Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

Scientific Name: *Mya arenaria*

Common Name *softshell clam*

Phylum Mollusca

Class Bivalvia

Order Myoida

Family Myidae

Final Rank 59.50

Data Deficiency: 0.00

Species Occurrence by Ecoregion

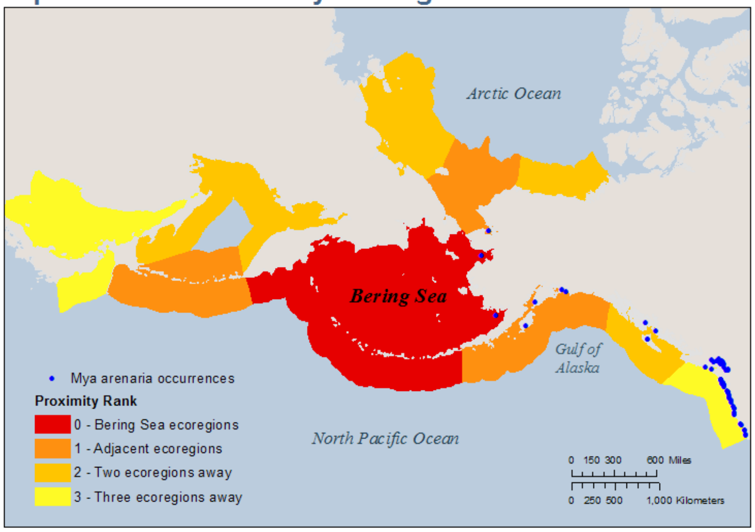

Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

Category Scores and Data Deficiencies

Category	Score	Total Possible	Data Deficient Points
Distribution and Habitat:	25.25	30	0
Anthropogenic Influence:	6	10	0
Biological Characteristics:	22.75	30	0
Impacts:	5.5	30	0
Totals:	59.50	100.00	0.00

General Biological Information

Tolerances and Thresholds

Minimum Temperature (°C)	-0.2	Minimum Salinity (ppt)	3
Maximum Temperature (°C)	32.5	Maximum Salinity (ppt)	35
Minimum Reproductive Temperature (°C)	4	Minimum Reproductive Salinity (ppt)	10
Maximum Reproductive Temperature (°C)	23	Maximum Reproductive Salinity (ppt)	35*

Additional Notes

Mya arenaria is a burrowing bivalve that buries deeply in soft-bottom substrates. In its native range in eastern North America, it supports both commercial and recreational fisheries. It also supports a recreational fishery in parts of its introduced range on the West Coast. M. arenaria has apparently had little to no negative effects in its introduced range.

The paleontological record suggests that M. arenaria occupied many areas in the northeast Pacific during the Miocene and Pliocene, before becoming extirpated (Powers et al. 2006). However, over the last 300 to 700 years, M. arenaria has successfully reinvaded many areas within its paleontological range through intentional and unintentional introductions, and range expansions. Introductions of M. arenaria on the northeastern Pacific coast is recent, and occurred via plantings of Eastern oysters (Crassostrea virginica) from the eastern Unites States in the late 1800s and early 1900s (Powers et al. 2006). Although M. arenaria may have occurred in Alaska 5 mya, today it is considered as an invasive species in southcentral Alaska (Powers et al. 2006).

Reviewed by Nora R. Foster, NRF Taxonomic Services, Fairbanks AK

Review Date: 9/27/2017

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. This species is already found in the Bering Sea.

Background Information:
Temperature range: -0.2 to 32.5°C. Upper limit is based on 24-hour experiment (qtd. in Fofonoff et al. 2003). Relatively high abundances of juveniles were observed following winters with average water temperatures of -0.2°C (Möller 1986).

