Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

Scientific Name: *Molgula citrina*

Common Name *sea grape*

Phylum	Chordata
Class	Ascidiacea
Order	Stolidobranchia
Family	Molgulidae

Final Rank 53.15

Data Deficiency: 8.75

Species Occurrence by Ecoregion

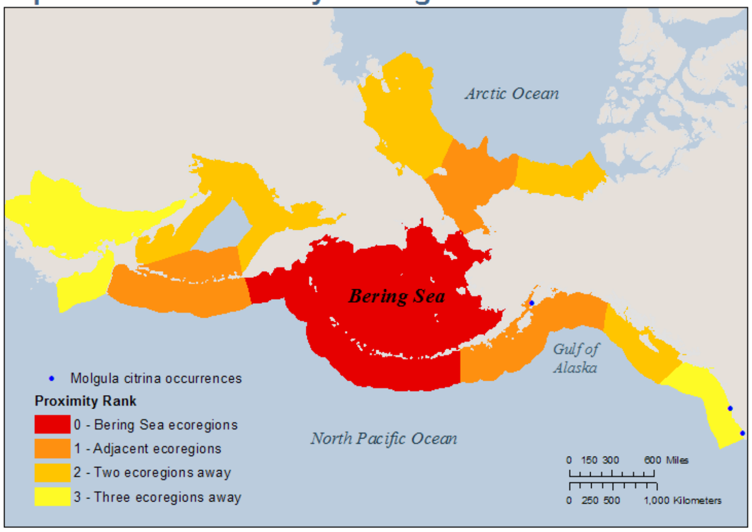

Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

Category Scores and Data Deficiencies

Category	Score	Total Possible	Data Deficient Points
Distribution and Habitat:	20.5	26	3.75
Anthropogenic Influence:	4.75	10	0
Biological Characteristics:	19.5	30	0
Impacts:	3.75	25	5.00
Totals:	48.50	91.25	8.75

General Biological Information

Tolerances and Thresholds

Minimum Temperature (°C)	-1.4	Minimum Salinity (ppt)	17
Maximum Temperature (°C)	12.2	Maximum Salinity (ppt)	35
Minimum Reproductive Temperature (°C)	NA	Minimum Reproductive Salinity (ppt)	31*
Maximum Reproductive Temperature (°C)	NA	Maximum Reproductive Salinity (ppt)	35*

Additional Notes

M. citrina is a prominent member of the fouling community. It is widely distributed in the North Atlantic, and has been reported as far north as 78°N (Lambert et al. 2010). In North America, it has been found from eastern Canada to Massachusetts. In 2008, it was found in Kachemak Bay in Alaska, the first time it had been detected in the Pacific Ocean (Lambert et al. 2010). While it is possible that these individuals are native to AK, preliminary DNA results suggest that they are genetically identical to specimens of the NE Atlantic. It may have been transported through the Arctic Ocean as biofouling in a heated part of the ship (Fofonoff et al. 2003).

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: **B**

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

Score: 2.5 **of** 3.75

High uncertainty? ✔

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

Background Information:
Based on observations, temperature range for survival of M. citrina - 1.4°C to 12.2°C (EOL).

Sources:
EOL 2016   Lambert et al. 2010   Bursch and McCann 2016

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:
Based on observations, salinity range for survival of M. citrina is 17 ppt to 35 ppt.

Sources:
Lambert et al. 2010   NEMESIS; Fofonoff et al. 2003

1.3 Establishment requirements - Water temperature

Choice: **U**

Unknown/Data Deficient

Score: **of**

Ranking Rationale:

Background Information:
No information available in the literature.

Sources:
None listed

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: **B** Present in an ecoregion adjacent to the Bering Sea

Score: 3.75 of 5

Ranking Rationale:

Background Information:
Found in Kachemak Bay, Alaska. On the North American Pacific coast, has also been found in Oregon and northern California.

