RISK ASSESSMENT SUMMARY SHEET

## Striped barnacle (*Amphibalanus amphitrite*)

- Medium sized barnacle (c. 2cm diameter), with distinctive stripes and diamond shaped operculum.
- Established in GB, probably introduced with hull fouling and / or ballast water.
- A biofouling organisms, encrusting hard surfaces in estuaries and coastal waters.
- Little known impact in GB, some evidence of impact elsewhere.


Photograph: Auguste Le Roux, Wikipedia

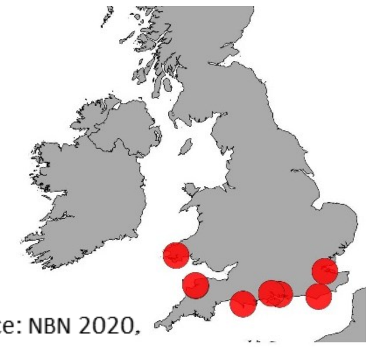
## History in GB

Widely spread across warm and temperate seas of the world. First recorded in the 1937 in Shoreham Harbour, Sussex. Since then, populations have been reported on the southern coasts of England and Wales. Also recorded from Shetland, although a self-sustaining population has apparently not established there.

## Native Distribution

Not known with certainty, but thought to be native throughout the West Pacific and Indian Oceans from South East Africa to South China.

## GB Distribution


Source: NBN 2020.

## Impacts

### Environmental

- None known in GB.
- Limited evidence elsewhere of ability to displace native species.
- Little evidence of wider ecosystem impacts.

### Economic

- Attachment to ship hulls may cause damage, increase fuel costs and reduce manoeuvrability of affected boats.
- Unlikely to cause more impact than other native barnacles.

### Social

- None known

## Introduction pathway

Hull fouling and ballast water – the most likely pathways of introduction to GB and worldwide

## Spread pathway

Natural – evidence from GB suggests natural dispersal is slow

Human mediated – main form of spread, most likely with hull fouling, ballast or aquaculture stock

## Summary

| | Response | Confidence |
|---|---|---|
| Entry | VERY LIKELY | HIGH |
| Establishment | VERY LIKELY | HIGH |
| Spread | INTERMEDIATE | MEDIUM |
| Impact | MINIMAL | MEDIUM |
| Overall risk | LOW | MEDIUM |

**Rapid Risk Assessment of:** *Amphibalanus amphitrite*
**Author:** Hannah Tidbury and Debbie Murphy (Cefas)
**Draft:** Draft 1 (Mar 2015), PR (July 2017), NNRAP 1 (May 2018), Draft 2 (Aug 2019), NNRAP 2 (Feb 2020), Draft 3 (Aug 2020)
**Signed off by NNRAP:** February 2020
**Approved by Programme Board:** November 2020
**Placed on NNSS website:** February 2022

## GB Non-native species Rapid Risk Assessment (NRRA)

**Introduction:**
The rapid risk assessment is used to assess invasive non-native species more rapidly than the larger GB Non-native Risk Assessment. The principles remain the same, relying on scientific knowledge of the species, expert judgement and peer review. For some species the rapid assessment alone will be sufficient, others may go on to be assessed under the larger scheme if requested by the Non-native Species Programme Board.

**1** - What is the principal reason for performing the Risk Assessment? (Include any other reasons as comments)

**Response:**

In line with requirements under the UK Marine Strategy (UKMS), this risk screening was performed as part of a series of risk assessments conducted to identify high and moderate risk species, already present or at risk of introduction, which should be prioritised for monitoring and surveillance.

**2** - What is the Risk Assessment Area?

**Response:** Great Britain (GB)

**3** - What is the name of the organism (scientific and accepted common; include common synonyms and notes on taxonomic complexity if relevant)?

**Response:** *Amphibalanus amphitrite* (Darwin, 1854)

Common names: Striped barnacle

Synonyms:
*Balanus amphitrite forma hawaiiensis* (Broch, 1922)
*Balanus amphitrite ssp. amphitrite* (Darwin, 1854)
*Balanus amphitrite ssp. franciscanus* (Rogers, 1949)
*Balanus amphitrite ssp. herzi* (Rogers, 1949)
*Balanus amphitrite ssp. venustus* (Sundra Raj, 1927)
*Balanus amphitrite var. aeratus* (Oliveira, 1941)
*Balanus amphitrite var. cochinensis* (Nilsson-Cantell, 1938)
*Balanus amphitrite var. communis* (Darwin, 1854)

*Balanus amphitrite var. denticulata* (Broch, 1927)
*Balanus amphitrite var. fluminensis* (Oliveira, 1941)
*Balanus amphitrite ssp. Saltonensis* (Rogers, 1949)

Note that misidentification of this species is possible as it is one of a complex of similar species (Fofonoff et al, 2003 and references there in).

