ROYAL SOCIETY OPEN SCIENCE

royalsocietypublishing.org/rsos

Research

Cite this article: Castro Ayala C *et al*. 2026 First evidence of bidirectional exchange between distant humpback whale breeding populations in eastern Australia and Brazil. *R. Soc. Open Sci.* **13**: 260251.
https://doi.org/10.1098/rsos.260251

Received: 4 February 2026
Accepted: 29 April 2026

Subject Category:
Ecology, conservation, and global change biology

Subject Areas:
ecology, structural biology, ecosystem

Keywords:
humpback whale, photo-identification, record distance movements, Southern Hemisphere, population connectivity, Happywhale, breeding stock, Southern Ocean Exchange, environmental variability, inter-basin connectivity

Author for correspondence:
Cristina Castro Ayala
e-mail: cristinacastro@pacificwhale.org

First evidence of bidirectional exchange between distant humpback whale breeding populations in eastern Australia and Brazil

Cristina Castro Ayala[1,†], Stephanie Stack[2,3,†], Milton Marcondes[4], Julio Cardoso[5], Ted Cheeseman[6,7], Jens Currie[3], Arlaine Francisco[5], Marilia Olio[6], Bianca Righi[8], Silke Stuckenbrock[9] and Renata Santoro Sousa-Lima[10]

[1]Pacific Whale Foundation, Puerto Lopez, Manabi, Ecuador
[2]Southern Ocean Persistent Organic Pollutants Program, Griffith University Environmental Science, Nathan, Queensland, Australia
[3]Pacific Whale Foundation, Wailuku, HI, USA
[4]Instituto Baleia Jubarte, Caravelas, Brazil
[5]Projeto Baleia à Vista, Ilhabela, Brazil
[6]Happywhale, Santa Cruz, CA, USA
[7]Bio-Telemetry and Behavioral Ecology Lab, University of California Santa Cruz, Santa Cruz, CA, USA
[8]Instituto Baleia Jubarte. R. Barão, Caravelas, Brazil
[9]Adrift Lab, Underwood, Tasmania, Australia
[10]Laboratory of Bioacoustics, UFRN, Natal, Brazil

CCA, 0000-0002-5166-0389; TC, 0000-0002-5805-2431

Movements between humpback whale (*Megaptera novaeangliae*) breeding stocks are exceedingly rare, and exchange between distant breeding grounds in both directions has not previously been documented between eastern Australia and Brazil. Using 19 283 curated photo-identification images from eastern Australia (breeding stock E1 (BSE1)) and Brazil (breeding stock A (BSA)) collected between 1984 and 2025, we identified two individuals photographed in both areas, representing the first recorded exchange in both directions between BSE1 and BSA. The breeding grounds are separated by minimum great-circle distances of 14 200 km and 15 100 km, respectively, distances that reflect the separation between sighting locations rather than actual distances

[†]These authors contributed equally to the study.

THE ROYAL SOCIETY PUBLISHING

travelled, as photo-identification records only the endpoints of each individual's travel. Resighting intervals of 6 and 22 years suggest that these are rare, possibly single-lifetime events rather than regular migratory shifts. These findings extend the known spatial limits of inter-basin connectivity for Southern Hemisphere humpback whales and support the 'Southern Ocean Exchange' hypothesis, whereby population recovery and environmental variability may create opportunities for exceptional exchange between ocean basins. Although such events occurred in only 0.01% of identified whales, continued global collaboration through photo-identification platforms will be essential for detecting and quantifying these rare exchanges.

1. Introduction

Humpback whales (*Megaptera novaeangliae*) are one of the large whale species known to seasonally perform long-distance migrations from high-latitude feeding areas to low-latitude breeding grounds [1]. Most reproductive activity occurs in tropical or subtropical regions while feeding is mainly observed in high latitudes [2]. During migration, females with a calf from continental populations tend to remain near the coastline where possible, while other demographic classes may take more direct or offshore routes, though evidence for consistent sex-specific route differences in humpback whales is equivocal [3,4]. Despite the fact that individuals usually show a high degree of fidelity to migratory routes learnt from their mothers, there have been reports of humpback whales occasionally switching feeding and/or breeding grounds [5–7]. These long-range movements facilitate genetic exchange [8] and, in the case of males, spread singing styles unique to their own populations [9,10].

In the Southern Hemisphere, seven humpback whale breeding stocks are recognized by the International Whaling Commission (IWC), designated A through G based on geographic distribution and migratory destinations [11]. The humpback whale population along the eastern coast of South America, known as breeding stock A (BSA), breeds primarily off the coast of Brazil, particularly around the Abrolhos Bank (16°–19°30′ S, 37°–39° W) in the western South Atlantic Ocean [12–14]. This population migrates to feeding grounds in South Georgia [15–19] and the South Sandwich Islands (54°31′ S, 37°24′ W) and adjacent Antarctic waters [15–17,20]. The breeding season extends from June to November, with peak activity between August and September [14,21].

The humpback whale population that migrates along the east coast of Australia is known as breeding stock E1 (BSE1). Its terminal breeding grounds are in the Great Barrier Reef, and its terminal feeding grounds are in Antarctic Area V, spanning 130° E to 170° W [22]. Humpback whales are observed migrating along the east Australian coast from May to November, with whales stopping in Hervey Bay between July and October on the southern migration [23].

Both the BSA and BSE1 populations have shown a recovery following the end of commercial whaling. The BSA population has grown at an estimated annual rate of 7–10% since the 1960s, when it reached approximately 3.5–5% of its pre-exploitation abundance [24,25]. Similarly, the BSE1 population, which was previously thought to contain a few hundred individuals, has recovered to approximately 24 500 whales by 2015, expanding at a rate of around 11% per year [26].