Sources:
NEMESIS; Fofonoff et al. 2003 Möller 1986

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:
Can tolerate salinity ranges from 3 to 35 PSU (Fofonoff et al. 2003), but lower salinities may lead to reduced growth and survivorship (Powers et al. 2006). Powers et al. (2006) found lowest abundances of M. arenaria at a site of freshwater outflow with high turbidity and salinity between 2 and 26 PSU.

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

1.3 Establishment requirements - Water temperature

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

Score: 3.75 of 3.75

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

Background Information:
This species' reproductive temperature range ranges from 4 to 23°C (qtd. in Fofonoff et al. 2003). Some authors have suggested that this species requires spawning temperatures between 10 and 12°C; however, a spawning peak was observed in Massachusetts at temperatures of 4 to 6°C, and a water temperature of 10°C is rarely reached in Labrador, where this species is established (qtd. in Strasser 1999). Stickney (1964) observed high mortality and poor development at temperatures 8°C and below, with optimal larval development occuring between 17 and 23°C (qtd. in Stasser 1999).

Sources:
NEMESIS; Fofonoff et al. 2003 Strasser 1999

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:
This species' reproductive salinity range is from 10 to 35 PSU (qtd. in Fofonoff et al. 2003).

Sources:
NEMESIS; Fofonoff et al. 2003

1.5 Local ecoregional distribution

Choice: **A** — Present in the Bering Sea

Score: 5 of 5

Ranking Rationale:
This species is already present in the Bering Sea.

Background Information:
This species has been recorded north to Bristol Bay and Norton Sound. Established populations are already present in southcentral Alaska (Prince William Sound).

Sources:
NEMESIS; Fofonoff et al. 2003 Powers et al., 2006

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 subarctic, cold temperate, and some warm temperate ecoregions.

Background Information:
Mya arenaria is native to North America’s Atlantic coast, from Newfoundland to North Carolina. It was introduced to the West Coast, and now occurs from California north to Alaska. Globally, it has a circumpolar distribution from Iceland to the Barents Sea (Norway to eastern Russia). In Europe, it is found along the Atlantic coast, from Scandinavia to Portugal, Italy, and Greece. In Asia, it is established from the Yellow Sea to the Bering Sea.

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

1.7 Current distribution trends

Choice: **B** — History of rapid expansion or long-distance dispersal (prior to the last ten years)

Score: 3.25 of 5

Ranking Rationale:

Both rapid range expansion and natural, long-distance dispersal have been proposed to explain the low genetic variability amongst some populations of Mya arenaria. These expansion events took place several (> 10) years ago.

Background Information:

Strasser and Barber (2009) found low genetic diversity across populations in the Northwest Atlantic. The authors proposed either natural, long-distance dispersal (promoted by strong oceanic currents) or population expansion to explain their findings. Lasota et al. (2004) found similarly low levels of genetic variability amongst European populations, and point to rapid range expansion, high gene flow or allele neutrality as possible explanatory mechanisms. Neither of these expansion events took place in the last ten years.

Sources:

NEMESIS; Fofonoff et al. 2003   Lasota et al., 2004   Strasser and Barber 2009

Section Total - Scored Points:	25.25
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:
Can be transported using several anthropogenic vectors including intentional introductions for aquaculture, hitchhiking, and ballast water. Once introduced, can disperse naturally.

Background Information:
This species has been intentionally introduced in certain parts of its non-native range. It can also be accidentally introduced when transporting or introducing Eastern oysters. Its long-lived larval stage can be transported in ballast water. Its current range in Europe is largely the result of natural range expansions (Strasser 1999).

Sources:
Strasser 1999

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

Choice: D Does not use anthropogenic disturbance/infrastructure to establish

Score: 0 of 4

Ranking Rationale:
This species establishes on natural, soft-bottom substrates.

Background Information:
Its current range in Europe is largely the result of natural range expansions (Strasser 1999). It can establish in undisturbed areas on sand, mud, and gravel substrates.

Sources:
Strasser 1999 NEMESIS; Fofonoff et al. 2003

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

Choice: A Yes

Score: 2 of 2

Ranking Rationale:
This species is commercially and/or recreationally harvested in its native and introduced range.