**4** - Is the organism known to be invasive anywhere in the world?

**Response:** *A. amphitrite* was described by Darwin (1854), using specimens collected from Portugal, the Mediterranean, West Africa, the West Indies, the Indo-Pacific, Australia, and New Zealand.

*A. amphitrite* is thought to be native throughout the West Pacific and Indian Oceans from South East Africa to South China (Fofonoff et al., 2003; Cohen, 2011; Occhipinti-Ambrogi, 2013).

The species has been introduced to the East Pacific (Panama-California), North West Pacific (Korea-Japan-Russia), South West Pacific (including New Zealand and possibly South Australia), Pacific Islands (Hawaii) and the West Atlantic (Caribbean-Long Island Sound), and North East Atlantic (Germany-England-France) (Fofonoff et al., 2003). Resources also suggest that *A. amphitrite* is present in Belgium, the Netherlands, France, Portugal, Spain, Republic of Ireland and UK (CABI, 2011).

*A. amphitrite* is reported to have a natural distribution that has been blurred by centuries of transfer (GISP 2008). *A. amphritrite* is commonly referred to as a cryptogenic or a wide-spread and cosmopolitan marine organism. An extensive study of the literature on the impacts of *A. amphitrite* in introduced areas found few reports or studies. Several studies highlight the displacement of native species in locations where it has established, including in harbours of Yokohama and Tokyo, Japan, where it is reported to have largely replaced the native *Amphibalanus reticulatus* (Fofonoff et al., 2003).

A study carried out on interactions between oysters and barnacles highlighted that *A. amphitrite* reduced the growth of juvenile *Crassostrea virginica* in Mosquito Lagoon (Florida, USA) but no more so than the native barnacle *Amphiblanus eburneus (*Boudreaux et al., 2009). A study in the southern Gulf of Mexico found that *A. amphitrite* established across all sampling sites showing a wide environmental tolerance (salinity 9-35.7psu), temperature (24-32.7 ºC) but that its density was within the range of the three congeneric species with which it coexists (Ávila et. al., 2018).

In Tampa Bay (Florida, USA), *A. amphitrite* affected the composition of the fouling community, mainly by creating additional structure for the recruitment and colonisation of motile species. Removal of barnacle shells inhibited recruitment, whereas the addition of barnacle shells increased recruitment. However, impacts did not differ between the native and non-native barnacle species (see Fofonoff et al., 2003); reports do not state that the species became more abundant or troublesome than the displaced native species.

**5** - What is the current distribution status of the organism with respect to the Risk Assessment Area?

**Response:**

*A. amphitrite* was first recorded in the 1937 in Shoreham Harbour, Sussex. Since then, populations have been reported on the southern coasts of England and Wales (Wood et. al., 2015a, Wood et. al., 2015b, Wood et. al., 2016, Wood et.al., 2017). The species has also been recorded from Shetland in 1988 (Eno et al., 1997) although a self-sustaining population has apparently not established there.

**6** - Are there conditions present in the Risk Assessment Area that would enable the organism to survive and reproduce? Comment on any special conditions required by the species?

**Response:** The species is present in the risk assessment area.

*A. amphitrite* is typically found in the intertidal and shallow subtidal regions of sheltered marine waters, particularly harbours, and man-made structures. It grows on a wide range of hard surfaces, including docks, ship hulls, logs, mangroves, rocks, oysters, and other shellfish. This species can survive in water with temperatures below 12ºC but will not reproduce in water that is <15ºC, which limits range expansion. The species is most abundant in the warmest habitats, including thermal effluents. *A. amphitrite* prefers marine salinities (30–40 psu), but tolerates a range from 10–52 psu (Anil et al., 1995).

Sea temperatures in the risk assessment area currently limit the species to southern areas, whereas the species' salinity tolerances limit its ingress into transitional waters.