Individual humpback whales have been tracked over time via a method called photo-identification (hereafter, 'photo-ID') based on the unique shape and colour patterns on the ventral surface of their tail flukes. This technique has become a cornerstone of wildlife population studies, allowing researchers to monitor the migratory destinations and site fidelity of individuals across years and ocean basins [27]. More recently, the integration of multiple regional photo-ID catalogues into the global platform *Happywhale.com* has facilitated greater collaboration among researchers and helped monitor migratory destinations for individuals across regions [28].

Several cases of long-distance movements have been documented through photo-ID, revealing connections within and between ocean basins. Along the eastern South Pacific of South America, individuals have been recorded moving between BSA (Brazil) and BSG (Panama, Colombia, Ecuador and Peru) [16,29,30], including one whale photographed between Ecuador and the South Sandwich Islands [19]. Rarer still is exchange across ocean basins. The longest matches documented between distinct breeding areas include an adult male sighted in Colombia (eastern South Pacific) and subsequently at Zanzibar (Indian Ocean), whose breeding locations were separated by a minimum great-circle distance of 13 046 km [31]. A female was photographed in Brazil and subsequently at Madagascar (Indian Ocean), with sighting locations separated by over 9800 km [32]. An individual was also observed at the Antarctic Peninsula and subsequently in eastern Australia [33]. Genetic

studies indicate that such exchanges between populations help maintain gene flow among Southern Hemisphere breeding stocks [8,34,35]. Similar photo-ID matches have been reported across Oceania [36,37], between western Australia and eastern Australia [38] and between Brazil and South Africa [39], and Antarctic feeding grounds are now known to be shared by individuals from multiple Southern Hemisphere breeding stocks [34,40–42]. Overall, documented separations between breeding areas where exchange has been photographically confirmed range from approximately 6000 km among adjacent stocks to more than 13 000 km for the widest-known inter-basin cases [29–31].

Here, we document two individual humpback whales photographed in both eastern Australia (BSE1) and Brazil (BSA), whose sighting locations are separated by minimum great-circle distances of 14 200 km and 15 100 km between sighting locations (the South Pacific and South Atlantic Oceans), regardless of the actual route taken. Because photo-ID records only the sighting endpoints, the routes taken and total distances travelled cannot be determined. We discuss environmental variability, population recovery and individual behavioural flexibility as potential drivers of these exchanges and examine potential implications for Southern Hemisphere humpback whale stock management.

2. Material and methods

Photo-ID data from both research organizations and citizen scientists contributed to this study. High-quality photos of the ventral surface of humpback whale flukes (n = 19 283) were taken in two regions between 1984 and 2025: the South Atlantic (Brazil, n = 10 341 individual whales) and the South Pacific (eastern Australia, n = 8942 individual whales).

Photographs of the ventral side of the flukes were obtained both during dedicated research surveys and opportunistically aboard whale-watching tours conducted from June to October. Each sighting was documented with related sightings data, such as geographic location, observed behaviour, date, group composition and size. Only good-quality images that clearly revealed the shape, pigmentation and scarring patterns on the ventral surface of the flukes were included in the analyses.

These met the quality criteria established by [43], which require an adequate angle relative to both the observer and the water surface, at least 70% visibility of the ventral area, sharp focus, proper exposure and, ideally, a visible central notch.

All photographs were reviewed, curated and subsequently incorporated into the Happywhale platform. Cross-catalogue comparisons were conducted using the platform's automated image-recognition algorithm [43], which identifies potential matches based on trailing edge shape, fluke pigmentation and scars. All algorithm-proposed matches were independently verified by a trained researcher through direct visual comparison of the original photographs. Individual matches in both cases were independently verified by regional researchers.

3. Results

We analysed humpback whale fluke photographs submitted to Happywhale from eastern Australia (BSE1) and Brazil (BSA) across multiple years, and found two individuals that had been sighted in both regions. Both cases represent exchange between breeding grounds in two different ocean basins separated by more than 14 200 km, with resighting intervals of 6 and 22 years between the last sighting in the first region and the first sighting in the second (table 1). The actual routes connecting these locations remain unknown. Individual whales carry multiple identification codes reflecting contributions from different regional catalogues.

3.1. Case 1: individual PWF-SP_4134/PROBav-HBW-SP0071/HW-MN0700299

This individual (figure 1) was first photographed on 9 August 2007 in Hervey Bay, Queensland, Australia (25°1.33′ S, 153°2.87′ E) by Pacific Whale Foundation researchers. The whale was observed as part of a group of three individuals exhibiting active milling behaviour. The same individual was resighted on 31 August 2013 in the same region (25°0.69′ S, 152°59.02′ E), in a group of three individuals displaying slow swimming behaviour. Sex was not determined.

In Brazil, the resighting occurred on 15 July 2019 off São Paulo (23°56.19′ S, 45°28.56′ W), documented by Projeto Baleia à Vista (Ilhabela). The whale was swimming alone in a northeast direction at

Table 1. Summary of encounter histories for two individual humpback whales photographed in both breeding regions, including dates, locations, behavioural context and encounter duration. For each case, the elapsed time between first and last sightings and the minimum great-circle distance between sighting locations are provided. Case 1 documents an exchange from Australia to Brazil over 11 years and 10 months (approx. 14,200 km), while case 2 documents an exchange from Brazil to Australia over 22 years and 1 month (approx. 15 100 km).