Background Information:
In its native range, it is an important shellfish species and supports both commercial and recreational fisheries. It was intentionally introduced to the west coast of North America for aquaculture (Strasser 1999).

Sources:
Strasser 1999

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

3. Biological Characteristics

3.1 Dietary specialization

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

Score: 5 of 5

Ranking Rationale:

Phytoplankton is readily available in the Bering Sea.

Background Information:

This species is a suspension feeder that feeds on phytoplankton. An experiment by Bacon et al. (1998) found that Mya arenaria was able to retain high feeding rates even in habitats with high concentrations of low quality particles.

Sources:

NEMESIS; Fofonoff et al. 2003 Bacon et al., 1998

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:

Can tolerate a wide range of temperatures, salinities, and water depths, as well as high nitrogen loads. Adults can survive in anaerobic environments for several days.

Background Information:

Commonly found in intertidal and shallow subtidal areas with sandy or muddy substrates. Tolerates wide tidal ranges and salinities better than many native clams (Fofonoff et al. 2003). In estuaries such as Chesapeake Bay and brackish seas such as the Baltic, softshell clams can be abundant at salinities as low as 4-5 PSU; however, some studies have found that M. arenaria exhibits reduced growth at low salinities (Kube et al. 1996, qtd. in Powers et al. 2006; Carmichael et al. 2004). Locations with clean, fast-flowing water sustain the highest populations of M. arenaria (Tyler-Walters, 2003, qtd. in GISD 2007).

High nitrogen loads (e.g., as a result of eutrophication) were found to be beneficial for the shell growth of clams, because of increased food supply driven by N enrichment (Carmichael et al. 2004).

Adult clams are very tolerant of anaerobic environments and can survive in an oxygen depleted environment for up to 8 days (Cohen 2005, qtd. in GISD 2007). However, low oxygen concentrations may reduce juvenile survival (Carmichael et al. 2004).

Sources:

NEMESIS; Fofonoff et al. 2003 Carmichael et al. 2004 GISD 2016 Leblanc and Miron Powers et al. 2006

3.3 *Desiccation tolerance*

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

Score: 3.25 of 5

High uncertainty? ☑

Ranking Rationale:

This species can be exposed to air for at least 54 hours without showing signs of stress. The exposure time required to cause mortality is unknown. Exposure to air with < 100% humidity may elicit stress responses sooner.

Background Information:

A study exposing M. arenaria to air for 54 h at 10°C and 100% humidity found that these conditions were not stressful enough to alter the clam's burying behavior, or to cause a change in various biochemical markers (proteins, glycogen, and lipid classes) (Picard et al. 2014). Clams were able to burrow into sediment as soon as they were re-immersed in water. Picard et al. (2014) suggest that bivalves' ability to reduce their metabolism and activity during air exposure allows them to conserve their energy reserves, which are then still available to them when they are re-immersed. Experiments were conducted on young clams with an average shell length of 22.6 mm.

Sources:

Picard et al. 2014

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:

This species is highly fecund, has low parental investment, and fertilization is external. Hermaphroditic individuals are rare. This species is long-lived, and age to sexual maturity is high.

Background Information:

Sexual reproduction with external fertilization. Sexes are separate, but there are low incidences of hermaphroditism. No parental investment. The number of eggs per female varies from 120 000 to 5 million, depending on the environment and size of the female (Strasser 1999). Less than 0.1 % of the eggs produced in a spawning season result in successful settlement (Newell and Hidu 1986, qtd. in Abgrall et al. 2010).

Sexuality maturity and lifespan: Size appears more important than age in determining maturity. Maturity occurs at about 20 mm length (about 1 to 4 years, depending on the length of each growing season). Growth is dependent on water temperature. In Alaska, the softshell clam grows ~50 mm every 6 to 7 years (Abraham and Dillon 1986; Council PWSRCA 2004 – qtd. in NIMPIS 2016). The typical lifespan is between 10 to 12 years, but some can live up to 28 years (Cohen 2005, qtd. in GISD 2007).