**7** - Does the known geographical distribution of the organism include ecoclimatic zones comparable with those of the Risk Assessment Area or sufficiently similar for the organism to survive and thrive?

**Response:** Yes.

The species is already present in the risk assessment area and throughout European waters including those of the Netherlands, Belgium and France with closely matched ecoclimatic zones to the risk assessment area.

**8** - Has the organism established viable (reproducing) populations anywhere outside of its native range (do not answer this question if you have answered 'yes' to question 4)?

**Response:** N/A

**9** - Can the organism spread rapidly by natural means or by human assistance?

**Response:**

*A.amphitrite* was first reported in the risk assessment area in Shoreham Harbour in 1937. Subsequent reports in the risk assessment area are in ports including Milford Haven, Plymouth, Southampton and the Thames Estuary.

Monitoring by the Marine Biological Association (MBA) between 2005 and 2016 does show an absence of the species in many marinas along both the south and west coasts of England as well as the coast of Wales, including locations near and between the reported introductions (Wood et. al., 2015a, Wood et. al., 2015b, Wood et al 2016, Wood et. al., 2017), implying a lack of spread to marinas.

*A. amphritrite* is capable of natural dispersal – larvae are dispersed from the adult into the water column where they feed for 4 to 18 days before the cyprids will settle and metamorphose. If temperature conditions are suitable, then *A. amphritrite* can produce 1,000–10,000 larvae per brood, with as many as 24 broods produced per year (El-Komi and Kajihara, 1991). This barnacle species can also produce this number of larvae through self-fertilisation and breeding is not restricted by proximity to other barnacles. *A. amphritrite* is rare on open rocky coasts (Fofonoff et al., 2003) and it is possible that rocky areas of GB coastline and sea temperatures are hindering the establishment of the species outside ports. *A. amphitrite* commonly fouls ship hulls, suggesting that this may be a primary mechanism by which this species spreads. In addition, it has been suggested that early life stages of this species may be transported in ballast tanks (Gollasch, 2002). Darwin's early observations of the species observed that it was 'extremely common on ship's bottoms' (Fofonoff et al., 2003 and references therein).

There are a small number of reports documenting that barnacle species were transported by attachment to identification rings on birds legs (Tøttrup et al., 2010), on marine litter (Holmes et al., 2015) and on aquaculture species (Gollasch, 2006) such as oysters, which may all contribute to the species' spread.

The limited monitoring of marine non-native species in GB may have resulted in a lack of understanding of the true extent of this species in these locations.

**10** - Could the organism itself, or acting as a vector, cause economic, environmental or social harm in the Risk Assessment Area?

**Response:**

The attachment of this species to ship hulls may cause damage, increase fuel costs and reduce manoeuvrability of affected boats. In addition, fouling by this species may affect the general composition of the fouling community by creating additional structures and aiding recruitment and colonisation of motile species (Cohen, 2011; Fofonoff et al., 2003).

Fouling of aquaculture species such as pacific oysters by *A. amphitrite* in warmer waters has been documented. This may impact the production and harvest of such aquaculture species (Fofonoff et al., 2003).

There are limited reports of *A. amphitrite* replacing native species in some locations where it has been introduced (e.g. in harbours of Yokohama and Tokyo, Japan; see Fofonoff et al., 2003), but those reports do not indicate that it causes additional problems through increased abundance. There is no evidence for negative impacts of the species on food webs.

## Entry Summary

Estimate the overall likelihood of entry into the Risk Assessment Area for this organism (comment on key issues that lead to this conclusion).

**Response:** *very likely*
**Confidence:** *high*

**Comments (include list of entry pathways in your comments):**

The fact that this species has previously been introduced into the risk assessment area supports the response that further introductions are very likely, especially as there currently is no control on the main pathways of introduction (i.e. ballast water, hull fouling, marine litter, and hitchhiking on aquaculture species).

The introduction vectors *A. amphitrite* is most commonly associated with are hull fouling and ballast water. Given the high number of ports and marinas within the risk assessment area, the variety of crafts and the number of countries and ports that these crafts have visited, there is a risk of further introductions. The species has also been observed rafting on marine litter (Rech et. al. 2016).

