Centre for Marine Science and Technology

Curtin University

Southern right whale research and monitoring in the Great Australian Bight, South Australia

Field Report

2017

Authors: Claire Charlton[1], Rhianne Ward[1],

Data Contributed by: Stephen Burnell[3], J. Bannister[4], F. Christiansen

Report reviewed by: R. McCauley[1]

Field researchers: Rhianne Ward[1], Alice Morrison[1], Claire Charlton[1]

[1]Centre for Marine Science and Technology, Curtin University Western Australia

[2]Eubalaena Pty. Ltd.

[3]Western Australian Museum

[4]Murdoch University Cetacean Research Unit

Disclaimer

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Contact:

Dr. Claire Charlton

Centre for Marine Science and Technology

Email: claire.charlton@live.com.au

Tel: +61 474 854 454

Rhianne Ward, PhD Candidate

Centre for Marine Science and Technology

Email: rhiward@hotmail.com

Tel: +61 400 737 545

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Executive Summary

Southern right whales (*Eubalaena australis)* (SRWs) are listed as endangered and migratory species under the Australian Commonwealth Environment Protection Biodiversity and Conservation (EPBC) Act 1991. They migrate annually from southern feeding grounds to warmer, sheltered waters in Australia to breed, calve and rest in the Austral winters between May and October. SRWs were depleted to near extinction from commercial whaling in the 18th and 19th century. Whilst SRWs are now protected and are recovering, the population is yet to be considered secure.

SRWs are long lived, slow reproducing marine mammals and to assess their health and recovery, long term population monitoring in the order of decades is required. The 2017 season represented the 27th consecutive year of the long term southern right whale monitoring at the Head of Bight and the sixth year of research at Fowlers Bay, South Australia (SA). The Head of Bight is Australia's major aggregation ground for SRWs, in the sanctuary zone of the Commonwealth Great Australian Bight (GAB) Marine Reserve.

Objectives of the 2017 GABRWS field studies are aligned with the Commonwealth Conservation Management Plan for Southern Right Whales (2012-2021) and include:

1) Assess SRW relative abundance, distribution and life histories through shore based and vessel based research at Head of Bight and Fowlers Bay, respectively. Specifically, the study will continue the long term (1991-2017) population monitoring (photo identification (ID) and census of aggregation) at Head of Bight following historical methods for comparative studies requiring long term time series dataset;
2) Opportunistically collect sightings data on marine fauna within the GAB Right Whale Study area and contribute to the long-term dataset;
3) Complete compliance patrols for the Department of Environment, Water and Natural Resources including observations for: whale mortality events, entanglements, vessel presence and marine park compliance.

A total of 20 field days were completed at Head of Bight and five boat based surveys at Fowlers Bay between July 16 and September 26, 2017. Field studies included census of the aggregation ground, photo-ID and fine scale behavioural studies. At Head of Bight, field work was completed on 33-53 m high vantage points along an approximately 15 km stretch of coastline, following historical methods proven successful with this long-term field study (Burnell 2001; Charlton 2017). At Fowlers Bay, opportunistic vessel surveys were completed on board the Fowlers Bay Whale Tour charter boat in an area of approximately 15km x 2km.

The maximum daily count of SRW in our study sites were: 163 total individuals (including 74 cow calf pairs and 14 unaccompanied adults) on August 7th at Head of Bight and; 41 individuals (including 20 cow calf pair and 1 unaccompanied adult) at Fowlers Bay on August 13th, 2017. A total of 177 different individuals were photo-ID'd between Fowlers Bay and Head of Bight throughout the season, including 92 adults and 85 females with a calf. Movement of individuals was observed in and out of the study areas throughout the season and a greater number of individuals were photo ID'd than the maximum daily count at Head of Bight. Photo-ID mark recapture allows assessment of residency of individuals in each calving ground. The 2017 peak in relative abundance was observed between mid-July and early to mid-August at Head of Bight and Fowlers Bay.

Other observations recorded during the 2018 GABRWS field season included: humpback whales, dwarf minke whale, Australian Sea Lions, long nosed fur seal, bottlenose dolphins, common dolphins, seabirds, sharks, aircraft. No whale mortalities of entanglements were recorded.

Compliance patrols of the GAB Commonwealth Marine Reserve, under commission from the Department of Water and Natural Resources. A total of 96 patrol hours were completed within the Marine Mammal Protection Zone of the Marine Reserve. Three non-compliance events were recorded, including two planes flying beneath the no-fly zone limit of 1000ft, and one drone operating out of permit and flying over whales in the marine reserve. All non-compliance events were reported to DEWNR and marine Park Management.

A robust baseline understanding of migratory whale populations is critical for conservation management, informed risk assessment and before and after impact assessment. This research improves our understanding of SRWs in Australia. Outputs contribute to national recovery assessments and global comparative studies. Results are shared with the Department of Environment, International Whaling Commission, industry and scientists.

The GAB Right Whale Study is committed to communicating science and education through publication of scientific literature, presentation at national and international conferences, community engagement and media. A Community Whale Day was held at the Head of Bight in August 2017, with school groups from local aboriginal communities, in collaboration with DEWNR, Yalata Aboriginal Community, Murdoch University and Curtin University. Details on publications, conference presentations, community engagement and media are outlined in the discussion.

Introduction

Southern right whales (SRWs) *Eubalaena australis,* were reduced to near extinction globally from commercial whaling in the 19th (Dawbin, 1986) and 20th century (Tormosov *et al.,* 1998; IWC, 2013). An estimated 55,000 to 70,000 whales were present in the Southern Hemisphere in the late 1700s. By the 1920s there may have been fewer than 300 individuals remaining throughout the Southern Hemisphere (Tormosov *et al.,* 1998). The Australian population is thought to have been reduced from approximately 15,000 individuals (Bannister, 1990). Although SRWs became protected in 1935, there were signs of population increase but it was delayed until the 1960's and 1970's due in part to illegal pelagic catches by the Soviet Union (Tormosov *et al.,* 1998). As of 2009, global abundance estimates of SRWs were approximately 13,600 individuals (IWC, 2013).

SRWs have a circumpolar distribution between latitudes of 16°S and 65°S. They migrate from southern feeding grounds in Sub-Antarctic waters to temperate northern breeding grounds to breed, calve and rest during the austral winter. Genetically distinct populations exist in South Africa, Argentina, Australia and New Zealand (Patenaude *et al*., 2007; Rosenbaum *et al*., 2000). A further, population exists off Chile and Peru (Galletti *et al.,* 2014). Whilst SRWs are listed as least concern under the International Union for Conservation of Nature (IUCN) red list, in Australia they remain listed as endangered under the Commonwealth Environment Protection Biodiversity and Conservation (EPBC) Act 1999.

SRWs are baleen whales, feeding on large amounts of krill and other copepods to sustain their large body size. SRWs grow to a maximum length of approximately 17.5 m and weigh up to 80 tonnes, with males slightly smaller than females. SRWs can be recognised by the lack of a dorsal fin, rotund body shape and whitish callosities on their head. Callosities are patches of keratinised skin colonised by cyamids - small crustaceans that persist throughout life (Payne *et al*., 1983). SRWs have two blowholes on the top of their heads and can be recognised by their v-shaped blow.

In Australian coastal waters, SRWs occur along the southern coastline of the mainland and Tasmania and generally extend as far north as Sydney (33°53'S, 151°13'E) on the east coast and Perth (31°55'S, 115°50'E) on the west coast (DSEWPaC, 2012). There are occasional sightings further north, with the extremities of their range recorded at Hervey Bay (25°00'S, 152°50'E) and Exmouth (22°23'S, 114°07'E) (DSEWPaC, 2012). For management purposes, the Australian population of SRWs is divided into two sub-populations or management units, one in the south-west and the other in the south-east of Australia (DSEWPaC, 2012). Genetic studies suggest that the south-'eastern' sub-population of SRWs represents a remnant stock, distinct from the 'western' sub-population based on significant differentiation in mitochondrial DNA haplotype frequencies and contrasting patterns of recovery (Baker *et*

al., 1999; Bannister, 2001; Carroll *et al*., 2011, Jackson *et al.,* 2016). However, some limited movement between the two areas has been recorded (Burnell, 2001; Pirzl *et al*., 2009).

The 'western' sub-population occurs predominantly between Cape Leeuwin, Western Australia (WA) and Ceduna, South Australia (SA). This sub-population comprises most of the Australian population and is estimated at around 2,200 individuals in 2016, increasing at an annual rate of approximately 5.5 % per annum (p.a.) (Bannister, 2017). The 'eastern' sub-population can be found along the south-eastern coast, including the region from Tasmania to Sydney, with key aggregation areas in Portland and Warrnambool in Victoria. The 'eastern' sub-population is estimated at less than 300 individuals and is showing no signs of increase (Bannister, 2017). A rate of around 6-7% p.a. is considered the maximum biological rate of increase for SRWs (IWC, 2013). The Australian Government's SRW Conservation Management Plan (2011-2021) has given high priority to understanding population dynamics and measuring population recovery of both Australian sub-populations (DSEWPaC, 2012).

