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SUMMARY

Southern right whales (*Eubalaena australis*; SRWs) migrate from winter breeding grounds into the Southern Ocean to feed during the warmer months. However, where modern-day SRWs from the Australian wintering grounds feed, and their migratory paths, remain poorly understood. The aim of this research was to track foraging movements of SRWs from Western Australia (WA) using satellite tags that were deployed towards the end of the breeding season in September 2022. Some tags remained on for >176 days, providing new insights into migration routes and foraging locations. Potential foraging areas were the Subtropical Front, the Kerguelen Islands, the Crozet Islands and Antarctica. Here, we provide preliminary analyses of the spatial and temporal overlap among populations of SRWs. Specifically, there was spatial and temporal overlap with right whales from the Aotearoa New Zealand and the South African breeding population. This research highlights a high degree of variability in where WA SRW forage. Future work will use state space modelling to confirm foraging regions and investigate the use of oceanic features (*e.g.,* continental slopes, frontal systems and eddies, transform faults and seamounts) through modelling.

INTRODUCTION

Several whaling stations across the south coast of Australia conducted bay and pelagic whaling on southern right whales (*Eubalaena australis*; SRWs) in the 1800s, reaching a peak in 1840 (Bannister 1986a). The total number of SRWs caught off Western Australia (WA) is unknown due to poor differentiation between SRWs and humpback whales in catch records, the number 'lost/sunk', and reference to annual yields rather than total catches (Bannister 1986a). In the early to mid-1900s, there were no confirmed sightings of SRWs off Australia; the first new sighting of a mother-calf pair off Albany, WA, occurred in 1955 (Chittleborough 1956). This was followed by intermittent records of SRWs off WA until 1969 when sightings became annual (Bannister 1986b). In 1976, annual aerial surveys began, from Augusta, WA, to Ceduna,

South Australia, and counts of SRWs have steadily increased over the years (*e.g.,* from 167 in 1993 to 847 in 2017: Smith et al. 2021). From 2018 estimates, the western sub-population (WA and South Australia west of Ceduna) has risen approximately 6% per year to around 3,191 whales (Smith et al. 2021). As the population numbers are still below estimated historic abundance and the rate of increase is low, the whales remain on the endangered status list in Australia (EPBC Act 1999).

What was previously known of Australian SRW foraging grounds was primarily pieced together from whaling records (Townsend 1935, Bannister 2001). This historical whaling data show that SRWs were captured in the Southern Ocean off WA (Bannister 1986a, Richards 2009), Amsterdam Island (Townsend 1935, Richards 2009), Kerguelen Islands (Îles Kerguelen; Tormosov et al. 1998, Duhamel and Williams 2011), Crozet Islands (Îles Crozet; Townsend 1935, Tormosov et al. 1998), Heard Island (Keage 1981, McGowan 2000), and also east Antarctica from Soviet catches (73-120°E, 63°S in January-March, 23 in 1963 and 19 in 1965) (Tormosov et al. 1998).

Since Soviet whaling, much of the information on the offshore distribution of SRWs linked to Australia has come from Japanese vessels undertaking surveys (Japanese Whale Research Programme JARPA under Special Permit). JARPA sighted 75 SRWs south of WA (in a specific area between 41-44°S and 116-124°E) across December-January 1981/82 (Ohsumi and Kasamatsu 1986). A dedicated right whale cruise in this same location did not observe any SRWs later in the feeding season in February-March 1993, however, 35 SRWs were encountered there in December-January 1995/96 (Bannister et al. 1997). From these surveys, it was assumed that SRWs would be located further south later in the feeding season (*e.g.,* February). It was in February 1996 that two SRWs were sighted in Antarctic waters by JARPA (Nishiwaki 1996). One of these individuals was a photo-identification match to a WA whale named "Match WA75", showing that SRWs from WA do indeed migrate to Antarctic waters (Bannister et al. 1999). Following this, there were aerial surveys flown between 16 December 2009 – 5 February 2010 off Casey Station, Antarctica, with three SRWs recorded during February only (64°29'S, 105°14'E and 64°40'S, 108°42'E) (Gales et al. 2019). In February 2015, 27 groups of SRWs (43 individuals, including five mother and calf pairs) were sighted in Antarctic waters between 70°E - 115°E, south of 60°S by JARPA (Matsuoka et al. 2015), further highlighting the importance of Antarctic waters as foraging grounds for SRWs from February.

To examine migration routes of Australian SRWs in detail, a satellite tag was deployed on a subadult SRW off Eaglehawk Neck, Tasmania, from the eastern sub-population in October 2010, which transmitted for 103 days (Mackay et al. 2020). Nine satellite tags were then deployed on SRWs off Head of Bight, South Australia, from the western sub-population at the end of the breeding season in 2014 (three tags transmitting for 29, 32, 57 days). The tags had a high failure rate, and the tag design has since been superseded. Limited information was provided on foraging areas of Australian SRWs (Mackay et al. 2020). Recent isotopic modelling work suggests that while the western sub-population of SRW has decreased its use of foraging grounds in high latitudes in recent decades, the eastern sub-population has increased its use of such foraging grounds (Derville et al. 2023). It is hypothesised that SRW populations that are more dependent on mid-latitude foraging grounds may have a steadier recovery trajectories than those with significant use of high-latitude habitat (Derville et al. 2023). Drawing on combined information from stable isotopes, satellite tags, JARPA sightings

and commercial whaling records, it appears there is a variety of migratory pathways and foraging areas used by SRWs in the Southern Ocean south of Australia, and these may change over time in response to climate change.

Detailed information on the Australian SRW migration routes and foraging grounds are required to gain an understanding of where SRWs are feeding (*i.e.,* areas of ecological significance/biological important areas), and how their movements relate to oceanic conditions. This is especially relevant as there are changes occurring in the Southern Ocean ecosystem due to global warming and warming waters (Chapman et al. 2020, Li et al. 2023), where "it is unequivocal that human influence has warmed the atmosphere, ocean and land" (IPCC 2021). There are projected changes in frontal systems, where the position of fronts are influenced by changes in the climate and large-scale climate modes (such as the El Niño Southern Oscillation) (Chapman et al. 2020). It is predicted that lower trophic level organisms will move further south and the distribution of species such as krill (*Euphausia superba*) will depend on their tolerance to a warming ocean (Constable et al. 2014). In response to changes in the availability/density of their prey (copepods and krill), SRWs may be required to change their feeding patterns (Dedden and Rogers 2022) and/or to entirely shift their migration paths to different foraging patches if their preferred prey becomes sub-optimal or unavailable (van den Berg et al. 2021). Ultimately, SRWs are expected to show a decrease in reproductive output when foraging is affected, as they are not able to gain the fat stores required for successful reproduction (Leaper et al. 2006, Seyboth et al. 2016, van den Berg et al. 2021, Vermeulen et al. 2023). Furthermore, extreme climatic events (*e.g.,* El Niño/La Niña), which are increasing in frequency and intensity due to global warming, may lead to an increase in mortality rates in SRWs (Agrelo et al. 2021).

Satellite tracking has been reviewed and improved for large whales (Best et al. 2015, Andrews et al. 2019, Smies et al. 2022), and has been shown to have direct conservation benefits for right whales (Mate et al. 2011, Zerbini et al. 2015, Zerbini et al. 2016, Zerbini et al. 2018, Riekkola et al. 2021). The aim of this project is to use satellite telemetry to investigate:

i) The migration paths and foraging grounds of WA SRW
ii) How the whales use oceanic fronts or water masses for foraging
iii) Whether migration paths or foraging grounds overlap with those identified in historical data and those used by other SRW populations.

