Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

Scientific Name: *Amphibalanus amphitrite*

Common Name *striped barnacle*

Phylum	Arthropoda
Class	Maxillopoda
Order	Sessilia
Family	Balanidae

Final Rank 57.50

Data Deficiency: 0.00

Species Occurrence by Ecoregion

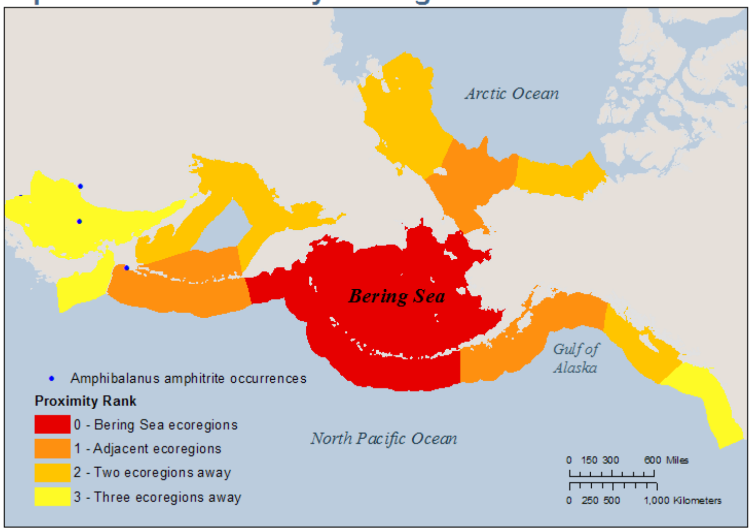

Figure 1. Occurrence records for non-native species, and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Occurrence record data source(s): NEMESIS and NAS databases.

Category Scores and Data Deficiencies

Category	Score	Total Possible	Data Deficient Points
Distribution and Habitat:	21.75	30	0
Anthropogenic Influence:	4.75	10	0
Biological Characteristics:	22	30	0
Impacts:	9	30	0
Totals:	57.50	100.00	0.00

General Biological Information

Tolerances and Thresholds

Minimum Temperature (°C)	0	Minimum Salinity (ppt)	10
Maximum Temperature (°C)	40	Maximum Salinity (ppt)	52
Minimum Reproductive Temperature (°C)	12	Minimum Reproductive Salinity (ppt)	20
Maximum Reproductive Temperature (°C)	23	Maximum Reproductive Salinity (ppt)	35

Additional Notes

Amphibalanus amphitrite is a barnacle species with a conical, toothed shell. The shell is white with vertical purple stripes. Shells can grow up to 30.2 mm in diameter, but diameters of 5.5 to 15 mm are more common. This species is easily transported through fouling of hulls and other marine infrastructure. Its native range is difficult to determine because it is part of a species complex that has been introduced worldwide.

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. Thresholds are based on geographic distribution, which may not represent physiological tolerances; moreover, models disagree with respect to their estimates of suitable area. We therefore ranked this question with "High uncertainty".

Background Information:
Maximum temperature threshold (40°C) is based on an experimental study (qtd. in Fofonoff et al. 2003). According to observations at a field site in Argentina, this species can survive under freezing water (Calcagno et al. 1998).

Sources:
Calcagno et al. 1998   NEMESIS; Fofonoff et al. 2003

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:
Minimum salinity: 10 ppt (from lab experiments)
Maximum salinity: 52 ppt (based on field observations in San Francisco Bay; qtd. in Fofonoff et al. 2003).

Sources:
Anil et al. 1995   Qiu and Qian 1999   NEMESIS; Fofonoff et al. 2003

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:
In Hong Kong, low water temperatures (<15°C) in the winter had negative effects on recruitment and survivorship (Qiu and Qian 1999). Similarly, Anil et al. (1995) found that larval mortality rates were highest at 15°C and lowest at 23°C. In Russia's Peter the Great Bay, larvae were observed in water temperatures between 12 and 22.5°C (Zvyagintsev and Korn 2003). No reproduction was observed at temperatures below 12°C (Zvyagintsev and Korn 2003).

Sources:
Anil et al. 1995   Qiu and Qian 1999   Zvyagintsev and Korn 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

High uncertainty? ✔

Ranking Rationale:
Although upper salinity thresholds are unknown, we assume that it can reproduce in saltwater up to 35 ppt. Salinities required for reproduction occur over a large (>75%) area of the Bering Sea.

