Centre for Marine Science and Technology

Curtin University

SOUTHERN RIGHT WHALE (*EUBALAENA AUSTRALIS*) ACOUSTICS AT FOWLERS BAY, SOUTH AUSTRALIA

DATA SUMMARY OF PRELIMINARY RECORDINGS FROM AUGUST 2013

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Contents

1. Executive Summary

Southern right whale vocalisations were collected on August 24 2013 to August 26 2013 during a pilot study to assess population dynamics and underwater acoustics at Fowlers Bay, South Australia. Fowlers Bay is a small established aggregation ground for EPBC listed endangered southern right whales. Southern right whales migrate to sheltered coastal waters in Australia annually between May and October to calve, mate and rest. In 2013, a maximum of 15 southern right whales were sighted at Fowlers Bay on August 24, including six females and calves and three unaccompanied adults.

This report presents the acoustic data that was collected over the three day period and identifies a number of southern right whale (SRW) call types, as well as other biological noise sources including bottlenose dolphin whistles and proposed humpback whale calls. SRW call types are identified using those categorised by Clark (1982). A table of Clark's call types is presented in Table 1. The upcall is the most common call type for SRWs (Cummings *et al.* 1971, 1972; Clark 1982; Webster & Dawson 2011).

32 SRW calls were analysed and included three different call types; 23 upcalls, 8 constant calls and 1 unknown. The average maximum frequency of all calls was 177.59 ± 43.80 Hz and the average minimum frequency was 77.68 ± 28.32 Hz. The average duration of all calls was 0.83 ± 0.38 seconds. A total of six female and calf pairs and three unaccompanied adults (sex unknown) were sighted in Fowlers Bay during the time of acoustic recordings.

The 2013 pilot study on southern right whales acoustics in Fowlers Bay provides the first documentation of southern right whale call types and acoustic repertoire in Australia. The acoustic study is being continued by the Curtin University Great Australian Bight Right Whale Study Team between June and October 2014. The objective of the 2014 study is to characterise the acoustic repertoire of southern right whales in nearshore (<20m water depth) and offshore (>20m water depth) waters of South Australia. This study will include data reported herein and aims to provide information required for passive acoustic monitoring in future.

2. Background

2.1 Literature Review

2.1.1 Southern right whales in Australia

Southern right whales (SRW) (*Eubalaena australis*) occupy southern hemisphere latitudes of 16°S and 65°S and migrate to northern coastal aggregation grounds to breed, calve and rest during the austral winter. The current status of the species is listed as endangered under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (the EPBC Act), following depletion to near extinction as a result of commercial whaling in the 19th century. Post the protection of the species against whaling in 1935, the Australian population has been slowly recovering with an estimated recovery rate of approximately 7% per annum (Bannister 2014). However, recovery has not been consistent across the Australian population.

Genetic study suggests that SRW in Australia belong to two subpopulations, the south-east and south-west (Carroll *et al.* 2011). The south-west subpopulation occupies areas between Cape Leeuwin, Western Australia and Ceduna, South Australia, with an estimated population size of approximately 2500 individuals (Bannister 2014). Whereas the south-east subpopulation, consisting of fewer than 300 individuals, can be found along the south eastern coast including Tasmania, although extend no further north than Sydney (Bannister 2014). The south-west subpopulation has experienced a higher number of returning individuals who come to calve than the south-east subpopulation, which has shown little evidence of increase (DSEWPaC 2012).

SRW visit the sheltered bays of the south Australian coastline between May and November each year to calve, mate and raise their young (Burnell 2001). Once females have reached the age of sexual maturity at 7-8 years, they are known to exhibit a three to four year calving cycle. Females have been recorded repeatedly returning to specific aggregation areas to calve and rear young, showing high levels of site fidelity (Burnell 2001). Between 1991 and 1995 Burnell (2001) calculated that 92% of breeding female SRW displayed some level of fidelity to the Head of Bight (HOB) aggregation. Individual variation still exists within this, with photo identification records of calving females sighted at Fowlers Bay, South Australia having also been sighted with a calf at Twilight Cove, Western Australia and at Auckland Island, New Zealand across years (Charlton *et al.* 2014b). There are still many unknowns when it comes to coastal migration of SRW within calving seasons and between years.

There is limited information known about the offshore migration pathways and foraging distribution of SRW. Patenaude *et al.* 2007 documented the migration of SRW in the summer months to offshore feeding grounds in the Southern Ocean and Bannister *et al.* (1999) was able to document the movement of a photo identified SRW across these great distances. The animal was first identified in the winter of 1978, close to the West Australian coast. It was then identified in late February 1996 at 64°26'S, 114°54'E, 3150 km due south of Cape Leeuwin, Western Australia. At the time, this was the only example of seasonal movement of an indentified SRW to offshore feeding areas, and suggested the species were capable of large-scale migration between seasons.

