Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

Scientific Name: *Amphibalanus improvisus*

Common Name *bay barnacle*

Phylum	Arthropoda
Class	Maxillopoda
Order	Sessilia
Family	Balanidae

Final Rank 65.21

Data Deficiency: 3.00

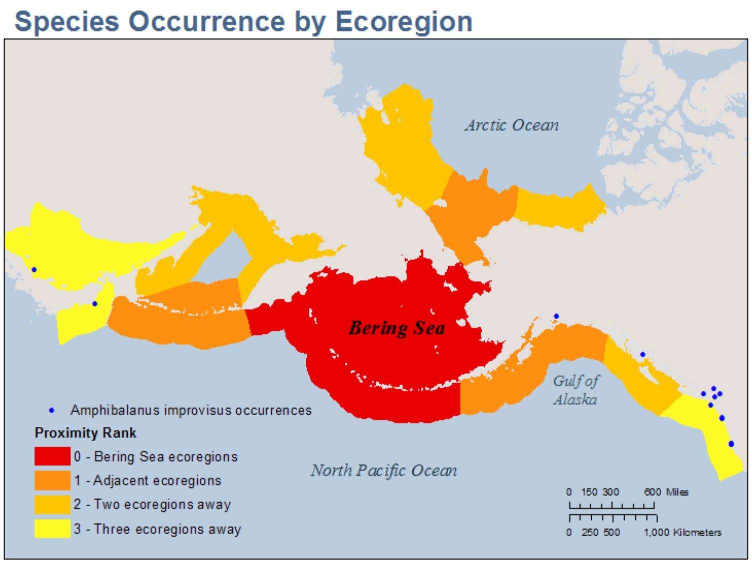

Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

Category Scores and Data Deficiencies

Category	Score	Total Possible	Data Deficient Points
Distribution and Habitat:	26.25	30	0
Anthropogenic Influence:	4.75	10	0
Biological Characteristics:	23.75	30	0
Impacts:	8.5	27	3.00
Totals:	63.25	97.00	3.00

General Biological Information

Tolerances and Thresholds

Minimum Temperature (°C)	-2	Minimum Salinity (ppt)	0
Maximum Temperature (°C)	38	Maximum Salinity (ppt)	40
Minimum Reproductive Temperature (°C)	10	Minimum Reproductive Salinity (ppt)	2
Maximum Reproductive Temperature (°C)	30	Maximum Reproductive Salinity (ppt)	40

Additional Notes

A barnacle that attaches itself to natural and anthropogenic substrates on the sea floor and inhabits estuaries and coastal areas. Native to the Atlantic and Gulf coasts of North America, with a northward expansion predicted towards Alaska (de Rivera et al. 2007). In Europe, fouling of shipping gear, infrastructure and other species (e.g. oysters) have imposed a major economic cost.

1. Distribution and Habitat

1.1 Survival requirements - Water temperature

Choice: **A**

Considerable overlap – A large area (>75%) of the Bering Sea has temperatures suitable for year-round survival

Score: 3.75 of 3.75

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

Background Information:
Inhabits numerous waters from cold temperate to tropical. Can tolerate temperatures from -2ºC to 38ºC with an optimal range of 10ºC to 20ºC (Fofonoff et al. 2003; Shalaeva 2011).

Sources:
NEMESIS; Fofonoff et al. 2003   Shalaeva 2011

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:
Tolerant of a large range of salinities. Inhabits water ranging from 0 to 40 PSU with an optimal range of 10 to 20 parts per thousand (Fofonoff et al. 2003; Shalaeva 2011).

Sources:
NEMESIS; Fofonoff et al. 2003   Shalaeva 2011

1.3 Establishment requirements - Water temperature

Choice: **C**

Little overlap – A small area (<25%) of the Bering Sea has temperatures suitable for reproduction

Score: 1.25 of 3.75

Ranking Rationale:
Temperatures required for reproduction occur in a limited area (<25%) of the Bering Sea.

Background Information:
The temperature range for reproduction is 10ºC to 30ºC (Fofonoff et al. 2003).