Background Information:
Of the three salinity treatments that were tested, Anil et al. (1995) observed 99% and 58% mortality of larvae at 10 ppt and 20 ppt in 15°C. Lowest larval mortality rates occurred at 30 ppt (Anil et al. 1995).

Sources:
Anil et al. 1995 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:
Occurs in southern Russia and the Sea of Okhotsk.

Background Information:
Present in the Northwestern Pacific (Korea, Japan, Russia). Recently detected in the Nanaimo, British Columbia, but is not thought to be established there (Brown et al. 2016).

Sources:
Brown et al. 2016

1.6 Global ecoregional distribution

Choice: A In many ecoregions globally

Score: 5 of 5

Ranking Rationale:
This species has a wide global distribution, and is found in temperate and tropical waters in Europe, North America, Africa, Asia, and New Zealand. Its native range is difficult to determine because it is part of a species complex that has been introduced worldwide.

Background Information:
Occurs from southeastern Africa to southern China, and in the northwestern Pacific (Korea, Japan, Russia). Also found in New Zealand (and possibly in Australia), as well as in Hawaii. In North America, it occurs from Panama to California, and from the Caribbean to New York. In Europe, it occurs in the northern Atlantic (Germany, England, France), but its distribution in this region is largely confined to warmer waters.

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

High uncertainty? ✔

Ranking Rationale:
Colonization of new sites is likely due to transport by anthropogenic vectors, rather than long-distance dispersal.

Background Information:

Sources:
Masterson 2007

Section Total - Scored Points:	21.75
Section Total - Possible Points:	30
Section Total -Data Deficient Points:	0

2. Anthropogenic Transportation and Establishment

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

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

Score: 2 **of** 4

Ranking Rationale:
This species can be transported as a fouling organism on ship hulls and other infrastructure, but colonization of new sites is likely due to anthropogenic transport rather than long-distance dispersal.

Background Information:

Sources:
Masterson 2007 Cohen 2011

2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish

Choice: **B** Readily establishes in areas with anthropogenic disturbance/infrastructure; occasionally establishes in undisturbed areas

Score: 2.75 **of** 4

Ranking Rationale:
Increase in hard, anthropogenic substrates may have facilitated the invasion of A. amphitrite on the east coast of North America.

Background Information:
Common fouling species that readily attaches itself to hard substrates including rocks, oysters, and docks. The proliferation of anthropogenic structures in marine environments may have increased the abundance of this species on the east coast of North America (Boudreaux et al. 2009).

Sources:
NEMESIS; Fofonoff et al. 2003 Boudreaux 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 currently cultivated.

Background Information:

Sources:
NEMESIS; Fofonoff et al. 2003

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

3. Biological Characteristics

3.1 Dietary specialization

Choice: **A**

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

Score: 5 of 5

Ranking Rationale:
Food is readily available in study area.

Background Information:
Nauplii larvae feed on plankton and eventually molt into a non-feeding cyprid stage. Juvenile and adult barnacles are filter feeders, and feed on phytoplankton, zooplankton, and detritus.

Sources:
NEMESIS; Fofonoff et al. 2003

3.2 Habitat specialization and water tolerances

Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc?

Choice: **A**

Generalist; wide range of habitat tolerances at all life stages

Score: 5 of 5

Ranking Rationale:
Generalist at all life stages with respect to habitat, food, temperature and salinity requirements.

Background Information:

Sources:
Masterson 2007 Boudreaux et al. 2009 Calcagno et al. 1998

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:
Did not find information on desiccation tolerance specific to this species. However, a study on a related species, as well as A. amphitrite's occurrence in intertidal and spray zones, suggests that this species is at least moderately tolerant to desiccation.

Background Information:
A study by Ware and Hartnoli (1996) considered the desiccation tolerance of a related species, Semibalanus balanoides, across individiuals of different shell sizes and different shore levels. Median lethal time varied from 6 to 48 hours. Desiccation tolerance increased with shell size. Individuals in high tide zones exhibited the greatest tolerance to desiccation. Amphibalanus amphitrite inhabits a wide range of tidal zones, from supralittoral (“spray zone”) to subtidal, and have physiological mechanisms that allow them to survive exposure to air (Desai and Prakash 2009; Anil et al. 2010).