The greatest body of knowledge regarding SRW population biology in Australia is a direct result of the two long term monitoring programs on SRW in Australia, the annual aerial study run by Western Australian Museum and the Southern Right Whale Population Census and Photo Identification (ID) study at Head of Bight (HOB). As a result of increased reports of SRW sightings off the south- western coast of Australia an annual program of aerial surveys was developed to measure distribution, counts of whales and photo identification (ID) of individuals from the 'western' subpopulation (Charlton *et al.* 2014b). The current flight path has existed from 1993 to present day. Following on from this, in 1991 an annual shore-based programme was introduced at HOB, South Australia to collect fine scale population biology and relative abundance data at a key aggregation site through cliff top population census and photo ID conducted at vantage points 60-80m above sea level (Burnell & Bryden 1997; Charlton *et al.* 2014b). The HOB study has been completed during the peak of calving season during mid-late August; although prior to 2007 the study was completed over three, two week periods at the start, middle and end of the season (Charlton *et al.* 2014a). The HOB is known as the largest aggregation of SRW in South Australia, and has been protected under the Great Australian Bight Commonwealth Marine Reserve (DSEWPaC 2012a). The maximum abundance of SRW ever recorded at HOB was in 2011, with a total of 174 individuals, including 67 cow calf pairs being counted (Charlton *et al.* 2014a). In this same year, Fowlers Bay also received a record abundance of SRW calving in the area.

Fowlers Bay is recognised as a small-established aggregation area (DSEWPaC 2012). It is south-east of HOB, approximately 170km. Data collection at Fowlers Bay began in 1993 through the Western Australian Museum aerial surveys, run by John Bannister. In 2011, the highest ever maximum count of SRW was recorded at Fowlers Bay, with 55 individuals, including 16 female and calf pairs and 22 unaccompanied adults (Charlton *et al.* 2014b). A recent cross-matching study has shown connectivity with HOB and the south-west population to this growing small aggregation area (Charlton *et al.* 2014b). Over a third (39%) of southern right whales sighted in Fowlers Bay between 2007 and 2013 were cross matched to the HOB photo ID catalogue sighted at HOB previously (Charlton *et al*. 2014b). The study suggests that density factors and carrying capacity of HOB aggregation need to be addressed to predict and manage spill over. Despite the growing visitation of calving SRW to Fowlers Bay, it is outside of the Great Australian Bight Commonwealth Marine Reserve and therefore, is currently not protected.

The Commonwealth Management Plan for SRW states the long-term recovery objective is to minimise anthropogenic threats to allow the conservation status of the SRW to improve. Under this plan, noise interference is listed as a potential threat to the Australian population of SRW, with seismic surveys and other industrial activities included as a potential form of harmful noise. At present there are four key operators proposing to drill exploration wells for oil and gas in the Great Australian Bight (GAB); BP, Chevron, Santos and Murphy. Multi-client surveys are also being completed by companies including TGS, CGG and PGS to collect geological data that will then inform oil and gas exploration. Seismic surveys are proposed between October and June for the next three years. The oil and gas permit areas are approximately 200km offshore from the HOB, while seismic fields are even closer. These seismic surveys will involve the towing of an array of air guns, which generate a pulse that is emitted every 10 - 60 seconds for days or weeks at a time (Nieukirk *et al.* 2011). The pulses are broadband, primarily concentrated in the low frequency range of 10 – 200 Hz, with lower energy levels in the range of 200 Hz – 1 kHz (DEWHA 2008).

SRW have been shown to have a call repertoire that shares the concentrated range of seismic pulses, 10 - 200 Hz (Cummings *et al.* 1971, 1972; Clark 1982; Webster & Dawson 2011). Whales use vocalisations to communicate over large distances. Masking of calls can have a profoundly negative effect on communication, which may indirectly effect foraging, socialising and behaviour. Noise pollution from shipping traffic has been suggested to have a significant impact on the health of critically endangered North Atlantic right whales (*Eubalaena glacialis*) (Clarke *et al.* 2009; Rice *et al.* 2014), as well as increased risk of ship strike (Rolland *et al.* 2012). SRWs in south-eastern Australia are exposed to high levels of shipping traffic and greater recreational marine use around aggregation areas, which has been recognised as a key threat to population recovery (DSEWPaC 2012). The Great Australian Bight is a multiuse area and the increase in underwater noise pollution and vessel traffic is of concern, particularly because offshore distribution, migratory pathways and feeding grounds are poorly understood. More information is required for effective mitigation against anthropogenic noise disturbance to the species.

The field of acoustics is being increasingly used to detect marine mammals over long ranges in environments that are not favourable for visual monitoring (Nosal 2012). Acoustics can provide information about the movement of animals underwater and far-field bio acoustic signal properties (Nosal 2012). To contribute to the development of acoustic monitoring applications for SRW in Australia information is needed on their sound repertoire. To date, published data on SRW calls has been collected in inshore environments, and no information has been published on SRW vocalisations in Australia.