Very little is known about the summer feeding grounds or the offshore distribution and migration pathways of SRWs. Current knowledge on the potential location of SRW feeding grounds and movement to and from coastal aggregation areas is based on historical whaling data (Townsend, 1935), *Discovery* marks (Tormosov *et al.,* 1998), photo-ID matches (Bannister *et al.,* 1997) and satellite tracks of SRWs from New Zealand (NZ) (Childerhouse *et al.,* 2010) and Tasmania to the South Pacific Ocean (DSEWPaC, 2012). It is generally thought that SRWs from Australian populations probably forage between about 40°S and 65°S, generally south of Australia (Bannister *et al.,* 1999). They mainly consume copepods between latitudes of approximately 41 - 44°S, in the region of the Sub-Tropical Front and they mainly feed on krill in higher latitudes south of 50°S. SRWs are thought to be primarily surface skim feeders, completing shallow dives and skimming across the surface, filtering plankton through their baleen plates. The migration pathways of SRWs are generally unknown. SRWs satellite tagged off New Zealand (NZ) (Childerhouse *et al.,* 2010), South Africa (Mate *et al.,* 2011) and Argentina (Zerbini *et al.,* 2015) showed that SRW distribution in the summer feeding months was associated with the Southern Tropical Convergence. A satellite tagging study conducted at Head of Bight in 2014 by Mackay *et al.,* (2015) successfully obtained location data from three female SRWs accompanied by a calf. These data showed that two whales had a southern migration pathway directly south from Head of Bight and the other travelled west from Head of Bight parallel to the coast and into the Indian Ocean. Burnell (2001) hypothesised that SRWs show a general east to west movement along the southern Australian coastline within the breeding season, based on observations of SRWs arriving and leaving calving grounds and from photo-ID matches of individuals between southeast and southwest Australia (Burnell, 2001; 2008). The movements of SRWs from Head of Bight obtained by satellite tagging suggest movement of females with calves

does occur directly south from Head of Bight as well as to the west. Mean recorded swim speeds of SRWs are between 3 - 3.3 km/hr (Mate *et al.,* 2011; Mackay *et al.,* 2015).

Known and potential threats that may have individual or population level impacts to SRWs include: entanglement in fishing gear, vessel disturbance, climate variability and change, noise interference, habitat modification and overharvesting of prey. Ship strike and elevated underwater noise from vessel traffic has had a significant impact on critically endangered North Atlantic right whales (*Eubalaena glacialis*) (Clarke *et al.,* 2009; Rice *et al.,* 2014). Currently, entanglement in fishing gear is the major cause of death in North Atlantic right whales.

In winter/spring adult females approach the coast to calve, mate and rest, where they distribute across thirteen primary aggregation areas along the southern coast of Australia (Figure 1) (Bannister, 2017; DSEWPaC, 2012). The largest established calving areas in Australia include Head of Bight in SA, and Doubtful Island Bay and Israelite Bay in WA. Smaller but established aggregation areas regularly occupied by SRWs include Yokinup Bay in WA, Fowlers Bay in SA and the Warrnambool and Portland in Victoria. Emerging aggregation areas include Flinders Bay, Hassell Beach, Cheyne/Wray Bays, and Twilight Cove in WA, and sporadically occupied areas include Encounter Bay in SA (DSEWPaC, 2012). SRWs generally occupy shallow sheltered bays within 2 km of shore and within water depths of less than 10m.

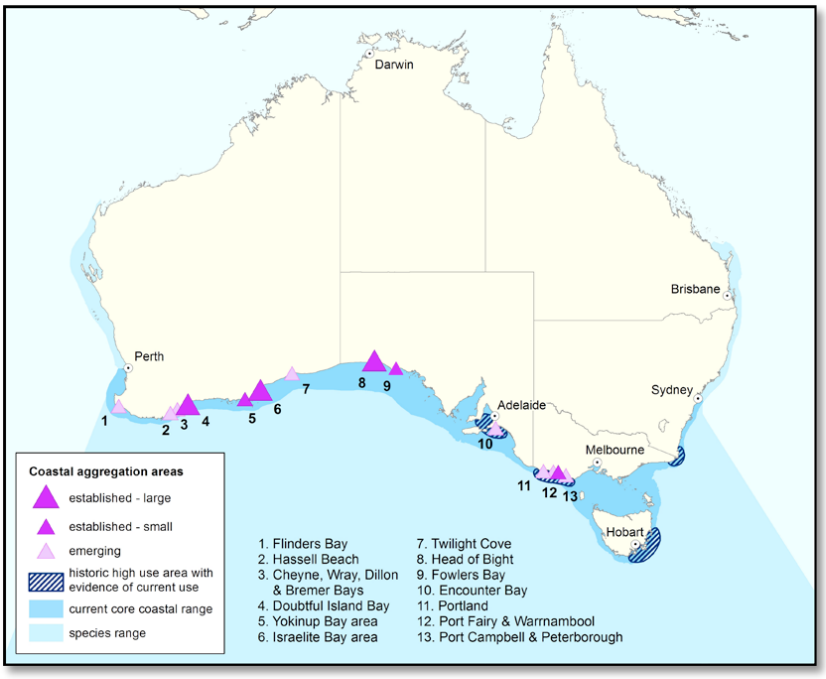

Figure 1: Southern right whale distribution range in Australia. Source: DSEWPaC, 2012

SRWs show strong philopatry to calving grounds (Burnell, 2001; Charlton, 2017). However, movement of calving and non-calving adults has been recorded across broad distances both within and across seasons (Pirzl *et al*., 2009). SRWs have a three-year calving cycle on average; causing cohort structured breeding cycles and variability in inter-annual calf production (Brandão *et al*., 2011; Burnell, 2001; Best *et al.,* 2001; Charlton, 2017; Cooke, 2001; Payne *et al.,* 1990). It is assumed that the year of calving is followed by a resting year with no migration (or migration to elsewhere), and then a mating year when animals migrate to areas alternate to their selected calving ground (Brandão *et al.,* 2011; Burnell, 2001; Cooke *et al.,* 2001). Female and calf pairs generally stay within the calving ground for 2–3 months (Burnell, 2001). Gestation is estimated to last 11-12 months and lactation for at least 7-8 months with weaning completed within 12 months (Best *et al.,* 2001; Burnell, 2001).

Two key long-term population monitoring studies have been undertaken in Australia to monitor the south-'western' sub-population of SRWs. Annual aerial surveys have been completed through the Western Australian Museum (WAM) since the mid-1970s (Bannister, 1999; 2001; 2011; 2016), and annual cliff based count and photo-ID surveys at the major aggregation ground at the Head of Bight in the GAB, SA since 1991 (Burnell and Bryden, 1997; Burnell, 2001; Burnell, 2008; Charlton and Burnell, 2011; Charlton *et al.,* 2014; Charlton 2017; Charlton *et al.,* 2018). Long-term monitoring studies have assessed abundance and rate of increase in SRWs in the south-west of Australia and provided information on long term trends in abundance over time, population biology and life histories for species assessments (Bannister, 2017; Burnell, 2001; Charlton *et al.,* 2018).

Head of Bight, SA is the most important calving aggregation ground for the 'western' sub-population of SRWs in Australia. Head of Bight is within the GAB Commonwealth Marine Reserve, which was established in 1995 to provide protection and a sanctuary to recovering SRWs (Figure 2). SRWs are protected within the GAB Marine Reserve at Head of Bight with vessel closures between May 1 and October 31 in the Marine Mammal Protection Zone (MMPZ). The Head of Bight aggregation remains one of the largest wintering aggregations in Australia. Head of Bight represented between up to 48% of the Australian population. The relative proportion of the overall 'western' sub-population that visited the Australian coastline each year that Head of Bight represented ranged from a maximum of 48% in 1994 to a minimum of 21% in 2002 (Charlton, 2017). The geographic isolation, limited shoreline access and harsh weather conditions of the Southern Ocean served as natural protection for the whales from being hunted at Head of Bight during the whaling era, though not at Fowlers Bay. The rates of population increase estimated for Head of Bight were 3.7% for all individuals and 4.6% for females accompanied by a calf for years 1992-2016 (Charlton, 2017).

The wider GAB is a multi-use area for commercial fisheries, marine parks, tourism and offshore oil and gas activities (Figure 2). Ongoing and planned offshore oil and gas activities in the GAB include seismic exploration and exploratory drilling. Oil and Gas activities have been undertaken in the GAB basin since the 1970s, with the first two wells drilled in 1972. The last of the nine wells drilled to date was drilled in 2003. No oil discoveries have been made. Seismic exploration has occurred in the 'eastern' GAB over the last three decades, with the most recent campaigns operating from 2011-2015. Existing permit lease holders in the 'eastern' GAB include: Statoil, Murphy Oil, Santos, Karoon Gas and Bight petroleum. The major player Statoil are scheduled to start a four-well exploration drilling programme in the next 12-24 months, pending environmental approval.