This Australian research is part of the IWC-Southern Ocean Research Partnership[1]theme on SRW, where the foraging grounds of SRWs are already being examined off Argentina[2], South Africa[3] and Aotearoa New Zealand[4]. The Australian SRW research component is entitled Mirnong Maat (akin to Whale Journeys) in local First Nations Menang/Merningar language[5]. Here, we present a description of the movements of the whales that indicate putative foraging grounds, which will be rigorously assessed using movement models. Data are also shared with the Australian Antarctic Division and the Department of Department of Climate Change, Energy, the Environment and Water for the purpose of SRW Biological Important Area (BIA) assessment and identification in Australian waters. The research is intended to assist managers and policy makers to assess anthropogenic impacts including changes in the climate conditions in the Southern Ocean and consequent effects on SRWs.

[1] https://www.marinemammals.gov.au/sorp/the-right-sentinel-for-climate-change/
[2] https://siguiendoballenas.org/en/home/
[3] https://www.mammalresearchinstitute.science/whale-unit
[4] https://tohoravoyages.ac.nz/
[5] https://tohoravoyages.ac.nz/welcome-to-mirnong-maat/

METHODS

Satellite tagging was conducted off Busselton in Geographe Bay, an area currently proposed as a 'reproductive area location', and off two previously known aggregation areas, Flinders Bay off Augusta and Cheyne Beach east of Albany, Western Australia (Fig. 1) (DCCEEW 2022). Transdermal satellite tags were deployed, including Wildlife Computer SPOT-372 and Splash10-373 Argos satellite tags (Table 1). The SPOT tag provides data on location and water temperature, whereas the Splash tag also provided data on depth. These tag designs are fully integrated (*i.e.,* there is not interface between the electronics package and the anchoring system), to improve tag performance and safety for individual whales (Zerbini et al. 2017) and have been used on large baleen whale species since 2017 (Bamford et al. 2022, Bedriñana-Romano et al. 2022). Tag dimensions are 293 x 24 mm in length and diameter, respectively, and 390 g in weight. Assuming the weight of an adult lactating SRW is around 40 tonnes (Christiansen et al. 2019), the tag corresponds to less than 0.001% of the whale's body weight. The tags were made from surgical-quality stainless steel, and Tristel Trio wipes system was used to provide a high-level of disinfection, following previous studies (incl. Goetz et al. 2018). The tags were deployed with an Air Rocket Transmitter System (ARTS), a modified pneumatic line-thrower (Heide-Jørgensen et al. 2001, Gales et al. 2009). Tags were only deployed by highly skilled and trained personnel (N. Gales) at 14 bar of pressure. Deployments followed previous studies on right whales (Zerbini et al. 2015) and best-practice guidelines (Andrews et al. 2019). Tags were only deployed in good weather conditions, and on whales that were in good body condition. As migration routes and feeding locations may differ by sex and/or age, tags were deployed on different sexes and ages (excluding calves and small juveniles). On SRWs, the transmission duration of these tags has been five months on average (Zerbini et al., unpublished data), with some cases of transmissions for more than one year (Riekkola et al. 2021).

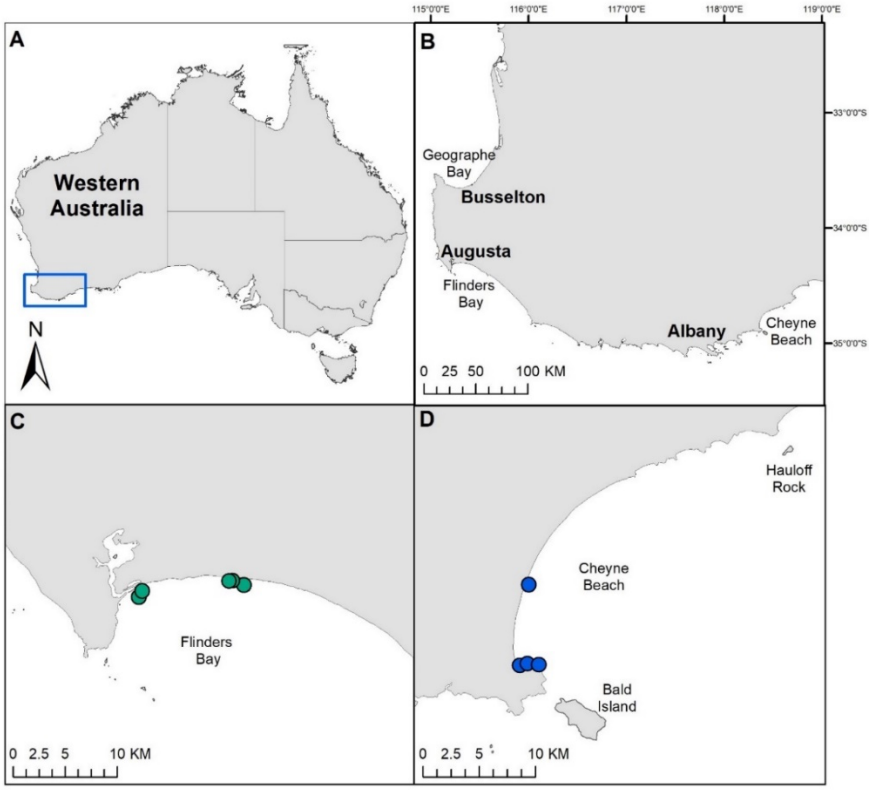

Figure 1. Study locations for tag deployments off A) Western Australia, B) Busselton, C) Augusta and D) Cheyne Beach. Green/blue circles represent tagging and biopsy sampling locations.

RESULTS AND DISCUSSION

Some tag durations extended over 176 days (as two tags were still transmitting at the time of writing this report) (Table 1). Some tags remained transmitting long enough to provide new information on the migration routes of Western Australian whales. Tracks of the tagged whales are illustrated in Fig. 2. These tracks suggest that potential feeding destinations include the Subtropical Front, the Kerguelen and Crozet Islands and the Southern Ocean (likely in association with the ice edge). These results highlight that the western sub-population of Australian SRWs are utilising mid-latitude and high-latitude habitats, and crossing the Indian Ocean basin. State space modelling to identify regions where the SRW display area restricted search behaviour is planned, and potential foraging regions discussed below were identified by recursive tracks from raw data, which may be subject to position and other errors, and so should be considered preliminary and subject to change.