2.1.2 Southern right whale calls

SRW calls have been divided into five types; belches, simple moans, complex moans, pulses and miscellaneous sounds (Cummings *et al.* 1971, 1972). Cummings *et al.* (1971, 1972) found the most common sound type was the belch. Recorded belch sounds had an average duration of 0.14s and an average frequency of 235 Hz, and were reported to end in an upward frequency increase of approx. 150 Hz. Simple moans lasted from 0.6 – 1.6s with an average frequency of 160 Hz, while complex moans had a duration of 0.2 – 4.1s and an average frequency of 235 Hz. Pulse sounds lasted only approx. 0.06s with a frequency range of 20 Hz – 2.1 kHz. Remaining sounds were grouped as miscellaneous. Cummings *et al.* (1974) later documented a very strong pulse sound resembling a gunshot.

Clark (1982) later divided SRW calls into six types; upcalls, downcalls, constant calls, high calls, hybrid calls and pulsive calls. Two other sound types, blows and slaps were also documented. The most common call type observed was the upcall. Upcalls had a frequency range of 50 – 200 Hz with a duration of 0.5 – 1.5s, downcalls had a frequency range of 100 – 200 Hz with a duration of 0.5 – 1.5s, constant calls had a frequency range of 50 – 500Hz with a duration of 0.5 – 6s, high calls had a frequency range of 200 – 500 Hz with a duration of 0.5 – 2.5s, hybrid calls had a frequency range of 50 – 500 Hz with a duration of 0.5 – 2.5s and pulse calls had a frequency range of 50 – 200 Hz with a duration of 0.5 – 3.5s (Clark 1982). These calls can be compared to Cummings *et al.* (1971, 1972); upcalls correspond to belches, downcalls correspond to simple moans, constant calls correspond to complex moans and high calls, hybrid and pulsive calls correspond to pulses.

A current PhD study by Trudi Webster looking at a population of Southern Right Whales in New Zealand divided vocalisations into five types; upcalls, constants, screams, gunshots and low rumbles (Webster & Dawson 2011). Webster & Dawson (2011) found all vocalisations to be predominantly below 1 kHz, with some harmonics extending to 5 KHz. This study reported an average peak frequency of calls of 156 Hz, and an average duration of 0.99s; the gunshot had the shortest duration of 0.01s and the low frequency rumble the longest duration of 22.11s. Again, the most common call was the upcall with an average peak frequency of 127 Hz and an average duration of 0.74s (Webster & Dawson 2011).

Similarly, North Pacific RW calls were divided into five types; upcalls, down-up calls, downcalls, constants and unclassified (McDonald & Moore 2002). The most common call type was the upcall, with a frequency range of 90 – 150 Hz and an average duration of 0.7s (McDonald & Moore 2002). North Atlantic RW calls were divided into six types; screams, gunshots, blows, upcalls, warbles and downcalls (Parks & Tyack 2005). NARW sounds have been recorded in the frequency range of 300-600 Hz, with sounds lower than 200 Hz or higher than 900 Hz rarely seen (Vanderlaan *et al.* 2003). The average call duration of NARW recorded in the Bay of Fundy, a feeding ground for migrating whales, was 0.42 ± 0.26 (Vanderlaan *et al.* 2003).

The repertoire of SRW calls can be divided into two functional subdivisions; discrete calls (upcalls, downcalls and constant calls) associated with resting and swimming whales, and highly variable, integrated signals (hybrid and pulsive calls) associated with groups of active whales and sexually active groups (Clark 1982, 1983). The rate of sound production in SRW's has been found to vary quite substantially depending on the sound type, the activity of the whales, the size of the aggregation and the sexual composition of the aggregation (Clark 1983). Webster & Dawson (2011) noted that vocalisation rates were highest in social groups, and Cummings *et al.* (1974) found that underwater sounds were most numerous, diverse and spectacular when the animals were courting or copulating. However, an earlier study by Cummings *et al.* (1971) found no association between call type and behaviour. Matthews *et al.* (2001) found moan rates of NARW were correlated with aggregation size; single individuals produced less moans than small aggregations, and small aggregations (2-10 individuals) produced less moans than larger aggregations (>10 individuals). In contrast, Clark et al. (2010) found no strong relationship between the number of NARW present and the number of calls detected.

Interestingly, although the upcall defined by Clark (1982) is similar to the belch sound defined by Cummings *et al.* (1971, 1972) the behaviour associated with the sound is different. Cummings *et al.* (1972, 1974) reported this sound was common among mating whales and was likely to be part of breeding behaviour, while Clark (1982) found these calls were associated with swimming and resting behaviours. Clark (1982) suggests that perhaps nearby swimming or resting animals were responsible for these sounds rather than the mating animals, although this was not obvious to the observers. Further studies are required to confirm this theory.