Sources:
NEMESIS; Fofonoff et al. 2003

1.4 Establishment requirements - Water salinity

Choice: **A**

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

Score: 3.75 of 3.75

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

Background Information:
The salinity range required for reproduction is 2 to 40ppt as determined by experimental results (Fofonoff et al. 2003).

Sources:
NEMESIS; Fofonoff et al. 2003

1.5 Local ecoregional distribution

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

Score: 3.75 of 5

Ranking Rationale:
Ocurrence records exist for coastal southeast Alaska.

Background Information:
A. improvisus has been observed in coastal southeast Alaska and British Columbia (Chan 2010; Fofonoff et al. 2003).

Sources:
NEMESIS; Fofonoff et al. 2003 Chan 2010

1.6 Global ecoregional distribution

Choice: A In many ecoregions globally

Score: 5 of 5

Ranking Rationale:
Wide global distribution.

Background Information:
Native to the Atlantic and Gulf coasts of North America, ranging south to South America. The bay barnacle has a long history of invasions. Found in Europe (England, Scotland), West Coast of North America (California, Washington), the Northwest Pacific (Japan, Russia, South Korea). Has been recorded in Australia, but is not established there.

Sources:
NEMESIS; Fofonoff et al. 2003 Chan 2010

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:
Recent documentation of long-distance dispersal and range expansion.

Background Information:
Rapid colonization and long-distance dispersal (through anthropogenic vectors) have both been documented (Chan 2010; Fofonoff et al. 2003). The ability for A. improvises to establish in the Bering Sea is not known – NEMESIS lists colonization of Alaska as “failed” (Fofonoff et al. 2003).

Sources:
Chan 2010 NEMESIS; Fofonoff et al. 2003 Shalaeva 2011

Section Total - Scored Points:	26.25
Section Total - Possible Points:	30
Section Total -Data Deficient Points:	0

2. Anthropogenic Transportation and Establishment

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

Choice: 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:

Readily transported via hull fouling and ballast water, however it is a sessile species with little ability to transport independent of a vector.

Background Information:

Long-distance dispersal is associated with anthropogenic vectors such as ship fouling, ballast water and hitchhiking on other organisms transported for mariculture (e.g. oysters) (Carlton et al. 2011; Gruet et al. 1976 cited in Shalaeva 2011). Natural dispersal is restricted to water currents and range in annual distance of 13.9 to 30km/year (Iwasaki and Kinoshita 2004; Leppakoski and Olenin 2000).

Sources:

Shalaeva 2011   Carlton et al. 2011   Gruet et al. 1976   Iwasaki and Kinoshita 2004   Leppakoski and Olenin 2000

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:

Readily establishes on hard surfaces such as marine infrastructure, in addition to natural substrates.

Background Information:

A hard substrate is required for establishment. This may include anthropogenic structures such as docks and ships, or natural substrates such as woody debris, rocks and shelled organisms (e.g. crabs and molluscs) (Fofonoff et al. 2003; Shalaeva 2011).

Sources:

NEMESIS; Fofonoff et al. 2003   Shalaeva 2011

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

Choice: B

No

Score: 0 of 2

Ranking Rationale:

Background Information:

This species 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:
Feed on foods that are redily available in the study area.

Background Information:
Adults and juveniles are filter feeders and consume microplankton and deitritus (Fofonoff et al. 2003; Olenin 2006; Shalaeva 2011).

Sources:
NEMESIS; Fofonoff et al. 2003   Olenin 2006   Shalaeva 2011

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:
Tolerant of a wide range of habitats and water quality.

Background Information:
Tolerant of a wide range of water temperatures and salinities and has a wide tolerance for oxygen concentration in the water; found in the polluted and eutrophical parts of the Baltic, Black, Caspian and other Seas (described in Shalaeva 2011). Inhabitas sheltered estuaries along the coast as well as lagoons and intertidal zones of depths up to 10 m (Fofonoff et al. 2003; Shalaeva 2011).

