



Short Note

A near miss: invasive non-indigenous mussels and barnacles transported deep into Antarctic waters

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Abstract

The Southern Ocean around Antarctica remains the only large area on the planet populated by almost entirely native and mainly endemic species. Despite being one of the most constant environments for millions of years and still the least human populated, the polar regions are now hotspots of physical climate change, and this is likely to make the shallow waters less inhospitable to invading non-indigenous species (NIS). A key vector for such potential invasive NIS are ship hulls, and the highest-risk species (likelihood × impact of establishment) are mytilid mussels. Here, we report finding live balanomorph barnacles *Amphibalanus improvises* and variously sized/aged (3–31 mm) *Mytilus* cf. *chilensis* mussels on the water intake grills of a research ship docked at a UK research station at 68°S. The discovery of these NIS shows that they were not just surviving deep into Antarctic waters but included multiple life stages and were actively feeding at ambient (−0.36°C) temperatures. With rising ship traffic and sea temperatures, this discovery should reinforce recent literature showing that some current, regional marine biosecurity monitoring needs urgent reassessment and improvement.

Keywords: Antarctica; fouling; invasive; *Mytilus*; non-indigenous species; Southern Ocean

(Received 1 April 2026 UTC; revised 1 April 2026 UTC; accepted 8 July 2026 UTC)

Introduction

The Southern Ocean is the last frontier for non-indigenous species (NIS) establishment, spread and disruption of native communities and ecosystems (McCarthy *et al.* 2019). It is the only ocean where almost all biota are native, and very many of those are indigenous (see biodiversity open access databases of OBIS, GBIF and SCAR-MarBIN). The polar regions are hotspots of physical climate change, and, with warming, the shallow waters are likely to become less inhospitable to invaders. Ships (Lewis *et al.* 2003, Lee & Chown 2009, McCarthy *et al.* 2019) and floating debris, such as plastic (Barnes 2002), can carry fouling biota between continents, and such vectors are becoming more frequent (McCarthy *et al.* 2019, 2022). Top of an internationally compiled NIS threat list are mytilid mussels (Hughes *et al.* 2020), and recently some were transient colonists in the shallows of the northern tip of the Antarctic Peninsula (Cárdenas *et al.* 2020).

The Antarctic Treaty Consultative Meeting has advocated for the implementation of strong biosecurity practices to limit the likelihood of transporting terrestrial NIS to Antarctica and its surrounding archipelagos. Exchange of ballast water protocols have similarly been addressed to minimize the chances of transporting ‘warm water’ plankton or nekton into the Southern Ocean (Australia *et al.* 2023), but fouling of hulls, particularly thruster-ports, intakes, rudders and complex spaces, has yet to be ade-

quately considered. The vast majority of vessel journeys between southern continents (South America, Africa and Australasia) and Antarctic waters are touristic. Thus, the scientific focus has been on the risk posed by transiting vessels. However, foulers of scientific and national operator support vessels might be more likely to be detected due to the affected vessels visiting research stations with scientists, divers and inspection devices, such as (underwater) remotely operated vehicles. There seems to be little question of opportunity of NIS transport (Barnes 2002, Lewis *et al.* 2003, Lee & Chown 2009, McCarthy *et al.* 2019), but there is little information available regarding how active or viable lower-latitude, potentially invasive species might be on arrival in Antarctic waters. This matters because, unlike on land, pest invasives have rarely if ever been successfully removed once established in the sea (Giakoumi *et al.* 2019), so smothering species like mytilid mussels could prove catastrophic if they establish and invade Antarctica’s shallows (Hughes *et al.* 2020).

Methods and results

In January 2025, the RRS *Sir David Attenborough* underwent hull inspection by SCUBA divers at a routine visit to Rothera Research Station (67°34’S, 68°08’ W), West Antarctic Peninsula. The main area of the hull was clean of macroscopic colonization, but some water intake grills had established macrofauna, which was carefully scraped into vials and sealed (Fig. 1). These were then transported to an on-site ambient-temperature aquarium and maintained at ~0°C in water that was not returned to the sea (in case of larval release). These included five mussels identified as *Mytilus* cf.