ID	encounter #	date	location	latitude/ longitude	encounter description	encounter duration
case 1: PWF-SP_4134/PROBav-HBW-SP0071/HW-MN0700299	1	9/8/07	Hervey Bay, Queensland, Australia	25°1.33′ S, 153°2.87′ E	active milling; 3 individuals (1 adult, 2 subadults)	40 min
	2	31/8/13	Hervey Bay, Queensland, Australia	25°0.69′ S, 152°59.02′ E	slow swimming; 3 individuals (2 adults, 1 subadult)	1 h 23 min
	3	15/7/19	São Paulo, Brazil	23°56.19′ S, 45°28.56′ W	swimming alone northeast direction, approx. 4 knots	20 min
case 2: IBJ-1386 / RSL-360 / HWMN0700643	1	7/8/03	Abrolhos Bank, Bahia, Brazil	18°4.46′ S, 38°23.27′ W	competitive group; 9 individuals (adults) in the pod	40 min
	2	22/9/25	Hervey Bay, Queensland, Australia	25°6.56′ S, 153°2.46′ E	swimming alone, fluke-up dive	10 min

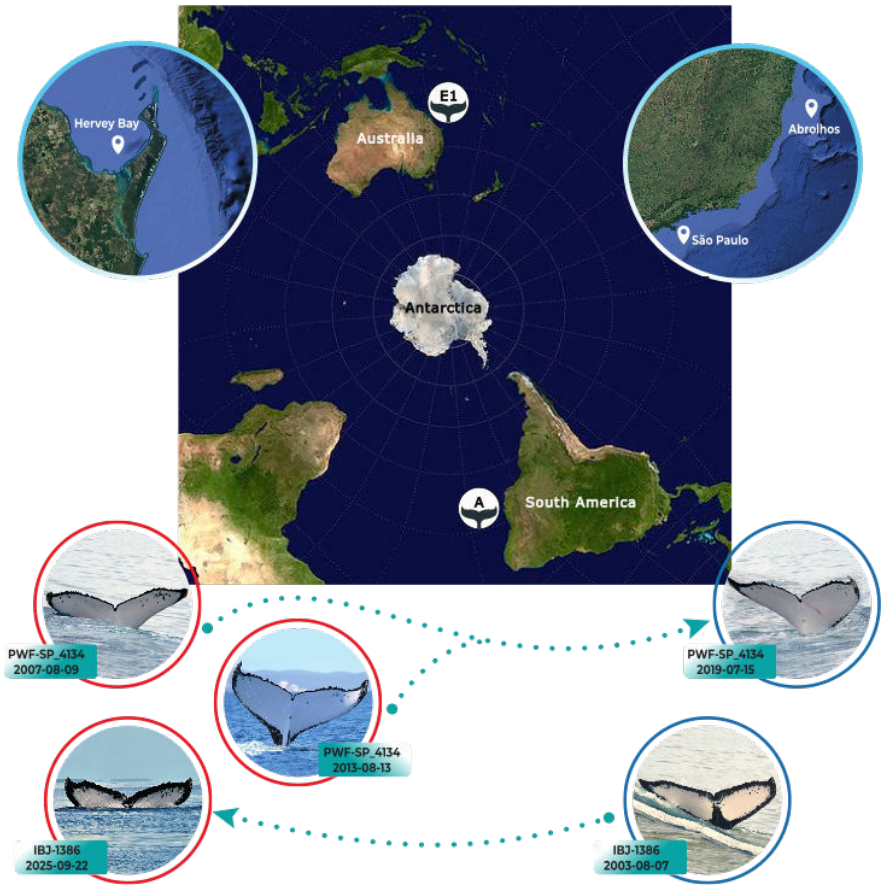

Figure 1. Geographic locations and photographic documentation of exchange between eastern Australia (breeding stock E1 (BSE1)) and Brazil (breeding stock A (BSA)) humpback whales. The map shows the sighting locations in Hervey Bay, Queensland, Australia, and in coastal waters of Brazil. The actual routes between sightings are not known and are not depicted. Photo-identification confirmed two individuals sighted in both regions. Case 1 (Australia to Brazil): Individual *PWF-SP_4134/PROBav-HBW-SP0071/HW-MN0700299* was photographed in (A) Hervey Bay, Australia, on 9 August 2007; (B) Hervey Bay, Australia, on 31 August 2013; and (C) São Paulo, Brazil, on 15 July 2019, with the breeding grounds separated by a minimum great-circle distance of 14 200 km. Case 2 (Brazil to Australia): Individual *IBJ-1386/RSL-360/HW-MN0700643* was photographed in (D) Abrolhos Bank, Brazil, on 7 August 2003; and (E) Hervey Bay, Australia, on 22 September 2025, with the breeding grounds separated by a minimum great-circle distance of 15 100 km over a 22 year interval.

a speed of approximately 3 knots, consistent with humpback whales transiting this region towards the Abrolhos Bank breeding ground in Bahia. The time elapsed between the last Australian sighting (2013) and the Brazilian resighting (2019) was approximately 6 years, while 11 years and 10 months elapsed between the first Australian sighting and the Brazilian resighting. The two breeding grounds are separated by a minimum great-circle distance of 14 200 km.

3.2. Case 2: individual IBJ-1386/RSL-360/HW-MN0700643

This individual (figure 1) was first photographed on 7 August 2003 in Abrolhos, Brazil (18°4.46′ S, 38°23.27′ W) by members of the Instituto Baleia Jubarte (IBJ) and the Laboratory of Bioacoustics (LaB, Universidade Federal do Rio Grande do Norte). The whale was observed in a competitive group of nine whales which displayed behaviours such as pectoral slapping, head slapping and fluke-up diving. The dorsal fin and body had multiple scars. Sex was not determined, although competitive group participation is most commonly associated with male humpback whales.