Sources:
Shalaeva 2011   NEMESIS; Fofonoff et al. 2003

3.3 Desiccation tolerance

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

Score: 3.25 of 5

Ranking Rationale:
Desiccation tolerance is inferred from other barnacle studies.

Background Information:
Based on dessication studies for Semibalanus balanoides (Ware and Hartnoli 1996), a barnacle from the low tidal zone, the size of A. improvisus should be able to survive dessication for more than 24 hours.

Sources:
Ware and Hartnoli

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:
Hermaphroditic, high fecundity, capable of self-fertilization and short generation time.

Background Information:
A hermaphroditic species, capable of self-fertilization but mainly relies on cross-fertilization. Reaches maximum size in 2 to 3 weeks (Elfimov et al. 1995), can produce 1000 to 10,000 eggs per season (Costlow and Bookhout, 1957) and can generate 7 to 10 generations a month (Brayko 1982).

Sources:
NEMESIS; Fofonoff et al. 2003 Shalaeva 2011 Costlow and Bookhout 1957 Brayko 1982 Elfimov et al. 1995

3.5 Likelihood of long-distance dispersal or movements

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

Choice: A Disperses long (>10 km) distances

Score: 2.5 of 2.5

Ranking Rationale:
Natural dispersal via water currents range from 13.9 to 30km/year.

Background Information:
Larvae are mobile while adults remain sessile and are limited to transportation via movement of the substrate they area attached to. Transporation via water currents range in annual distance of 13.9 to 30km/year (Iwasaki and Kinoshita 2004; Leppakoski and Olenin 2000). Long-distance dispersal is associated with anthropogenic vectors such as ship fouling, ballast water and hitchhiking on other organisms transported for mariculture (e.g. oysters) (Carlton et al. 2011; Gruet et al. 1976 cited in Shalaeva 2011).

Sources:
Iwasaki and Kinoshita 2004 Leppakoski and Olenin 2000 Carlton et al. 2011 Gruet et al. 1976 Shalaeva 2011 NEMESIS; Fofonoff et al. 2003

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:
Can actively dispersal in larval form, adult dispersal is limited to the movement of habitat substrate.

Background Information:
Adult form is sessile. Range expansion and establishment of populations in the central and northern Baltic has most likely been due to the dispersal of planktonic larvae on ocean currents (Leppäkoski and Olenin 2000; Shalaeva 2011).

Sources:
Leppakoski and Olenin 2000 Shalaeva 2011

3.7 Vulnerability to predators

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

Ranking Rationale:
Barnacles are predated upon by several taxa that occur in the Bering Sea.

Background Information:
Barnacles are eaten by worms, whelks, sea stars, fish, and shorebirds (MESA 2015; Shalaeva 2011).

Sources:
MESA 2015 Shalaeva 2011

Section Total - Scored Points:	23.75
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:
Studies have shown no significant effect on community structure.

Background Information:
Barnacles in general have been found to have no significant effect on community structure (Durr and Wahl 2004). Potential positive effect include increased abundance of other invertebrates due to facilitating the settlement of other organisms and providing new microhabitats for other species such as small annelids, crustaceans and chironomids by providing empty shells for occupancy (Leppäkoski and Olenin 2000; Leppäkoski 1999; Fofonoff et al. 2003; Shalaeva 2011).

Sources:
Durr and Wahl 2004   Leppakoski and Olenin 2000   Leppakoski 1999   NEMESIS; Fofonoff et al. 2003   Shalaeva 2011

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:
Large densities can alter habitat structure and availability for other species.

Background Information:
Has the ability to change habitat structure and availability, especially in areas where it occurs in high densities, by settling on natural substrates (rocks, trees) and anthropogenic structures (Shalaeva 2011). Barnacle shells provide habitat and refugia for many invertebrate and epibiotic species. An experiment by Bros (1987) showed that the addition of barnacle shells increased the abundance and diversity of motile species.

Sources:
Shalaeva 2011   Bros 1987

4.3 Impact on ecosystem function and processes

Choice: **D** No impact

Score: 0 of 2.5

Ranking Rationale:
Limited impact predicted with little to no impact expected in Alaska where other barnacles and fouling organisms already occur.

