Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

Scientific Name: *Diadumene lineata*

Common Name *orange-striped anemone*

Phylum	Cnidaria
Class	Anthozoa
Order	Actiniaria
Family	Diadumenidae

Final Rank 50.13

Data Deficiency: 3.75

Species Occurrence by Ecoregion

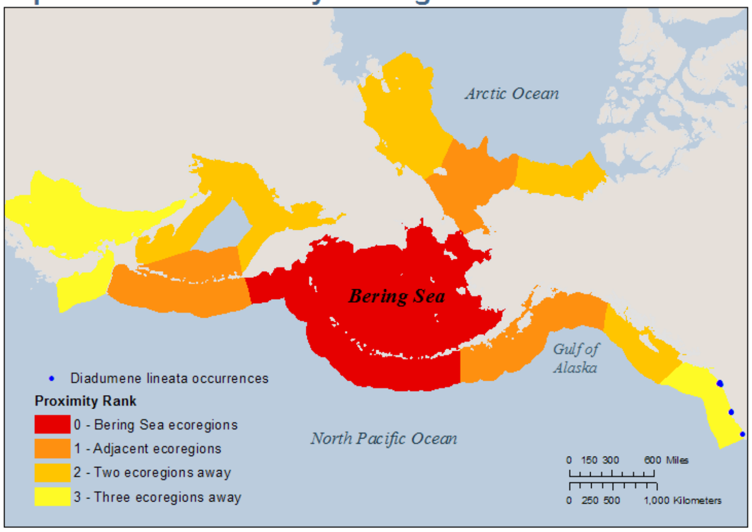

Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

Category Scores and Data Deficiencies

Category	Score	Total Possible	Data Deficient Points
Distribution and Habitat:	19.5	26	3.75
Anthropogenic Influence:	6	10	0
Biological Characteristics:	22	30	0
Impacts:	0.75	30	0
Totals:	48.25	96.25	3.75

General Biological Information

Tolerances and Thresholds

Minimum Temperature (°C)	0	Minimum Salinity (ppt)	7
Maximum Temperature (°C)	27.5	Maximum Salinity (ppt)	74
Minimum Reproductive Temperature (°C)	NA	Minimum Reproductive Salinity (ppt)	8
Maximum Reproductive Temperature (°C)	NA	Maximum Reproductive Salinity (ppt)	35*

Additional Notes

Diadumene lineata is a sea anemone with 50-100 long, thin tentacles. Tentacles are usually colourless, but may be gray or light green. The column can be brown to green, or gray, and can be plain or with white or orange-red stripes. Individuals are small-bodied: the largest specimen found was 31 mm in height and 22 mm wide.

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. This species may have adaptations that allow it to tolerate temperature extremes; moreover, models disagree with respect to their estimates of suitable area. We therefore ranked this question with "High uncertainty".

Background Information:
This species can tolerate temperatures from 0 to 27.5°C (Shick 1976, qtd. in Fofonoff et al. 2003). At least in the short-term, it can survive drastic temperatures e.g., being under ice (Shick and Lamb 1977) and temperatures as high as 40°C (Shick 1976, qtd. in Fofonoff et al. 2003). This species can secrete a thick layer of mucous or a hard coating, which can protect it against environmental extremes (qtd. in Fofonoff et al. 2003).

Sources:
NEMESIS; Fofonoff et al. 2003 Shick and Lamb 1977

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:
This species can tolerate salinities between 8 and 74 PSU (based on experimental data). Although it can survive at lower salinities (<8 PSU), it exhibits stress responses and is unable to reproduce asexually (Podbielski et al. 2016). Salinities below 8 PSU are likely a physiological limit for this species (Podbielski et al. 2016).

Sources:
NEMESIS; Fofonoff et al. 2003 Podbielski et al. 2016

1.3 Establishment requirements - Water temperature

Choice: U Unknown/Data Deficient

Score: of

Ranking Rationale:
In its introduced range, only asexual reproduction has been reported. Temperature requirements for asexual reproduction are unknown.

Background Information:
In Japan, spawning occurred when water temperatures reached 25°C (Fukui 1989). However, in its introduced range, D. lineata is only known to reproduce asexually (Fofonoff et al. 2003). The temperature requirements for asexual reproduction are unknown.

Sources:
NEMESIS; Fofonoff et al. 2003 Fukui 1989

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

Background Information:
Podbielski et al. (2016) observed that asexual reproduction stopped at salinities below 7 PSU.

