Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

Scientific Name: *Petricolaria pholadiformis*

Common Name *false angelwing*

Phylum Mollusca

Class Bivalvia

Order Veneroida

Family Petricolidae

Final Rank 44.11

Data Deficiency: 8.75

Species Occurrence by Ecoregion

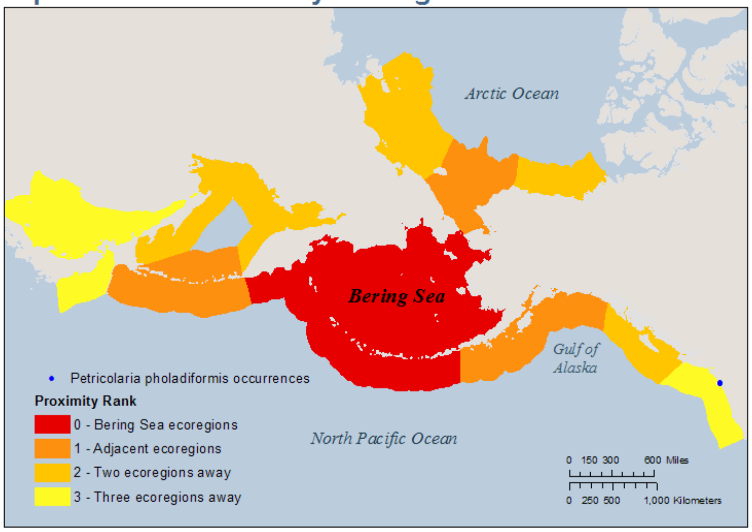

Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

Category Scores and Data Deficiencies

Category	Score	Total Possible	Data Deficient Points
Distribution and Habitat:	13.5	26	3.75
Anthropogenic Influence:	4	10	0
Biological Characteristics:	19.5	25	5.00
Impacts:	3.25	30	0
Totals:	40.25	91.25	8.75

General Biological Information

Tolerances and Thresholds

Minimum Temperature (°C)	1	Minimum Salinity (ppt)	10
Maximum Temperature (°C)	26	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

Petricolaria pholadiformis is a bivalve with an elongated white shell. Many lines radiate from the umbo, and the first ten of these are rather well-defined. The shell is also marked by concentric growth lines. Adult shells measure ~55 mm. Adults live burrowed in substrates such as mud, soft rock, or clay. P. pholadiformis is native to eastern North America, and has been introduced to Europe and the western coast of North America. The most likely vectors of introduction for this species are accidental transport with the Eastern oyster (Crassostrea virginica), and transport via ballast water.

1. Distribution and Habitat

1.1 Survival requirements - Water temperature

Choice: **C** Little overlap – A small area (<25%) of the Bering Sea has temperatures suitable for year-round survival

Score: 1.25 of 3.75

High uncertainty? ✔

Ranking Rationale:
Temperatures required for year-round survival occur in a limited area (<25%) 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:
This species has been reported from Penobscot Bay, ME where water temperatures range from 1.1 to 14.1°C (NERACOOS 2016). In its native range, this species occurs as far south as Padre Island, TX (in the Gulf of Mexico), where water temperatures >26°C have been recorded (NOAA 2017).

Sources:
NERACOOS 2016 NOAA 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

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

Background Information:
Based on its geographic distribution, this species can tolerate salinities up to 35 ppt (Fofonoff et al. 2003). Although it is a marine species, it is usually associated with sites that have some freshwater inflow. Experiments by Castagna and Chalney (1973, qtd. in Fofonoff et al. 2003) found high (90%) survival rates in individuals exposed to 10 ppt water for 52 to 92 days.

Sources:
NEMESIS; Fofonoff et al. 2003

1.3 Establishment requirements - Water temperature

Choice: **U** Unknown/Data Deficient

Score: of

Ranking Rationale:
More information is needed to establish reproductive temperature requirements for this species.

Background Information:
Duval (1963) observed larvae and spawning at water temperatures between 16 and 19°C.

Sources:
NEMESIS; Fofonoff et al. 2003 Duval 1963

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 found.

Sources:
NEMESIS; Fofonoff et al. 2003

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:
This species is found in southern BC and in WA.

Background Information:
On the west coast of North America, this species occurs in WA and southern BC. Individuals have been found in CA, but it is unknown whether there are established populations.

Sources:
NEMESIS; Fofonoff et al. 2003

1.6 Global ecoregional distribution

Choice: C In few ecoregions globally

Score: 1.75 **of** 5

Ranking Rationale:
This species has only been reported from a few ecoregions, mostly in northern Europe and in limited areas of western North America.

Background Information:
This species has a broad native range, from PEI to FL, and west to TX. On the west coast of North America, populations are established in WA and BC. In Europe, this species has been found in England, and in the North Sea off the coasts of Belgium, Denmark, and Norway. It is also present in western Sweden. Populations have also been found in Greece, where they were likely introduced by ballast water.