Sources:
NEMESIS; Fofonoff et al. 2003

1.6 Global ecoregional distribution

Choice: **C** In few ecoregions globally

Score: 1.75 of 5

Ranking Rationale:

Background Information:
Largely restricted to polar and cold temperate ecoregions, from ~ 78°N to 39°N. May be more widespread, but data is sparse.

Sources:
NEMESIS; Fofonoff et al. 2003

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:

Background Information:
Potential for long-distance dispersal, but perhaps only in light of anthropogenic vectors. Since discovery in AK in 2008, has been found in OR and CA. If these are new introductions, suggests expansion towards study area.

Sources:
Lambert et al. 2010

Section Total - Scored Points:	20.5
Section Total - Possible Points:	26.25
Section Total -Data Deficient Points:	3.75

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:

Free-swimming larval stage is very short (≤2 hours), most transportation likely occurs from attaching to anthropogenic vectors.

Background Information:

Transport in ship ballast water is unlikely, because the free-swimming tadpole stage is very short (minutes to maybe a few hours) (Lambert et al. 2010). A more likely vector is transport through sea chests. M. citrina probably could not survive a ship's passage through the warm waters of the Caribbean and Panama Canal, but it could survive a trip across the NW Passage – which, the authors suggest, is how M. citrina arrived in Alaska (Lambert et al. 2010). The NW Passage is expected to become an increasingly popular shipping route as conditions warm and the passage remains ice-free for longer periods of time.a

Sources:

Lambert et al. 2010

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

High uncertainty? ✔

Ranking Rationale:

Short dispersal potential. Lack of information about spread and spatial distribution pattern of M. citrina. Unsure if M. citrina can establish in natural areas once it has been introduced.

Background Information:

In its native range, M. citrina attaches on a variety of substrates, including mussels, hydroids, and red algae (Railkin and Dysina 1997). A study along the Mediterranean coast, where it is introduced, found that non-native tunicates were abundant in most of the 32 surveyed harbors (López-Legentil et al. 2015).

Sources:

Lopez-Legentil et al. 2015   Railkin and Dysina 1997

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

Choice: B

No

Score: 0 of 2

Ranking Rationale:

Background Information:

M. citrina is not currently farmed or intentionally cultivated.

Sources:

None listed

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

3. Biological Characteristics

3.1 Dietary specialization

Choice: **A**

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

Score: 5 of 5

Ranking Rationale:
Consumes numerous taxa.

Background Information:
Tunicates in general are suspension feeders and feed on diatoms, detritus, and invertebrate larvae. Short-lived larval form is non-feeding.

Sources:
O'Clair and O'Clair 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:

Background Information:
Habitat is restricted to rocky, unstructured bottom, marinas and docks, which is plentiful in the Bering Sea.

Sources:
O'Clair and O'Clair 1998

3.3 Desiccation tolerance

Choice: **C**

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

Score: 1.75 of 5

Ranking Rationale:

Background Information:
Tunicates in general have little to no desiccation tolerance (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:		Score:
A	High – Exhibits three or four of the above characteristics	5 of 5

Ranking Rationale:

Hermaphroditic with self-fertilization possible, short generation time, moderate parental investment (brood eggs before releasing tadpole juveniles)

Background Information:

M. citrina broods its young (Lambert et al. 2010), but there is no parental investment once the larvae are released. Solitary tunicates (such as M. citrina) do not reproduce asexually (i.e. through budding, O'Clair and O'Clair 1998).
General info: Ascidians are hermaphroditic, and self-fertilization is possible. Many species common in fouling communities grow rapidly and reach sexual maturity within just a few weeks (Lambert and Lambert 1998). The lifespan of 4 solitary tunicate species in Connecticut, including the closely related M. manhattensis, all had a lifespan between 1-2 years (Team Benthos).
Tunicates have a relatively short generation time (e.g. Thalia democratica; Heron 1972).