A study of 29 vessels in Scottish dry docks confirmed the presence of *A. amphitrite*. This includes specimens on a vessel that had spent time in Turkish waters before returning to the North Sea for four months and subsequently went into dry docking in GB, showing that arrival is possible (McCollin & Brown, 2014).

However, the risk greatly depends on the pathway's origin and the presence and abundance of the species at that source location. There therefore remains a level of uncertainty regarding the likelihood of introduction of this species.

Current reports within the risk assessment area relate to harbours and therefore indicate likely arrival via ballast water and/ or hull fouling

## Establishment Summary

Estimate the overall likelihood of establishment (comment on key issues that lead to this conclusion).

**Response:** *very likely*
**Confidence:** *high*

**Comments (state where in GB this species could establish in your comments, include map if possible):**

The fact that *A. amphitrite* has formed established populations within the risk assessment area previously (i.e. on the south coasts of Wales and England) supports the conclusion that establishment of further populations is likely in southern parts of the risk assessment area.

Following successful entry this species is only likely to become established in locations where temperature is suitable and hard substrata are available. In the northern limits of its range, it is most abundant in the warmest habitats, including thermal effluents (Fofonoff et al., 2003).

Having been first reported in within the risk assessment area in 1937, subsequent reports are all limited to south Wales and southern England, with the most northerly reports currently being Milford Haven and Thames Estuary, respectfully. A JNCC report (Eno et al., 1997) stated that *A. amphitrite* has also been recorded from Shetland in 1988, although a breeding population is apparently not established there. Given reports of the species being found on vessels entering Scottish waters, this record may have been the result of an introduction event that failed to establish.

*A. amphitrite* prefers marine salinities (30–40 psu), does not reproduce in water that is less than 15ºC and is typically found in the intertidal and shallow subtidal regions of sheltered marine waters, particularly harbours, and man-made structures, and is rare on open rocky coasts. The specifics of these conditions limit the availability sites within the risk assessment area suitable establishment.

Data on www.seatemperature.org (2019) show that mean monthly sea temperatures along the south and south west coasts of England, the east coast of England as far north as Lowestoft, and the south coast of Wales are >15ºC from July to October.  This would, currently, limit the likelihood of reproduction taking place to the southern coasts of the risk assessment area.

## Spread Summary

Estimate overall potential for spread (comment on key issues that lead to this conclusion).

**Response:** *moderately likely*
**Confidence:** *medium*

**Comments (in your comments discuss how much of the total habitat that the species could occupy has already been occupied; also comment on how much of that currently unoccupied area is likely to be occupied within 5 years; also list all of the spread pathways):**

Thought to be native throughout the West Pacific and Indian Oceans from South East Africa to Southern China (Fofonoff et al., 2003; Cohen, 2011; Occhipinti-Ambrogi, 2013) it has been introduced to the East Pacific, North Western Pacific, South West Pacific, Pacific Islands and West Atlantic, and North East Atlantic. *A. amphitrite* was described by Darwin (1854), using specimens collected from Portugal, the Mediterranean, West Africa, the West Indies, the Indo-Pacific, Australia, and New Zealand.

The species appears to be cosmopolitan within the ecoclimatic zones suitable for its establishment.

*A. amphitrite* favours hard structures over rocky coasts, marine salinities of 30–40 psu and requires temperatures > 15°C to reproduce. Therefore, locations within the risk assessment area offering suitable conditions are limited most likely to marine harbours in southern locations perhaps even requiring a thermal source such as a power plant discharge (Bamber, 1990)

Work by the MBA has shown that *A. amphitrite* has a limited distribution at marina sites around the UK, for example, between 2013 to 2016 they surveyed 60 marinas and recorded *A. amphitrite* at 5 of these locations (Wood et. al., 2015a, Wood et. al., 2015b, Wood et al 2016, Wood et. al., 2017). Given that the species was first recorded in 1937 it does not appear to have spread widely to date within the risk assessment area.

The most likely method of dispersal for the species is human assisted via hull fouling and ballast water. The later life stages can settle on vessels while earlier life stages may be taken up as ballast water within both the native range and introduced locations.

It is also possible for *A. amphitrite* to be moved, attached to or within water, with aquaculture consignments (Reise et al., 1998), and there is limited evidence of barnacles being moved via identification rings on birds legs and on marine litter.