Sources:
Podbielski et al. 2016

1.5 Local ecoregional distribution

Choice: **D** Present in an ecoregion greater than two regions away from the Bering Sea

Score: 1.25 of 5

Ranking Rationale:
D. lineata has been reported as far north as Vancouver Island.

Background Information:
D. lineata has been reported as far north as Vancouver Island.

Sources:
NEMESIS; Fofonoff et al. 2003

1.6 Global ecoregional distribution

Choice: **A** In many ecoregions globally

Score: 5 of 5

Ranking Rationale:
This species has a global distribution, and has been introduced to both coasts of North America, temperate South America, western Europe, and some Pacific islands.

Background Information:
D. lineata is native to the Northwest Pacific, from Japan to Hong Kong (Fofonoff et al. 2003). It has been introduced on both coasts of North America, from AK to CA in the west and from Halifax to Texas in the east. In South America, it has recently been reported in South America (Chile, Argentina). In Europe, it occurs from Ireland and England, south to Spain, and east to the Mediterranean, Black, and Aegean Seas. It is also considered introduced on Pacific islands (New Zealand, Hawaii) (Fofonoff et al. 2003).

Sources:
NEMESIS; Fofonoff et al. 2003

1.7 Current distribution trends

Choice:		Score:
B	History of rapid expansion or long-distance dispersal (prior to the last ten years)	**3.25** of **5**

Ranking Rationale:
This species has been reported from new areas, but rapid spread has not been documented recently.

Background Information:
This species sometimes undergoes boom and bust cycles, spreading rapidly and then dying back (Stephenson 1935, qtd. in Häussermann et al. 2015). It has recently been reported in Argentina (Molina et al. 2009), in Chile (Häussermann et al. 2015), and in the Baltic Sea (Podbielski et al. 2016).

Sources:
Podbielski et al. 2016   Häussermann et al. 2015   Molina et al. 2009

Section Total - Scored Points:	19.5
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:
This species is known to use anthropogenic vectors for transport, but independent spread following its introduction has not been reported.

Background Information:
This species is sesille, but can be spread via hull fouling or with introductions of other species such as oysters. This species is not known to reproduce sexually in its introduced range, which may limit its potential for independent transport.

Sources:
NEMESIS; Fofonoff et al. 2003

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:
In its introduced range, this species can establish on natural and anthropogenic substrates.

Background Information:
This species has been observed growing on the roots and stems of the marsh grass Spartina alterniflora (Molina et al. 2009). In the Baltic Sea, it was reported on both natural and anthropogenic hard substrates (Podbielski et al. 2016).

Sources:
Molina et al. 2009   Podbielski et al. 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 or cultivated.

Background Information:

Sources:
NEMESIS; Fofonoff et al. 2003

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:
D. lineate has a generalist diet and prey items are readily available in the Bering Sea.

Background Information:
This species eats zooplankton and other small organisms.

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 can tolerate a wide range of temperatures and salinities, and can settle on a range of substrates.

Background Information:
This species is usually found in protected coastal areas. It can grow on a range of substrates including aquatic vegetation, mussels, and marine infrastructure (Shick and Lamb 1977; Fofonoff et al. 2003). It can tolerate a wide range of salinities and temperatures, and has established populations in the brackish Baltic Sea (Podbielski et al. 2016).

Sources:
Podbielski et al. 2016   NEMESIS; Fofonoff et al. 2003   Shick and Lamb 1977

3.3 Desiccation tolerance

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

High uncertainty? ✔

Score: 3.25 of 5

Ranking Rationale:
This species is able to tolerate environmental extremes. Although information on its dessication tolerance is scarce, we suspect that it can survive for at least 24 hours.

Background Information:
D. lineata can survive exposure to high heat in the intertidal zone (Shick and Lamb 1997). Larger individuals may be able to tolerate being exposed to air for ~24 hours (Clodius 2013, access to abstract only). Individuals exposed to air for ~20 hours were still viable after returning to saltwater (Gollasch and Riemann-Zürneck 1996).

Sources:
Shick and Lamb 1977   Clodius 2013   Gollasch and Riemann-Zürneck 1996

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:

In its introduced range, this species is known to reproduce exclusively by asexual means. Fertilization is likely external, and asexual reproduction requires low parental investment. Fecundity estimates are unknown, but its ability to reach high densities through asexual reproduction suggests high output and survival of clones. Several authors have highlighted the success of this species' reproductive strategy.