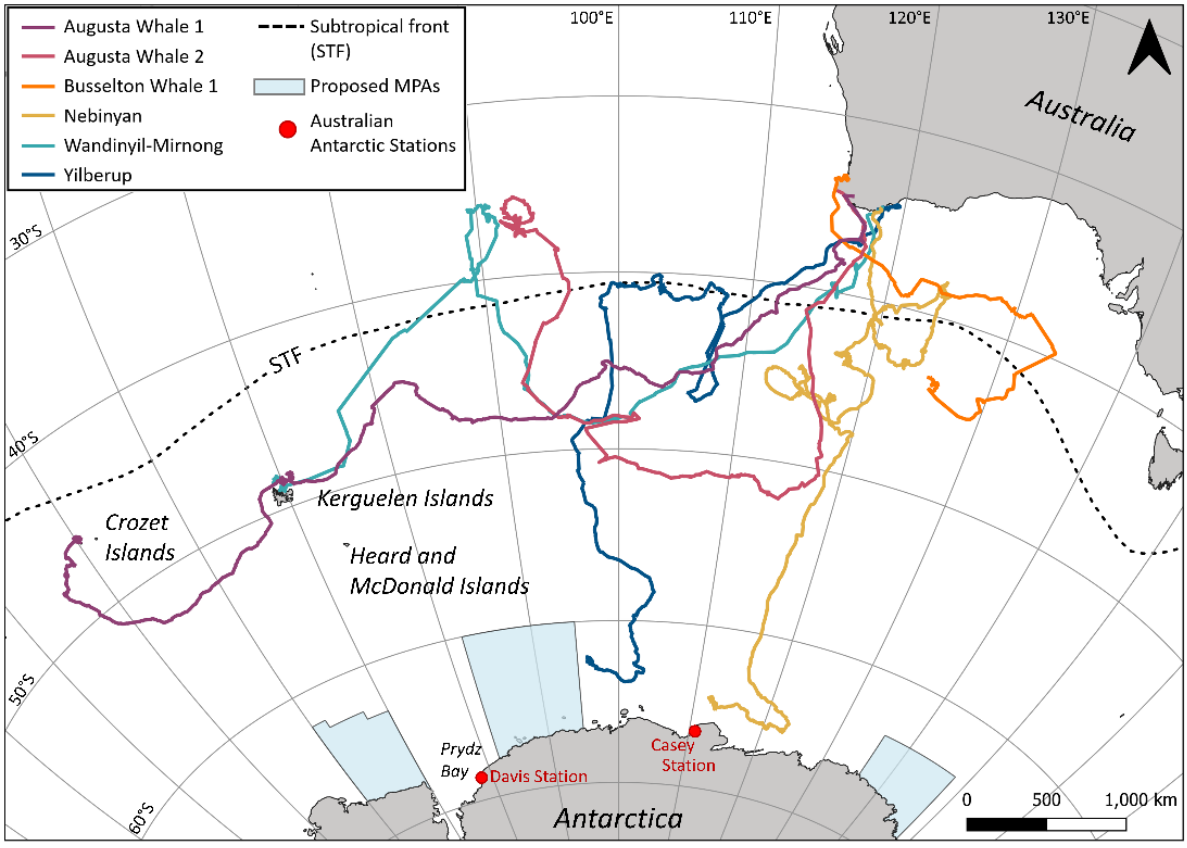

Figure 2. Tracks of SRW tagged on breeding grounds in WA into the presumed Southern Ocean feeding grounds. Each different coloured track line represents an individual satellite tagged whale (names of the whales are provided in the legend). The map shows the arrival of the tagged whales to the Kerguelen Islands, Crozet Islands and Antarctica. The Subtropical Front (STF) is represented by a dotted line. The proposed Antarctic marine protected areas are shaded in light blue.

Coastal movements in southwest Australia

Lactating mothers travelled back and forth around their respective aggregation areas in shallow waters (*e.g.,* Busselton Whale 1, Augusta Whale 3, Yilberup; Fig. 3). This is the typical habitat

usage of lactating mother and calves whilst on the breeding ground. Once the calf reaches a larger size (up to ~9 m in length (Christiansen et al. 2018)), mother-calves may then be able to undertake larger scale movements, such as, Yilberup who swum from Cheyne Beach to Bremer Bay and back (~160 km). These movements showed that SRWs move along the coast of Australia even though there are preferred aggregation areas (such as Augusta and Cheyne Beach). The coastal movements of these SRWs provide relevant information for the proposed South Coast marine protected areas (Sutton and Day 2021). One proposed marine park section is recommended to include the Cheyne Beach (Sutton and Day 2021). From this fieldwork, we confirm the importance of Cheyne Beach SRW aggregation across all age classes (not just mother-calf pairs). Augusta Whale 4, a mother with calf, also used coastal waters until September 13, and then travelled offshore at increased speed (3-6 ms-1) south west towards the continental shelf, with what appeared to be a fairly directed path of travel and regular transmissions (Fig. 1). After crossing a shipping lane, the track of the whale changed direction to the north east on 15 September with a gap in transmissions. It was later found dead on a beach: expert advice and opinion has been sought on this whale, with a full report has been prepared on this event and is expected to be presented at the IWC SC in 2024.

A SRW tagged off Maungahuka Auckland Islands in July 2021, named Whitu, arrived to shallow, coastal waters of WA in September 2022. Whitu traversed west along the coast from Esperance to Bremer Bay through the Recherche Archipelago and the Fitzgerald Biosphere Reserve proposed marine parks (Carroll et al. 2022).

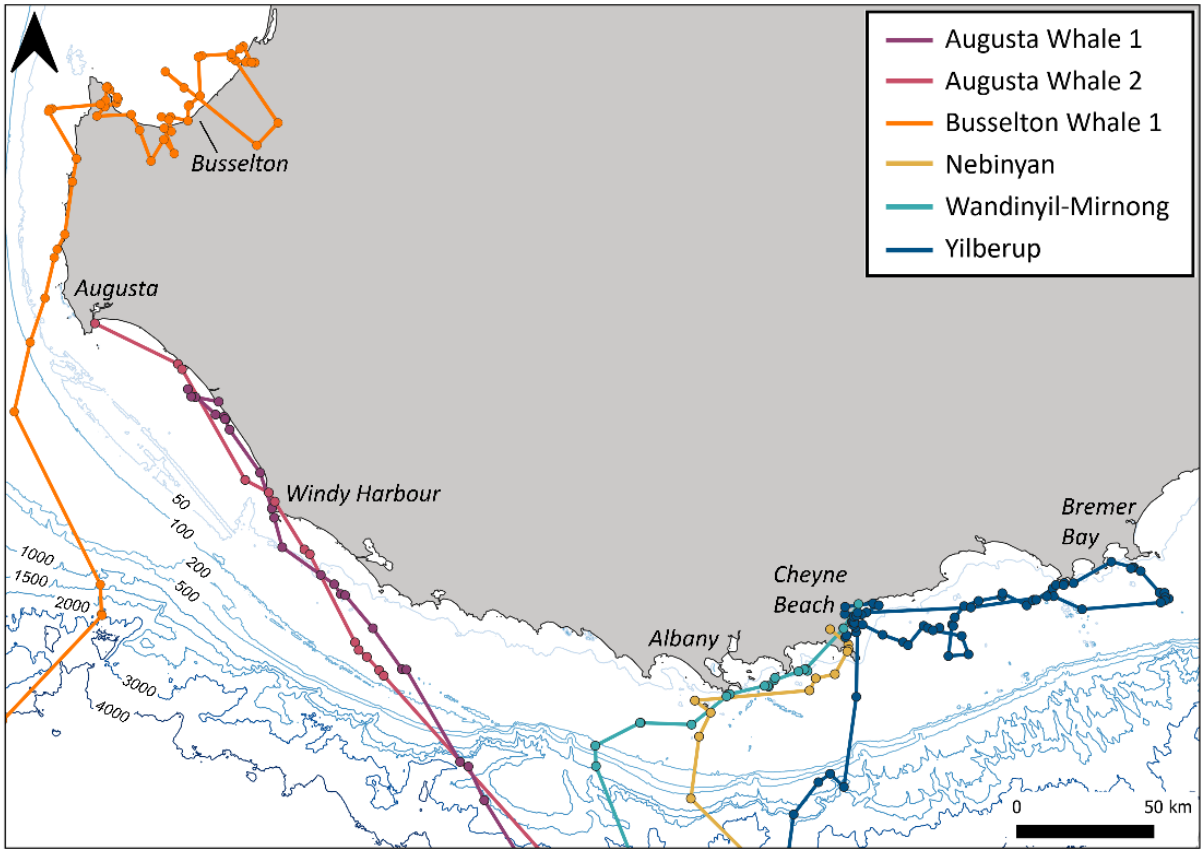

Figure 3. Map of the WA where the SRW were satellite tagged off Busselton, Augusta and Cheyne Beach. The blue coloured lines are the depth contours and the continental slope. Note: due to the location error associated with the Argos System (which can range from tens of metres to hundreds of kilometres) some position fixes of the tracked whales occur on land.

Table 1. Details of whales tagged off southwestern Australia, displaying the date and latitude/longitude of the tag deployment location, the satellite tag type, the tag deployment distance (Dist. m from boat to whale), the percentage the tag implanted, if the sex remains as unknown (U) or to be determined (TBD) using genetics from a biopsy sample collected from the same whale, and if the tag is still transmitting or the last date data was received.