The same individual was resighted on 22 September 2025 in Hervey Bay, Australia (25°6.56′ S, 153°2.46′ E). The whale was travelling alone and executed a fluke-up dive during an opportunistic sighting as a whale-watching boat returned to port. The time elapsed between the Brazilian and

Australian sightings was 22 years and 1 month, representing one of the longest documented intervals between re-sightings of an individual humpback whale in different breeding grounds.

Complete encounter histories and identification photographs for both cases are available through Happywhale (case 1: https://happywhale.com/individual/37625; case 2: https://happywhale.com/individual/55442).

4. Discussion

We documented two individual humpback whales photographed in both the eastern Australian (BSE1) and Brazilian (BSA) breeding populations, representing the first photo-ID evidence of exchange in both directions between these two geographically distant Southern Hemisphere breeding stocks. The two breeding grounds are separated by minimum great-circle distances of 14 200 km and 15 100 km between the South Pacific and South Atlantic, respectively. The type 1 'high white sides' lateral body coloration of the case 1 individual, commonly seen in Australian humpback whales [44], is consistent with an Australian origin. Because photo-ID records only endpoints, the actual routes and distances travelled by each whale cannot be inferred from these matches. These records nevertheless demonstrate a degree of migratory flexibility in humpback whales that extends beyond traditionally recognized breeding-population boundaries.

Despite the exceptional separation between sighting locations, the observed rate of exchange between BSE1 and BSA was extremely low. Across a combined 41 year dataset (1984–2025), only two matches were identified among 19 283 individuals, corresponding to an exchange rate of approximately 0.05 individuals per year, or 0.01% of identified whales. This low rate is congruent with the genetic differentiation observed between Southern Hemisphere breeding stocks [8,45] and is consistent with the interpretation that some degree of exchange occurs across population boundaries. The photo-ID matches presented here add individual-level observational evidence of exchange between these stocks while reinforcing that such events are unlikely to have demographic significance at the population scale.

The 'Southern Ocean Exchange' hypothesis posits that movement of individual humpback whales between Southern Hemisphere breeding populations is facilitated by shared use of circumpolar feeding grounds in the Southern Ocean [16]. Comparative song analyses, migratory-route evaluations, and feeding-ground observations indicate that whales from multiple Southern Hemisphere breeding stocks can co-occur in Antarctic feeding areas, including the Antarctic Sound Ocean Area (ASSO) [41]. Mixing between Brazilian (BSA) and eastern South Pacific (BSG) whales has been documented in the West Antarctic Peninsula feeding area [16]. Marcondes *et al.* [17] proposed that population growth, shifting krill availability and reduced sea-ice extent may increase opportunities for exchange between ocean basins. Our findings of exchange in both directions between (BSE1) and (BSA) reinforce and extend this hypothesis by showing that such connectivity is not limited to shared Antarctic feeding areas but can also be reflected in matches between geographically distant breeding grounds. Even at the low rate observed here, such exchanges could, over time, contribute to the maintenance of genetic diversity and to the horizontal transmission of song traditions among Southern Hemisphere populations [9,10,46,47].

The 15 100 km minimum separation recorded in case 2 represents the greatest distance between sighting locations ever reported for an individual humpback whale, exceeding the previous maximum inter-breeding-ground separation (13 046 km between Colombia and Zanzibar) [31] by approximately 15%. The 14 200 km separation in case 1 also surpasses this earlier record by approximately 9%. Both cases far surpass other documented exchanges between breeding areas, such as those between Brazil and Madagascar (9800 km) [32] and between several South Pacific breeding areas (6000–7000 km) [16,29]. Notably, case 2 also involved a 22 year interval between sightings in the two breeding grounds, highlighting that such events could represent rare, possibly single-lifetime occurrences rather than typical migratory patterns (table 2). These distances represent the separation between the locations where the whales were photographed, not the actual distance travelled by each individual. Given the years elapsed between sightings, each whale would have completed multiple annual migrations between the events.

Prior photo-ID records of long-distance exchange have primarily involved the South Atlantic and Indian Oceans [32,39], and more recently the eastern South Pacific and South Atlantic Oceans [29,30,48]. Other long-distance matches have documented movement between the Antarctic Peninsula and eastern Australia [33]. The matches between eastern Australia and Brazil reported here represent

Table 2. Summary of previously reported long-distance exchanges between humpback whale breeding (or breeding-to-feeding) areas in the Southern Hemisphere, including oceanic connections, source and destination regions and the minimum great-circle distance between the two sighting locations. These distances represent the separation between where each individual was photographed rather than the actual distance travelled. The two cases documented in the present study represent the greatest known separations between sightings of an individual humpback whale and the first photographic evidence of exchange in both directions between eastern Australia (BSE1) and Brazil (BSA).