Background Information:

This species can reproduce both sexually and asexually. Sexual reproduction has not been reported in any introduced population (Fofonoff et al. 2003). In Maine, this species was able to reach extremely high densities (4000 individuals/m2) solely through asexual reproduction. Asexual reproduction in this species may contribute to its invasion success (Shick and Lamb 1977; Ting and Geller 2000; Molina et al. 2009; Podbielski et al. 2016). Most species in this genus exhibit external fertilization (Fofonoff et al. 2003).

Sources:

NEMESIS; Fofonoff et al. 2003 Shick and Lamb 1977 Podbielski et al. 2016 Molina et al. 2009 Ting and Geller 2000

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

High uncertainty? ☑

Score: 1.75 of 2.5

Ranking Rationale:

Estimates for this species' dispersal distance is unknown. The dispersal potential for this species is likely limited in its introduced range, where only asexual reproduction has been documented. Long-distance (>10 km) dispersals are possible, but genetic analyses suggest that these events are rare. Given this information, it is likely that this species typically disperses moderate or low distances.

Background Information:

This species exhibits external fertilization, and larvae can remain in the water column for up to 26 days if no suitable substrate is found (Fukui 1989). However, sexual reproduction has not been observed in non-native populations (Fofonoff et al. 2003). Asexual fragments may disperse via rafting on floating material to which it is attached (Ting and Geller 2000). Genetic analyses by Ting and Geller (2000) revealed that the majority of the genotypes they identified (52 of 56) were only present in one population. Populations with the same genotype were separated by a maximum distance of 43 km (Ting and Geller 2000).

Sources:

Fukui 1989 NEMESIS; Fofonoff et al. 2003 Ting and Geller 2000

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:

This species can disperse at different life stages and has a long-lived larval stage. However, because it is only known to reproduce asexually in its introduced range, we have downgraded its ranking to "Low" to reflect the limited dispersal potential when the gametic and larval stage are discounted.

Background Information:

This species has a long-lived larval stage (Fukui 1989). Adults are sessile, but polyps can disperse by rafting on floating vegetation or wood (Ting and Geller 2000). This species exhibits external fertilization (Fukui 1989), which allows gametes to be dispersed passively.

Sources:

Fukui 1989 Ting and Geller 2000

3.7 Vulnerability to predators

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

Score: 1.25 of 5

Ranking Rationale:
Predators of this species are present in the Bering Sea.

Background Information:
This species is eaten by nudibranchs and gastropods (Molina et al. 2009).

Sources:
Molina et al. 2009

Section Total - Scored Points:	22
Section Total - Possible Points:	30
Section Total -Data Deficient Points:	0

4. Ecological and Socioeconomic Impacts

4.1 *Impact on community composition*

Choice: **D** No impact

Score: 0 of 2.5

Ranking Rationale:
No impacts have been reported so far.

Background Information:
No impacts have been reported to date (Fofonoff et al. 2003), however the ecological impacts of this species are unknown (Molina et al. 2009; Häussermann et al. 2015). As a predator, D. lineata has the potential to affect invertebrate communities (Molina et al. 2009). Competition with native species are estimated to be minimal (Masterson 2007).

Sources:
Molina et al. 2009 Häussermann et al. 2015 Masterson 2007

4.2 *Impact on habitat for other species*

Choice: **D** No impact

Score: 0 of 2.5

Ranking Rationale:
No impacts have been reported. Based on its biology, we do not expect D. lineata to affect habitat in the Bering Sea.

Background Information:
No ecological impacts have been reported for this species (Fofonoff 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 impacts have been reported. Based on its biology, we do not expect D. lineata to affect ecosystem function in the Bering Sea.

Background Information:
No impacts have been reported for this species (Fofonoff et al. 2003).

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:
No impacts have been reported for this species, and we do not expect D. lineata to impact high-value species in the Bering Sea.

Background Information:
No impacts have been reported (Fofonoff et al. 2003).

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 known to transport diseases, parasites, or hitchhikers.

Background Information:
No impacts have been reported (Fofonoff et al. 2003).

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 for this species. In its introduced range, D. lineata is only known to reproduce asexually; thus, we do not expect this species to hybridize with native anemones.

Background Information:
No impacts have been reported (Fofonoff et al. 2003).

Sources:
NEMESIS; Fofonoff et al. 2003

4.7 Infrastructure

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

Score: 0.75 of 3

Ranking Rationale:
This species fouls anthropogenic substrates, but is not known to have a significant impact.

Background Information:
Although this species fouls anthropogenic substrates, but no economic impacts have been reported (Fofonoff et al. 2003).

Sources:
NEMESIS; Fofonoff et al. 2003

4.8 Commercial fisheries and aquaculture

Choice: D No impact

Score: 0 of 3

Ranking Rationale:
This species is not expected to impact commercial fisheries in the Bering Sea.