Sources:

Strasser 1999 Abgrall et al. 2010

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: **A** Disperses long (>10 km) distances

Score: 2.5 **of** 2.5

Ranking Rationale:

Larvae are long-lived and can disperse across long distances. Juveniles can disperse over small to moderate spatial scales.

Background Information:

This species has a long, free-swimming larval stage (2 to 5 weeks). Shanks (2009) estimated a mean larval dispersal distance of 35 km. Juveniles can be transported with sediment even after initial settlement. Jennings and Hunt (2009) reported dispersal distances of up to 50 cm during short (3.5 - 5 hours) field observations. A dispersal model by Hunt et al. (2009) estimated that transport by sediment could alter distribution patterns over a scale of several kilometers in one month. If disturbed, young clams can re-burrow, but adults have limited mobility because of their large shell size (Tyler-Walters 2003, qtd. in GISD 2007).

Sources:

Shanks 2009 Jennings and Hunt Hunt et al. 2009 GISD 2016

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:

This species can disperse at various life stages: eggs (external fertilization), larvae, juveniles. Planktonic larval stage is long-lived (2 to 5 weeks). Eggs and larvae can disperse passively with water currents. Larvae are free-swimming. Juveniles are mobile, but movement is limited.

Background Information:

The larval stage in this species is long-lived. Larvae are free-swimming and spend 2 to 5 weeks moving in the water column before metamorphosizing and settling to the bottom of the sea floor. Shanks et al. (2009) estimated that larvae disperse an average of 35 km. Larvae then spend another 2 to 5 weeks in this juvenile stage moving small distances along the sea floor or temporarily attaching themselves to objects, before burrowing in the substrate. Juvenile dispersal can be facilitated by sediment transport (e.g., erosion). Once burrowed, young adults may be able to move if they are disturbed, but older individuals have limited mobility because of their large shell (Tyler-Walters 2003, qtd. in GISD 2007).

Sources:

Shanks 2009 GISD 2016

3.7 Vulnerability to predators

Choice: **D**

Multiple predators present in the Bering Sea or neighboring regions

Score: 1.25 of 5

Ranking Rationale:

Several taxa found in the Bering Sea prey upon larvae and juveniles.

Background Information:

Larvae and newly settled spat are very vulnerable to predation. Small clams are eaten by fishes, crabs, clam worms (Nereidae), moon snails (Naticidae), ducks, shorebirds, and fishes. Clams are less vulnerable to predation when they reach ~ 60 mm in length (Newell and Hidu 1986, qtd. in Fofonoff et al. 2003).

Sources:

NEMESIS; Fofonoff et al. 2003

Section Total - Scored Points:	22.75
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:
This species may compete with and reduce populations of native bivalves. These effects may be more pronounced in areas where Mya arenaria occurs at very high densities.

Background Information:
Introduced populations of Mya arenaria may outcompete native bivalves, including Macoma balthica in the Baltic Sea (Obolewski and Piesik 2005), Lentidium mediterraneum and Corbula mediterranea in the Black Sea (Gollasch and Leppakoski 1999, qtd. in NIMPIS 2016; Skolka and Preda 2010), and Cerastoderma edule in Sweden (Möller 1986). In the case of C. edule, competition was reciprocal, with one species or the other having heavy recruitment in some years, and inhibiting recruitment of the other (Möller 1986). In San Francisco Bay, where it occurs at high densities (100 to >1000 clams/m2), it is reported to have replaced populations of the native bent-nosed clam (Macoma nasuta) (qtd. in Molnar et al. 2008). The impacts of M. arenaria are difficult to determine in many regions because it has been present for several hundred years (Jensen 2010a).