Sources:

Heron 1972 Lambert and Lambert 1998 Lambert et al. 2010 O'Clair and O'Clair 1998 Team Benthos 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:		Score:
C	Disperses short (< 1 km) distances	0.75 of 2.5

Ranking Rationale:

Larva have a short free-swimming stage that permits dispersal distances of less than 1 km. Adults are sessile and transport only if their substrate is moved (e.g. floating eel grass beds, ship hulls, etc.).

Background Information:

M. citrina has a free-swimming larval stage that lasts $\leq$ 2 hours (Lambert et al. 2010). A study on a tropical tunicate Lissoclinum patella suggests that larvae of these species have a potential dispersal distance of several hundred meters (dependent on speed of currents), but their realized dispersal is <10m (Olson and McPherson 1987).
Adults are sessile, but a study on a colonial species complex Botrylloides sp. suggested that adults can travel over 200 times farther than swimming larvae by rafting on drifting eelgrass (Worcester 1994).

Sources:

Lambert et al. 2010 Olson and McPherson 1987 Worcester 1994

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: **C** Low – Exhibits none of the above characteristics

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

Ranking Rationale:

Larvae are mobile for ~2 hours, adults are sessile.

Background Information:

Although free-swimming larval stage is very short (≤2 hours), post-metamorphosis juveniles could survive attached in sea chests or free-floating in ballast water (Lambert et al. 2010). Lambert et al. (2010) suggests that M. citrina could survive in these human environments for generations and sustain a viable population with which to invade new habitats. Though sessile, adults can disperse through rafting (e.g. on vegetation) or attachment to moveable substrates such as boats and fishing gear.

Sources:

Lambert et al. 2010

3.7 Vulnerability to predators

Choice: **D** Multiple predators present in the Bering Sea or neighboring regions

Score: **1.25** **of** **5**

Ranking Rationale:

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

Background Information:

Tunicates predators include flatworms, mollusks, crabs, sea stars, and some fishes.
Study on a tropical tunicate Lissoclinum patella: larvae are heavily predated upon by fish and corals (Olson and McPherson 1987).

Sources:

Olson and McPherson 1987 O'Clair and O'Clair 1998

Section Total - Scored Points:	19.5
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:

Background Information:
A study on invasive tunicates (not including M. citrina), found that, although tunicates were feeding on similar resources as commercial shellfish species and native tunicates, tunicates did not have a measurable impact on the food web (Colarusso et al. 2016). No ecological impacts have been reported for M. citrina.

Sources:
Colarusso et al. 2016

4.2 Impact on habitat for other species

Choice: **D** No impact

High uncertainty? ☑

Score: 0 **of** 2.5

Ranking Rationale:

Background Information:
No ecological impacts have been reported for M. citrina (Foffonoff et al. 2003)

Sources:
NEMESIS; Fofonoff et al. 2003

4.3 Impact on ecosystem function and processes

Choice: **D** No impact

Score: 0 **of** 2.5

Ranking Rationale:
No measurable impacts on ecosystem function or processes have been reported for M. citrina.

Background Information:
A study on invasive tunicates (not including M. citrina), found that, although tunicates were feeding on similar resources as commercial shellfish species and native tunicates, tunicates did not have a measurable impact on the food web (Colarusso et al. 2016). No ecological impacts have been reported for M. citrina.

Sources:
Colarusso et al. 2016 Lambert and Lambert 1998

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

Choice: **D** No impact

Score: 0 **of** 2.5

Ranking Rationale:
No ecological impacts have been reported for M. citrina.

Background Information:

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: **U** Unknown

Score: of

Ranking Rationale:

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: **U** Unknown

Score: of

Ranking Rationale:

Background Information:
No information available in the literature.

Sources:
None listed

4.7 Infrastructure

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

Score: 1.5 of 3

Ranking Rationale:
M. citrina is a fouling organism that grows on industrial surfaces.