Name/PTT	Location	Lat/Lon	Date deployed	Tag type	Dist.	Implant	Age class	Sex	With calf	Biopsy sample	Transmit end date	Total days transmit
Busselton Whale 1/ 235621	Busselton	33°36'22"S 115°24'37"E	8/09/2022	Spot	7	100%	Adult	F	Yes	Yes	06/12/2022	89
Augusta Whale 1/ 235410	Augusta	34°19'26"S 115°11'31"E	9/09/2022	Spot	7	100%	Adult	TBD	No	Yes	still transmitting	200
Augusta Whale 2/ 235413	Augusta	34°18'41"S 115°17'26"E	11/09/2022	Splash	5	100%	Adult	U	No	No	19/12/2022	99
Augusta Whale 3/ 235622	Augusta	34°18'55"S 115°18'08"E	10/09/2022	Spot	5	100%	Adult	F	Yes	No	29/09/2022	19
Augusta Whale 4/ 235411	Augusta	34°18'38"S 115°15'11"E	9/09/2022	Spot	4	100%	Adult	F	Yes	Yes	20/09/2022	11
Yilberup/ 235407	Cheyne Beach	34°52'41"S 118°24'07"E	16/09/2022	Spot	7	95%	Adult	F	Yes	Yes	11/03/2023	176
Wandinyil-Mirnong/ 235414	Cheyne Beach	34°52'36.4"S 118°24'35"E	19/09/2022	Splash	7	85%	Adult/sub-adult	U	No	No	07/02/2023	141
Nebinyan/ 235405	Cheyne Beach	34°52'38"S 118°25'14"E	19/09/2022	Spot	3	65%	Adult/sub-adult	U	No	No	still transmitting	190

The Subtropical Front and Southeast Indian Ridge

Three SRWs swam by the Southeast Indian Ridge where the Australian plate is divergent from the Antarctic plate, near a transform fault around 48°07'S, 99°23'E (Augusta Whale 2 and Wandinyil-Mirnong; 22 October 2022; Fig. 2). Yilberup reached the Southeast Indian Ridge a day after Wandinyil-Mirnong and Augusta Whale 2 (in a similar area near the transform fault, 48°06'S, 98°49'E). This region has seamounts which are greater than 3 km in diameter (Sempéré and Cochran 1997). Wandinyil-Mirnong and Augusta Whale 2 then appeared to travel in close proximity northwards for around 11 days despite being tagged in different breeding aggregations >400 km apart. Augusta Whale 2 and Wandinyil-Mirnong putatively foraged (around 37°22'S, 92°49'E and 36°24'S, 90°52'E, respectively) around the Subtropical Front from ~18 November (Fig. 2). SRWs from other circumpolar areas also engage in foraging-like behaviour (*e.g.,* area-restricted-search) in the Subtropical Front and within cyclonic, cold eddies characterised by upwelling and high productivity (Zerbini et al. 2016, Mackay et al. 2020). Further analyses into the Splash tags on Wandinyil-Mirnong and Augusta Whale 2, with water temperature and depth information, is required to comprehend the importance of the Subtropical Front and its eddies and meanders, and also the Southeast Indian Ridge oceanic features.

Kerguelen Islands

Two tagged SRWs reached the Kerguelen Islands (Augusta whale 1 and Wandinyil-Mirnong). Augusta whale 1 reached the islands on the 12 November 2022 (Fig. 4), 62 days after migrating from Windy Harbour, WA. Recursive tracks by Augusta whale 1 could indicate foraging (48°31'S, 70°42'E, and 48°12'S, 70°53'E) to the northeast of the main island Grande Terre off Cap Noir, around the 500 m continental slope, over a two-month period (November and December). This area off the continental slope coincides with where the Antarctic Polar Front flows (Pauthenet et al. 2018). Ocean-wide, apex predators are known to rely on these frontal zones for foraging (Bost et al. 2009), and shelf breaks are also areas of importance for foraging SRWs off Argentina (*e.g.,* the Patagonia Shelf and the South Georgia shelf break (Zerbini et al. 2016)). Augusta whale 1 visited shallower waters on the continental shelf north of the Kerguelen Islands (48°28'S, 70°03'E) from 20 December 2022 for 25 days. Wandinyil-Mirnong reached the Kerguelen Islands on 20 January 2023, just after Augusta Whale 1 had departed the area. Wandinyil-Mirnong showed potential foraging behaviour in a specific location (48°14'S, 69°24'E) on the continental shelf to the north of the island, a short distance away to where Augusta Whale 1 is suspected to have been feeding the month prior (Fig. 4). SRWs have been occasionally sighted around the Kerguelen Islands (Gasco et al. 2019), and in Golfe du Morbihan on the eastern side of the main island Grande Terre (Borsa 1997), however, “they are mostly seen in the Golfe des Baleiniers (north west of the Courbet peninsula)” (Christophe Guinet pers. comm.). The latter is where Wandinyil-Mirnong passed by in January (Fig. 4).

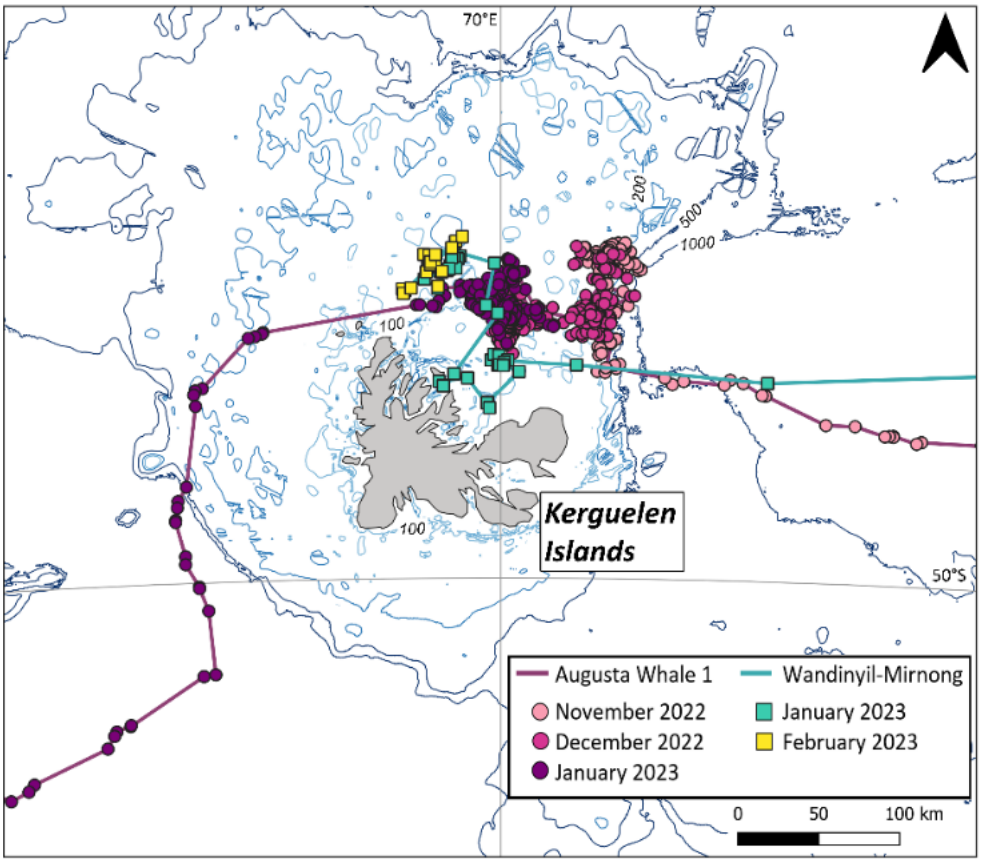

Figure 4. A map of the Kerguelen Islands (French sub-Antarctic Islands) showing the satellite tracks for Augusta Whale 1 and Wandinyil-Mirnong, both of whom were potentially feeding to the north of the island.