Additional reports since in 1937 have all been in harbours and marinas but it is unclear if this is as a result of spread from other GB locations or new introductions from further afield via ballast/hulls. It is also possible that monitoring is only targeting these high risk locations and that therefore other introductions have not been reported.

## Impact Summary

Estimate overall severity of impact (comment on key issues that lead to this conclusion)

**Response:** *minimal*
**Confidence:** *medium*

**Comments (include list of impacts in your comments):**

There is limited evidence on the impact the *A. amphitrite* in locations where it has established.  It would appear little research or monitoring has been carried out regarding this cosmopolitan species.  Darwin described the species using specimens collected from Portugal and the Mediterranean in 1854. It is known to have been present in the risk assessment area for over 80 years. With limited information relating to community composition etc before its arrival, relative changes and impacts are difficult to determine with confidence.

On arrival in a new location, the condition of the animal coupled with the timing of suitable stages in its life cycle and environmental factors, such as salinity, temperature, food supply, and the presence of suitable structures will affect the survival and therefore establishment of the species.

This species is known to foul boat hulls, marina structures, equipment and aquaculture species resulting in both environmental and economic consequences. However, despite the cosmopolitan distribution of *A. Amphitrite*, no reports were found to suggest that impacts associated with the species were more severe than other barnacle species.

There have been reports of the species displacing native barnacles in locations where it has been introduced but these reports do not highlight the species having a higher impact than other native species, or affecting the local food web.

## Climate Change

What is the likelihood that the risk posed by this species will increase as a result of climate change?

**Response:** *medium*
**Confidence:** *low*

**Comments (include aspects of species biology likely to be effected by climate change (e.g. ability to establish, key impacts that might change and timescale over which significant change may occur):**

This species can survive in water below 12ºC but will not reproduce in water that is <15ºC and prefers marine salinities (30–40 psu), but tolerates a range from 10–52 Psu (Anil et al., 1995).

A study has shown that embryonic development of *A. amphitrite* is accelerated by increased temperature (Anil & Kurian, 1996).Warmer waters associated with climate change may, therefore, be favourable to this species and increase its invasiveness risk. However, it is not clear how other factors related to climate change will influence the risk posed by this species. For example, McDonald et al. (2009) showed no effect of ocean acidification, a consequence of increased $CO_2$ levels on characteristics including larval condition, cyprid size and attachment and metamorphosis, *A. amphitrite* reared at lower pH (ocean acidification) had weaker shells and may therefore be more vulnerable to predation or extreme weather conditions. The impact of climate change on this species is likely to be complex and requires further study.

## Conclusion

Estimate the overall risk (comment on the key issues that lead to this conclusion).

**Response:** *low*
**Confidence:** *medium*

**Comments:**

The likelihood of introduction and establishment of this species into the risk assessment area is high. *A. amphitrite* does not appear to pose a high risk of environmental or economic impacts..In the risk assessment area, there is limited evidence that the species can displace native species. There is potential for this species to expand its range and population size in the future with warming sea temperatures.

## Management options (brief summary):

**1** - Has the species been managed elsewhere? If so, how effective has management been?

**Response:**

Hull antifouling treatments are commonly used against fouling barnacles such as *A. amphitrite*. However, there are several antifouling treatments available which may differ in their effectiveness (Dafforn et al., 2008; Piola et al., 2009).

**2** - List the available control / eradication options for this organism and indicate their efficacy.

**Response:**

This species is a fouling barnacle, and therefore the primary control option may be permitted antifoul treatment or boat cleaning. The eradication of this species from larger submerged structures such as harbour walls is likely to prove impractical.

**3** - List the available pathway management options (to reduce spread) for this organism and indicate their efficacy.

**Response:**

Management of shipping is required to reduce the spread of *A. amphitrite*. The increasing adoption of the IMO International Convention for the Control and Management of Ships' Ballast Water and Sediments and The Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species are expected to steadily decrease the risk posed of initial introduction of the species into GB waters. Raising awareness of non-native species including *A. amphitrite* is essential. In addition, biosecurity measures will need to be undertaken regarding cleaning boats and equipment.

Efforts to raise awareness of the link between marine litter and NIS, and reduce marine litter can be made to reduce the risk of NIS arrival on marine litter.

**4** - How quickly would management need to be implemented in order to work?

**Response:**

Preventative and quick response management will best prevent recruitment of this organism and spread via ships hulls.

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