case/reference	oceanic connection	from (breeding stock/region)	to (breeding stock/region)	approx. distance (km)
Stevick *et al*. [32]	South Atlantic → Indian Ocean	Abrolhos Bank, Brazil (BSA)	Île Sainte Marie, Madagascar (BSC)	~9800
Ramos *et al*. [39]	South Atlantic ↔ Indian Ocean	Brazil (BSA)	South Africa (BSB2 and BSC1)	~7000–9000
Kalashnikova *et al*. [31]	Pacific → Indian Ocean	Colombia (BSG)	Zanzibar (BSC)	13 046
Stevick *et al*. [29]	Pacific → Atlantic	Ecuador (BSG)	Brazil (BSA)	~12 800
Félix *et al*. [30]	Pacific ↔ Atlantic	Ecuador (BSG)	Brazil (BSA)	~12 000
Marcondes *et al*. [16]	Atlantic ↔ Pacific	Brazil (BSA)	Colombia, Ecuador, Peru (Stock G)	~12 000
Castro *et al*. [19]	Pacific ↔ Atlantic (feeding overlap)	Ecuador (BSG)	South Sandwich Islands (feeding area for Stock A)	~8,000 -10,000
Acevedo *et al*. [33]	Southern Ocean → South Pacific	Antarctic Peninsula (feeding area)	Eastern Australia (BSE1)	~9800
Acevedo [48]	Pacific ↔ Atlantic	Colombia, Ecuador, Peru (BSG)	Brazil (BSA), Magellan Strait (AI)	~12 000
present study	South Pacific ↔ South Atlantic South Atlantic → South Pacific	Australia (BSE1)	Brazil (BSA)	~14 200 and~15 100

a previously undocumented connection between the South Pacific and the South Atlantic, crossing the widest longitudinal separation between populated Southern Hemisphere breeding grounds. The actual routes travelled by these whales cannot be determined from photo-ID alone.

The two cases also differ in the behavioural context at the time of sighting. In case 1, the individual was photographed on three occasions in Hervey Bay, Australia and later in coastal waters off São Paulo, Brazil. In case 2, the individual was observed in a competitive group in the Abrolhos Bank breeding area in Brazil, and subsequently sighted alone in Hervey Bay, Australia.

Sex was not determined for either individual, and we therefore refrain from interpreting these matches in terms of sex-biased dispersal. Published records of long-distance exchange include both female-mediated [29,32,48] and male-mediated [31,40] cases, and the two matches reported here do not allow us to distinguish between these possibilities. Age-class at each sighting likewise could not be verified from photographs, so speculation about individual life-history stage at the time of exchange is not warranted.

Environmental variability in Antarctic prey availability, particularly changes in krill distribution associated with sea-ice extent, ocean primary production and climatic oscillations such as ENSO [49,50], may occasionally prompt individuals to exploit feeding grounds outside their usual range. Such events, although rare, could bring individuals into contact with whales from other breeding stocks and offer occasional opportunities for exchange between populations [7].

The inter-basin exchanges documented in this study, even infrequent, have important implications for the conservation of Southern Hemisphere humpback whale populations, if the individuals are able to successfully breed in the new region. These rare individual movements may become increasingly important as environmental change continues to reshape the Southern Ocean ecosystem. In a context of accelerated climate change affecting the entire continent of Antarctica [51], in which the distribution and availability of Antarctic prey may alter traditional migratory patterns, the ability of some

individuals to explore alternative routes and use different breeding areas could have adaptive value [52].

Although the rate of exchange documented here is too low to have demographic consequences at the population scale, these records illustrate the broad, transboundary nature of humpback whale migration and connectivity. Continued photographic monitoring across Southern Hemisphere breeding and feeding grounds, enabled by collaborative platforms such as Happywhale, will be important for detecting further exchange events, refining estimates of exchange rates and assessing whether the frequency of such events changes over time in response to continued population recovery and environmental change. Such monitoring aligns with the Convention on the Conservation of Migratory Species of Wild Animals, which provides an international framework for coordinating conservation actions across the full migratory range of highly mobile species [53]. Integrating photographic monitoring with satellite telemetry and genetic analyses will further help to quantify exchange rates, identify range expansions and clarify the ecological contexts under which exchanges occur.

Ethics. Research surveys conducted in Hervey Bay, Australia were carried out under approval from the Animal Ethics Committee of the Queensland Government and complied with relevant national and state regulations. The Brazilian sighting corresponding to case 2 was conducted under approval from the Ethics Committee on Animal Use of the Universidade Federal do Rio Grande do Norte (CEUA/UFRN 042/2022) and complied with relevant national regulations. Additional sightings and photographic records, including the Brazilian sighting corresponding to case 1, were obtained through citizen science efforts and public contributions to the Happywhale platform. These opportunistic observations involved only photo-identification using observational methods and, therefore, did not require separate animal ethics approval.

Data accessibility. Photo-identification records and associated sighting metadata for the two individuals documented in this study (case 1: PWF-SP_4134 / HBW-sp0071 / HW-MN0700299; case 2: IBJ-1386 / HW-MN0700643 / RSL-360) are publicly available for viewing on the citizen science platform Happywhale (www.happywhale.com) via the individual profile links provided in this manuscript.

The full regional photo-identification catalogues contributing to this study are archived within Happywhale and are accessible in accordance with the data-sharing policies of the contributing organizations. Due to ethical agreements and data-sharing restrictions, these catalogues cannot be downloaded in bulk; however, all individual encounter records relevant to this study are publicly viewable and independently verifiable through the Happywhale platform.

Declaration of AI use. AI-assisted tools were used for language editing and clarity only. No AI technologies were used to generate data, perform analyses, create figures, or interpret results. All scientific content and conclusions are the responsibility of the authors.

Authors' contributions. C.C.A.: conceptualization, formal analysis, investigation, writing—original draft, writing—review and editing; S.S.: conceptualization, formal analysis, investigation, writing—original draft, writing—review and editing; M.M.: conceptualization, investigation, writing—review and editing; J.C.: conceptualization, investigation, writing—review and editing; T.C.: conceptualization, data curation, writing—review and editing; J.C.: conceptualization, investigation, writing—review and editing; A.F.: investigation, writing—review and editing; M.O.: data curation, writing—review and editing; B.R.: investigation, writing—review and editing; S.S.: investigation, writing—review and editing; R.S.S.-L.: conceptualization, investigation, writing—review and editing.