Crozet Islands

Augusta whale 1 travelled from Kerguelen Islands to the Crozet Islands around 2 March 2023 (174 days since leaving WA). Augusta whale 1 showed putative foraging in a specific location for several weeks to the north of Ile aux Cochons ('Pig Island', -45°48'S, 50°04'E) near the 500 m depth contour (Fig. 5). Here, the Subantarctic Front flows north between the Del Cano Rise and the Crozet Plateau (where Ile aux Cochons lies), from where the front then flows eastwards (Sanial et al. 2014). The Crozet Islands is also a likely foraging ground for SRWs that breed off Madagascar, another (sub-) population that may be slowly recovering (Rosenbaum 2020). The putative foraging ground around Crozet Islands was also utilised by three SRWs tagged in South Africa in 2022 (Indigo, Disa, Senecio) and one SRW tagged in 2021 (PTT 222172) (Fig 5). This indicates that Crozet Islands is visited by SRWs from at least two breeding grounds in different ocean basins. "At least 100 right whales were seen [few weeks ago] in Crozet"[6,7]. Predation on adult SRWs by killer whales (*Orcinus orca*) have been observed in inshore and offshore waters of the Crozet Islands, including at Baie du Marin[7] (Guinet and Jouventin 1990, Guinet 1992, Tixier et al. 2019b). One predation attempt from killer whales (group CR013/CR111) was on a group of SRWs, to the north-west of Ile aux Cochons on 8 February 2012[8], as observed by fishery observers as part of a photo-ID monitoring program on killer

[6] Nicolas Gasco pers. comm., 20 March 2023, Muséum National D'Histoire Naturelle, Paris, France.
[7] Christophe Guinet, CNRS French National Centre for Scientific Research, France.
[8] Paul Tixier, Institute for Research Development, France.

whales and sperm whales (Tixier et al. 2021). Stable isotope analyses confirm that SRWs are a prey species for Crozet killer whales (Tixier et al. 2019a).

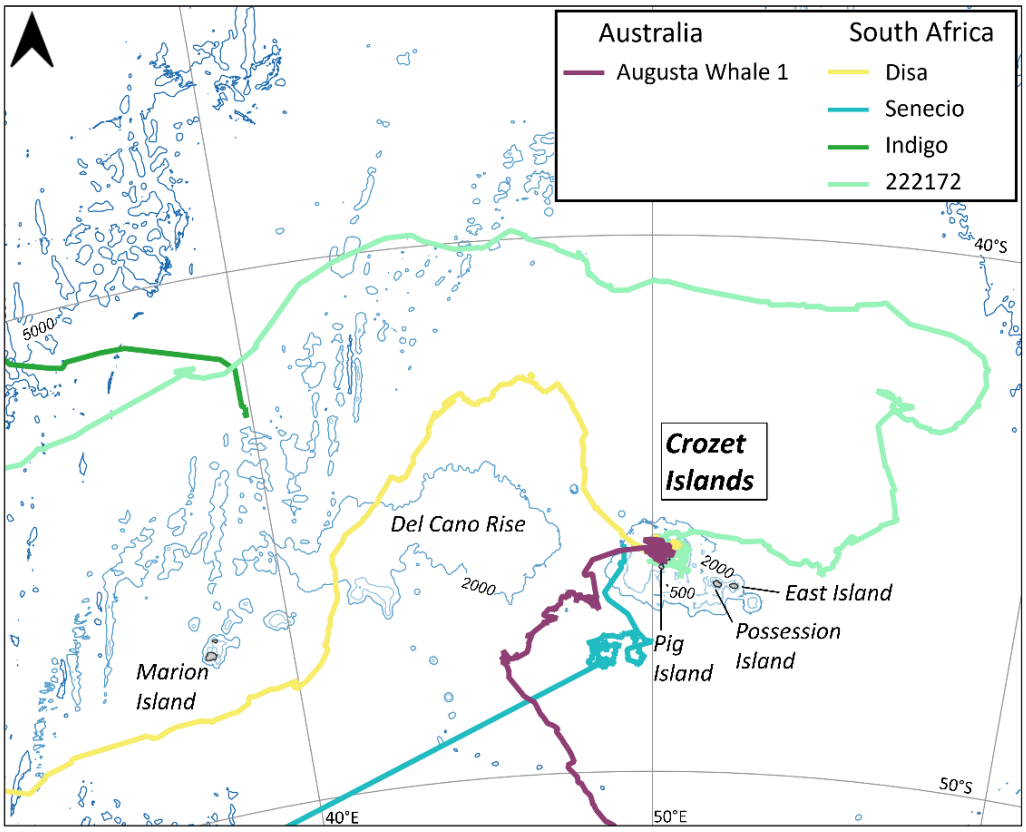

Figure 5. A map of Crozet Islands (French sub-Antarctic Islands) showing Augusta Whale 1 (tagged 2022) feeding to the north off Ile aux Cochons (Pig Island) in 2023. South African tagged whales also feeding in the Crozet Islands in 2023 (tagged in 2022; Indigo, Disa, Senecio). PTT 222172 was also added to the map, who was tagged in 2021 off South Africa.

Antarctica

Previous works have indicated that SRWs reach Antarctic waters from early February onwards, for example, JARPA voyages (Nishiwaki 1996, Bannister et al. 1999, Matsuoka et al. 2015) and Australian Antarctic Division aerial surveys (Gales et al. 2019). Furthermore, the SRW previously satellite tagged off Tasmania reached its most southerly point, foraging along the ice edge (65°S, 140°E) at the beginning of February (Mackay et al. 2020). In alignment, Yilberup reached her most southern point in February (63°40'S west of Casey station; 151 days after leaving Cheyne Beach, mainland Australia), and Nebinyan reached Antarctica in March with a southerly latitude of 65°30'S (east of Casey station; 153 days after leaving Bald Head, mainland Australia). The location between Yilberup (63°40'S, 100°43'E) and Nebinyan (65°30'S, 120°29'E), is fittingly, where other SRWs have been sighted: Match WA75 (64°26'S, 114°54'E) and another SRW sighted on JARPA (Bannister et al. 1999), and three SRWs (64°29'S, 105°14'E and 64°40'S, 108°42'E) sighted on an Australian Antarctic Division aerial survey (Gales et al. 2019). During the migration of the Australian SRWs, it is likely that whales' cross paths with SRWs from the Auckland Islands population. This is likely the case, as one tagged SRW named Wiremu/Bill, migrated from the Auckland Islands (August 2020) to the south of WA by October, south to the southern Kerguelen Plateau by February 2021, then to Australian Antarctic waters by March, travelling eastwards through one of the proposed

marine protected areas and past Casey Station at the most southerly point (Morris 2021, Riekkola et al. 2021) (Fig. 6). From SRW sightings and tracking data, this area from ~80-145°E could be examined for the distribution, foraging hotspots, and numbers of SRWs. Furthermore, sections of east Antarctica are predicted to experience ice loss (Stokes et al. 2022), and the Antarctic Circumpolar Current is projected to shift poleward (Chapman et al. 2020). Consequently, SRW prey such as Antarctic krill and other zooplankton species will likely be affected (Nicol et al. 2000, Nicol 2006), with unknown consequences on the SRWs that feed in these waters (Nicol et al. 2008).

Shared foraging grounds among populations (South Africa, Australia and New Zealand)
In 2023, Augusta Whale 1 and three tagged SRWs from the breeding grounds in South Africa were concurrently utilising waters around the Crozet Islands (outlined above under 'Crozet Islands' subheading; Fig. 6). The Crozet Islands have been long described as a foraging ground for South African SRWs (Best and Folkens 2007, van den Berg et al. 2021) but this is the first direct evidence that Australian SRWs also migrated to the Crozet Islands. Furthermore, Busselton Whale 1 and Nebinyan travelled easterly from their initial tag locations to an area utilised by SRWs tagged at the Auckland Islands (Riekkola et al 2021), south of Western Australia (Fig. 6).