Sources:
NEMESIS; Fofonoff et al. 2003

1.7 Current distribution trends

Choice: **C** Established outside of native range, but no evidence of rapid expansion or long-distance dispersal

Score: 1.75 **of** 5

Ranking Rationale:
This species has failed to establish in CA. Introductions have been attributed to transport by anthropogenic vectors, rather than natural dispersal. This species has a restricted worldwide distribution, and we have not found evidence of a rapid range expansion for this species.

Background Information:
This species has likely been introduced accidentally with Eastern oysters, or by ballast water (Fofonoff et al. 2003). Individuals have been found in CA, but do not seem to have established populations there. Zenetos et al. (2009) rejected the possibility that this soecies was introduced to the Mediterranean by natural dispersal.

Sources:
NEMESIS; Fofonoff et al. 2003 Zenetos et al. 2009

Section Total - Scored Points:	13.5
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: A — Has been observed using anthropogenic vectors for transport and transports independent of any anthropogenic vector once introduced

Score: 4 of 4

Ranking Rationale:
Believed to be transported by hitchhiking or ballast water. Its spread in northern Europe has been attributed to natural, larval dispersal.

Background Information:
Introduced outside of its native range by hitchhiking or by ballast water (Fofonoff et al. 2003). Rosenthal (1980) claims that this species spread through northern Europe naturally. In Greece, however, this species has a very disjunct distribution, occurring there and nowhere else along the Mediterranean. For this reason, Zenetos et al. (2009) believe that P. pholadiformis was introduced in Greece by human vectors.

Sources:
NEMESIS; Fofonoff et al. 2003 Zenetos et al. 2009 Rosenthal 1980

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 burrows and establishes in natural substrates.

Background Information:
Burrows in natural substrates including mud, peat, clay, and wood (Zenetos et al. 2009).

Sources:
Zenetos et al. 2009

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 farmed or cultivated.

Background Information:
Although this species is edible, it is not farmed.

Sources:
NEMESIS; Fofonoff et al. 2003

Section Total - Scored Points:	4
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 for this species are readily available in the Bering Sea.

Background Information:
This species is a filter feeder that consumes phytoplankton and other particles.

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 range of environmental conditions and substrate types.

Background Information:
This species requires a burrows in moderately soft substrates (e.g., clay, mud, chalk, wood) (Tillin and Budd 2008; Zenetos et al. 2009). However, this species is not a boring specialist and cannot burrow into very hard substrates or in soft, loose mud (Tillin and Budd 2008; Jensen 2010). It usually inhabits shallow depths, but has been reported from a range of tidal zones (Tillin and Budd 2008; Zenetos et al. 2009). It is usually associated with sites that receive freshwater input (Zenetos et al. 2009). This species can tolerate a broad range of temperatures and salinities.

Sources:
Zenetos et al. 2009 Tillin and Budd 2008 Jensen 2010

3.3 Desiccation tolerance

Choice: U — Unknown

Score: of

Ranking Rationale:
The desiccation tolerance of this species is unknown.

Background Information:
No information found.

Sources:
NEMESIS; Fofonoff et al. 2003

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 dioecious and exhibits sexual reproduction, external fertilization, and high fecundity.

Background Information:

This species reproduces sexually and exhibits external fertilization. Hermaphoriditism has not been observed (Duval 1963). Fecundity estimates for this species vary widely: ranging from ~ 325 000 to > 3 million eggs (Brousseau 1981, qtd. in Fofonoff et al. 2003; Duval 1963). P. pholadiformis can live up to 10 years, and Duval (1963) estimate they reach sexual maturity at 3 years or later.

Sources:

NEMESIS; Fofonoff et al. 2003 Duval 1963

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

High uncertainty? ☑

Score: 2.5 of 2.5

Ranking Rationale:

Although dispersal distances for this species are unknown, given the longevity of the planktonic larval stage, we assume that this species is capable of long-distance dispersal under favorable hydrologic conditions.

Background Information:

This species has a long-lived, planktonic larval stage that can last between 10 to 14 days (Duval 1963). Larval dispersal is thought to have contributed to the spread of P. pholadiformis in northern Europe (Rosenthal 1980).

Sources:

Duval 1963 Rosenthal 1980

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 has a long-lived, planktonic larval stage. Larvae and eggs can be passively dispersed by water currents. Although adults are sessile, they may be disperse by drifting on wood.

Background Information:

The larval stage is planktonic, and is estimated to last between 10 to 14 days (Duval 1963). Adults are largely sessile and burrow in substrates, including wood; thus, they may be transported by drifting (Zenetos et al. 2009).

Sources:

Duval 1963 Zenetos et al. 2009

3.7 Vulnerability to predators

Choice: **D**	Multiple predators present in the Bering Sea or neighboring regions	**Score:** 1.25 **of** 5

Ranking Rationale:
This species is preyed upon by several taxa that occur in the Bering Sea.

Background Information:
P. pholadiformis can be eaten by crabs, fishes, birds, and fossorial mammals.

Sources:
NEMESIS; Fofonoff et al. 2003

Section Total - Scored Points:	19.5
Section Total - Possible Points:	25
Section Total -Data Deficient Points:	5

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 in its introduced range, and this species is not expected to impact communities in the Bering Sea.