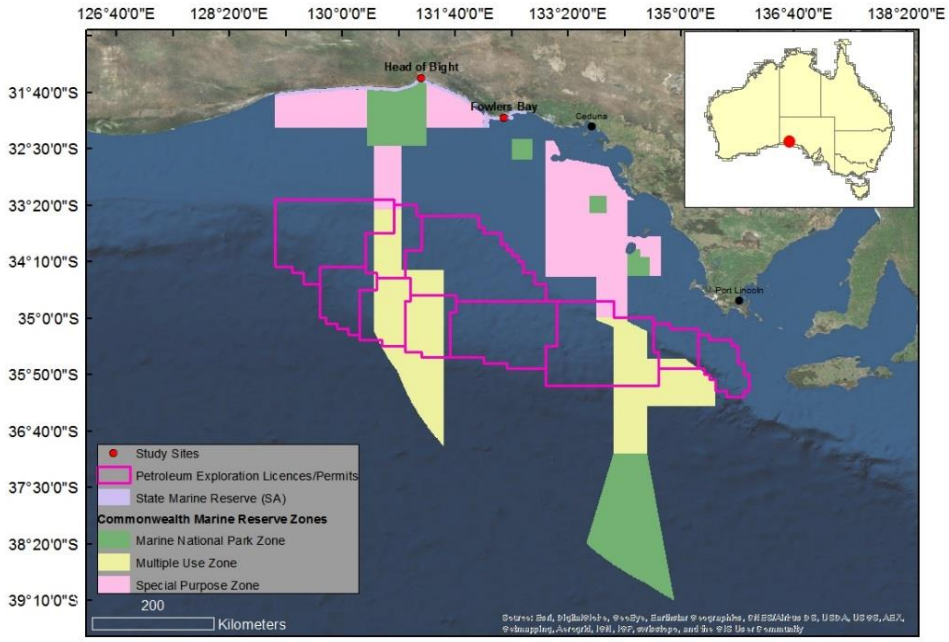

Figure 2: Regional map of the GAB, including southern right whale aggregation areas and study sites at Head of Bight and Fowlers Bay, South Australia, marine park boundaries and oil and gas permit lease areas in South Australia.

Fowlers Bay in the GAB is a small established aggregation area for SRWs in the Nuyts Archipelago State Marine Park (Figure 2) approximately 160 km southeast of Head of Bight. Increased sightings of SRWs at Fowlers Bay have occurred since the mid-2000s based on aerial survey data (Bannister, 2011) and anecdotal reports by tourism operators. Understanding of the characteristics of SRWs in established and emerging aggregation areas such as Fowlers Bay is required to facilitate recovery planning, including management of potential anthropogenic impacts and the setting of population recovery targets, with the aim to see the species delisted from endangered status in Australia.

The Australian Government's SRW Conservation Management Plan 2011-2021 has given high priority to understanding life history parameters and measuring population growth of both Australian sub-populations (DSEWPaC, 2012). Life histories are an important indicator of population health and recovery potential. Therefore, analyses of long-term datasets that enable assessment of life histories and changes to these parameters over time are critical for conservation and management. For effective management of the marine park and management of human activities in the GAB, an understanding of the seasonal trends in distribution and abundance, timing of arrival and departure from the site and peak abundance periods is required.

Objectives

Objectives of the 2017 GABRWS field studies are aligned with the Commonwealth Conservation Management Plan for Southern Right Whales (2012-2021) and include:

4) Assess SRW relative abundance, distribution and life histories through shore based and vessel based research at Head of Bight and Fowlers Bay, respectively. Specifically, the study will continue the long term (1991-2017) population monitoring (photo identification (ID) and census of aggregation) at Head of Bight following historical methods for comparative studies requiring long term time series dataset;
5) Opportunistically collect sightings data on marine fauna within the GAB Right Whale Study area and contribute to the long-term dataset;
6) Complete compliance patrols for the Department of Environment, Water and Natural Resources including observations for: whale mortality events, entanglements, vessel presence and marine park compliance.

Methods

Study area

The GABRWS includes two study sites, Head of Bight and Fowlers Bay, South Australia.

Head of Bight

The study area at the Head of the Great Australian Bight (31° 29' S, 131° 08' E) is in the broader region of the GAB and is located on the far west coast of SA, 300 km west of Ceduna and 200 km east of the WA border. The wider GAB is a multi-use area for commercial fisheries, marine parks, tourism and oil and gas activities offshore. Ongoing and planned oil and gas activities in the GAB include seismic exploration and exploratory drilling. Current oil and gas lease areas granted in the GAB cover approximately 115,000 km² (~750 km x ~150 km) and are located approximately 200 km offshore from the coastal aggregation area at Head of Bight, on the continental shelf. Head of Bight is within the Marine Mammal Protection Zone (MMPZ) of the GAB Commonwealth Marine Reserve that covers State and Commonwealth waters. The study area is also within the Far West Coast State Marine Park that covers the state waters out to 3 nautical miles (nm). Head of Bight is adjacent to Yalata Aboriginal Land on the Nullarbor Plain. The MMPZ of the GAB Commonwealth Marine Reserve was established in 1995 to provide a sanctuary for these whales (Figure 2). All vessels and general access are prohibited in the MMPZ of the GAB Marine Reserve between 1 May and 31 October each year (there is a complete no access zone- no fishing or recreational activities). The MMPZ area is approximately 9,000 km² in area (~100 km x ~90 km). The study area for this research is within the MMPZ and covers an area approximately 75 km² in size spanning approximately 15 km east to west along the coast and out to 8 km offshore (Figure 3).

Habitat characteristics of the study area at Head of Bight include a shallow, gently sloping, sandy bay in the east leading at the 'western' end of the study site to the 33-53 m high

Bunda Cliffs which provide some shelter from the dominating south westerly wind and swell. Along these cliffs, water depths drop to around 20 m within approximately 300 m of shore. Whales are often sighted directly below these cliffs within 50 m of shore (Figure 3).

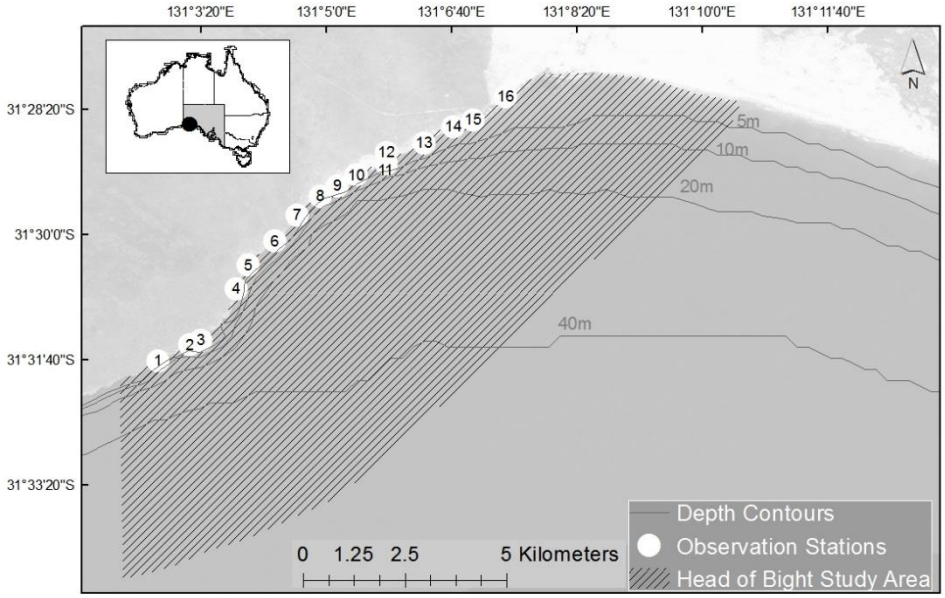

Figure 3: Study area and Southern right whales shore-based observation stations southern right whales at Head of Bight in the eastern GAB, South Australia. Observations sites on the cliffs are labelled west to east.

Fowlers Bay

Fowlers Bay (32° 0' S 132° 30' E) is on the far west coast of SA approximately 710 km west of Adelaide, SA (34° 55' S, 138° 35' E), 110 km west of Ceduna (32° 08' S, 133° 41' E), which is the 'eastern' range of the 'western' subpopulation, and 370 km east of the SA/WA state border (31°41' S, 129° 00 'E) (Figure 4). Fowlers Bay is approximately 160 km south-east of the aggregation area at Head of Bight, SA (31° 29' S, 131° 08' E) in the GAB Commonwealth Marine Reserve, and is located within the GAB which extends from Cape Arid, WA to Port Lincoln, SA. Fowlers Bay is approximately 95 km^2 in area and is in a habitat protection zone within the Nuyts Archipelago Marine Park (Figure 5). No access or fishing restrictions apply in the Marine Protected Area. SRWs are known to occupy shallow gently sloping sandy bays in water depths of less than 10 m and within 2 km of the coast (Pirzl, 2008). Fowlers Bay provides sheltered sandy habitat, protected from the prevailing south-westerly weather conditions, and has water depths ranging from 0-20 m within five km of the shore.