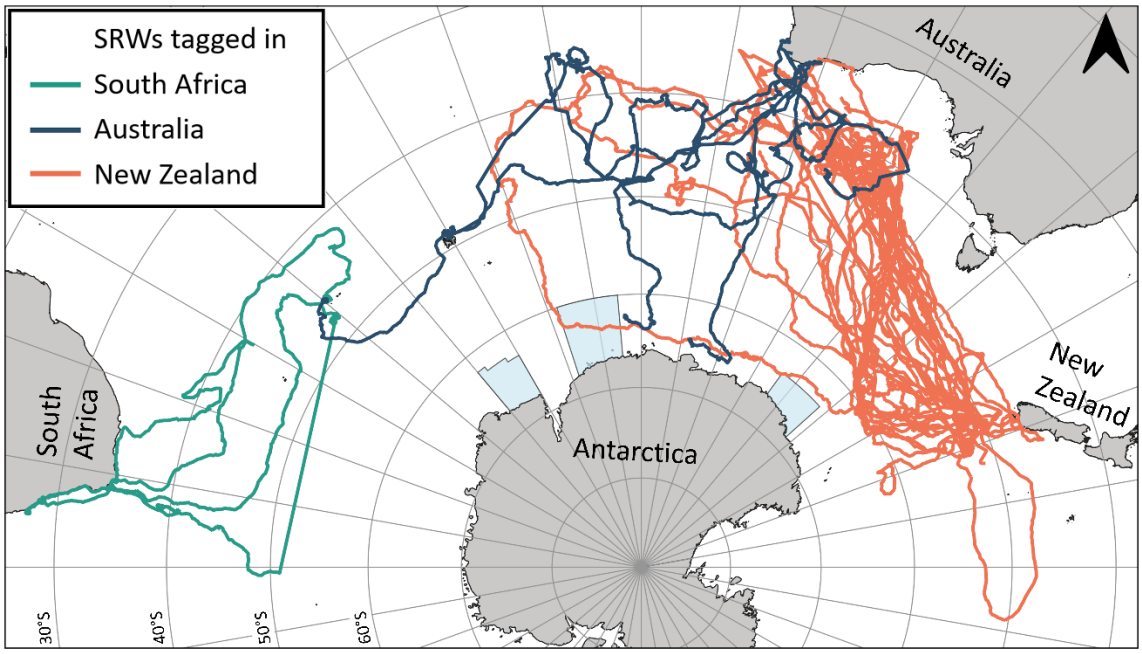

Figure 6. A map showing the mixing of southern right whale populations during the feeding season. South African tracks are from whales tagged in 2021-22, Australian tracks from whales tagged in 2022, and New Zealand tracks are from whales tagged in 2020-22.

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REFERENCES

Agrelo, M., F. G. Daura-Jorge, V. J. Rowntree, M. Sironi, P. S. Hammond, S. N. Ingram, C. F. Marón, F. O. Vilches, J. Seger, and R. Payne. 2021. Ocean warming threatens southern right whale population recovery. Science Advances **7**:eabh2823.

Andrews, R. D., R. W. Baird, J. Calambokidis, C. E. Goertz, F. M. Gulland, M. Heide-Jorgensen, S. K. Hooker, M. Johnson, B. Mate, Y. Mitani, K. Owen, L. T. Quakenbush, S. Raverty, J. Robbins, G. S. Schorr, O. V. Shpak, F. I. Townsend Jr., M. Uhart, R. S. Wells, and A. N. Zerbini. 2019. Best practice guidelines for cetacean tagging. Journal of Cetacean Research & Management **20**:27-66.

Baker, C., N. Patenaude, J. Bannister, J. Robins, and H. Kato. 1999. Distribution and diversity of mtDNA lineages among southern right whales (*Eubalaena australis*) from Australia and New Zealand. Marine Biology **134**:1-7.

Bamford, C., J. Jackson, A. Kennedy, P. Trathan, I. Staniland, A. Andriolo, L. Bedriñana-Romano, E. Carroll, S. Martin, and A. Zerbini. 2022. Humpback whale (*Megaptera novaeangliae*) distribution and movements in the vicinity of South Georgia and the South Sandwich Islands Marine Protected Area. Deep Sea Research Part II: Topical Studies in Oceanography **198**:105074.

Bannister, J. 1986a. Notes on nineteenth century catches of southern right whales (*Eubalaena australis*) off the southern coasts of Western Australia. Report of the International Whaling Commission (Special Issue) **10**:255-259.

Bannister, J. 1986b. Southern right whales: status off Australia from twentieth-century 'incidental' sightings and aerial survey. Report of the International Whaling Commission (Special issue- Right whales: past and present status) **10**:153-160.

Bannister, J. 2001. Status of southern right whales (*Eubalaena australia*) off Australia. Journal of Cetacean Research and Management:103-110.

Bannister, J., S. Burnell, C. Burton, and H. Kato. 1997. Right whales off southern Australia: direct evidence for a link between onshore breeding grounds and offshore probable feeding grounds. Report of the International Whaling Commission **47**:441-444.

Bannister, J., L. Pastene, and S. Burnell. 1999. First record of a southern right whale (*Eubalaena australis*) between warm water breeding grounds and the Antarctic Ocean south of 60°S. Marine Mammal Science **15**:1337-1342.

Bedriñana-Romano, L., A. N. Zerbini, A. Andriolo, D. Danilewicz, and F. Sucunza. 2022. Individual and joint estimation of humpback whale migratory patterns and their environmental drivers in the Southwest Atlantic Ocean. Scientific Reports **12**:7487.

Best, P. B., and P. A. Folkens. 2007. Whales and dolphins of the southern African subregion. Cambridge University Press.

Best, P. B., B. Mate, and B. Lagerquist. 2015. Tag retention, wound healing, and subsequent reproductive history of southern right whales following satellite-tagging. Marine Mammal Science **31**:520-539.

Borsa, P. 1997. Seasonal trends in the occurrence of marine mammals in the Golfe du Morbihan, Kerguelen Islands. Marine Mammal Science **13**:314-316.

Bost, C. A., C. Cotté, F. Bailleul, Y. Cherel, J. B. Charrassin, C. Guinet, D. G. Ainley, and H. Weimerskirch. 2009. The importance of oceanographic fronts to marine birds and mammals of the southern oceans. Journal of Marine Systems **78**:363-376.

Carroll, E., N. Patenaude, A. Alexander, D. Steel, R. Harcourt, S. Childerhouse, S. Smith, J. Bannister, R. Constantine, and C. S. Baker. 2011. Population structure and individual movement of southern right whales around New Zealand and Australia. Marine Ecology Progress Series **432**:257-268.

Carroll, E., L. Riekkola, R. Constantine, R. Cole, E. Stuck, A. Zerbini, V. Andrews-Goff, and S. Childerhouse. 2020a. Tohorā nō Aotearoa - New Zealand Southern Right Whale Research Programme 2020 Expedition Report.

Carroll, E. L., R. Alderman, J. Bannister, M. Bérubé, P. Best, L. Boren, C. Baker, R. Constantine, K. Findlay, and R. Harcourt. 2019. Incorporating non-equilibrium dynamics into demographic history inferences of a migratory marine species. Heredity **122**:53-68.

Carroll, E. L., C. S. Baker, M. Watson, R. Alderman, J. Bannister, O. E. Gaggiotti, D. Gröcke, N. Patenaude, and R. Harcourt. 2015. Cultural traditions across a migratory network shape the genetic structure of southern right whales around Australia and New Zealand. Scientific Reports **5**:1-15.

Carroll, E. L., R. Harcourt, K. R. Sprogis, H. Raudino, K. Waples, and S. Bell. 2022. Migration mysteries: Solving the puzzle of southern right whales' migration. Pages 28-33 Landscope. Department of Biodiversity, Conservation and Attractions and WA Naturally, Perth, Western Australia.

Carroll, E. L., P. H. Ott, L. F. McMillan, B. Galletti Vernazzani, P. Neveceralova, E. Vermeulen, O. E. Gaggiotti, A. Andriolo, C. S. Baker, and C. Bamford. 2020b. Genetic Diversity and Connectivity of Southern Right Whales (*Eubalaena australis*) Found in the Brazil and Chile–Peru Wintering Grounds and the South Georgia (Islas Georgias del Sur) Feeding Ground. Journal of Heredity **111**:263-276.