SRW's can differentiate between the calls of their conspecifics and other underwater noises (Clark & Clark 1980). The physical characteristics of the upcall imply that it is best suited for long-range communication. Clark (1982) noted that the main energy band of the upcall coincided with the low noise band in the ambient noise spectrum, suggesting it has come under selective pressure from environmental conditions to increase the range of detection. The upcall is proposed to be the primary contact call of the right whale (Clark 1982; Cummings *et al.* 1974). A single swimming whale which made an upcall was joined by other single swimming whales which returned this call. The call is also the only call known to be made by newborn calves and vocalising exchanges occur when a mother and calf lose sight of each other (Clark 1982, 1983; Edds-Walton 1997). This suggests the upcall may relate to the identity of the caller (Clark 1982, 1983). A similar phenomenon is seen in bottlenose dolphins; Caldwell & Caldwell (1965) suggested that each dolphin has a signature whistle which is associated with its identity.

Unpublished raw data reviewed by Sacha Guggenheimer of data collected by Rob McCauley noted the presence of a speculated SRW offshore call named the 'spot call'. The duration of the 'spot call' is approximately 10 seconds, forming a symmetrical envelope of sound ranging between 22-28Hz (Figure 1) Guggenheimer & McCauley (2013) suggested that this call is an offshore call used by southern right whales during their migration along the southwest of Australia, although there is speculation that it may in fact be a cut-off segment of a z-call made by pygmy blue whales.

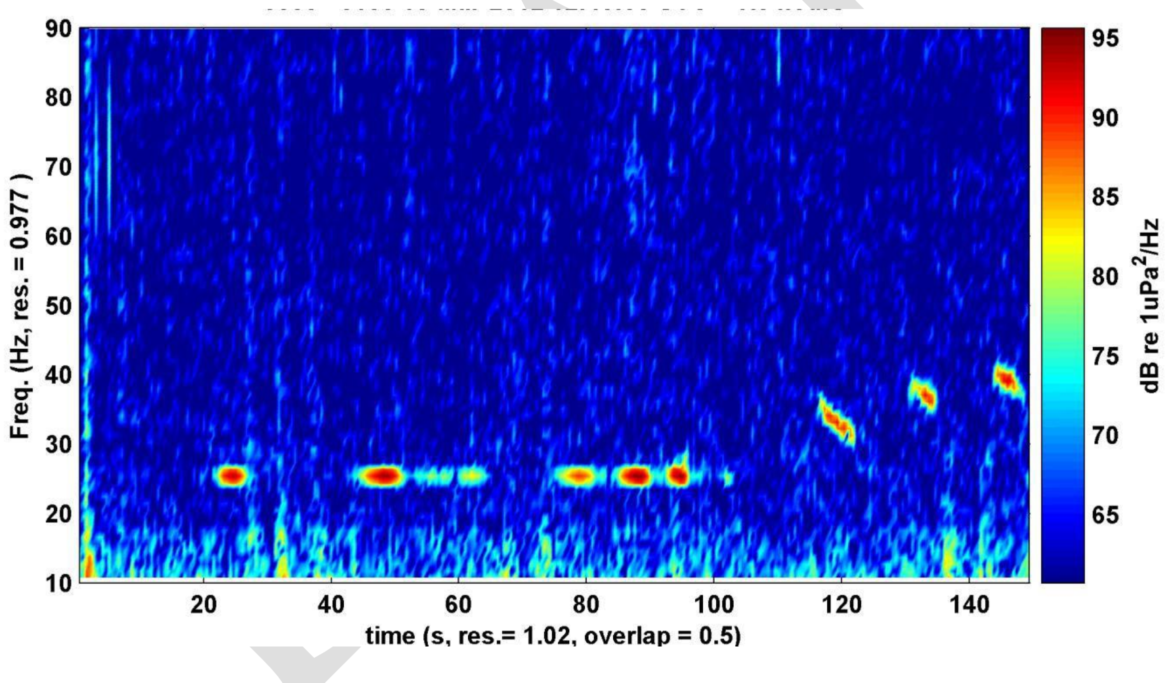


Figure 1: Spectrogram of a 'spot' call as described by Guggenheimer & McCauley (2013)

2.1.3 Importance of Passive Acoustic Monitoring

Passive acoustic monitoring (PAM) of SRW has the ability to increase the understanding of social interactions, offshore distribution, migration times and movement of whales between aggregation areas. PAM is being increasingly used by industry to mitigate noise impacts. Under New Zealand regulations at least two passive acoustic monitors must be present during all level 1 surveys (including most large-scale high power geophysical investigations that would routinely be employed in oil and gas exploration activities with dedicated seismic survey vessels) as a method of detecting cetaceans and ensuring the compliance of exclusion zones during operations (DoC 2013).