Background Information:
No impacts have been reported for this species.

Sources:
NEMESIS; Fofonoff et al. 2003 Molnar et al. 2008

4.9 Subsistence

Choice: **D** No impact

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

Ranking Rationale:
This species is not expected to impact subsistence resources in the Bering Sea.

Background Information:
No impacts have been reported.

Sources:
NEMESIS; Fofonoff et al. 2003 Molnar et al. 2008

4.101 Recreation

Choice: **D** No impact

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

Ranking Rationale:
This species is not expected to impact recreational opportunities in the Bering Sea.

Background Information:
No impacts have been reported.

Sources:
NEMESIS; Fofonoff et al. 2003 Molnar et al. 2008

4.11 Human health and water quality

Choice: **D** No impact

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

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

Background Information:
No impacts have been reported.

Sources:
NEMESIS; Fofonoff et al. 2003 Molnar et al. 2008

Section Total - Scored Points:	0.75
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: **B** Not attempted

Score: of

Ranking Rationale:
Control or eradication has not been attempted for this species.

Background Information:
No information found.

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:
This species can be transported via fouling and hitchhiking. Methods to control the spread of invasive species via these vectors are being developed, and currently necessitate major long-term investments.

Background Information:

Sources:
CFR 2017 Hagan et al. 2014

5.3 Regulatory barriers to prevent introductions and transport

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

Score: of

Ranking Rationale:
This species is transported by numerous vectors and no species-specific regulations are currently in place. Although there are federal regulations for hull fouling, compliance with these regulations is largely voluntary.

Background Information:

Sources:
Hagan et al. 2014 CFR 2017

5.4 Presence and frequency of monitoring programs

Choice: **A** No surveillance takes place

Score: of

Ranking Rationale:
No surveillance programs are in place for this species.

Background Information:

Sources:
None listed

5.5 Current efforts for outreach and education

Choice: **A** No education or outreach takes place

Score: of

Ranking Rationale:

No education or outreach programs are in place for this species.

Background Information:

Sources:

None listed

Section Total - Scored Points:

Section Total - Possible Points:

Section Total -Data Deficient Points:

Literature Cited for *Diadumene lineata*

- 33 CFR § 151.2050 Additional requirements - nonindigenous species reduction practices
- Clodius, N. 2013. The influence of body size, temperature and aerial exposure on the reproduction and survival of an invasive sea anemone. Undergraduate Thesis, Mount Holyoke College, South Hadley, MA.
- Fukui, Y. 1991. Embryonic and larval development of the sea anemone Haliplanella lineata from Japan. Pages 137-142 in Williams, R. B., Cornelius, P. F. S., Hughes, R. G., and E. A. Robson, editors. Coelenterate biology: Recent research on Cnidaria and Cte
- Gollasch, S., and K. Riemann-Zürneck. 1996. Transoceanic dispersal of benthic macrofauna: Haliplanella luciae (Verrill, 1898) (Anthozoa, Actiniaria) found on a ship's hull in a shipyard dock in Hamburg Harbour, Germany. Helgoländer Meeresuntersuchungen 50
- 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.
- Häussermann, V., Spano, C., Thiel, M., and K. B. Lohrmann. 2015. First record of the sea anemone Diadumene lineata (Verrill, 1869) from the Chilean coast. Spixiana 38(1):39-42.
- Masterson, J. 2007. Indian River Lagoon Species Inventory. Smithsonian Marine Station. Available from: http://www.sms.si.edu/irlspec/Compl_Reports.htm. Accessed 01-Nov-2016.
- Molina, L. M., Valinas, M. S., Pratolongo, P. D., Elias, R., and G. M. E. Perillo. 2009. First record of the sea anemone Diadumene lineata (Verrill 1871) associated to Spartina alterniflora roots and stems, in marshes at the Bahia Blanca estuary, Argentin
- 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.
- Podbielski, I., Bock, C., Lenz, M., and F. Melzner. 2016. Using the critical salinity (Scrit) concept to predict invasion potential of the anemone Diadumene lineata in the Baltic Sea. Marine Biology 163(11):1-15.
- Shick, J. M., and A. N. Lamb. 1977. Asexual reproduction and genetic population structure in the colonizing sea anemone Haliplanella luciae. Biological Bulletin 153(3):604-617.
- Ting, J. H., and J. B. Geller. 2000. Clonal diversity in introduced populations of an Asian sea anemone in North America. Biological Invasions 2:23-32.