Sources:
Jensen 2010a   NEMESIS; Fofonoff et al. 2003   Molnar et al. 2008   Möller 1986   NIMPIS 2009   Obolewski and Piesik 2005   Skolka and Preda 2010

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:
This species' has the potential to change habitat through its burrowing activities. Its shell provides hard habitat for other marine organisms.

Background Information:
Mya arenaria burrows deeply (10 to 25 cm) in soft substrate habitats. In doing so, it increases habitat availability for other organisms such as nematodes by enabling them to penetrate deeper in the sediment layer (Urban-Malinga et al. 2016). Mya arenaria often dies in situ, forming “death assemblages” (Strasser 1999), which can persist for more than 100 years and serve as habitats for other species (Palacios et al., 2000, qtd. in Jensen 2010a).

Sources:
Jensen 2010a   Urban-Malinga et al. 2016   Strasser 1999

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

Ranking Rationale:
Through its burrowing, excretory, and feeding activities, Mya arenaria can impact water clarity and sedimentation.

Background Information:
As a powerful burrower and filterer, it has the potential to alter ecosystem characteristics through bioturbation and deposition of pseudofeces, as well as through suspension feeding, which can increase water clarity and light penetration (Obolewski and Piesik 2005; Forster and Zettler 2004; de Moura Queiros et al. 2011; Zaiko et al. 2011). In addition, water leaking from its shell can irrigate the sediment in which it is burrowed, with potential impacts on sediment biogeochemistry (Forster and Zettler 2004). In Poole Harbour, UK, Mya arenaria was considered to be most important bioturbator (de Moura Queiros et al. 2011).

Microcosm experiments on several bivalve species, including M. arenaria, found no overall effect on total meiobenthic densities (Urban-Malinga et al. 2016). However, the burrowing activities of M. arenaria might facilitate meiobenthos to penetrate to deeper sediment layers. In addition, the faeces and pseudofaeces deposited at the sediment surface might increase microbial activity and sulfur reduction rates, and promote microbial communities (Hansen et al. 1996; Urban-Malinga et al. 2016). The microbial community in turn supports rotifers and bivalves species (Urban-Malinga et al. 2016).

Skolka and Preda (2010) claim that Mya arenaria induced structural changes in ecosystems previously dominated by Lentidium mediterraneum, but the authors do not provide any additional information.

Sources:
Zaiko et al. 2011 Obolewski and Piesik 2005 Forster and Zettler 2004 de Moura Queiros et al. 2011 Urban-Malinga et al. 2016 Hansen et al. 1996 Skolka and Preda 2010

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

Choice: **C** Limited – Has limited potential to cause degradation of one more species or communities, with limited impact and/or within a very limited region

Score: 0.75 **of** 2.5

High uncertainty? ☑

Ranking Rationale:
Two native Mya species occur in the Bering Sea. One of them (M. truncata) is the major food source for the Pacific walrus. Although no studies have been conducted on the interaction between these native species and M. arenaria, M. arenaria is known to compete and replace native bivalves in some parts of its introduced range.

Background Information:
Two native Mya species occur in the Bering Sea: Mya truncata and M. pseudoarenaria; both are found in soft sediments in upper intertidal to subtidal zones (N. Foster, pers. comm., 27 September 2017). Although we are not aware of any studies on the potential effects of M. arenaria on these two species, M. arenaria is known to compete with native bivalves in parts of its introduced range. Competition with M. truncata could have implications for Bering Sea food webs because M. truncata is the main food source for the Pacific walrus (Odobenus rosmarus).

Sources:
NEMESIS; Fofonoff et al. 2003

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:
No impacts have been reported.

Background Information:

Sources:
NEMESIS; Fofonoff et al. 2003

4.6 Level of genetic impact on native species

Can this invasive species hybridize with native species?

Choice: **D** No impact

Score: **0** **of** **2.5**

Ranking Rationale:
No impacts have been reported.