A relatively new approach for tracking, it has had success in revealing migration pathways and times of pygmy blue whales (*Balaenoptera musculus brevicauda*) down the west coast of Australia, across the Great Australian Bight and into the Bonney Upwelling in Victoria (McCauley *et al.* 2004). This method can have many low cost and high return outcomes for research. Noise loggers can be mounted in location and left to record for several months or more, requiring low field effort and giving a high return of 24 hour acoustic monitoring for the duration of the deployment.

Visual surveys have high importance for cetacean monitoring purposes, especially in understanding behaviour and for gathering mark-recapture data. However, they often only detect a small proportion of marine mammals in an area. These surveys are limited to daylight hours and are often biased by animal behaviour (i.e. an animal will only be detected if at the surface), weather conditions (i.e. observers detect less animals in poor weather conditions) and observer bias (Mellinger & Barlow 2003; Parks *et al.* 2011; Erbe 2013). In contrast, PAM can be used at night and in poor weather conditions, can detect vocalising animals in all directions and over much longer ranges and often detects higher numbers of animals than visual detection alone (Erbe 2013). For example, PAM of leopard seals in Antarctica found high numbers of males occupying the water, where previous visual surveys were biased towards females inhabiting the sea ice (Rogers *et al.* 2012) and a recent PAM study allowed for the successful classification and tracking of a number of beaked whales in turn identifying areas of habitat use that were previously unknown (Yack *et al.* 2013). Used in conjunction, PAM and visual surveys can provide high quality data about behaviour and movement of marine mammal species.

Passive acoustics has previously been used to investigate the migration of several cetacean species (Mellinger & Barlow 2003) and to estimate population size and seasonal variations in habitat use (Parks et al. 2011). PAM can be successful when collecting data on the number of animals passing through a migration route as they typically only pass once, however complications occur in areas of milling, as it is difficult to determine the number of times a single animal is vocalising and therefore been counted (Erbe 2013). Acoustics can supply continuous coverage of an environment, therefore providing information on seasonal presence (Mellinger & Barlow 2003; Parks *et al.* 2011). Passive acoustics can be particularly useful in offshore environments to determine the frequency of marine mammals in these areas, and to determine whether historically important offshore environments are still being used today (Mellinger & Barlow 2003). Knowledge of an animal's sound repertoire and the characterisation of their calls are a critical input for the success of PAM.

PAM also has its downfalls; not all species vocalise and all not all animals in a population vocalise, calling behaviour depends on the age and health of the animal, small cetaceans often travel in large groups and therefore the chances of one or more vocalising at any time is higher than larger cetaceans that often travel alone or in small groups, and lastly, calls change over time (Erbe 2013). PAM is also limited by a lack of understanding of many marine species' call types, as well as being able to detect these calls in a given environment. Active acoustic detection can be useful for species which do not vocalise or in high noise environments where masking may occur (Erbe 2013). To effectively use PAM for management, impact mitigation and species monitoring it is important to understand 1) the sound repertoire of the species of interest, 2) the sound transmission through the given environment and 3) the ambient noise including biological and anthropogenic sources (DEWHA 2008).

2.1.4 Impacts of underwater noise on marine fauna

The noise level of an ocean environment is determined by physical characteristics, as well as the level of biological, environmental and anthropogenic noise (Rice et al. 2014). Biological and physical sea noise is believed to play a critical role in the life functions of marine mammals in providing acoustic environmental cues (Erbe 2013). Cetaceans are heavily dependent on sound for finding food, communication, reproduction, detection of predators and navigation (Weilgart 2007). Animals migrating over large areas are exposed to a number of marine environments and therefore noise levels, within which they must forage, navigate and reproduce (Rice *et al.* 2014). Increasing levels of anthropogenic noise at low frequencies (<1 kHz) may result in masking of marine mammal communication, echolocation and the sounds of predators, prey and the environment (Stone & Tasker 2006; Weilgart 2007; Clark *et al.* 2009; Erbe 2013; Rice *et al.* 2014). The risk of masking is especially worrying for baleen whales, including right whales which specialise in low frequency calls (Clark *et al.* 2009). In certain circumstances, noise can also affect the vestibular system, reproductive system, nervous system and other tissues and organs of marine animals (Erbe 2013). The biological significance of acoustics is poorly understood, and there is currently no clear measure of what levels and impacts can threaten the survival of a population (Erbe 2013).

Marine seismic surveys often produce some of the most intense man made noises in the ocean (Gordon *et al.* 2004). As sound travels so well in water, air-gin signals can travel tens of kilometres, and have been reported nearly 4000km from the source vessel (Nieukirk *et al.* 2011), far beyond the view of visual observers (Malakoff 2002; Pamboris 2004). Although seismic air guns are thought to primarily concentrate around a frequency range of 10 – 200 Hz (DEWHA 2008), Goold & Fish (1998) found that noise from seismic airguns dominated frequencies between 200 Hz – 22 kHz at ranges of up to 2km from the source, and still exceeded background noise of up to 8 kHz at a distance

8km from the source. Exposure to this intense noise over long periods of time can have adverse effects on acoustically sensitive marine mammals including physical effects, perceptual effects, behavioural effects and indirect effects (Gordon *et al.* 2004). Unfortunately, the impacts of sound are hard to detect in species such as cetaceans due to difficulties associated with observations (Weilgart 2007).