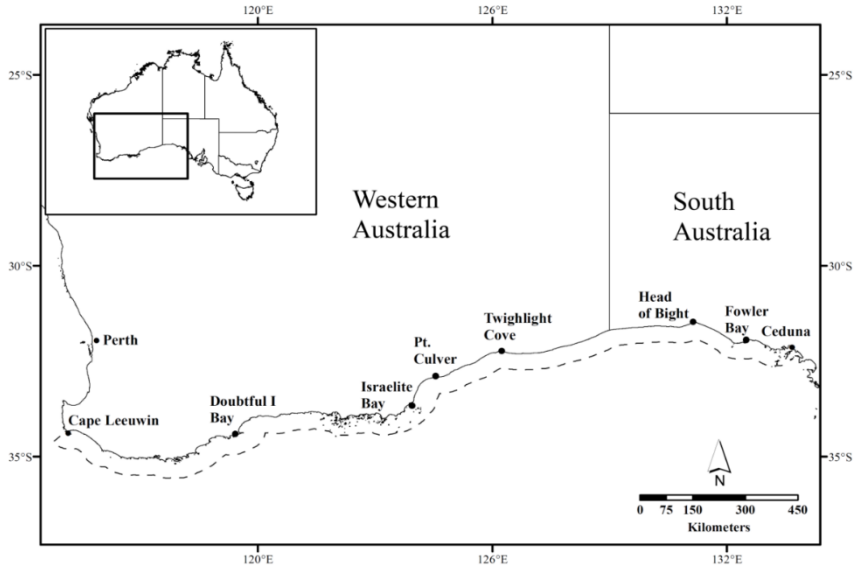

Figure 4. Southern right whale aerial survey off southern Australia from 1993 to 2016. Dashed line represents approximate survey route but further offshore so that contour is visible (Source: Bannister, 2017).

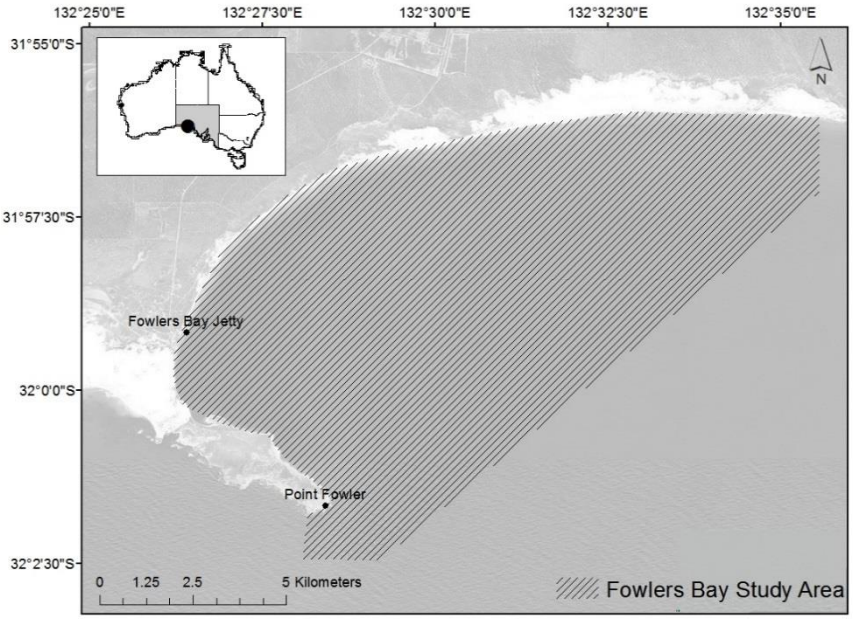

Figure 5*:* Southern right whale vessel survey study area at Fowlers Bay, South Australia.

Data collection

The study methods are consistent with the population census and photo-ID study completed annually at Head of Bight between 1991 and 2016 described in Burnell and Bryden (1997), Burnell (2001) and Charlton, 2017. Seasonal trends in abundance were assessed for SRWs at Head of Bight using daily counts over 26 of the 27 years since the study began in 1991. Count data from 1991 were excluded because in that year the number of groups was recorded rather than number of individual whales, and therefore the data are not consistent with the rest of the dataset. Daily counts provide a snap shot of whale numbers and location

on a given day. While the maximum value of the daily counts within a year was indicative of numbers using the site at on any one day during that season, they are likely an underestimate of the true maximum number of individual whales visiting the site since whales are known to immigrate and emigrate, to and from the site over the course of a season.

Counts

SRWs within the study area were surveyed from 16 land based observation stations (Figure 3) along a stretch of approximately 15 km of coastline. Observation stations on Bunda Cliffs ranged in height from 53 m towards the west to 33 m towards the east of the study area, and were between 300 and 1000 metres apart. Observation stations were selected based on safety and topographic features to ensure full visual coverage of the study site (i.e. if the contour of the cliff line obstructed observer view, then the observation stations were closer together to allow unobstructed observations of whales along the 15 km stretch of coastline). During each daily survey, surveys from each station were conducted beginning at the 'western'-most station and ending at the 'eastern'-most station. The time spent travelling between stations ranged from 2 to 6 minutes.

Observations at each station consisted of systematic scans using 10x50 Bushnell binoculars and the naked eye at an angle of approximately 180° east to west and as far as the eye could see offshore to the south from the horizon down to the cliffs. To avoid duplicate sampling between adjacent stations, only individuals in front or to the west of observation stations were recorded. To further reduce the risk of duplicate sightings, the location of sighted whales at each station was mapped in real time based on measurements of distance and angle to whale, individuals were identified using photo-ID, and the location and ID was cross checked with sightings at a similar location at the next adjacent station. The maximum transit time between stations was 6 minutes. All surveys were completed in Beaufort Sea States of 3 or less and wind speeds less than 18 knots to reduce bias in counts due to weather conditions. Environmental conditions including wind speed and direction in knots, cloud cover in percentage, sea state using the Beaufort scale and swell height were recorded qualitatively at the start and end of each census. Glare was not recorded as observations were timed to avoid glare. Daily cliff-based survey effort ranged from 2.9 hours to 4.9 hours (mean=3.6 hours). Start times were roughly 08:30 and end times ranged between 12:30 and 16:00. Observations were timed to avoid glare in the early morning and sea breeze in the afternoon. Effort reported here excludes travel times between vantage points.

Most animals, particularly females accompanied by a calf, were easily observed in the relatively clear and shallow waters within a few hundred metres of observation stations, even

when they were below the surface of the water. Thus, the probability of whales being available to be sighted within this distance of the observation stations was assumed to be 1 (Burnell, 2001; Bannister, 2017). A minimum of 10 minutes was spent observing at each station based on the assumption that at ranges beyond 5 km (where the larger incident angles of observation make detections of animals below the surface of the water more difficult), SRWs were at the surface at some point during that period. The minimum 10-min survey period at each observation station improved the detection probability of animals at a distance from observation stations while ensuring that whale movements were visually tracked to avoid double counting. Female and calf pairs spend the majority of their time on the surface and in the absence of any published literature on mean surfacing intervals of SRWs in a calving ground, a maximum of 10-minute dive times for calves is assumed. Surface behaviour is common for young calves and dive times are generally less than a few minutes (Charlton *unpublished observations* 2017). The data are biased towards potentially having greater detection probability for females and calves than unaccompanied adults. However, the overlap in observation stations and methodology moving west to east, increases the likelihood of sighting most animals. Longer time periods were spent at a location if additional time was required to capture photo ID's. A maximum of 50 minutes was spent at a location. In this instance, a dedicated observer watched the position of the whales to ensure that no animals had moved into or out of the observation station range. If a whale moved out of the observation station range to the east, it was later counted. If it moved out of the observation station range to the west, there was no risk of double counting the individual so it was still marked at the location station where it was first sighted. Photo-ID was abandoned if there was a risk of jeopardising the accuracy of the count. Whale location and assessment of distribution in the study area is biased by the movement of whales into an area when longer than 10 minutes was spent at an observation station. The whales move around the area frequently so the bias is not considered a limiting factor for the assessment of distribution and abundance.

