Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

Scientific Name: *Molgula manhattensis*

Common Name *sea grapes*

Phylum	Chordata
Class	Ascidiacea
Order	Stolidobranchia
Family	Molgulidae

Species Occurrence by Ecoregion

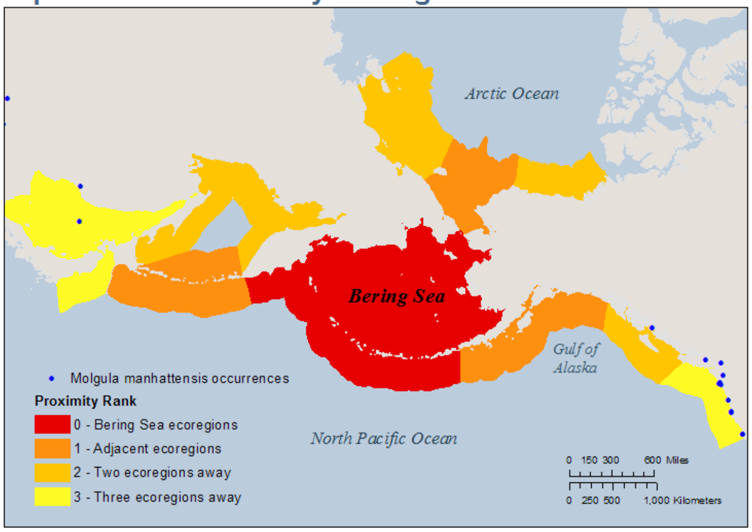

Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

Final Rank 45.00

Data Deficiency: 0.00

Category Scores and Data Deficiencies

Category	Score	Total Possible	Data Deficient Points
Distribution and Habitat:	14.5	30	0
Anthropogenic Influence:	4.75	10	0
Biological Characteristics:	20.5	30	0
Impacts:	5.25	30	0
Totals:	45.00	100.00	0.00

General Biological Information

Tolerances and Thresholds

Minimum Temperature (°C)	5	Minimum Salinity (ppt)	10
Maximum Temperature (°C)	NA	Maximum Salinity (ppt)	35
Minimum Reproductive Temperature (°C)	10	Minimum Reproductive Salinity (ppt)	31*
Maximum Reproductive Temperature (°C)	NA	Maximum Reproductive Salinity (ppt)	35*

Additional Notes

This species is a solitary tunicate with a round, globular body. It is greenish-grey in color and 20-30 mm in length. M. manhattensis is native to the East and Gulf Coasts of the United States and has been introduced to Europe, Japan, Australia, Argentina, and the West Coast of North America. It is a common fouling species that was likely transported on ship hulls or with Eastern oyster (Crassostrea virginica) aquaculture. It can negatively affect oysters and related industries through fouling, and has also been observed competing with other fouling species. It is tolerant of a wide range of temperatures, salinities and pollution levels.

Confused taxonomy: Several species had, until recently, been included in Molgula manhattensis: Molgula simplex Alder & Hancock, 1870, Molgula siphonata Alder 1850, Molgula socialis Alder 1848, and Molgula tubifera Orstedt 1844. Currently, M. tubifera is considered synonymous with M. manhattensis, while M. socialis has been found to be genetically distinct and is presumably native to the northeast Atlantic.

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

Review Date: 9/15/2017

1. Distribution and Habitat

1.1 Survival requirements - Water temperature

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

Score: 0 of 3.75

High uncertainty? ✔

Ranking Rationale:
Although year-round temperature requirements do not exist in the Bering Sea, thresholds are based on geographic distribution, which may not represent physiological tolerances. We therefore ranked this question with "High uncertainty".

Background Information:
This species has been reported as far north as Bergen, Norway (61.3°N), where water temperatures average 5°C to 18°C (Fofonoff et al. 2003; IMR 2017). It is native to the east coast of North America, from New Hampshire to the Gulf of Mexico.

Sources:
NEMESIS; Fofonoff et al. 2003 IMR 2017

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

High uncertainty? ✔

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

Background Information:
Based on its geographic distribution, this species can tolerate salinities from 10 to 35 ppt, if not higher (Fofonoff et al. 2003).

Sources:
NEMESIS; Fofonoff et al. 2003

1.3 Establishment requirements - Water temperature

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

Score: 0 of 3.75

Ranking Rationale:
This species cannot survive year-round in the Bering Sea. Year-round survival is required to establish a self-sustaining population.