As mentioned previously, high noise levels can result in the masking of biological sounds and thereby loss of communication among conspecifics and a reduced ability to navigate and detect predators and prey (Gordon *et al.* 2004; Clark *et al.* 2009; Erbe 2013; Rice *et al.* 2014). These are known as perceptual effects. It has been suggested that there are five potential mechanisms which animals may use to increase the detectability of their calls; 1) increasing the intensity of their calls (Scheifele *et al.* 2005; Parks *et al.* 2011a), 2) increasing the rate of calling (Buckstaff 2004), 3) increasing the duration of calls (Foote *et al.* 2004), 4) shifting the frequency of calls (Lesage *et al.* 1999) and lastly 5) waiting for the noise source to decrease before calling (Lesage *et al.* 1999). Parks *et al.* (2007) found North Atlantic and South Atlantic right whales produce calls with a higher average frequency and call less often in high noise environments. In some instances whales have decreased call rates or stopped calling altogether (IWC 2007). The IWC (2007) reported approximately 250 male Fin whales stopped singing for the entire duration of a seismic survey, resuming singing within hours to days after the survey ended.

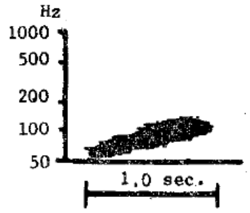
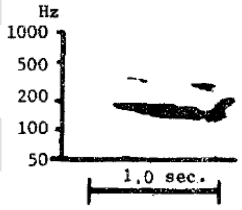
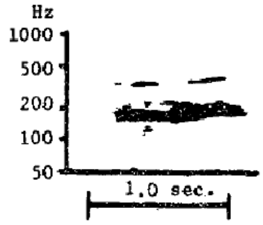
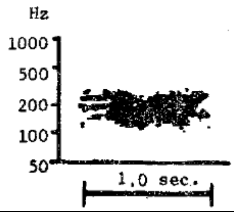
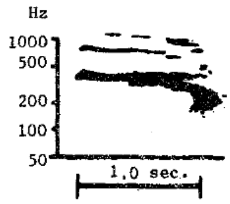
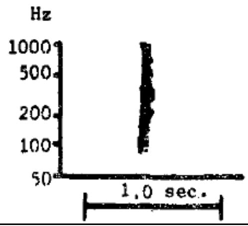
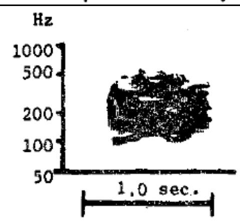
A documented behavioural response of seismic surveys is marine mammal stranding. In 2002 a seismic survey conducted in the Gulf of California was suspended due to the stranding and subsequent death of two beaked whales (Malakoff 2002). The same seismic vessel 'R/V Maurice Ewing' was also linked to the stranding of four beaked whales off the Galapagos Islands in 2000 (Gentry 2002). Another example of behavioural change as a result of anthropogenic noise is increased surface activity (Stone & Tasker 2006; IWC 2007; Brownell 2009). Melon-head whales are typically found offshore and in deep waters, however as a result of mid-frequency sonar exploration approximately 150-200 individuals were driven inshore and frequented waters as shallow as 4m or less (Brownell 2009). Additional behavioural responses may include disruption of foraging, avoidance of particular areas, disruption of mating and changes in dive and respiratory rates (Gordon *et al*. 2004; IWC 2007). Stone & Tasker (2006) reported fewer cetaceans feeding, fewer interacting with the vessel and its equipment, and more altering their course during times when the airguns were active, as well as significantly reduced sightings during periods of seismic shooting compared with periods when the airgun was silent. Tyack & Clark (1998) also noted shifts in the migration patterns of grey whales as to avoid a sonar source. An ongoing study researching the behavioural response of Australian humpback whalesto seismic surveys hopes to determine if and when whales respond to the noise source, and to determine if cow-calf pairs are more sensitive than males to the noise (Cato *et al.* 2012). This study also includes any vocal responses such as a change in song or social sound production (Cato *et al.* 2012).

Physical effects may include damage to body tissues and organs, damage to ears, permanent or temporary threshold shifts and stress (Gordon *et al.* 2004). It is believed that the body tissues of marine mammals become super-saturated during long dives (Ridgeway & Howard 1982) which can have serious implications as a result of a change in behaviour of increased diving activity. Noise induced hearing loss in the form of Temporary Threshold Shift (TTS) has been found in bottlenose dolphins that were exposed to just a few milliseconds of seismic noise (Finneran, et al. 2005), as well as bottlenose dolphins and beluga whales that were exposed to one second sonar signals (Schlundt, *et al.* 2000). Autopsies of some animals involved in mass stranding events in areas of seismic exploration have found signs of physical damage including chronic and acute tissue damage as a result of gas and fat emboli, haemorrhaging in the acoustic fats and other legions consistent with acute trauma (Jepsen et al. 2003; Gordon et al. 2004).