Chapman, C. C., M.-A. Lea, A. Meyer, J.-B. Sallée, and M. Hindell. 2020. Defining Southern Ocean fronts and their influence on biological and physical processes in a changing climate. Nature Climate Change **10**:209-219.

Chittleborough, R. 1956. Southern right whale in Australian waters. Journal of Mammalogy **37**:456-457.

Christiansen, F., M. Sironi, M. J. Moore, M. Di Martino, M. Ricciardi, H. A. Warick, D. J. Irschick, R. Gutierrez, and M. M. Uhart. 2019. Estimating body mass of free-living whales using aerial photogrammetry and 3D volumetrics. Methods in Ecology and Evolution **10**:2034–2044.

Christiansen, F., F. Vivier, C. Charlton, R. Ward, A. Amerson, S. Burnell, and L. Bejder. 2018. Maternal body size and condition determine calf growth rates in southern right whales. Marine Ecology Progress Series **592**:267-281.

Constable, A. J., J. Melbourne-Thomas, S. P. Corney, K. R. Arrigo, C. Barbraud, D. K. Barnes, N. L. Bindoff, P. W. Boyd, A. Brandt, and D. P. Costa. 2014. Climate change and Southern Ocean ecosystems I: how changes in physical habitats directly affect marine biota. Global Change Biology **20**:3004-3025.

Davies, C. H., L. E. Beckley, and A. J. Richardson. 2022. Copepods and mixotrophic Rhizaria dominate zooplankton abundances in the oligotrophic Indian Ocean. Deep Sea Research Part II: Topical Studies in Oceanography **202**:105136.

DCCEEW. 2022. Draft National Recovery Plan for the Southern Right Whale. Department of Climate Change, Energy, the Environment and Water, Canberra.

Dedden, A. V., and T. L. Rogers. 2022. Stable isotope oscillations in whale baleen are linked to climate cycles, which may reflect changes in feeding for humpback and southern right whales in the Southern Hemisphere. Frontiers in Marine Science **9**.

Derville, S., L. G. Torres, S. D. Newsome, C. J. Somes, L. O. Valenzuela, H. B. Vander Zanden, C. S. Baker, M. Bérubé, G. Busquets-Vass, and K. Carlyon. 2023. Long-term stability in the circumpolar foraging range of a Southern Ocean predator between the eras of whaling and rapid climate change. Proceedings of the National Academy of Sciences **120**:e2214035120.

Duhamel, G., and R. Williams. 2011. History of whaling, sealing, fishery and aquaculture trials in the area of the Kerguelen Plateau. The Kerguelen Plateau: marine ecosystem and fisheries. Société française d'ichtyologie, Paris:15-28.

Gales, N., M. C. Double, S. Robinson, C. Jenner, M. Jenner, E. King, J. Gedamke, D. Paton, and B. Raymond. 2009. Satellite tracking of southbound East Australian humpback whales (*Megaptera novaeangliae*): challenging the feast or famine model for migrating whales. Int Whal Comm: SC61/SH17.

Gales, N., N. Kelly, D. Peel, M. Bravington, and C. Johnson. 2019. Cetacean (whales) aerial survey data from the Antarctic collected between 2008 and 2010, Ver. 1, *.in* A. A. D. Centre, editor., Tasmania, Australia.

Gasco, N., P. Tixier, K. Delord, C. Guinet, and G. Duhamel. 2019. Scientific observation program around Kerguelen Island, a ship-of-opportunity for bird and mammal data collection.

Goetz, K., S. Childerhouse, D. Paton, M. Ogle, K. Hupman, R. Constantine, M. Double, V. Andrews-Goff, A. Zerbini, and P. Olson. 2018. Satellite tracking of blue whales in New Zealand waters, 2018 voyage report. Bled, Slovenia.

Guinet, C. 1992. Comportement de chasse des orques (*Orcinus orca*) autour des iles Crozet. Canadian Journal of Zoology **70**:1656-1667.

Guinet, C., and P. Jouventin. 1990. La vie sociale des "baleines tueuses". La Recherche **21**:508-510.

Heide-Jørgensen, M. P., L. Kleivane, N. ØIen, K. L. Laidre, and M. V. Jensen. 2001. A new technique for deploying satellite transmitters on baleen whales: Tracking a blue whale (*Balaenoptera musculus*) in the North Atlantic. Marine Mammal Science **17**:949-954.

Hindell, M. A., M.-A. Lea, C.-A. Bost, J.-B. Charrassin, N. Gales, S. Goldsworthy, B. Page, G. Robertson, B. Wienecke, and M. O'Toole. 2011. Foraging habitats of top predators, and areas of ecological significance, on the Kerguelen Plateau. The Kerguelen Plateau: marine ecosystem and fisheries:203-215.

IPCC. 2021. Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge, United Kingdom and New York, NY, USA.

James, C., M. Tomczak, I. Helmond, and L. Pender. 2002. Summer and winter surveys of the Subtropical Front of the southeastern Indian Ocean 1997–1998. Journal of Marine Systems **37**:129-149.

Keage, P. L. 1981. The conservation status of Heard Island and the McDonald Islands. University of Tasmania.

Lea, M.-A., C. Guinet, Y. Cherel, M. Hindell, L. Dubroca, and S. Thalmann. 2008. Colony-based foraging segregation by Antarctic fur seals at the Kerguelen Archipelago. Marine Ecology Progress Series **358**:273-287.

Leaper, R., J. Cooke, P. Trathan, K. Reid, V. Rowntree, and R. Payne. 2006. Global climate drives southern right whale (*Eubalaena australis*) population dynamics. Biology Letters **2**:289-292.

Li, Q., M. H. England, A. M. Hogg, S. R. Rintoul, and A. K. Morrison. 2023. Abyssal ocean overturning slowdown and warming driven by Antarctic meltwater. Nature **615**:841-847.

Mackay, A. I., F. Bailleul, E. L. Carroll, V. Andrews-Goff, C. S. Baker, J. Bannister, L. Boren, K. Carlyon, D. M. Donnelly, M. Double, S. D. Goldsworthy, R. Harcourt, D. Holman, A. Lowther, G. J. Parra, and S. J. Childerhouse. 2020. Satellite derived offshore migratory movements of southern right whales (*Eubalaena australis*) from Australian and New Zealand wintering grounds. PLoS ONE **15**:e0231577.

Mate, B., P. B. Best, B. Lagerquist, and M. Winsor. 2011. Coastal, offshore, and migratory movements of South African right whales revealed by satellite telemetry. Marine Mammal Science **27**:455-476.

Matsuoka, K., M. Tsunekawa, F. Yamaguchi, H. Honma, C. Ohkoshi, and N. Abe. 2015. Cruise report of the 2014/15 Japanese dedicated whale sighting survey in the Antarctic in Area IV. Paper SC/66a/IA07 presented to the IWC Scientific Committee.

McGowan, A. 2000. On their own: towards an analysis of sealers' sites on Heard Island. Pages 61-70 *in* Papers and proceedings of the Royal Society of Tasmania.

Morris, B. 2021. Bill and tag's excellent adventure: A year in the life of one southern right whale. The Guardian, Dunedin, New Zealand.

Nicol, S. 2006. Krill, currents, and sea ice: Euphausia superba and its changing environment. Bioscience **56**:111-120.

Nicol, S., J. Kitchener, R. King, G. Hosie, and K. William. 2000. Population structure and condition of Antarctic krill (*Euphausia superba*) off East Antarctica (80–150 E) during the Austral summer of 1995/1996. Deep Sea Research Part II: Topical Studies in Oceanography **47**:2489-2517.

Nicol, S., A. Worby, and R. Leaper. 2008. Changes in the Antarctic sea ice ecosystem: potential effects on krill and baleen whales. Marine and Freshwater Research **59**:361-382.