Sources:
Desai and Prakash 2009 Anil et al. 2010 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: **B** Moderate – Exhibits one or two of the above characteristics

Score: 3.25 of 5

Ranking Rationale:
This species exhibits moderate fecundity, with the ability to produce several broods per year. Eggs are brooded in the mantle cavity, and parental investment is relatively high. This species is hermaphroditic and has a short generation time.

Background Information:
Hermaphroditic, but typically requires cross-fertilization. Experiments with B. amphitrite indicate high egg production: this species breeds several times a year, at intervals of 5–8 days (Crisp and Davis 1955; El-Komi and Kajihara 1991, qtd. in Anil et al. 2010). Individuals produce 1,000 to 10,000 eggs, depending on body size (qtd. in Fofonoff et al. 2003). Fertilized eggs are brooded in the mantle cavity, sometimes for several months, and are released as larvae (qtd. in Fofonoff et al. 2003).

Sources:
Anil et al. 2010 El-Komi and Kajihara NEMESIS; Fofonoff et al. 2003

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

High uncertainty? ✔

Ranking Rationale:
Favourable water currents can likely disperse long-lived planktonic larvae over long distances.

Background Information:
Barnacles have a long-lived planktonic larval stage that can remain in the water column for up to two months (qtd. in Anil et al. 1995).

Sources:
Anil et al. 1995

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:
Larval stage is long-lived, but adults are sessile. Eggs are brooded.

Background Information:
Planktonic larval stage can remain in the water column for up to two months before settling (Anil et al. 1995). Adults are sessile and eggs are brooded (Fofonoff et al. 2003).

Sources:
Anil et al. 1995 NEMESIS; Fofonoff et al. 2003

3.7 Vulnerability to predators

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

Sources:
MESA 2015

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

Score: 0.75 of 2.5

Ranking Rationale:
Can compete for space with other species in the same trophic level, such as native barnacles, other fouling organisms, bivalves, and corals. These taxa are also found in the Bering Sea.

Background Information:
Competition may occur among A. amphitrite and other barnacle species, and other hard fouling taxa, though vertical zonation may moderate competition. Boudreaux and Walters (2005) report coexistence between A. amphitrite and the native Balanus eburneus (qtd. in Masterson 2007). In the Indian River Lagoon, FL, it competes with Eastern Oyster (Crassostrea virginica) for settlement sites, and reduces their growth and survival by settling on their shells (Boudreaux et al. 2009). By settling on substrates, A. amphitrite may compete for space and prevent recruitment of corals in marginal environments (Chui and Ang 2010).

Sources:
Masterson 2007   Boudreaux et al. 2009   Chui and Ang 2010

4.2 Impact on habitat for other species

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

Score: 0.75 of 2.5

Ranking Rationale:
This species may change habitats by settling on natural and anthropogenic substrates.

Background Information:
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 mobile fouling species. By heavily fouling substrates, it decreases habitat availability for other species and can prevent other species such as coral from settling (Chui and Ang 2010).

Sources:
Bros 1987   Chui and Ang 2010

4.3 Impact on ecosystem function and processes

Choice: **D** No impact

Score: 0 of 2.5

Ranking Rationale:
No impacts on ecosystem functions or processes have been reported.

Background Information:

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

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

Choice: C Limited – Has limited potential to cause degradation of one more species or communities, with limited impact and/or within a very limited region

Score: 0.75 **of** 2.5

Ranking Rationale:
Along with other barnacle species, Amphibalanus amphitrite may negatively impact Eastern oysters.

Background Information:
Barnacles affect the settlement, growth, and survival of Eastern oysters (Crassostrea virginica), a species currently experiencing population declines. Negative impacts did not seem to be caused by A. amphitrite in particular, but rather by an overall increase in barnacle numbers (Boudreaux et al. 2009). Other factors such as an increase in boating activity may also be contributing to the decline of Eastern oysters (Boudreaux et al. 2009).

Sources:
Boudreaux et al. 2009

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:
No impacts have been reported.

Background Information:
Boschmaella japonica is a parasite that is known to infect the striped barnacle (Deichmann and Hoeg 1990). This parasite also affects at least one other barnacle species that is found in Japan.

Sources:
Deichmann and Hoeg 1990

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 reported.

Background Information:

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

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:
High impacts on infrastructure are predicted given its abundance as a fouling organism.