Lastly, indirect effects may be a reduction in prey availability, thereby reducing feeding rates (Gordon *et al.* 2004). Reduced catch rates have been reported for a number of fish species (McCauley 1994), as well as evidence of damage to fish auditory structures, as a result of high anthropogenic noise (McCauley *et al.* 2003). If high noise levels result in prey becoming less accessible either due limited numbers, avoidance of areas or a lack of echolocation it is likely that marine mammal distributions and feeding rates will be affected (Gordon *et al.* 2004). Another important factor to consider is that prey species may become damaged or disorientated and inadvertently attract marine mammals to the noise source, which will then increase the mammals level of exposure (Gordon *et al.* 2004).

2.2 Example of acoustic repertoire

Table 1: Southern right whale acoustic repertoire as described by Clark (1982)

Name	Characteristics	Example
Upcall	Low, tonal, FM upsweeps Major energy 50 – 200 Hz Duration 0.5 – 1.5 sec Simple, uniformly tonal, frequency increases toward end of sound	
Downcall	Low, tonal FM downsweeps Major energy 100 – 200 Hz Duration 0.5 – 1.5 sec Simple, uniformly tonal	
Constant	Tonal with very, little FM Major energy 50 – 500 Hz Duration 0.5 – 6 sec Simple, uniformly tonal	
Pulsive	Complex mixtures with amplitude modulation or noise and/or FM Major energy 50 – 200 Hz Duration 0.5 – 3.5 sec Usually very harsh or growly	
Hybrid	Complex mixtures of FM sweeps or amplitude modulation Major energy 50 – 500 Hz Duration 0.5 – 2.5 sec Multiple frequency shifts, often end in downsweep, pulsive at the end	
Slap	Noisy, broadband sharp onset Major energy 50 – 1000 Hz Duration 0.2 sec When produced underwater very intense	
Blow	Noisy, broadband Major energy 100 – 400 Hz Duration 0.5 – 26 sec Sometimes tonal like a long moan, sometimes noisy and pulsive	

2.3 Project objective

1) To characterise the sound repertoire of Southern Right whales in the Great Australian Bight, South Australia.

3. Methods

3.1 Study site

Fowlers Bay is in South Australia (31°59'18.43"S, 132°26'13.96"E) (Figure 2) approximately 170 km south-east of the Head of Bight, the primary Southern right whale aggregation area in Australia. Fowlers Bay was chosen as the study site for acoustic monitoring due to vessel access and availability and a recent increase in whale occupancy including females with calves observed residing in the bay for extended periods of time.

Figure 2: A satellite image of the Fowlers Bay study area (Source: Google Earth)

3.2 Acoustic recordings

Vocalisations were recorded using a HTI-96-MIN hydrophone with a built in preamplifier (with a flat response between 2 Hz and 30 kHz) and a Jammin Pro HR-5 recorder with a 96 kHz sampling rate, and stored as 24-Bit WAV files. Prior to field deployment, the recording system was calibrated with white noise of a known level to determine the influence of the recorder (including the recorder gain). The white noise recording was done in an aluminium box to minimise electrical interference. The calibration curve was then combined with the sensitivity the HTI-96-MIN hydrophone provided by the manufacturer (-163.9 V/µPa). These values were applied to the data in post-processing.

During recordings the hydrophone was lowered over the stern of the boat on the port side to a distance of approximately half the water depth. An on board GPS was used to determine the water depth at each location. Recordings commenced once whales were observed and all vessel noise had ceased. Recordings were on average 5 minutes duration.

3.3 Data processing and analysis

All recordings were stored as WAV files and analysed using Adobe Audition CS6 (Adobe Systems Inc. 2013) to allow the playback of audio files in conjunction with viewing of the spectrogram. Vocalisation analysis was performed independent of the context in which they were produced and the identity of the animal. The call duration, minimum frequency, maximum frequency and call type was recorded. Spectrograms were created using Matlab R2013a (The MathWorks Inc., Natick, M. A. 2000), however some calls were faint and not clearly visible in Matlab spectrograms. To maintain uniformity a screen shot of Audition spectrograms was used in our results.

4. Results

4.1 Data summary

A total of 111 minutes and 37 seconds of data was recorded over the three day period from 24 August 2013 to 26 August 2013 (Table 2). Three hydrophone recordings taken on 24.8.2013(File 16, file 17, file 18) were done so with the boat running and noise below approximately 80 Hz was masked. As a result no calls were characterised because the minimum frequency could not be seen. In file 16 there were two upcalls and one constant call visible, and in file 17 one upcall was seen. On the 24.8.2013 calls were recorded around the coordinates of 31°57.89'S, 132°27.35'E.