Nishiwaki, S., R. 1996. Report of the Japanese whale research program under special permit in the Antarctic (JARPA) in Area IV and eastern part of Area III.

O'Toole, M., C. Guinet, M.-A. Lea, and M. A. Hindell. 2017. Marine predators and phytoplankton: how elephant seals use the recurrent Kerguelen plume. Marine Ecology Progress Series **581**:215-227.

Ohsumi, S., and F. Kasamatsu. 1986. Recent off-shore distribution of the southern right whale in summer. Reports of the International Whaling Commission (Special issue- Right whales: past and present status) **10**:177-185.

Olivar, M. P., and L. E. Beckley. 2022. Latitudinal variation in diversity and abundance of mesopelagic fishes associated with change in oceanographic variables along 110°E, south-east Indian Ocean. Deep Sea Research Part II: Topical Studies in Oceanography **198**:105053.

Pauthenet, E., F. Roquet, G. Madec, C. Guinet, M. Hindell, C. R. Mcmahon, R. Harcourt, and D. Nerini. 2018. Seasonal meandering of the Polar Front upstream of the Kerguelen Plateau. Geophysical Research Letters **45**:9774-9781.

Phillips, H. E., R. S. Patel, J. A. Benthuysen, E. R. Duran, and M. Marin. 2022. Watermass characteristics and circulation near 110°E in the southeast Indian Ocean. Deep Sea Research Part II: Topical Studies in Oceanography **202**:105149.

Richards, R. 2009. Past and present distributions of southern right whales (*Eubalaena australis*). New Zealand Journal of Zoology **36**:447-459.

Riekkola, L., S. J. Childerhouse, A. Zerbini, V. Andrews-Goff, R. Constantine, R. Cole, E. Stuck, and E. L. Carroll. 2021. An unexpected journey: tracking southern right whales from the New Zealand subantarctic wintering grounds.

Rosenbaum, H. C. 2020. A note on recent sightings of southern right whales (Eubalaena australis) along the east coast of Madagascar. Journal of Cetacean Research and Management:177-180.

Sanial, V., P. Van Beek, B. Lansard, F. d'Ovidio, E. Kestenare, M. Souhaut, M. Zhou, and S. Blain. 2014. Study of the phytoplankton plume dynamics off the Crozet Islands (Southern Ocean): A geochemical-physical coupled approach. Journal of Geophysical Research: Oceans **119**:2227-2237.

Sempéré, J.-C., and J. R. Cochran. 1997. The Southeast Indian Ridge between 88°E and 118°E: Variations in crustal accretion at constant spreading rate. Journal of Geophysical Research: Solid Earth **102**:15489-15505.

Seyboth, E., K. R. Groch, L. Dalla Rosa, K. Reid, P. A. C. Flores, and E. R. Secchi. 2016. Southern right whale (*Eubalaena australis*) reproductive success is influenced by krill *(Euphausia superba*) density and climate. Scientific Reports **6**:28205.

Smies, A., J. Wales, M. Hennenfent, L. Lyons, C. Dunn, J. Robbins, B. P. Lee, A. Zerbini, and R. M. Rajachar. 2022. Non-antibiotic antimicrobial polydopamine surface coating to prevent stable biofilm formation on satellite telemetry tags used in cetacean conservation applications. Frontiers in Marine Science **9**.

Smith, J., D. Jones, K. Travouillon, N. Kelly, M. Double, and J. L. Bannister. 2021. Monitoring population dynamics of 'western' right whales off southern Australia 2018-2021: final report on activities for 2018. Perth, Western Australia.

Sprogis, K. R., A. L. Sutton, M.-N. Jenner, R. D. McCauley, and K. C. S. Jenner. 2022. Occurrence of cetaceans and seabirds along the Indian Ocean 110°E meridian from temperate to tropical waters. Deep Sea Research (Part II, Topical Studies in Oceanography).

Stokes, C. R., N. J. Abram, M. J. Bentley, T. L. Edwards, M. H. England, A. Foppert, S. S. Jamieson, R. S. Jones, M. A. King, and J. T. Lenaerts. 2022. Response of the East Antarctic Ice Sheet to past and future climate change. Nature **608**:275-286.

Sutton, A. L., and L. E. Beckley. 2022. Krill along the 110°E meridian: Oceanographic influences on assemblages in the eastern Indian Ocean. Deep Sea Research Part II: Topical Studies in Oceanography **202**:105133.

Sutton, A. L., and P. B. Day. 2021. A review of the south coast marine environment and proposed areas for state marine reservation between Albany and Eucla, Western Australia. Carijoa Marine Consulting, Fremantle, Western Australia.

Tixier, P., N. Gasco, J. Towers, and C. Guinet. 2021. Killer whales of the Crozet Archipelago and adjacent waters: photo-identification catalogue, population status and distribution in 2020.

Tixier, P., J. Giménez, R. R. Reisinger, P. Méndez-Fernandez, J. P. Arnould, Y. Cherel, and C. Guinet. 2019a. Importance of toothfish in the diet of generalist subantarctic killer whales: implications for fisheries interactions. Marine Ecology Progress Series **613**:197-210.

Tixier, P., D. Welsford, M.-A. Lea, M. A. Hindell, C. Guinet, A. Janc, G. Richard, N. Gasco, G. Duhamel, and R. Arangio. 2019b. Fisheries interaction data suggest variations in the distribution of sperm whales on the Kerguelen Plateau. Pages 259-270 *in* The Kerguelen Plateau: marine ecosystem and fisheries. Proceedings of the Second Symposium. Australian Antarctic Division.

Tormosov, D., Y. Mikhaliev, P. Best, V. Zemsky, K. Sekiguchi, and R. Brownell Jr. 1998. Soviet catches of southern right whales Eubalaena australis, 1951–1971. Biological data and conservation implications. Biological Conservation **86**:185-197.

Townsend, C. H. 1935. The distribution of certain whales as shown by logbook records of American whaleships. Zoologica **19**:1–50 plus maps.

van den Berg, G. L., E. Vermeulen, L. O. Valenzuela, M. Bérubé, A. Ganswindt, D. R. Gröcke, G. Hall, P. Hulva, P. Neveceralova, and P. J. Palsbøll. 2021. Decadal shift in foraging strategy of a migratory southern ocean predator. Global Change Biology **27**:1052-1067.

Vermeulen, E., T. Thavar, M. Glarou, A. Ganswindt, and F. Christiansen. 2023. Decadal decline in maternal body condition of a Southern Ocean capital breeder. Scientific Reports.

Zerbini, A., J. Robbins, R. Andrews, V. Andrews-Goff, M. Baumgartner, P. Clapham, M. Double, A. Kennedy, A. Leask, G. Schorr, and W. S. 2017. Development of robust large whale satellite tags improves tag performance and reduces animal welfare problems.*in* 22nd Biennial on the Biology of Marine Mammals, Halifax, Nova Scotia.

Zerbini, A. N., M. F. Baumgartner, A. S. Kennedy, B. K. Rone, P. R. Wade, and P. J. Clapham. 2015. Space use patterns of the endangered North Pacific right whale *Eubalaena japonica* in the Bering Sea. Marine Ecology Progress Series **532**:269-281.

Zerbini, A. N., A. Fernandez Ajos, A. Andriolo, P. J. Clapham, E. Crespo, and R. Gonzalez. 2018. Satellite tracking of Southern right whales (*Eubalaena australis*) from Golfo San Matias, Rio Negro Province, Argentina. Scientific Committee of the International Whaling Commission SC67b, Bled, Slovenia **14**.

Zerbini, A. N., H. Rosenbaum, M. Mendez, F. Sucunza, A. Andriolo, G. Harris, P. J. Clapham, M. Sironi, M. Uhart, and A. F. Ajó. 2016. Tracking southern right whales through the southwest Atlantic: An update on movements, migratory routes and feeding grounds. Committee of the International Whaling Commission SC66b, Bled, Slovenia. SC/66b/BRG26.