines in a solution of bleach (0.5%) or hydrated lime (1–5%) for 2-5 minutes (Rolheiser et al. 2012; Muñoz and McDonald 2014). The latter treatment resulted in the greatest reduction of D. vexillum biomass (>90%) and maximum survival rate (>80%) of the farmed oysters.

In British Columbia, both chemical (4% hydrated lime) and physical removal methods reduced D. vexillum fouling on Pacific oysters by 85 to 96%; however, the reduction in D. vexillum fouling freed up space that allowed botryllid invasive species to establish (Switzer et al. 2011).

Structures such as pylons and floating pontoons can be treated in highly concentrated acetic acid (20%) to prevent fouling from D. vexillum. Acetic acid is inexpensive and presents a low environmental risk (highly soluble in water) compared to other chemicals. Encapsulation of structures has been proven to be the most effective method for the eradication of D. vexillum if anoxic conditions are achieved. The time required to achieve full eradication depends on the type of affected structure (e.g. size, surface characteristics). For example, for pylons and vessels, eradication can be achieved in 7 days, while for infected seabed it might take up to 14 days. However, this method, like many other control methods, is indiscriminate (non-target specific) and is likely to kill all the organisms attached to the structure (Muñoz and McDonald 2014).

In Sitka, AK, aquarium-scale immersion experiments were conducted using six different treatments: freshwater, brine (62ppt salinity), hypoxia, 10% acetic acid, and 1% bleach (McCann et al. 2013). Continuous immersion in a brine solution with at least twice the salinity of ambient seawater produced 100% mortality after 24 h and 98% die-back after four hours (McCann et al. 2013). However, achieving such treatment at larger scales still needs to be evaluated, when considering application of larger spatial scale in a complex habitat that is porous and difficult to isolate from the surrounding waters (McCann et al. 2013). Indeed, larger-scale attempts in 2015 reveal the difficulties of extrapolating aquarium experiments to the open environment of the seafloor (Davis 2015).

Sources:

Davis 2016   McCann et al. 2013   Muñoz and McDonald 2014   Rolheiser et al. 2012   Switzer et al. 2011

5.3 Regulatory barriers to prevent introductions and transport

Choice: B Regulatory oversight, but compliance is voluntary

Score: of

Ranking Rationale:
Alaska and New Zealand have regulations in place.

Background Information:
In New Zealand, a sustained (2006–2008) intensive surveillance and eradication program was set up afterwards and obtained a substantial reduction or eradication of populations in the Marlborough Sounds area (Forrest and Hopkins 2013).

Since its discovery in 2010 in Sitka, AK, monitoring and control attempts have been ongoing. As of 2016, D. vexillum remains contained within Whiting Harbour.
No regulations are currently in place to prevent the spread of invasive species via ship fouling or transport in sea chests. Given the short-lived larval phase, transport in ballast water is unlikely.

Sources:
Davis 2016 Forrest and Hopkins 2013 McCann et al. 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:
The Alaska Department of Fish & Game has been closely monitoring and controlling D. vexillum with some success.

Background Information:
Since its discovery in 2010 in Sitka, AK, monitoring and control attempts have been ongoing. As of 2016, D. vexillum remains contained within Whiting Harbour (McCann et al. 2013; Davis 2016).

Sources:
Davis 2016 McCann et al. 2013

5.5 Current efforts for outreach and education

Choice: C Educational materials are available and outreach occurs only sporadically in the Bering Sea or adjacent regions

Score: of

Ranking Rationale:
Educational material are available for D. vexillum, but outreach only occurs sporadically.

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:

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