Observer bias was reduced by using two trained and experienced observers during surveys and minimising rotation of researchers across the duration of the long-term study. For each SRW sighting the following variables were recorded: date, time, observation station (1-16), group composition (number, age class, and group type which included female accompanied by a calf, unaccompanied adult or unknown status). Unknown status was recorded when the observer could not be sure if the individual had a calf or was unaccompanied. A group of whales was defined as one or more whales within 100 m of each other that were seen to be interacting or travelling together. Range and bearing of the whale to the observer was recorded using a Bushnell 1600 laser range finder and marine grade Bushnell 10x50 binoculars fitted with a compass. Compass readings were taken in the absence of any metal

objects that could have interfered with the accuracy of the reading. In instances where the whale was outside the rangefinder detection range (typically greater than approximately 450 m), reticule binoculars fitted with a compass were used to measure increments below the horizon to the whale. Various handheld GPS units were used to log the position of each observation station, all using the WGS 84 chart datum (equivalent to GDA 90).

Photo Identification

Photographs of individual whales were obtained for comparing and matching individuals photographed previously. Photographs used for identifying individuals (photo-IDs) taken from the 33-53 m high Bunda Cliffs provided the required vantage point for collecting high quality images of the dorsal surface of the whale at proximity. Photographs of the dorsal surface allow callosity patterns on the head that are unique to each individual to be documented. Callosity patterns are keratinised skin patches colonised by cyamids that provide unique markings on the dorsal surface of the rostrum, the lip line of the lower jaw and just posterior to the blowhole that persist throughout life (Payne *et al.,* 1983). To capture the unique callosity patterns, photographs of the rostrum from above and left and right lateral perspectives of the dorsal side of the whale were obtained when possible. The ventral side of whales was also photographed if presented, to document the size and shape of ventral pigmentation (also persistent and unique) and the ano-genital configuration (to give information on sex). Evident markings and scarring were also photographed. Photographs were taken using a Nikon 7100 or D100 digital SLR camera with a Nikon 500 mm (effective 750 mm) or Sigma 500 mm lens mounted on a tripod.

For the purposes of this study, collection of photo-ID of all individuals was targeted with females with a calf and unaccompanied adults prioritised because their callosity patterns are well developed. Photo-ID effort for calves increased later each season when their callosity patterns were developed enough to enable future resights. This study currently provides the only individuals of known age for the Australian SRW population because photo-ID images of calves in their year of birth could be collected. For cliff-based photo-ID, capturing photos of adequate quality was not possible when whales were at greater distances than approximately 300 m from the cliff top. However, since whales commonly move within the aggregation area, many individual whales present at locations where photo-ID was not possible on a particular day, were photographed at a location amenable to photo-ID later. Furthermore, in 2016 and 2017, the use of Unmanned Aerial Vehicles (UAVs or drones) in collaboration with Murdoch University Cetacean Research Unit provided access to all whales in the site for photo-ID. The whale position, behaviour, group composition, age class and reproductive status were recorded for each whale. Photo-ID images obtained during this study were supplemented by similar images provided in-kind from aerial surveys across the

entire 'western' population range completed through the Western Australian Museum (1993-2017) courtesy of J. Bannister.

Vessel surveys

Vessel-based surveys were undertaken on-board the Fowlers Bay Whale Tours charter vessels opportunistically during the field season FB to assess SRW relative abundance and distribution, spatial use patterns, behaviour, calf production and life histories. (Table 1). The vessel was a 13.58 m (45 ft.), aluminium Cathedral hull vessel, with 600HP Yanmar inboard engines, with a 4.5 m vantage height (named *Asheera*). Surveys were conducted opportunistically in Beaufort Sea State conditions of three or less. The operational area extended approximately 12 km in the SW to NE direction and six km from shore in the NE to SE direction, covering an approximate area of 35 km². Tracks were haphazard in their spatial coverage since they were determined by the tourism operation. Vessel tracks were recorded using a Holux M-1000C GPS data logger that recorded the latitude and longitude of the vessel every second.

During vessel surveys, two observers searched for whales using a combination of the naked eye and Nikon 10 x 50 marine grade binoculars from the foredeck of the boat. This vantage point allowed unrestricted, 180° views forward of the vessel. When searching, one observer scanned from 0° forward to 180° on the port side of the vessel, while the second observer scanned from 0° forward to 180° on the starboard side of the vessel. Scanning was undertaken by continuously searching the entire visible area of the ocean from the horizon down to the vessel, or shore to the vessel. The detection range was limited to approximately 4 km by the relatively low vantage point.

When an individual or group of SRWs was sighted, the vessel changed from search mode to closing mode with a minimum approach distance of 150 m (required by the licence conditions). Once the group of whales was approached, the following data were recorded at the closest distance reached to the whale: GPS location of the vessel in latitude and longitude; range (if possible) using Bushnell Elite 1600 ARC laser rangefinders; bearing from the vessel to whale using a compass; group size and group composition (female accompanied by a calf, unaccompanied adult i.e. juvenile or adult not accompanied by a calf of the year, or unknown); behaviour; time and date. To ensure that error in the compass was not introduced by nearby ferromagnetic metal, observers did not stand near non-aluminium metal and ensured they did not have any metal objects on them. The following weather conditions were recorded qualitatively at the start of each survey: wind speed, wind direction, Beaufort Sea State, swell height (m), and percentage of cloud cover. In addition, water and air temperature were recorded from instruments on the vessel. Photographs of individual whales were collected opportunistically for identification. Once data were obtained from the

group and the whale-watch interaction terminated, the vessel departed the group and continued its search. Interactions with whales generally ranged from 2 to 30 minutes.

Analysis

Distribution

Whale distribution was mapped using location data calculated from range and bearing of whale plus elevation of observer. The equivalent measure in degrees for vertical angles associated with binocular reticules was calibrated using the distances and heights of known targets. Whale ranges using the reticules were calculated assuming a spherical earth and allowing for observer-eye elevation. Height above sea level and GPS location of the observer eye was calculated for each of the 16 observation stations by using a theodolite to determine the angle below the horizontal down to a feature at the water's edge (usually a rock) to which the range was established using the laser range finders. Geometry then gave the theodolite elevation. Whale positions were calculated using code developed at the Centre for Marine Science and Technology, Curtin University (CMST) using MATLAB (The MathWorks, Inc.). The mapping toolbox was used to plot the location of whales based on the range estimate and true compass heading (corrected for variation at the site). The error associated with tide was considered minimal given the tidal changes (<1.5 metres) relative to the distance that whales were sited (most within 1 km) and measurement errors. There was some error in the precision of sighting locations between 1° and 120° (horizontal angle) at observation station 16 caused by land blocking the horizon. The vertical angle of the horizon was estimated from which location data in this area were estimated to have an error in the range of 1-300 m.

Spatial data processing used purpose-built programs in MATLAB software to generate whale locations. Maps were generated in MATLAB using Australian Hydrographic Service charts under Seafarer GeoTIFF license No 2618SG (Curtin University). Spatial data were normalised for effort (time spent at each observation station) and displayed as Kernel Density distribution plots (whales/0.5km^2) using ArcMap v10. All times were presented in Australian Central Standard Time (UTC + 9.5 hours). Bathymetry was retrieved from the Geoscience Australia 0.00250 grid (Whiteway 2009).

Abundance

Within seasonal trends in abundance between June and October (1992-2017) were analysed by plotting the abundance of female and calf pairs and unaccompanied adults and calculating the proportion of each group type that was present in the study area during each month surveyed. The variation in abundance of each group type (females accompanied by a calf, unaccompanied adult) was assessed to provide information on immigration and emigration into and out of the site.

Results

A total of 20 field days were completed at Head of Bight and five boat based surveys at Fowlers Bay between July 16th and September 26th, 2017. Field studies included census of the aggregation ground, photo ID and fine scale behavioural studies.

Abundance

Head of Bight

The maximum daily count of SRWs at Head of Bight was 163 individuals on August 7th, 2017 including 74 female and calf pairs and 14 unaccompanied adults (Figure 6). The maximum number of unaccompanied adults sighted during the study period was 27 individuals, on the 12th of August.

There was variation in abundance observed across the season, attributed to the movement of individuals into and out of the study are throughout the season. The number of whales present at the start of the field study on July 19th was 49 female and calf pairs and ten unaccompanied adults. At the end of the field study on August 28th, there was 58 female and calf pairs and two unaccompanied adults.

During the 20 days of field work, a total of 1417 individual whale sightings were recorded.

Photo ID images of SRW were collected by researchers during each of the 20 field days, with additional images provided by Head of Bight Interpretive Centre manager Bernice, Murdoch University researchers and the WAM aerial survey. Images provided by Bernice were collected between 17th June – 14th July, drone images provided by Murdoch University were collected between 13th July – 23rd August and the WAM aerial survey provided images taken on the 25th of August. A total of 87 female and calf pairs and 96 unaccompanied adults were photo identified. The maximum number of sightings of a female and calf pair was 19, and for an unaccompanied adult was six. The maximum number of sightings of a whale using only cliff based photo-ID was nine, with a minimum of zero. Seven female and calf pairs and 21 unaccompanied adults were identified using only photo-ID images provided by additional sources.