Background Information:

Sources:
NEMESIS; Fofonoff et al. 2003

4.7 Infrastructure

Choice: **D** No impact

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

Ranking Rationale:
No impacts have been reported. This species is not known to foul ships or infrastructure.

Background Information:

Sources:
NEMESIS; Fofonoff et al. 2003

4.8 Commercial fisheries and aquaculture

Choice: **D** No impact

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

Ranking Rationale:
Mya arenaria is an important commercial shellfish species. No negative impacts on other commercial fisheries have been reported.

Background Information:
In its native range, Mya arenaria is an important commercial shellfish species. In New Brunswick, Canada, the estimated mean annual landing value of the commercial softshell clam fishery reached $700,000 in 2003 (Fisheries and Oceans Canada 2005a, qtd. in Abgrall et al. 2010).

Sources:
Abgrall et al. 2010

4.9 Subsistence

Choice: D No impact

Score: 0 of 3

Ranking Rationale:
No impacts have been reported.

Background Information:

Sources:
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

Ranking Rationale:
Accumulations of dead individuals can reduce the aesthetic value of shorelines.

Background Information:
The accumulation of dead (and foul-smelling) individuals along shorelines can reduce recreational opportunities. This problem has been reported in tourist areas around the Black Sea (Gollasch and Leppakoski 1999, qtd. in NIMPIS).

Sources:
NIMPIS 2009

4.11 Human health and water quality

Choice: C Limited – Has limited potential to pose a threat to human health, with limited impact and/or within a very limited region

Score: 0.75 of 3

Ranking Rationale:
Cases of PSP and other shellfish syndromes are rare in Alaska. Current regulations and safety procedures greatly reduce the risk of bacterial transmission, especially in cultivated mussels. Recreational harvesting of shellfish in the Bering Sea is limited.

Background Information:
All bivalves can bioaccumulate toxins in their tissues as a result of consuming toxic dinoflagellates. Consuming raw or cooked bivalves can lead to Paralytic Shellfish Poisoning (PSP), which can cause health issues and even death (NIMPIS 2009). The state of Alaska discourages harvesting on untested beaches (ADEC 2013).

Sources:
NIMPIS 2009 ADEC 2013

Section Total - Scored Points:	5.5
Section Total - Possible Points:	30
Section Total -Data Deficient Points:	0

5. Feasibility of prevention, detection and control

5.1 *History of management, containment, and eradication*

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

Score: of

Ranking Rationale:
To our knowledge, there have been no attempts to control or eradicate soft-shell clams. More generally, controlling the spread of invasive species that use anthropogenic vectors for transport is an active area of research (e.g. Ruiz and Reid 2007, Hagan et al. 2014).

Background Information:

Sources:
Ruiz and Reid 2007   Hagan et al. 2014

5.2 *Cost and methods of management, containment, and eradication*

Choice: **A** Major long-term investment, or is not feasible at this time

Score: of

Ranking Rationale:
Because this species is well-established in its introduced range, eradication is not currently feasible.

Background Information:
This species is well-established in its non-native range, which makes eradication unfeasible (Hoagland & Jin 2006, qtd. in GISD 2007).

Sources:
GISD 2016

5.3 *Regulatory barriers to prevent introductions and transport*

Choice: **C** Regulatory oversight and/or trade restrictions

Score: of

Ranking Rationale:
This species has been intentionally introduced, and accidentally introduced with other species such as the Eastern oyster. Ballast water is likely the most prevalent vector for introductions today. The management of ballast water in Alaska is regulated by the U.S. Coast Guard and the Environmental Protection Agency.

Background Information:
In the U.S., ballast water management is mandatory and regulated by the U.S. Coast Guard, with additional permitting by the Environmental Protection Agency (CFR 33 § 151.2; EPA 2013; EPA 2014). Certain vessels are exempted from USCG and EPA regulations.