Background Information:
A. amphitrite is one of the most abundant fouling barnacles on ships and harbours in warmer parts of the U.S. and worldwide (qtd. in Fofonoff et al. 2003). Fouling organisms cost the U.S. Navy over $50 million a year in fuel costs due to drag (Cleere 2001).

Sources:
NEMESIS; Fofonoff et al. 2003 Cleere 2001

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:
Pacific oysters and other bivalves are commercially harvested in the Bering Sea. Shellfish aquaculture is a small industry in Alaska and is limited in the Bering Sea by cold water temperatures.

Background Information:
Frequently fouls cultured Pacific oysters (Crassostrea gigas) and Eastern oysters (Crassostrea virginica) (qtd. in Boudreaux et al. 2009). By settling on the shells of bivalves, A. amphitrite may affect their growth and survival (Boudreaux et al. 2009). Barnacles were not listed as one of the main threats to Eastern oyster populations (Eastern Oyster Biological Review Team 2007).

Sources:
Boudreaux et al. 2009 Eastern Oyster Biological Review Team 2007

4.9 *Subsistence*

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

Score: 1.5 of 3

Ranking Rationale:
Settlement on oyster and mussel shells by Amphibalnus amphitrite may reduce the growth and survival of bivalves. Several bivalve species are harvested for subsistence in the Bering Sea. In the Aleutians West, shellfish harvesting comprised nearly 20% of subsistence catch when measured by weight. However, most municipalities in the Bering Sea recorded much lower percentages (<5%) (Mathis et al. 2015).

Background Information:
Compared to salmon and finfish, shellfish such as oysters, clams, and mussels comprise a smaller percentage of subsistence catch in the Bering Sea (when measured by weight; Mathis et al. 2015). Values ranged from < 1% in Bethel and Wade Hampton, to almost 20% in Aleutians West; however, most municipalities in the Bering Sea recorded low percentages (< 5%) of subsistence shellfish.

Sources:
Mathis et al. 2015

4.101 Recreation

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

Score: 0.75 of 3

Ranking Rationale:
This species is predicted to have limited impacts on recreational harvesting of bivalves, and on the aesthetic value of beaches in the Bering Sea.

Background Information:
Sharp shells may be dangerous for beachgoers. Settlement of Amphibalanus amphitrite on bivalve shells may affect these species' growth and survival. Bivalves are recreationally harvested in Alaska, but is discouraged on most beaches because of the potential for paralytic shellfish poisoning (PSP).

Sources:
ADEC 2013

4.11 Human health and water quality

Choice: D No impact

Score: 0 of 3

Ranking Rationale:
No negative impacts have been reported. This species has been used as a bioindicator of water quality.

Background Information:
Barnacles, particularly a widespread cosmopolitan species such as Amphibalanus amphitrite, have been used worldwide as indicators of water quality in coastal waters (Reis et al. 2011). Barnacles are sensitive to heavy metal contamination, but an increase in barnacle settlement may also point to poor water quality (e.g. urban run-off increases phytoplankton via eutrophication, which provides food for barnacles) (Courtenay et al. 2009).

Sources:
Reis et al. 2011 Courtenay et al. 2011

Section Total - Scored Points:	9
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: 0 of

Ranking Rationale:
Hull fouling technologies that treat and/or safely dispose of marine organisms are currently being studied.

Background Information:
No species-specific control methods are being developed for A. amphibalanus, 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:
Hagan et al. 2014   Franmarine 2013

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 is largely voluntary (Hagan et al. 2014). Cleaning of recreational vessels is also voluntary on most lakes, although state and federal programs are in place to encourage owners to clean their boats (Davis et al. 2016).

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:

Hagan et al. 2014   CFR 2017   Davis 2016

5.4 Presence and frequency of monitoring programs

Choice: A No surveillance takes place

Score: of

Ranking Rationale:

This species is not currently monitored.

Background Information:

No information found to suggest this species is being monitored.

Sources:

XXX

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:

Because of its abundance as a fouling organism, A. amphitrite is mentioned in a few educational materials about invasive species and hull foulers.

Background Information:

Amphibalanus amphitrite is occasionally mentioned in fact sheets about invasive species and hull foulers (Cleere 2001; Johnson et al. 2006).

Sources:

Johnson et al. 2006   Cleere 2001

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

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