The maximum residence period for female and calf pairs in 2017 was 64 days (26th June – 28th August), and for unaccompanied adults was 37 days (17th June – 23rd July). Initial sightings date varied from the 24th June to 23rd August, while date of last sighting varied from the 7th August to 28th August (last survey day).

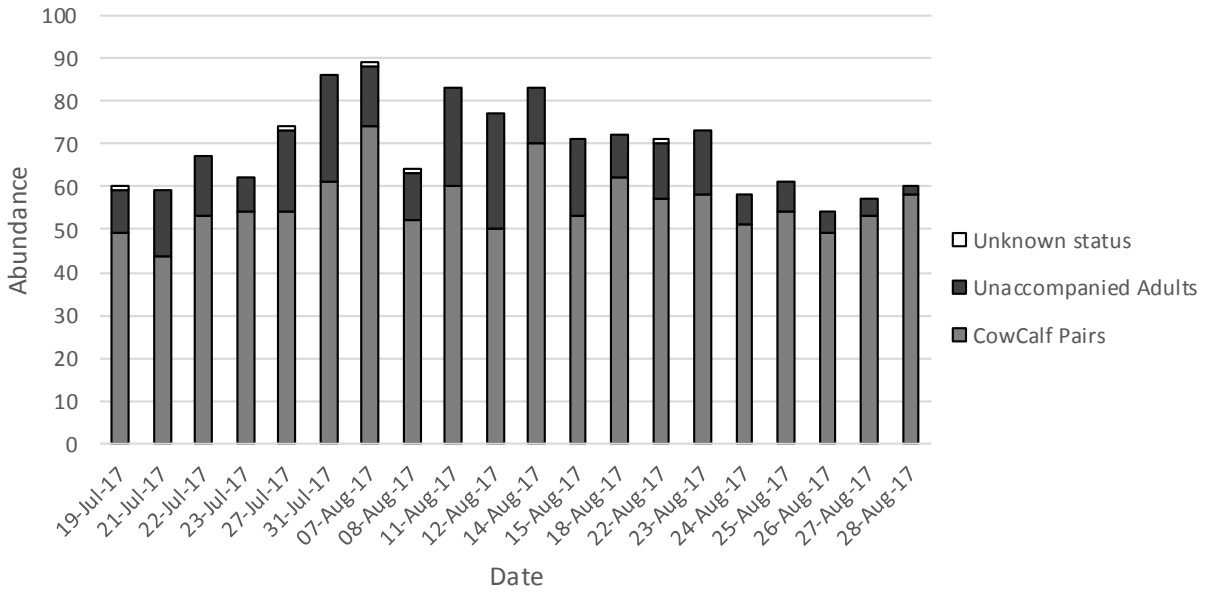

Figure 6 Southern right whale population abundance at Head of Bight 2017

Long term trends in abundance and life history parameters for SRWs at Head of Bight, SA were estimated using 27 years of photo identification mark recapture and 26 years of count data. The long-term cliff based SRW count and photo identification study was completed annually between 1991 and 2017. The estimated mean rate of increase in SRW at Head of Bight was 3.17% (SD= ± 95% CI) per annum (1992-2017). The corresponding mean rate of increase for females accompanied by a calf was 4.6% (SD= ± 95% CI). Owing to cohort structure and pulses in calf production, the annual maximum abundance recorded was highly variable across years ($\bar{X}$ =39, SD=17.8).

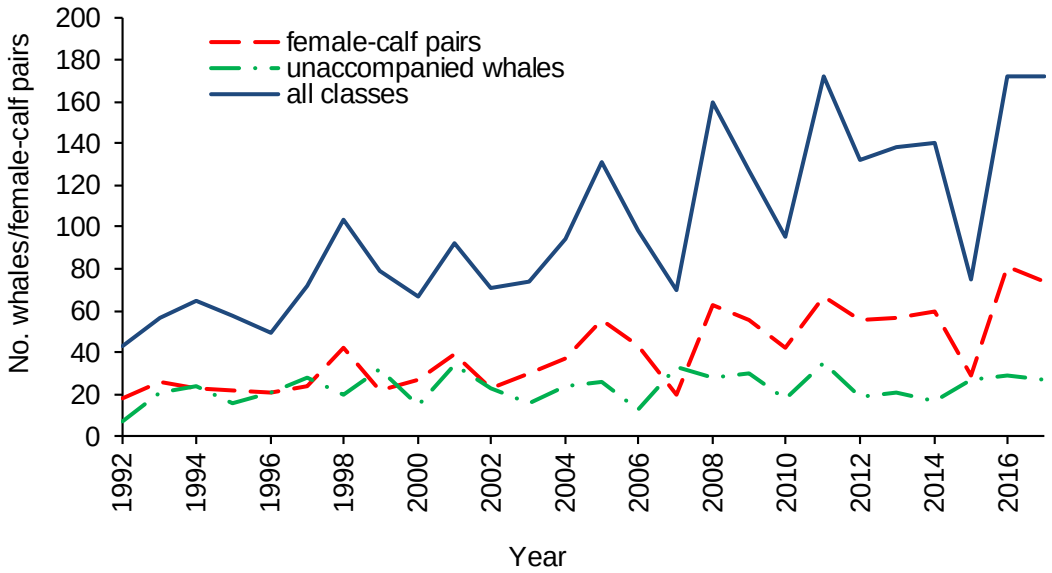

Figure 7: Long term abundance trend of southern right whales at the Head of the GAB, South Australia

Fowlers Bay

The maximum daily count of southern right whales at Fowlers Bay in 2017 was 41 individuals on August 13th, including 20 female and calf pairs and one unaccompanied adults (Figure 8). The maximum number of unaccompanied adults sighted during the study period was three individuals, on the 28th of August.

There was variation in abundance observed across the season, attributed to the movement of individuals into and out of the study are throughout the season. The number of whales present on the first field day at Fowlers Bay on July 25th was 17 female and calf pairs and two unaccompanied adults. On the last day of field work at Fowlers Bay, on August 28th, there was 15 female and calf pairs and three unaccompanied adults.

During the five days of field work, a total of 87 individual whale sightings were recorded. A total of 23 whales were photo identified, 20 female and calf pairs and three unaccompanied adults. The maximum number of sightings of a female and calf pair was two, and for unaccompanied adults was one. The maximum residency period for a female and calf pair was 27 days, and for unaccompanied adults was one day.

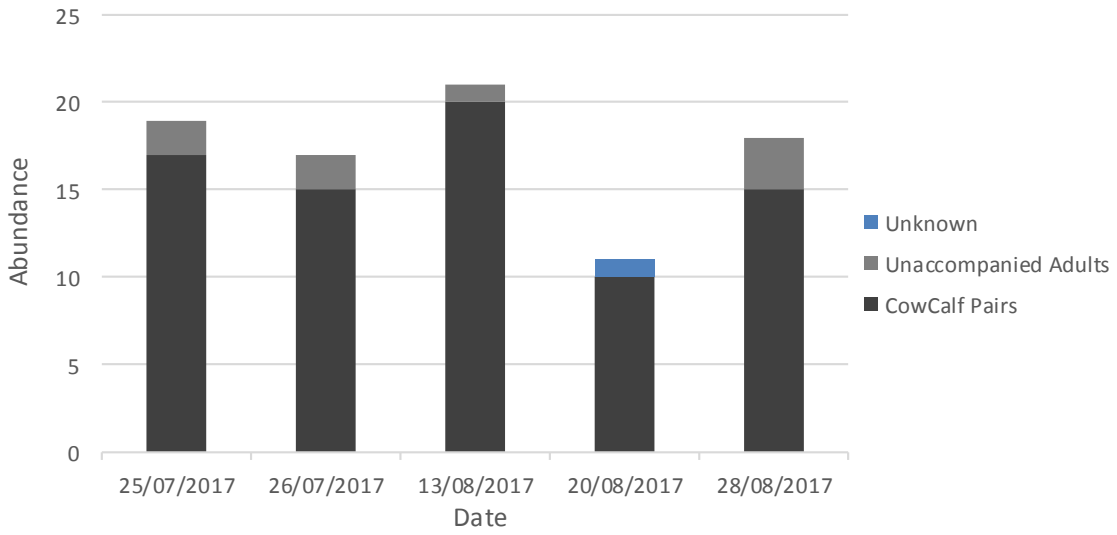

Figure 8: Southern right whale population abundance at Fowlers Bay 2017

Distribution

Head of Bight

Within, the study area, SRWs were predominantly distributed along 15 km of the coast and within 2 km from shore (95% were within 1 km of shore) in water depths less than 20 m (Figure 9). Females accompanied by a calf were mostly distributed in the shallow sandy bay

to the east, whilst sightings of unaccompanied adults were most frequently made along the cliff line in the centre and west of the study area (Figure 9).