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Cite this article: Barnes, D. K. A., Hughes, K. A., McLoughlin, S., Rodger, H., & Gilkinson, S. 2026. A near miss: invasive non-indigenous mussels and barnacles transported deep into Antarctic waters. *Antarctic Science*, 1–3. <https://doi.org/10.1017/S0954102026100881>



Figure 1. Non-indigenous species assemblage fouling a water intake grill of a research ship located deep into near-shore Antarctic waters in January 2025. Although the anti-foul-treated hull is clean to visual inspection, the water intakes are not similarly (anti-foul) treated, as they supply drinking water. The sizes of the mussels are given in Table I.

Table I. Morphometrics of live, adult, non-indigenous invasive *Mytilus* cf. *chilensis* recovered from the hull of the RRS Sir David Attenborough while docked at Rothera Research Station, Antarctica.

Individual	Length (cm)	Height (cm)	Width (cm)
1	3.07	1.82	1.27
2	2.75	1.51	0.98
3	2.58	1.52	0.92
4	2.50	1.46	0.86
5	2.17	1.16	0.83
6	2.19	1.22	0.71

chilensis of various sizes/ages from 3 mm long to 3.1 cm-long mature adults (lengths, heights and widths shown in Table I).

Also present were two adults of the balanamorph barnacle *Amphibalanus improvisus*. Of note and concern were that both of these NIS were not just alive but active (drawing a siphon current and trying to feed) at ambient typical summer sea surface temperatures of the Southern Ocean. On the day of discovery and collection, the air temperature at sea level was 1.1°C and the sea temperature at 21 m depth was −0.36°C. All specimens were fixed in 96% ethanol.

Discussion

Eradication of NIS from the sub-Antarctic islands is very costly in terms of time and effort, but at least some removals have been achieved. Some countries have established good terrestrial biosecurity practice, but marine protocols vary considerably (from very little action to inspections every season) and may have a much more considerable time/expense cost element for their implementation. The Protocol on Environmental Protection to the Antarctic Treaty prohibits the introduction of NIS to the Treaty area without a permit from a national authority. Nevertheless, some NIS macroalgae and a gymnolaemate bryozoan *Membranipora membranacea* have been reported to have travelled to Deception Island (Avila *et al.* 2020). Around Antarctica, a live mussel was first found at one of the most northerly (and warmer water) locations

of South Georgia (Ralph *et al.* 1976), but it did not persist. *M. cf. platensis* briefly arrived at King George Island (Cárdenas *et al.* 2020), also towards the northern tip of the Antarctic Peninsula. Such mussels, as reported here, have now not only travelled to 68°S alive but appeared to be active and feeding at ambient Southern Ocean temperatures (−0.36°C water temperature).

Regular and increasing ice scour in Antarctica’s shallows (Barnes *et al.* 2024) probably means that balanamorph barnacles such as *A. improvisus* (reported here) might struggle to persist on Antarctic shores. Scouring of local shallow sites there by icebergs is annual. However, as long as the whole life cycle of *M. cf. chilensis* could cope with freezing temperatures and seasonally low food availability, they might prove major pests because they can establish in deeper depths at which ice scour is less regular, yet right underneath the docking points of vessels.

Worrying aspects of both of the NIS reported here are that they are mass spawners of pelagic larvae. Thus, even unattachment from a ship surface is not required to establish populations in the surrounding shallows, merely larval release (assuming larval viability). However, there was no evidence that either species spawned while at Rothera Research Station. Of further concern, these NIS might not have any natural predators in an establishment scenario. This is because they are both heavily armoured with thick calcareous shells, and this is the only environment on Earth with almost no durophagus (crushing) predators (Aronson *et al.* 2015). By chance, this particular near miss was detected at an Antarctic research station with year-round marine science and SCUBA diving facilities, enabling regular monitoring of life in the shallows where detection of invading species might be possible.

Following the detection of these NIS, the vessel was thoroughly cleaned by marine divers outside the Antarctic Treaty area so that no macroscopic fouling was evident any longer. That multiple, high-threat NIS could travel to an Antarctic research station and be active at ambient temperatures, in a climate change hotspot, is a near miss that could have led to the establishment of difficult-to-remove pest species. Such an event will hopefully serve as an urgent warning that the southern polar community (scientific, national operator and touristic) must not take marine biosecurity for granted and must implement effective inspection and cleaning protocols.

Author contributions. David K.A. Barnes conceived the study, helped by Kevin Hughes, Sean McLoughlin, Hamish Rodger and Shea Gilkinson. The specimens were collected by Sean McLoughlin, Hamish Rodger and Shea Gilkinson, and they were identified by David K.A. Barnes. All authors drafted and reviewed the manuscript.

Competing interests. The authors declare none.

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