Background Information:
In Denmark, reproduction started when water temperatures reached 10°C (Lützen 1967, qtd. in Jensen 2010). In southern Russia, settlement of juveniles was observed between 13 and 22°C (Zvyagintsev et al. 2003).

Sources:
NOBANIS 2016 Zvyagintsev et al. 2003

1.4 Establishment requirements - Water salinity

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

Score: 0 of 3.75

Ranking Rationale:
This species cannot survive year-round in the Bering Sea. Year-round survival is required to establish a self-sustaining population.

Background Information:
No information found.

Sources:
NEMESIS; Fofonoff et al. 2003

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:
This species is found on Vancouver Island, BC and in the Sea of Japan.

Background Information:
This species has been introduced to the west coast of North America, where it occurs from CA to BC. It is also found on the Pacific west coast, from the Sea of Japan to China.

Sources:
NEMESIS; Fofonoff et al. 2003

1.6 *Global ecoregional distribution*

Choice: A — In many ecoregions globally

Score: 5 of 5

Ranking Rationale:
M. manhattensis is native to eastern North America. It has been introduced to the northwest Pacific, the western coast of North America, Europe, Argentina, and Australia.

Background Information:
Native to eastern North America, from Maine down the coast to Florida and west to Texas. Introduced on the West Coast from California to Vancouver Island, BC. In southern hemisphere, it has been found in temperate waters in Argentina and Australia. In Asia, it is found in southern Russia to southern China. It is relatively widespread in northwestern Europe, occurring in Norway, the Netherlands, Germany, Belgium, and France. It is also found along the Mediterranean Sea (Italy, Greece, and Bulgaria).

Sources:
NEMESIS; Fofonoff et al. 2003

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:
This species has historically been known to undergo rapid range expansions.

Background Information:
This species has spread rapidly and has been introduced worldwide (Zvyagintsev et al. 2003).

Sources:
Zvyagintsev and Korn 2003

Section Total - Scored Points:	14.5
Section Total - Possible Points:	30
Section Total -Data Deficient Points:	0

2. Anthropogenic Transportation and Establishment

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

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

Score: 2 of 4

Ranking Rationale:
This species uses anthropogenic vectors for transport and has low dispersal abilities.

Background Information:
This species is likely transported by fouling or hitchhiking. It has limited potential for long-distance dispersal (Haydar et al. 2011).

Sources:
NEMESIS; Fofonoff et al. 2003   Haydar et al. 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 more commonly reported from anthropogenic substrates.

Background Information:
Although it occurs on both artificial and natural substrates, it is most often found on anthropogenic substrates in ports and harbors.

Sources:
NEMESIS; Fofonoff et al. 2003   Hiscock 2016

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 currently farmed.

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:
Food items are readily available in the Bering Sea.

Background Information:
This species is a filter feeder that feeds 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 with respect to temperature, salinity, substrate type, water quality and water depth.

Background Information:
This species can tolerate a wide range of temperatures and salinities. It can also tolerate polluted waters, high turbidity, and high levels of organic content (Fofonoff et al. 2003, Haydar et al. 2011). It is found on both natural and artificial substrates, and usually occurs on hard substrates such as bivalves, rocks, and ship hulls. It is found in a range of habitats and water depths, from wave-exposed to sheltered sites, and up to 90 m in depth (Hiscock 2016).

Sources:
Hiscock 2016 NEMESIS; Fofonoff et al. 2003 Haydar et al. 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:
The desiccation tolerance of this species is unknown; however, in general, tunicates have a low tolerance to desiccation.

Background Information:
Tunicates have a low tolerance to desiccation (Pleus 2008).

Sources:
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 is hermaphroditic, and exhibits a short generation time and low parental investment. Fertilization is internal.

Background Information:

This species is hermaphroditic. Self-fertilization has been documented in the laboratory (Morgan 1942, qtd. in Haydar et al. 2011), but the frequency of self-fertilization in the field is unknown. Fertilization is internal. Eggs hatch within 24 h (Grave 1933, qtd. in Jensen 2010), but have been observed to hatch within 10 h at temperatures of 18°C (Berill 1931, qtd. in Hiscock 2016). The larval stage is free-swimming and lasts a few days at most, at which point they settle and metamorphose (Saffo & Davis 1982, qtd. in Jensen 2010). Berill (1931, qtd. in Hiscock 2016) observed larval settlement within 1 to 10 h. The larval stage may also be bypassed and metamorphosis may be completed in situ (Morgan 1942, qtd. in Jensen 2010). Individuals typically live less than 1 year, and reach sexual maturity in 3 weeks, though fertility increases after one month (Grave 1933, qtd. in Jensen 2010).