A study by Briski et al. (2012) found Mya arenaria present in ballast water samples. Mid-ocean ballast water exchange did not affect occurrence, which suggests that exchange of ballast water is ineffective for this taxonomic group.

Sources:
CFR 2017   Briski et al. 2012   EPA 2013   EPA 2014

5.4 Presence and frequency of monitoring programs

Choice: A No surveillance takes place

Score: of

Ranking Rationale:
This species is not currently monitored.

Background Information:
No information found.

Sources:
None listed

5.5 Current efforts for outreach and education

Choice: A No education or outreach takes place

Score: of

Ranking Rationale:
No outreach or education is currently taking place for this species.

Background Information:
No information found.

Sources:
None listed

Section Total - Scored Points:

Section Total - Possible Points:

Section Total -Data Deficient Points:

Literature Cited for *Mya arenaria*

- GISD (Global Invasive Species Database). 2016. IUCN SSC Invasive Species Specialist Group (ISSG). Available from: http://www.iucngisd.org/gisd/. Accessed 30-Jan-2017.

- NIMPIS. 2009. National Introduced Marine Pest Information System. Available from: http://www.marinepests.gov.au/nimpis

- Abgrall, M.-J., Bastien-Daigle, S., Miron, G., and M. Ouellete. 2010. Potential interactions between populations of Softshell Clams (Mya arenaria) and Eastern Oysters (Crassostrea virginica) in temperate estuaries, a literature review. Canadian Technical

- ADEC. 2013. Paralytic Shellfish Poisoning Fact Sheet. Alaska Department of Environmental Conservation. Available from: http://dec.alaska.gov/eh/fss/Food/Docs/fact_PST_6-4-2013_final%20(2).pdf. Accessed 02-Jan-2017.

- Briski, E., Ghabooli, S., Bailey, S. A., and H. J. MacIsaac. 2012. Invasion risk posed by macroinvertebrates transported in ships' ballast tanks. Biological Invasions 14:1843–1850. doi: 10.1007/s10530-012-0194-0

- Carmichael, R. H., Shriver, A. C., and I. Valiela. 2004. Changes in shell and soft tissue growth, tissue composition, and survival of quahogs, Mercenaria mercenaria, and softshell clams, Mya arenaria, in response to eutrophic-driven changes in food supply

- 33 CFR § 151.2050 Additional requirements - nonindigenous species reduction practices

- de Moura Queiros, A., Hiddink, J. G., Johnson, G., et al. 2011. Context dependence of marine ecosystem engineer invasion impacts on benthic ecosystem functioning. Biological Invasions 13:1059-1075. doi: 10.1007/s10530-011-9948-3

- Environmental Protection Agency (EPA). 2013. Vessel General Permit for Discharges Incidental to the Normal Operation of Vessels (VGP). Washington, D.C., USA. 194 pp.

- Forster, S. and M. L. Zettler. 2004. The capacity of the filter-feeding bivalve Mya arenaria L. to affect water transport in sandy beds. Marine Biology 144:1183-1189. doi: 10.1007/s00227-003-1278-2

- Hagan, P., Price, E., and D. King. 2014. Status of vessel biofouling regulations and compliance technologies – 2014. Maritime Environmental Resource Center (MERC) Economic Discussion Paper 14-HF-01.

- Hansen, K., King, G. M., and E. Kristensen. 1996. Impact of the soft-shell clam Mya arenaria on sulfate reduction in an intertidal sediment. Aquatic Microbial Ecology 10:181-194.

- Hunt, H. L., Fugate, D. C., and R. J. Chant. 2009. Modeling bedload transport of juvenile bivalves: Predicted changes in distribution and scale of postlarval dispersal. Estuaries and Coasts 32:1090-1102. doi: 10.1007/s12237-009-9205-5

- Jensen, K. R. 2010a. NOBANIS - Invasive Alien Species Fact Sheet – Mya arenaria. Identification key to marine invasive species in Nordic waters – NOBANIS. Available from: https://www.nobanis.org/globalassets/speciesinfo/m/mya-arenaria/mya-arenaria.pdf Acc

- Lasota, R., Hummel, H., and M. Wolowicz. 2004. Genetic diversity of European populations of the invasive soft-shell clam Mya arenaria (Bivalvia). Journal of the Marine Biological Association of the United Kingdom 84(5):1051-1056.