All authors gave final approval for publication and agreed to be held accountable for the work performed therein.

Conflict of interest declaration. We declare we have no competing interests.

Funding. This study was supported by multiple funding sources associated with contributing authors and institutions. C. Castro, S. H. Stack, and J. J. Currie were supported through Pacific Whale Foundation and PacWhale Eco-Adventures, with additional in-kind support provided to C. Castro by Palo Santo Travel. S. H. Stack also received funding through a Postgraduate Research Scholarship and an International Research Postgraduate Research Scholarship from Griffith University. T. Cheeseman and M. Olio were supported by Happywhale, which also provided photo-identification data management and analytical infrastructure. J. Cardoso and A. Francisco were supported through Projeto Baleia à Vista. M. C. C. Marcondes and B. M. Righi were supported through Projeto Baleia Jubarte, which is sponsored by Petróleo Brasileiro S.A. (Petrobras). R. S. Sousa-Lima was supported by a PhD scholarship from the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES; Finance Code 001), a research productivity fellowship from the Brazilian National Council for Scientific and Technological Development (CNPq PPq 311533/2022-1), and additional grants from the Society for Marine Mammalogy Small Grants-in-Aid of Research, the Canon National Parks Science Scholars Program Technology Innovation Grant (2003), Canon U.S.A., and the Animal Behavior Society Cetacean Conservation Grant. The funders had no role in the design of the study; the collection, analysis, or interpretation of data; the writing of the manuscript; or the decision to submit the work for publication.

Acknowledgements. We thank the numerous staff and volunteers who have contributed to the Pacific Whale Foundation, Instituto Baleia Jubarte, and Projeto Baleia à Vista catalogues over the years. We also thank the broader Happywhale community, whose research and citizen science contributions continue to build the global humpback whale photo-identification dataset that made this study possible.

C. Castro, S.H. Stack, and J.J. Currie thank Greg Kaufman, founder of Pacific Whale Foundation, who initiated the humpback whale photo-identification catalogue in eastern Australia and whose pioneering work in research and conservation has been a lasting inspiration for this study. R.S. Sousa-Lima thanks Dr. Christopher W. Clark for his mentorship and inspiration throughout her career in bioacoustics and cetacean research.

R.S. Sousa-Lima also thanks the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) and the Brazilian National Council for Scientific and Technological Development (CNPq) for their support throughout her research career.