Sources:

Haydar et al. 2011   NOBANIS 2016   Hiscock 2016

3.5 Likelihood of long-distance dispersal or movements

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

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

Score: 0.75 **of** 2.5

High uncertainty? ✔

Ranking Rationale:

This species has low potential for long-distance dispersal.

Background Information:

Haydar et al. (2011) suggests that M. manhattensis has low dispersal potential, because although larval stage is free-swimming, it is also short-lived, ranging from minutes to several hours. Rafting of eggs, juveniles or adults has not been reported (Thiel and Gutow 2005, qtd. in Haydar et al. 2011). Adults are sessile. Shanks (2009) estimated that Molgula pacifica, a related species, can disperse < 1 m under natural conditions. Gregarious settlement has been reported in this species, meaning that larvae are more likely to settle near conspecifics. In an experimental community, this settlement behavior was so extreme that it caused the entire Molgula aggregation to fall off the substrate (Stachowicz et al. 1999).

Sources:

Haydar et al. 2011   Shanks 2009   Stachowicz et al. 1999

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 only disperse during its larval stage. Larvae can be free-swimming from several hours to days.

Background Information:
This species' larval stage may last up to a few days (qtd. in Jensen 2010). Adults are sessile. Rafting of eggs, juveniles or adults has not been reported in this species (Thiel and Gutow 2005, qtd. in Haydar et al. 2011).

Sources:
Haydar et al. 2011 NOBANIS 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:
Ascidians are eaten by several taxa commonly found in the Bering Sea.

Background Information:
Predators of ascidians include flatworms, mollusks, crabs, sea stars, and some fishes.

Sources:
O'Clair and O'Clair 1998

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

Score: 0.75 of 2.5

Ranking Rationale:
At high densities, M. manhattensis may compete for space with other fouling organisms.

Background Information:
In Chesapeake Bay, where it is native, M. manhattensis can rapidly settle on and overgrow other fouling organisms. Molgula species are often found on hydroids and erect bryozoans (qtd. in Dijkstra et al. 2007). Complete cover of M. manhattensis was occasionally observed in Newport and Alamitos Bays, California; however, it was absent from most sites, and, where present, usually occurred at much lower densities (0.1 to 1 individuals/m2) (Lambert and Lambert 2003). The 13 other invasive species that were surveyed were either far more common and/or abundant across the study area (Lambert and Lambert 2003). Settlement panel experiments by Osman and Whitlatch (1995) found that the recruitment of other sessile invertebrates was not affected by the presence of M. manhattensis.

Sources:
Lambert and Lambert 2003   Dijkstra et al. 2007   Osman and Whitlatch 1995

4.2 Impact on habitat for other species

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

Score: 0.75 of 2.5

Ranking Rationale:
By fouling substrates, this species may reduce available habitat for some organisms. Conversely, it may create secondary settlement habitat for others.

Background Information:
M. manhattensis can cover substrates with layers of tunicates ~10 to 20 mm deep. Osman and Whitlatch (1995) found low levels of recruitment on panels fouled by M. manhattensis, suggesting that M. manhattensis did not create secondary habitat for fouling species. However, Otsuka and Dauer (1982) observed hydroids, bryozoans, and polychaetes settling on M. manhattensis.

Sources:
Osman and Whitlatch 1995   Otsuka and Dauer 1982

4.3 Impact on ecosystem function and processes

Choice: **D** No impact

Score: 0 of 2.5

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

Background Information:
No impacts have been reported.

Sources:
NEMESIS; Fofonoff et al. 2003

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

Choice: **D** No impact

Score: 0 of 2.5

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

Background Information:
No impacts have been reported.

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:
This species is not expected to transport diseases, parasites, or hitchhikers that will impact the Bering Sea.

Background Information:
M. manhattensis has a symbiotic relationship with a fungus-like protist, Nephromyces sp. (Saffo 1988). Nephromyces is found in the renal sac of M. manhattensis and is likely associated with urate metabolism. This organism is found in six other molgulid tunicates (Saffo 1988). No impacts have been reported.

Sources:
Saffo 1988

4.6 Level of genetic impact on native species

Can this invasive species hybridize with native species?

Choice: **D** No impact

Score: 0 of 2.5

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

Background Information:
No impacts have been reported.