Background Information:
Remineralizes nutrients and increases water clarity, which may promote the growth of green algae (Kotta et al. 2006). In high densities, populations may inhibit water flow by forming dense layers on natural and artificial structures (Shalaeva 2011). However, an experimental study by Durr and Wahl (2004) suggested that A. improvises does not have a significant impact on ecosystem function. In addition, in Alaska, where there already are barnacles and other fouling organisms, the ecosystem changes caused by A. improvisus (if any) are likely to be redundant. Alaska has at least four native Balanus spp. (Balanus nubilus, B. glandula, B. rostratus, and B. crenatus), as well as other barnacle species and a diverse fouling community.

Sources:
Durr and Wahl 2004   Shalaeva 2011   Kotta et al. 2006

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

Choice: D No impact

Score: 0 of 2.5

High uncertainty? ☑

Ranking Rationale:

Background Information:
No known impacts listed in the literature.

Sources:
Shalaeva 2011

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: C Limited – Has limited potential to spread one or more organisms, with limited impact and/or within a very limited region

Score: 0.75 of 2.5

High uncertainty? ☑

Ranking Rationale:
A. improvisus can carry viruses, however, the threat, if any, of these viruses has not been documented.

Background Information:
Boschmaella balani and Hemioniscus balani are listed as parasites present on adult bay barnacles, but no information on the threat of these viruses to other species was found in the literature (Shalavaeva 2011).

Sources:
Shalaeva 2011

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:

Background Information:
No sources were found in the literature to indicate hybridization or genetic impact with native barnacles.

Sources:
Shalaeva 2011

4.7 Infrastructure

Choice: A High – Is known to cause degradation to infrastructure and/or is expected to have severe impacts and/or will impact the entire region

Score: 3 of 3

Ranking Rationale:
Causes expensive destruction to marine infrastructure.

Background Information:
Well documented fouling by A. improvisus to shipping equipment and infrastructure, as well as power plant pipes (Shalaeva 2011; Fofonoff et al. 2003). In Sweden, the estimated cost of hull fouling by A. improvisus are 23-56 million dollars per year and estimated costs of power plant fouling are 1.5-5.5 million per year (Gren et al. 2009). Economic impacts have also been reported in the Baltic (Leppakoski and Olenin 2000; Leppakoski 1999).

Sources:
Gren et al. 2009   Shalaeva 2011   Leppakoski 1999   Leppakoski and Olenin 2000   NEMESIS; Fofonoff et al. 2003

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:
Causes reductions in aquaculture productivity and increased transit time and fuel consumption for fishing vessels.

Background Information:
Gear fouling of cages and mollusk shells (e.g. blue mussels, oysters) has been recorded as reducing aquaculture productivity (Leppakoski 1999). Hull fouling of fishing vessels can slow boat speed and increase transit time and fuel use due to drag (Gordon and Mawatari 1992; Shalaeva 2011).

Sources:
Gordon and Mawatari 1992   Shalaeva 2011

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

Ranking Rationale:
Limited potential for impact on shellfish harvesting activities.

Background Information:
A. improvisus can attach themselves onto oysters and mussels and can negatively impact these subsistence activities (Shalaeva 2011; Fofonoff et al. 2003). However, shellfish harvesting is not a popular activity in southeast Alaska because of paralytic shellfish poisoning (PSP).

Sources:
Shalaeva 2011   NEMESIS; Fofonoff et al. 2003

4.101 Recreation

Choice: C	Limited – Has limited potential to cause degradation to recreation opportunities, with limited impact and/or within a very limited region	Score: 0.75 of 3

Ranking Rationale:
Limited potential for beach fouling.

Background Information:
Can affect the recreational quality of shorelines by leaving an abundance of sharp shells along the beach and fouling rocks along the shore (Shalaeva 2011). Alternatively, it is a large filter-feeding speceis that in high densities may increase the clarity of the water (Olenin and Leppakoski 2000), providing a nicer experience for recreation.