References

1. Clapham PJ. 2018 Humpback whale: *Megaptera novaeangliae*. In *Encyclopedia of marine mammals* (eds B Würsig, JGM Thewissen, KM Kovacs), pp. 489–492, 3rd edn. Academic Press. (doi:10.1016/B978-0-12--804327-1.00154-0)
2. Mackintosh NA. 1946 The natural history of whalebone whales. *Biol. Rev*. **21**, 60–74. (doi:10.1111/j.1469-185x.1946.tb00453.x)
3. Forestell PH, Urbán R. J. 2007 Movement of a humpback whale (*Megaptera novaeangliae*) between the Revillagigedo and Hawaiian Archipelagos within a winter breeding season. *Lat. Am. J. Aquat. Mamm.* **6**, 97–102. (doi:10.5597/lajam00113)
4. Félix F, Guzmán HM. 2014 Satellite tracking and sighting data analyses of southeast pacific humpback whales *Megaptera novaeangliae*: is the migratory route coastal or oceanic? *Aquat. Mamm*. **40**, 329–340. (doi:10.1578/am.40.4.2014.329)
5. Horton TW, Holdaway RN, Zerbini AN, Hauser N, Garrigue C, Andriolo A, Clapham PJ. 2011 Straight as an arrow: humpback whales swim constant course tracks during long-distance migration. *Biol. Lett*. **7**, 674–679. (doi:10.1098/rsbl.2011.0279)
6. Guzman HM, Félix F. 2017 Movements and habitat use by southeast Pacific humpback whales *Megaptera novaeangliae* satellite tracked at two breeding sites. *Aquat. Mamm*. **43**, 139–155. (doi:10.1578/am.43.2.2017.139)
7. Millien V, Stafiej N, Félix F, Guzman HM. 2025 Migratory behaviour of humpback whales in the southeastern Pacific under climate change. *Sci. Rep*. **15**, 3989. (doi:10.1038/s41598-025-87489-4)
8. Rosenbaum H *et al*. 2017 First circumglobal assessment of Southern Hemisphere humpback whale mitochondrial genetic variation and implications for management. *Endanger. Species Res*. **32**, 551–567. (doi:10.3354/esr00822)
9. Garland EC, Gedamke J, Rekdahl ML, Noad MJ, Garrigue C, Gales N. 2013 Humpback whale song on the Southern Ocean feeding grounds: implications for cultural transmission. *PLoS One* **8**, e79422. (doi:10.1371/journal.pone.0079422)
10. Garland EC, Goldizen AW, Rekdahl ML, Constantine R, Garrigue C, Hauser ND, Poole MM, Robbins J, Noad MJ. 2011 Dynamic horizontal cultural transmission of humpback whale song at the ocean basin scale. *Curr. Biol*. **21**, 687–691. (doi:10.1016/j.cub.2011.03.01s)
11. Donovan GP. 1991 A review of IWC stock boundaries. *Rep. Int. Whal. Commn*. **13**, 39–68.
12. Andriolo A, Rocha JM da, Zerbini AN, Simões-Lopes PC, Moreno IB, Lucena A, Danilewicz D, Bassoi M. 2010 Distribution and relative abundance of large whales in a former whaling ground off eastern South America. *Zoologia* **27**, 741–750. (doi:10.1590/s1984-46702010000500011)
13. Baracho-Neto CG, Neto ES, Rossi-Santos MR, Wedekin LL, Neves MC, Lima F, Faria D. 2012 Site fidelity and residence times of humpback whales *Megaptera novaeangliae* on the Brazilian coast. *J. Mar. Biol. Assoc. U. K*. **92**, 1783–1791. (doi:10.1017/s0025315411002074)
14. Martins CCA, Andriolo A, Engel MH, Kinas PG, Saito CH. 2013 Identifying priority areas for humpback whale conservation at Eastern Brazilian Coast. *Ocean Coast. Manag*. **75**, 63–71. (doi:10.1016/j.ocecoaman.2013.02.006)
15. Stevick PT, De Godoy LP, McOsker M, Engel MH, Allen J. 2006 A note on the movement of a humpback whale from Abrolhos Bank, Brazil to South Georgia. *J. Cetacean Res. Manage*. **8**, 297–300. (doi:10.47536/jcrm.v8i3.726)
16. Marcondes MCC *et al*. The southern ocean exchange: porous boundaries between humpback whale breeding populations in southern polar waters. *Sci. Rep*. **11**. (doi:10.1038/s41598-021-02612-5)
17. Zerbini AN *et al*. 2006 Satellite-monitored movements of humpback whales *Megaptera novaeangliae* in the Southwest Atlantic ocean. *Mar. Ecol. Prog. Ser*. **313**, 295–304. (doi:10.3354/meps)
18. Engel MH, Martin AR. 2009 Feeding grounds of the western South Atlantic humpback whale population. *Mar. Mammal Sci*. **25**, 964–969. (doi:10.1111/j.1748-7692.2009.00301.x)
19. Castro C, Engel MH, Martin AR. 2023 First humpback whale movement between ecuador and the south Sandwich Islands: redefines the easternmost migration point of breeding stock G. *Aquat. Mamm*. **49**, 382–387. (doi:10.1578/AM.49.4.2023.382)
20. Zerbini AN, Andriolo A, Heide-Jorgensen MP, Moreira SC, Pizzorno JL, Maia YG, Vanblaricom GR, DeMaster DP. 2011 Migration and summer destinations of humpback whales *Megaptera novaeangliae* in the western South Atlantic Ocean. *J. Cetacean Res. Manage* 113–118. (doi:10.47536/jcrm.vi.315)
21. Morete ME, Marques ML, De Souza RCF, Tristão IA, Motta MC, Martins CCA, Cardoso J, Francisco A. 2022 Is the reproductive area of the humpback whale *Megaptera novaeangliae* in Brazilian waters increasing? Evidence of breeding and calving activities around Ilhabela, São Paulo, Brazil. *Lat. Am. J. Aquat. Mamm*. **17**, 63–67. (doi:10.5597/lajam00281)
22. Andrews-Goff V, Gales N, Childerhouse SJ, Laverick SM, Polanowski AM, Double MC. 2023 Australia's east coast humpback whales: satellite tag-derived movements on breeding grounds, feeding grounds and along the northern and southern migration. *Biodivers. Data J*. **11**, e114729. (doi:10.3897/BDJ.11.e114729)
23. Stack SH, Currie JJ, McCordic JA, Machernis AF, Olson GL. 2019 Distribution patterns of east Australian humpback whales *Megaptera novaeangliae* in Hervey Bay, Queensland: a historical perspective. *Aust. Mammal*. **42**, 16–27. (doi:10.1071/AM18029)