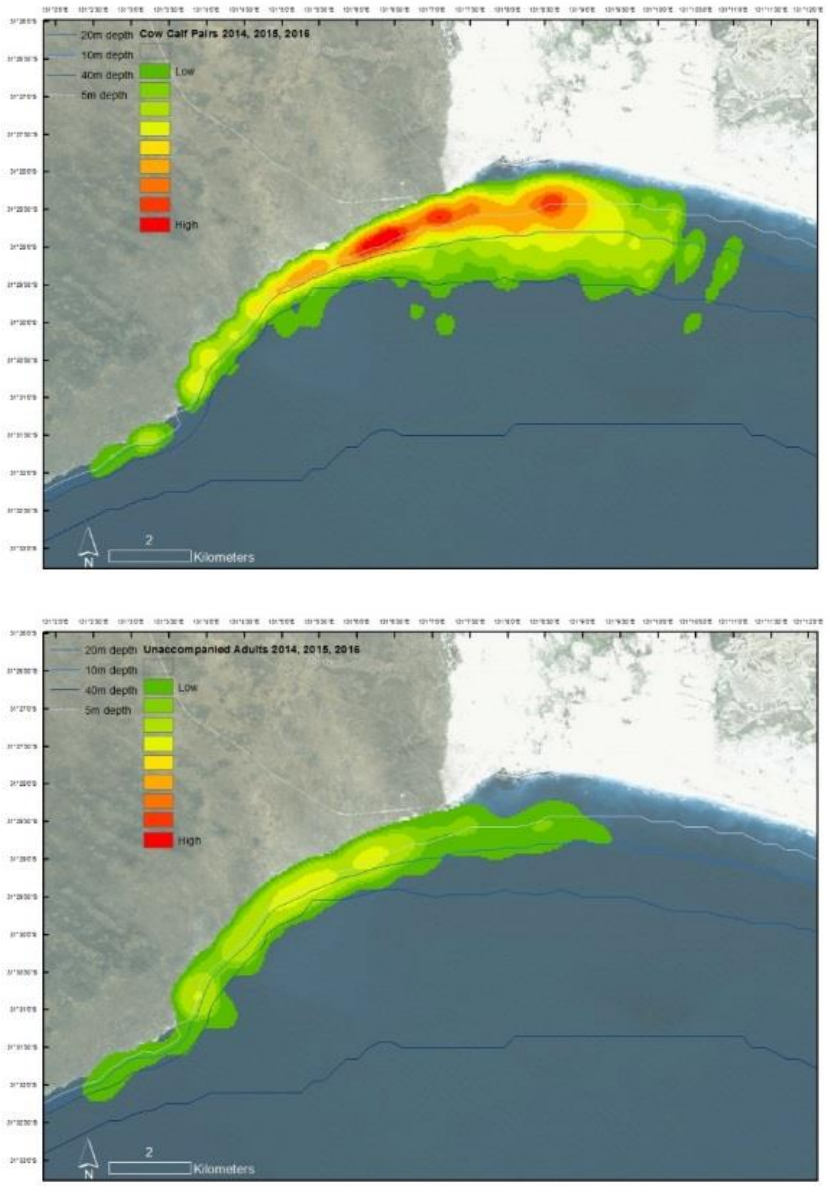

Figure 9: Southern right whale density distribution at Head of Bight, South Australia for female and calf pairs (above) and unaccompanied adults (below) collected 2014-2016.

Fowlers Bay

SRW sightings at Fowlers Bay during vessel surveys were predominantly within the 10m depth contour within 1-2km from shore, and most commonly within a few hundred metres of shore. SRW sightings in the study area were between Point Fowler and 8 km south east of the Fowlers Bay jetty and were most common 1-5 km north-east of the jetty, consistent with prior years (Figure 10).

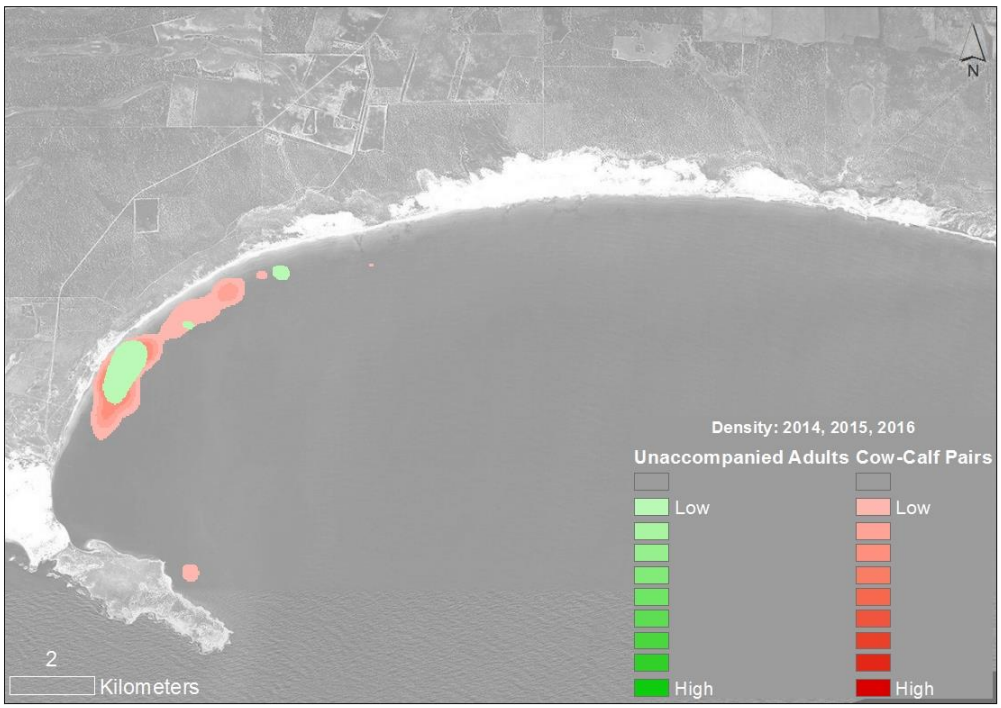

Figure 10: Distribution of southern right whales at Fowlers Bay, South Australia, data collected 2014-2016.

Photo Identification

A total of 206 different individuals were photo identified between Fowlers Bay and Head of Bight throughout the 2017 season, including 99 adults and 107 females with a calf. The number of individuals photo identified exceeded the maximum daily counts (including 74 cow calf pairs and 27 unaccompanied adults at Head of Bight and 20 cow calf pair and 3 unaccompanied adults at Fowlers Bay). Movement of individuals was observed in and out of the study areas throughout the season and a greater number of individuals were photo identified than the maximum daily counts. Photo Identification mark recapture allows assessment of residency of individuals in each calving ground. The 2017 peak in relative abundance was observed between mid-July and early to mid-August at Head of Bight and Fowlers Bay.

Other Observations

Other observations recorded during the 2018 GABRWS field season included: humpback whales, dwarf minke whale, Australian Sea Lions, long nosed fur seal, bottlenose dolphins, common dolphins, seabirds, sharks, aircraft. No whale mortalities of entanglements were recorded. The drawf minke whale appeared to be a juvenile with shark bites. The animal appeared unwell and the sighting was reported to the South Australian Museum.

Other observations are summarised in Table 1. Category, number of individuals, location, behaviour of opportunistic marine fauna sightings were recorded and archived in the Head of Bight BigFish photo ID and sightings database. Marine fauna sightings from the 2017 season will contribute to the publication in preparation on 'Marine fauna observations at the head of the great Australian Bight, 1991-2017".

Table 1: Other observation during the 2017 Great Australian Bight Right Whale Study, at Head of Bight, South Australia

Category	Species type	Number of sightings	Total individuals sighted
Marine mammal	Australian sea lion	5	6
	Bottlenose dolphin	17	~320
	Common dolphin	1	50+
	Dwarf minke whale	1	1
	Humpback whale	6	8
	Long-nosed fur seal	2	3
	Nankeen kestrel	8	12
Fish	Australian Salmon	1	~20
	Great White Shark	1	1
Seabird	Australasian gannet	1	3
	Australian bustard	1	8
	Little penguin	4	unknown
	Pacific gull	10	19
	Peregrine falcon	3	5
	White-bellied sea eagle	18	24
Aircraft	Fixed wing aircraft	21	21

Compliance Patrols

Compliance patrols of the GAB Commonwealth Marine Reserve, under commission from the Department of Water and Natural Resources. A total of 96 patrol hours were completed within the Marine Mammal Protection Zone of the Marine Reserve. Three non-compliance events were occurred:

I. 19 July 2017 at 11:10am: low flying plane beneath the no-fly zone limit of 1000ft heading west over the water then the cliffs before turning north
II. 22 July 2017 at 13:00: Drone in flight towards Bay from Head of Bight Centre. Drone operator was not seen.