Sources:
Shalaeva 2011   Olenin and Leppäkoski 1999

4.11 Human health and water quality

Choice: U	Unknown	Score: of

Ranking Rationale:
Barnacles, as filter feeders, can affect water quality. The impact of these behaviors on human health or water quality is not mentioned in the literature.

Background Information:
Impacts to human health and water quality are not mentioned in the literature.

Sources:
Shalaeva 2011   NEMESIS; Fofonoff et al. 2003

Section Total - Scored Points:	8.5
Section Total - Possible Points:	27
Section Total -Data Deficient Points:	3

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: 0 of

Ranking Rationale:

Hull fouling technologies that treat and/or safely dispose of marine fouling organisms, such as A. improvisus, are currently being studied.

Background Information:

No species-specific control methods are being developed for A. improvisus, but there are some control methods for fouling species in general. Current methods such as hull cleaning during dry-docking or in-water cleaning do not address all the areas in which fouling organisms may establish (e.g. sea chests, pipes) and do not properly dispose of the biological debris (Hagan et al. 2014). Technologies that address these issues are currently being studied (Hagan et al. 2014).

Sources:

Hagan et al. 2014

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:

Current hull fouling technologies that address invasive species require purchasing of specialized equipment and regular cleaning.

Background Information:

According to Franmarine Underwater Services (2013), a company that supplies an in-water hull cleaning system, the cost of dry docking (including cleaning and “loss of business” costs) varies from AUD $62 200 to more than $1.3 million, depending on vessel size. The Franmarine cleaning system, which collects, treats, and disposes of biological waste (e.g., organisms) has a purchasing cost between AUD ~ $500 000 to $750 000, depending on vessel size. In-water cleaning costs range from AUD $18 800 to $255 000+ (for offshore cleaning of large vessels), with cleaning times estimated between 16 to 48 hours. Hagan et al. (2014) proposed similar estimates for the cost and time of in-water cleaning.

Sources:

Franmarine 2013   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:

Compliance with fouling regulations are voluntary.

Background Information:

In the U.S., Coast Guard regulations require masters and ship owners to engage in practices that will reduce the spread of invasive species, including cleaning ballast tanks and removing fouling organisms from hulls, anchors, and other infrastructure on a "regular" basis (CFR 33 § 151.2050). Failure to remove fouling organisms is punishable with a fine (up to $27 500). However, the word "regular" is not defined, which makes the regulations hard to enforce. As a result of this technical ambiguity, compliance with ship fouling regulations remains largely voluntary (Hagan et al. 2014).

Cleaning of recreational vessels is also voluntary, although state and federal programs are in place to encourage owners to clean their boats. Boat inspection is mandatory on some lakes (e.g. Lake Tahoe in CA/NV, Lake George in NY). In summer 2016, state and federal agencies conducted voluntary inspections for aquatic invasive species on trailered boats entering the state of Alaska (Davis 2016).

Sources:

CFR 2017 Hagan et al. 2014 Davis 2016

5.4 Presence and frequency of monitoring programs

Choice: A No surveillance takes place

Score: of

Ranking Rationale:

No species-specific monitoring for A. improvisus occurs, and no regular monitoring effort currently exists for hull fouling.

Background Information:

The U.S. legal regime to control hull fouling and the transport of invasive species via ships' hulls is extremely sparse. Hull fouling is mentioned in the Coast Guard's new mandatory ballast water program and several states have adopted laws to address the problem, but there is little focused management to control fouling organisms (Johnson et al. 2006)

Sources:

Johnson et al. 2006

5.5 Current efforts for outreach and education

Choice: B Some educational materials are available and passive outreach is used (e.g. signs, information cards), or programs exist outside Bering Sea and adjacent regions

Score: of

Ranking Rationale:

No species-specific educaitonal material or outreach exists for A. improvisus. General educational material exists regarding hull fouling.

Background Information:

General educational material on aquatic invasive species, and their spread via hull fouling and/or ballast water, is available (e.g. Rhode Island Marine & Estuarine Invasive Species, Office of Naval Research, Sea Grant).

Sources:

"Needs Reference"

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

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