- LeBlanc, S., and G. Miron. 2006. Bentho-pelagic distribution of early stages of softshell clams (Mya arenaria) in tidally contrasted regimes. Canadian Journal of Zoology 84:459–472.

- Möller, P. 1986. Physical factors and biological interactions regulating infauna in shallow boreal areas. Marine Ecology Progress Series. 30:33-47.

- Molnar, J. L., Gamboa, R. L., Revenga, C., and M. D. Spalding. 2008. Assessing the global threat of invasive species to marine biodiversity. Frontiers in Ecology and the Environment 6(9):485-492. doi: 10.1890/070064
- Fofonoff, P. W., G. M. Ruiz, B. Steves, C. Simkanin, and J. T. Carlton. 2017. National Exotic Marine and Estuarine Species Information System. http://invasions.si.edu/nemesis/. Accessed: 15-Sep-2017.
- Obolewski, K., and Z. Piesik. 2005. Mya arenaria (L.) in the Polish Baltic Sea coast. Baltic Coastal Zone 9:13-27.
- Picard, R., Myrand, B., and R. Tremblay. 2014. Effect of emersion on soft-shell clam, Mya arenaria and the mussel, Mytilus edulis seeds in relation to development of vitality indices. Aquatic Living Resources 27:91-98. doi: 10.1051/alr/2014014
- Powers, S. P., Bishop, M. A., Grabowski, J. H., and C. H. Peterson. 2006. Distribution of the invasive bivalve Mya arenaria L. on intertidal flats of southcentral Alaska. Journal of Sea Research 55:207-216. doi: 10.1016/j.seares.2005.10.004
- Ruiz, G. M., and D. F. Reid. 2007. Current State of Understanding about the Effectiveness of Ballast Water Exchange (BWE) in Reducing Aquatic Nonindigenous Species (ANS) Introductions to the Great Lakes Basin and Chesapeake Bay, USA: Synthesis and Analysi
- Shanks, A. L. 2009. Pelagic larval duration and dispersal distance revisited. The Biological Bulletin 216(3):373–385.
- Skolka, M., and C. Preda. 2010. Alien invasive species at the Romanian Black Sea coast: Present and perspectives. Travaux du Muséum National d’Histoire Naturelle «Grigore Antipa» 53:443-467.
- Strasser, M. 1999. Mya arenaria – an ancient invader of the North Sea Coast. Helgoländer Meeresunters 52:309–324.
- Strasser, M. 1999. Mya arenaria – an ancient invader of the North Sea Coast. Helgoländer Meeresunters 52:309–324.
- Strasser, C. A., and P. H. Barber. 2009. Limited genetic variation and structure in softshell clams (Mya arenaria) across their native and introduced range. Conservation Genetics 10:803-814. doi: 10.1007/s10592-008-9641-y
- Urban-Malinga, B., Zalewski, M., and N. Barnes. 2016. Effects of various bivalves on meiobenthic and nematode assemblages in shallow sandy sediments. Hydrobiologia 772:131–144. doi: 10.1007/s10750-016-2650-9
- Zaiko, A., Lehtiniemi, M., Narscius, A., and S. Olenin. 2011. Assessment of bioinvasion impacts on a regional scale: A comparative approach. Biological Invasions 13:1739-1765. doi: 10.1007/s10530-010-9928-z
- Environmental Protection Agency (EPA). 2014. Small Vessel General Permit for Discharges Incidental to the Normal Operation of Vessels Less than 79 Feet (sVGP). Washington, D.C., USA. 53 pp.