24. Wedekin L, Engel M, Andriolo A, Prado P, Zerbini A, Marcondes M, Kinas P, Simões-Lopes P. 2017 Running fast in the slow lane: rapid population growth of humpback whales after exploitation. *Mar. Ecol. Prog. Ser*. **575**, 195–206. (doi:10.3354/meps12211)
25. Zerbini AN, Adams G, Best J, Clapham PJ, Jackson JA, Punt AE. 2019 Assessing the recovery of an Antarctic predator from historical exploitation. *R. Soc. Open Sci*. **6**, 190368. (doi:10.1098/rsos.190368)
26. Noad MJ, Kniest E, Dunlop RA. 2019 Boom to bust? Implications for the continued rapid growth of the eastern Australian humpback whale population despite recovery. *Popul. Ecol*. **61**, 198–209. (doi:10.1002/1438-390x.1014)
27. Katona SK, Whitehead HP. 1981 Identifying humpback whales using their natural markings. *Polar Record* **20**, 439–444. (doi:10.1017/S003224740000365X)
28. Cheeseman T *et al*. 2023 A collaborative and near-comprehensive North Pacific humpback whale photo-ID dataset. *Sci. Rep*. **13**, 10237. (doi:10.1038/s41598-023-36928-1)
29. Stevick PT, Allen JM, Engel MH, Felix F, Haase B, Neves MC. Inter-oceanic movement of an adult female humpback whale between Pacific and Atlantic breeding grounds off South America. *J. Cetacean Res. Manag*. **13**, 159–162. (doi:10.47536/jcrm.v13i2.545)
30. Félix F, Abras DR, Cheeseman T, Haase B, Santos JDF, Marcondes MCC, Southerland K, Acevedo J. 2020 A new case of interoceanic movement of a humpback whale in the southern hemisphere: the El Niño link. *Aquat. Mamm*. **46**, 578–583. (doi:10.1578/AM.46.6.2020.578)
31. Kalashnikova E, Botero-Acosta N, Duque Mesa E, Gascón MP, Lyne P, Cheeseman T, Vogel A, Kennedy A, Akkaya A. 2024 Interbreeding area movement of an adult humpback whale between the east Pacific Ocean and southwest Indian Ocean. *R. Soc. Open Sci*. **11**, 241361. (doi:10.1098/rsos.241361)
32. Stevick PT, Neves MC, Johansen F, Engel MH, Allen J, Marcondes MCC, Carlson C. 2011 A quarter of a world away: female humpback whale moves 10,000 km between breeding areas. *Biol. Lett*. **7**, 299–302. (doi:10.1098/rsbl.2010.0717)
33. Acevedo J, Aguayo-Lobo A, Beeman P, Cheeseman T, Olavarría C. 2022 From the Antarctic Peninsula to eastern Australia: the longest migration of a humpback whale through the South Pacific Ocean. *Mamm. Biol*. **102**, 1463–1468. (doi:10.1007/s42991-021-00195-2)
34. Jackson JA, Steel DJ, Beerli P, Congdon BC, Olavarría C, Leslie MS, Pomilla C, Rosenbaum H, Baker CS. 2014 Global diversity and oceanic divergence of humpback whales *Megaptera novaeangliae*. *Proc. R. Soc. B Biol. Sci*. **281**, 20133222. (doi:10.1098/rspb.2013.3222)
35. Kershaw F *et al*. 2016 Multiple processes drive genetic structure of humpback whale *Megaptera novaeangliae* populations across spatial scales. *Mol. Ecol*. **26**, 977–994. (doi:10.1111/mec.13943)
36. Franklin W *et al*. 2014 Photo-identification confirms that humpback whales *Megaptera novaeangliae* from eastern Australia migrate past New Zealand but indicates low levels of interchange with breeding grounds of Oceania. *J. Cetacean Res. Manage*. **14**, 133–140. (doi:10.47536/jcrm.v14i1.530)
37. Garrigue C *et al*. 2011 First assessment of interchange of humpback whales between Oceania and the East coast of Australia. *J. Cetacean Res. Manag*. 269–274. (doi:10.47536/jcrm.vi.314)
38. Kaufman G. 2011 Photographic evidence of interchange between east Australia (BS E-1) and west Australia (BS–D) humpback whale breeding populations. In *Paper SC/63/SH11 presented Scientific Committee of the International Whaling Commission*, p. 16. Cambridge, UK: IWC.
39. Ramos EA *et al*. 2023 Interchange of southern hemisphere humpback whales across the South Atlantic Ocean. *Sci. Rep*. **13**, 4621. (doi:10.1038/s41598-023-31358-5)
40. Pomilla C, Rosenbaum HC. 2005 Against the current: an inter-oceanic whale migration event. *Biol. Lett*. **1**, 476–479. (doi:10.1098/rsbl.2005.0351)
41. Schall E *et al*. 2022 Song recordings suggest feeding ground sharing in Southern Hemisphere humpback whales. *Sci. Rep*. **12**, 13924. (doi:10.1038/s41598-022-17999-y)
42. Riekkola L *et al*. 2018 Application of a multi-disciplinary approach to reveal population structure and Southern Ocean feeding grounds of humpback whales. *Ecol. Indic*. **89**, 455–465. (doi:10.1016/j.ecolind.2018.02.030)
43. Cheeseman T *et al*. 2022 Advanced image recognition: a fully automated, high-accuracy photo-identification matching system for humpback whales. *Mamm. Biol*. **102**, 915–929. (doi:10.1007/s42991-021-00180-9)
44. Kaufman GD, Smultea MA, Forestell PH. 1987 Use of lateral body pigmentation patterns for photographic identification of east Australian (Area V) humpback whales. *Cetus* **7**, 5–13.
45. Jackson JA. 2015 *Southern Hemisphere humpback whale comprehensive assessment: a synthesis and summary, 2005–2015. Report to the Scientific Committee of the International Whaling Commission, SC/66a/SH3*. Cambridge, UK: IWC.
46. Rosenbaum HC *et al*. 2009 Population structure of humpback whales from their breeding grounds in the South Atlantic and Indian Oceans. *PLoS One* **4**, e7318. (doi:10.1371/journal.pone.0007318)
47. Palsbøll PJ *et al*. 1997 Genetic tagging of humpback whales. *Nature* **388**, 767–769. (doi:10.1038/42005)
48. Acevedo J. New interoceanic and regional movements from Humpback whale populations of the west and east South America. *Rev. Polar Biol*. In press.
49. de Lima RC, Félix F, Haase B, Secchi ER. 2025 Antarctic sea ice as a driver of humpback whale migration timing in the southeast Pacific. *Polar Biol*. **48**, 92. (doi:10.1007/s00300-025-03410-9)
50. Atkinson A *et al*. 2019 Krill *Euphausia superba* distribution contracts southward during rapid regional warming. *Nat. Clim. Chang*. **9**, 142–147. (doi:10.1038/s41558-018-0370-z)
51. Bengtson Nash SM *et al*. 2018 Signals from the south; humpback whales carry messages of Antarctic sea-ice ecosystem variability. *Glob. Chang. Biol*. **24**, 1500–1510. (doi:10.1111/gcb.14035)

52. von Hammerstein H, Setter RO, van Aswegen M, Currie JJ, Stack SH. 2022 High-resolution projections of global sea surface temperatures reveal critical warming in humpback whale breeding grounds. *Front. Mar. Sci.* **9**, 837772. (doi:10.3389/fmars.2022.837772)
53. Convention on the Conservation of Migratory Species of Wild Animals (CMS). 1979 *Convention on the conservation of migratory species of wild animals: convention text*. Bonn, Germany: United Nations Environment Programme.