Background Information:
Ascidians in general contribute to the economic and technical problems of marine biofouling because of their growth on the surfaces of industrial objects, such as ships, buoys, and fishing nets (Feng et al. 2010). In Alaska, M. citrina was found attached to docks and ropes.

Sources:
Feng et al. 2010

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:
Has been known to have a limited impact for farmed mussels outsite of Alaska. Acts as a biofouling agent which decreases the efficiency of fisheries vessels.

Background Information:
In PEI, tunicates in general are a nuisance to the mussel farming industry. The solitary vase tunicate Ciona intestinalis overtakes mussel socks (where mussels are grown), competing for food and increasing costs through fouling and increased sock weight. In Massachusetts, invasive tunicates (not including M. citrina) competed with farmed mussels (and scallops), leading to a reduction in shell growth and tissue weight, and a resulting negative impact on farm productivity and profitability (Carman et al. 2016). No information on the effects of M. citrina specifically.

Sources:
Carman et al. 2016   DFO 2010

4.9 *Subsistence*

Choice: **D** No impact

Score: 0 of 3

Ranking Rationale:
To date, no impacts on subsistence have been reported for M. citrina, and given its ecology, none would be expected.

Background Information:
No information available in the literature.

Sources:
None listed

4.101 *Recreation*

Choice: **D** No impact

Score: 0 of 3

Ranking Rationale:
To date, no impacts on recreation have been reported for M. citrina, and given its ecology, none would be expected.

Background Information:
No information available in the literature.

Sources:
None listed

4.11 *Human health and water quality*

Choice: **D** No impact

Score: 0 of 3

Ranking Rationale:
To date, no impacts on human health and/or water quality have been reported for M. citrina.

Background Information:
No information available in the literature.

Sources:
None listed

Section Total - Scored Points:	3.75
Section Total - Possible Points:	25
Section Total -Data Deficient Points:	5

5. Feasibility of prevention, detection and control

5.1 History of management, containment, and eradication

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

Score: of

Ranking Rationale:
Containment and mitigation methods have been studied, tested and proven effective for several species of non-native, fouling tunicates.

Background Information:
Containment and mitigation methods for tunicates have been studies and trialed in Prince Edward Island, Canada by the Department of Fisheries and Oceans and the aquaculture industry (DFO 2010). Mitigation techniques have been tested on several species including Ciona intestinalis and Styela clava. Techniques and include high-pressure nozzles to wash off or pierce hull fouling tunicates, and the delivery of a lime solution to mussel socks infested with S. clava. Lime treatment caused mortality in approximately 90% of S. clava individuals, and a one-time spray application of hydrated lime on mussels may be sufficient to reduce tunicate fouling to a manageable level (DFO 2010).

Sources:
DFO 2010

5.2 Cost and methods of management, containment, and eradication

Choice: **C** Easy and inexpensive (minor investment)

Score: of

Ranking Rationale:
Deployment of lime solutions and/or high pressure water treatments are not time intensive and are relatively inexpensive.

Background Information:
Control methods for non-native, fouling tunicates are currently being researched. These tunicates have been successfully controlled in some cases using chemicals (e.g. salt or lime solutions), or high-pressure washing (DFO 2010; AISU 2011). Tunicates have also been physically removed off vessel hulls. Because mortality is not 100%, eradication is likely not a realistic option, but under certain scenarios populations may be controlled to reasonable levels (DFO 2010).

Sources:
AISU 2011 DFO 2010

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. citrina can be unintentionally transported. U.S. federal regulations require mandatory reporting and ballast water treatment or exchange, but compliance with 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). Ballast water management is mandatory and regulated by the U.S. Coast Guard (CFR 33 § 151.2), but compliance with ship fouling regulations are largely voluntary (Hagan et al. 2014).

Sources:
DFO 2010 Hagan et al. 2014 CFR 2017 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:
Invasive tunicates are monitored by volunteers from the Invasive Tunicate Network and KBNERR.

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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