III. 7 August 2017 at 9:32am: Fixed wing plane in flight over cliffs flying beneath the no-fly zone limit of 1000ft, travelling west over land, looped over whales.

All non-compliance events and patrol hours were reported to DEWNR and Marine Park Management.

Discussion

The 2017 GAB Right Whale Study field study fulfilled the objectives to:

1) Assess SRW relative abundance, distribution and life histories through shore based and vessel based research at Head of Bight and Fowlers Bay, respectively. Specifically, the study will continue the long term (1991-2017) population monitoring (photo identification (ID) and census of aggregation) at Head of Bight following historical methods for comparative studies requiring long term time series dataset;
2) Opportunistically collect sightings data on marine fauna within the GAB Right Whale Study area and contribute to the long-term dataset;
3) Complete compliance patrols for the Department of Environment, Water and Natural Resources including observations for: whale mortality events, entanglements, vessel presence and marine park compliance.

A robust baseline understanding of migratory whale populations is critical for conservation management, informed risk assessment and before and after impact assessment. This research improves our understanding of SRWs in Australia. Outputs contribute to national recovery assessments and global comparative studies. Results are shared with the Department of Environment, International Whaling Commission, industry and scientists.

To detect changes in the rates of increase and recovery of long-lived and slow to recover marine mammals, such as SRWs, long-term monitoring in the order of decades is required. Detecting changes in the rate of increase in SRWs requires annual monitoring due to their mainly three and less frequently four or five-year calving cycles (Bannister et al., 2011; Charlton, 2017). To detect change on a time scale relevant for management, assessment of each breeding cohort is required (Bannister et al., 2011; Burnell, 2001). The trend in abundance at Head of Bight is highly variable, due to the cohort structured breeding cycles driven by the mean three-year calving cycles of SRWs.

Daily counts provide a snap-shot of SRW distribution and abundance on a given day within the study area. Therefore, the maximum daily count is an underestimation of the true maximum number of individuals using the Head of Bight and Fowlers Bay aggregation areas during the season. Individuals that are outside of the visual detection range of 5 km from the cliff based observation stations at Head of Bight are not detected during daily counts. Helicopter surveys showed that in July of 2014, up to 17% of SRWs sighted in the Head of

Bight area were recorded outside of the Head of Bight cliff based study area (Mackay et al., 2015). Counts completed simultaneously between the WAM aerial survey and the cliff based count team resulted in comparable counts. For example, in 2016 the WAM aerial survey counted 66 female and calf pairs and 11 unaccompanied adults at Head of Bight and the count team sighted 66 female and calf pairs and 10 unaccompanied adults. Whilst it is acknowledged that the Head of Bight cliff counts have limitations in counting individuals outside of the visual detection range, the cliff based counts have compared favourably to the WAM aerial survey counts across years and the cliff surveys give greater precision in establishing a seasonal maximum daily count used as a long-term trend metric. The minimum two-week survey period at Head of Bight allows for most residing SRW individuals to be captured through photo-ID because they move around the study site within that period.

Photo-ID mark recapture shows that the number of individuals photographed often exceeds the maximum daily count, indicating immigration and emigration across a season, particularly for unaccompanied adults (Burnell, 2001; Charlton, 2017). The number of animals photo identified and the number of sightings for an animal is greatly increased by the use of UAV (drone) technology. In 2018 GABRWS researchers will be trialling the use of drones an additional method for photo-ID.

Long-term trends in abundance and life history parameters provide critical information for population recovery assessment and monitoring of changes to a population over time. This study reports on the long-term trends in abundance and life history parameters including apparent mean calving interval and age at first parturition of SRWs at the major aggregation area at Head of Bight.

The GAB Right Whale Study is committed to communicating science and education through publication of scientific literature, presentation at national and international conferences, community engagement and media. A Community Whale Day was held at the Head of Bight in August 2017, with school groups from local aboriginal communities, in collaboration with DEWNR, Yalata Aboriginal Community, Murdoch University and Curtin University.

This research directly addresses key priorities and objectives in the Commonwealth SRW Conservation Management Plan to understand life history parameters and to measure population growth. This research improves our understanding of seasonal trends in distribution and abundance of SRWs at the major aggregation area at Head of Bight (1991-2017). Information provided by this research can be used to inform marine park management, management of human activities outside of the marine reserve that require an understanding of timing of arrival and departure of whales to and from the site, and inform researchers on peak abundance periods for future research monitoring. Baseline data are provided for detection of population changes over time and to enable before and after

assessment of impacts associated with marine based activities proposed for the area. Information provided by this study can be used to inform population status and recovery assessment, linkages to health and climate factors, and global comparative studies of SRW populations. Recovery planning for the endangered SRWs would benefit from an Australia wide assessment with detailed mark recapture analysis and correlations to calving intervals, health and climate factors. Future monitoring and research should consider the full distribution of SRWs in Australia and connectivity between all the coastal wintering grounds in Australia and NZ, to ensure the protection of the population and continued recovery of the species.

Future Priorities

- Australian national assessment of southern right whale abundance
- Understand foraging areas and linkages to recovery
- Complete global comparative study of demographic parameters and linkages to environmental correlates
- Assess health and mortality and compare globally
- Assess coastal and offshore movements and migration pathways
- Assess shifts in habitat distribution in Australian aggregation areas
- Define new and emerging aggregation areas

Publications and conference presentations

In 2017/2018, the following publications and conference presentations resulted from this work:

- Charlton, C. M. (2017) Population demographics of southern right whales (*Eubalaena australis*) in Southern Australia. (PhD Thesis). Curtin University, Western Australia. Website link: https://espace.curtin.edu.au/bitstream/handle/20.500.11937/59638/Charlton%20C%202017.pdf?sequence=1
- Ward, R., Gavrilov, A.N., McCauley R.D. (2017). "Spot" call: A common sound from an unidentified great whale in Australian temperate waters. The Journal of the Acoustical Society of America 142, EL231 (2017); doi: 10.1121/1.4998608. https://doi.org/10.1121/1.4998608
- Christiansen F, Vivier F, Charlton C, Ward R, Amerson A, Burnell S, Bejder L (2018) Maternal body size and condition determine calf growth rates in southern right whales. Mar Ecol Prog Ser 592:267-281. https://doi.org/10.3354/meps12522
- Charlton C.M., R.McCauley., R. Ward, C.Salgado Kent., R.L. Brownell., S. Burnell. 2018. Southern right whale life histories at Head of Bight, South Australia. IWC SC67b
- Charlton C.M., R.McCauley., R. Ward, C.Salgado Kent., R.L. Brownell., S. Burnell. 2018. Southern right whale distribution and abundance at major aggregation ground at Head of Bight in the Commonwealth GAB Marine Reserve. Journal of Freshwater and Marine ecosystems (*In review)*

- Charlton C.M., R.McCauley., R. Ward, C.Salgado Kent., R.L. Brownell., J. Bannister. 2018. Southern right whales recolinize historical aggregation areas at Fowlers Bay, South Australia. Marine Mammal Science (*in review*)
- International Whaling Commission Science Committee Meeting – Invited Participant. Bled, Slovenia May 2018
- International Mammalogy Congress, July 2017, Perth Western Australia, Conference on southern right whale population demographics in South Australia. Oral presentation.
- International Society for Marine Mammal Biennial Conference, October 2017, Halifax, Canada. Conference oral presentation accepted, southern right whale population demographics in South Australia. Oral presentation.
- Australian Marine Science Association, Conference Adelaide July 2018. Oral presentation.

Media and Communications

In addition, the following media articles were released on this study in 2017/2018:

- Southern right whales back from the brink. July 15, 2017. The Australian – Front Page.
- https://www.theaustralian.com.au/news/health-science/southern-right-whales-are-all-right-back-from-brink/news-story/52f74b701868a0ae5f9f2dab5f836835
- From Sleaford Bay to Encounter Bay: Rare whale Murphy spotted again. March 22, 2018. https://www.portlincolntimes.com.au/story/5301447/from-sleaford-bay-to-encounter-bay-rare-whale-murphy-spotted-again-photos/
- New whale Murphy spotted in Encounter Bay waters. March 21, 2018 http://www.victorharbortimes.com.au/story/5293226/rare-whale-murphy-spotted-in-local-waters-photos/#slide=1
- First whale of 2018 season spotted at Encounter Bay. May 16, 2018 https://www.adelaidenow.com.au/news/south-australia/first-whale-of-2018-season-spotted-at-encounter-bay/news-story/ed602355cfd89b131891a651e1f62a60
- Drone right whale science at Head of Bight. April 5, 2018 https://www.businessinsider.com.au/drone-right-whales-science-head-of-bight-south-australia-2018-4
- GAB Right Whale Study website update and communication blog: https://www.gabrightwhales.com/
- Social media: Facebook and Instagram (@southernrightwhales): https://www.facebook.com/southernrightwhales/ and https://www.instagram.com/southernrightwhales/

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