Sources:
NEMESIS; Fofonoff et al. 2003

4.7 *Infrastructure*

Choice: **B**

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

Score: 1.5 of 3

Ranking Rationale:
This species is an abundant fouler of ships. Fouling organisms on ships cause drag and reduce maneuverability, and impose high economic costs on vessel owners.

Background Information:
M. manhattensis is a major fouling organism on ships (Fofonoff et al. 2003). Fouling organisms on ships cause drag and reduce maneuverability. They are estimated to cost the U.S. Navy over $50 million a year in fuel costs due to increased drag (Cleere 2001).

Sources:
NEMESIS; Fofonoff et al. 2003   Cleere 2001

4.8 *Commercial fisheries and aquaculture*

Choice: **C**

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

Score: 0.75 of 3

Ranking Rationale:
This species may affect the growth and development of bivalves by fouling their shells. However, no impacts have been reported. Shellfish aquaculture currently occurs only in a restricted area of the Bering Sea.

Background Information:
In its native range, M. manhattensis is a major fouling organism on oyster shells and trays used in aquaculture (Andrews 1973, qtd. in Fofonoff et al. 2003). Through fouling, it may double or triple the weight of oyster trays in one month (Andrews 1973, qtd. in Fofonoff et al. 2003). No other impacts have been reported.

Sources:
NEMESIS; Fofonoff et al. 2003

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:
This species may affect the growth and development of bivalves by fouling their shells, but no impacts have been reported. Shellfish is an important subsistence resource for certain communities in the Bering Sea (Mathis et al. 2015).

Background Information:
In its native range, M. manhattensis is a major fouling organism on oyster shells (Andrews 1973). No further impacts have been reported.

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

4.101 Recreation

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

Score: 0.75 of 3

High uncertainty? ✔

Ranking Rationale:
This species may affect the growth and development of bivalves by fouling their shells, but no impacts have been reported. Recreational harvesting of shellfish occurs in a limited area of the Bering Sea.

Background Information:
In its native range, M. manhattensis is a major fouling organism on oysters (Andrews 1973, qtd. in Fofonoff et al. 2003), but no further impacts have been reported.

Sources:
NEMESIS; Fofonoff et al. 2003

4.11 Human health and water quality

Choice: D — No impact

Score: 0 of 3

Ranking Rationale:
This species is not expected to impact human health and water quality in the Bering Sea.

Background Information:
No impacts have been reported.

Sources:
NEMESIS; Fofonoff et al. 2003

Section Total - Scored Points:	5.25
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:
No species-specific plans are in place to control or eradicate this species. This species is transported by fouling and hitchhiking. Controlling the spread of fouling organisms is an active area of research.

Background Information:

Sources:
NEMESIS; Fofonoff et al. 2003

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:
At this time, there are no known control methods for solitary tunicates.

Background Information:
Preliminary results suggest that exposure to freshwater may be effective against solitary tunicates, but further work is needed (Carman et al. 2016). Hand removal may be feasible for small areas with low densities.

Sources:
AISU 2011   Carman et al. 2016

5.3 Regulatory barriers to prevent introductions and transport

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

Score: of

Ranking Rationale:
In Alaska, there are regulations in place for the transport of bivalve species, via which M. manhattensis can be unintentionally transported. Compliance with U.S. hull fouling regulations - another transport vector for this species - are largely voluntary.

Background Information:
In Canada, Fisheries and Oceans Canada's require a license to move bivalves from tunicate infested waters. This regulation has been successful in containing and slowing the anticipated spread of several tunicate species, which can be unintentionally transported through their association with bivalves (DFO 2010). Similar regulations exist in Alaska regarding the transport and introduction of shellfish in water bodies. Under Alaska law, a permit must be obtained from the Alaska Department of Fish and Game (ADF&G) in order to collect, possess, or transport shellfish for educational, scientific, or propagative uses (AAC 2017). Compliance with ship fouling regulations are largely voluntary (Hagan et al. 2014).

Sources:
CFR 2017   DFO 2010   AAC 2017

5.4 *Presence and frequency of monitoring programs*

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

Score: of

Ranking Rationale:
Surveillance for invasive tunicates in Alaska is conducted by scientists and volunteers.

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

Sources:
iTunicate Plate Watch 2016

5.5 *Current efforts for outreach and education*

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

Score: of

Ranking Rationale:
Outreach and education programs are in place in Alaska to educate people on invasive tunicates.

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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