Background Information:
P. pholadiformis was believed to have replaced the native white piddock, Barnea candida, in Belgium, but B. candida is now much more abundant in Belgium than P. pholadiformis (Jensen 2010). It has had minimal impacts on the west coast of North America (Fofonoff et al. 2003).

Sources:
Jensen 2010   NEMESIS; Fofonoff et al. 2003

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 can alter habitats by burrowing in the substrate.

Background Information:
As a result of this species' burrowing activities, Duval (1963) observed semi-permanent mounds of sand that marks the entrance of burrows. Duval (1963) documented tunnel lengths between 2.7 and 14.5 cm deep. The burrows of Pholadidae species increase habitat complexity and, in so doing, increase species' diversity (qtd. in Pinn et al. 2005). Upon an individual's death, the burrows that were created may be used as habitat by other organisms (Fofonoff et al. 2003).

Sources:
Duval 1963   NEMESIS; Fofonoff et al. 2003   Pinn et al. 2005

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

High uncertainty? ☑

Ranking Rationale:
This species' burrowing behavior may increase siltation and erosion rates, especially in soft-bottomed habitats. However, themagnitude of this species' effects on ecosystems is unknown.

Background Information:
A study on the burrowing impacts of other piddocks suggests that piddocks may significantly contribute to erosion, especially in soft substrate habitats (Pinn et al. 2005). However, erosion estimates by Pinn et al. (2005) may be overly liberal for P. pholadiformis, because they were based on maximum burrowing depths > 80 cm. In a study on P. pholadiformis, Duval (1963) documented relatively short tunnel lengths between 2.7 and 14.5 cm deep. Through its burrowing activities, this species may also alter ecosystems by increasing siltation (Tillin and Budd 2008).

Sources:
Tillin and Budd 2008   Duval 1963   Pinn et al. 2005

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 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 known to transport diseases, parasites, or hitchhikers.

Background Information:
No impacts have been reported.

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:
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: D No impact

Score: 0 of 3

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

Background Information:
This species can bore into moderately hard material such as rock, wood, chalk, and limestone. However, no impacts to infrastructure have been reported.

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 fishing in the Bering Sea.

Background Information:
No impacts have been reported.

Sources:
NEMESIS; Fofonoff et al. 2003

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

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

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.

Background Information:
All bivalve species 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).

Sources:
NIMPIS 2009

Section Total - Scored Points:	3.25
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 attempts have been made to control or eradicate this species. This species can be transported by ballast water. Research to reduce the spread of species in ballast water in ongoing.

Background Information:
Ballast water exchange is the method currently used by most ships to reduce the spread of species by ballast water. However, it is considered a short-term or "stop-gap" option until more effective, technology-based methods become available e.g., ballast water treatment systems (Ruiz and Reid 2007). The treatment of ballast water is an active area of research as vessels are forced to comply with new regulations.

Sources:
Ruiz and Reid 2007

5.2 Cost and methods of management, containment, and eradication

Choice: **B** Major short-term and/or moderate long-term investment

Score: of

Ranking Rationale:
To comply with ballast water regulations, vessels will have to equip themselves with an onboard ballast water treatment system. These systems represent a major short-term cost for vessel owners (up to $3 million), with additional costs over time to maintain and replace equipment (e.g. chemicals, filters, UV light bulbs).

Background Information:
The costs associated with purchasing a ballast water treatment system depend on the volume of water that needs to be treated. Systems with a pump capacity of 200-250 m^3/h can cost from $175,000 to $490,000. The estimated price for larger systems with a pump capacity of around 2000 m^3/h range from $650,000 to nearly $3 million.

Sources:
Zagdan 2010

5.3 Regulatory barriers to prevent introductions and transport

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

Score: of

Ranking Rationale:
Alaska does not have state regulations on ballast water management, but two federal regulations (USCG and EPA) require mandatory reporting and ballast water treatment or exchange.

Background Information:
In the U.S., ballast water management (treatment or exchange) and record-keeping is mandatory and regulated by the USCG, with additional permitting by the Environmental Protection Agency (EPA). Certain vessels (e.g. small vessels or those traveling within 1 Captain of the Port Zone) are exempt from USCG and EPA regulations.

Alaska does not have a state regulations related to the management of aquatic invasive species in discharged ballast water. It relies on the U.S. Coast Guard (USCG) to enforce national standards. In Alaska, data from 2009-2012 show moderate to high compliance with USCG reporting requirements (Verna et al. 2016).

Sources:
CFR 2017 EPA 2013 Verna et al. 2016

5.4 Presence and frequency of monitoring programs

Choice: **A** — No surveillance takes place

Score: of

Ranking Rationale:
No surveillance is taking 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 efforts 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 *Petricolaria pholadiformis*

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- Pinn, E. H., Richardson, C. A., Thompson, R. C., and S. J. Hawkins. 2005. Burrow morphology, biometry, age and growth of piddocks (Mollusca: Bivalvia: Pholadidae) on the south coast of England. Marine Biology 147: 943–953. doi.org/10.1007/s00227-005-1582-