A total of 32 SRW calls were characterised (Table 3). Of these calls 23 were upcalls, 8 were constant and 1 call was unknown. No downcalls, hybrid or pulse calls were recorded.

Table 2: Effort, call type and number of calls recorded and characterised over the three day period at Fowlers Bay

Date	Time period recorded	Total recording time (mins)	Call type							Total number of calls
			Upcall	Downcall	Constant	Hybrid	Pulse	Unknown	Non - SRW	
24.8.13	11.47 – 15.56	53.63	✓	✓	✓	✗	✗	✓	✗	32
25.8.13	13.55 – 17.00	36.11	✗	✗	✗	✗	✗	✗	✓	++
26.8.13	11.34 – 12.44	21.88	✗	✗	✗	✗	✗	✗	✗	-

Table 3: Total number of Southern right whale calls recorded and characterised

Date	Real Time	File name	Call duration (s)	Min freq	Max freq	Call type	Associated observations
24.8.13	14.30	New_REC00008	1.06	58	161	Upcall	Socialising
24.8.13	14.30	New_REC00008	0.75	86	179	Upcall	Socialising
24.8.13	14.33	New_REC00008	0.86	57	208	Upcall	Socialising
24.8.13	14.33	New_REC00008	0.85	57	155	Upcall	Socialising
24.8.13	14.51	New_REC000013	0.67	84	183	Constant	Pec slapping
24.8.13	14.52	New_REC000013	0.73	63	168	Upcall	Pec slapping
24.8.13	14.52	New_REC000013	0.74	62	215	Upcall	Pec slapping
24.8.13	14.52	New_REC000013	1.37	49	177	Constant	Pec slapping
24.8.13	14.53	New_REC000013	0.42	76	120	Constant	Pec slapping
24.8.13	14.53	New_REC000013	0.43	76	155	Upcall	Pec slapping
24.8.13	14.53	New_REC000013	0.67	73	161	Constant	Pec slapping
24.8.13	14.53	New_REC000013	0.54	60	152	Upcall	Pec slapping
24.8.13	14.53	New_REC000013	0.55	50	172	Upcall	Pec slapping
24.8.13	14.53	New_REC000013	0.81	117	175	Constant	Pec slapping
24.8.13	14.53	New_REC000013	0.59	79	178	Upcall	Pec slapping
24.8.13	14.54	New_REC000014	0.77	73	252	Upcall	Milling, courting
24.8.13	14.55	New_REC000014	0.64	82	116	Constant	Milling, courting
24.8.13	14.55	New_REC000014	0.97	69	267	Upcall	Milling, courting
24.8.13	14.55	New_REC000014	0.59	93	224	Upcall	Milling, courting
24.8.13	14.55	New_REC000014	0.58	65	139	Upcall	Milling, courting
24.8.13	14.55	New_REC000014	0.62	77	162	Upcall	Milling, courting
24.8.13	14.56	New_REC000014	0.66	72	154	Upcall	Milling, courting
24.8.13	14.56	New_REC000014	0.68	64	167	Upcall	Milling, courting
24.8.13	14.57	New_REC000014	0.77	81	159	Upcall	Milling, courting
24.8.13	14.58	New_REC000014	2.43	88	140	Constant	Milling, courting
24.8.13	14.58	New_REC000014	1.58	211	329	Unknown	Milling, courting
24.8.13	14.58	New_REC000014	0.99	59	176	Upcall	Milling, courting
24.8.13	14.59	New_REC000014	0.75	68	163	Upcall	Milling, courting
24.8.13	14.59	New_REC000014	1.03	89	117	Constant	Milling, courting
24.8.13	15.11	New_REC000015	0.88	95	164	Upcall	Courting
24.8.13	15.12	New_REC000015	0.68	60	208	Upcall	Courting
24.8.13	15.13	New_REC000015	0.94	83	178	Upcall	Courting

4.2 Biological Sounds

Southern right whale calls were recorded inshore in the Bay within 500m from the shore and in water depths less than 10metres, while bottlenose dolphins whistles and unknown whale calls were only heard further offshore (>20m) along the migration path info Fowlers Bay.

4.2.1 Southern right whale

Only two SRW call types were identified; upcalls and constant calls, with one unknown call found. The average maximum frequency of all calls was 177.59 ± 43.80 Hz and the average minimum frequency was 77.68 ± 28.32 Hz. The average duration of all calls was 0.83 ± 0.38 seconds. The average maximum frequency of upcalls was 181.08 ± 32.86 Hz and the average minimum frequency was 70.30 ± 11.98 Hz. The average duration of upcalls was 0.73 ±0.16 seconds. The average maximum frequency of constant calls was 148.62 ± 28.76 Hz and the average minimum frequency was 82.25 ± 18.97 Hz. The average duration of constant calls was 1.0 ± 0.64 seconds.

Below are a number of spectrograms to show the call types (Figures 3 – 8).

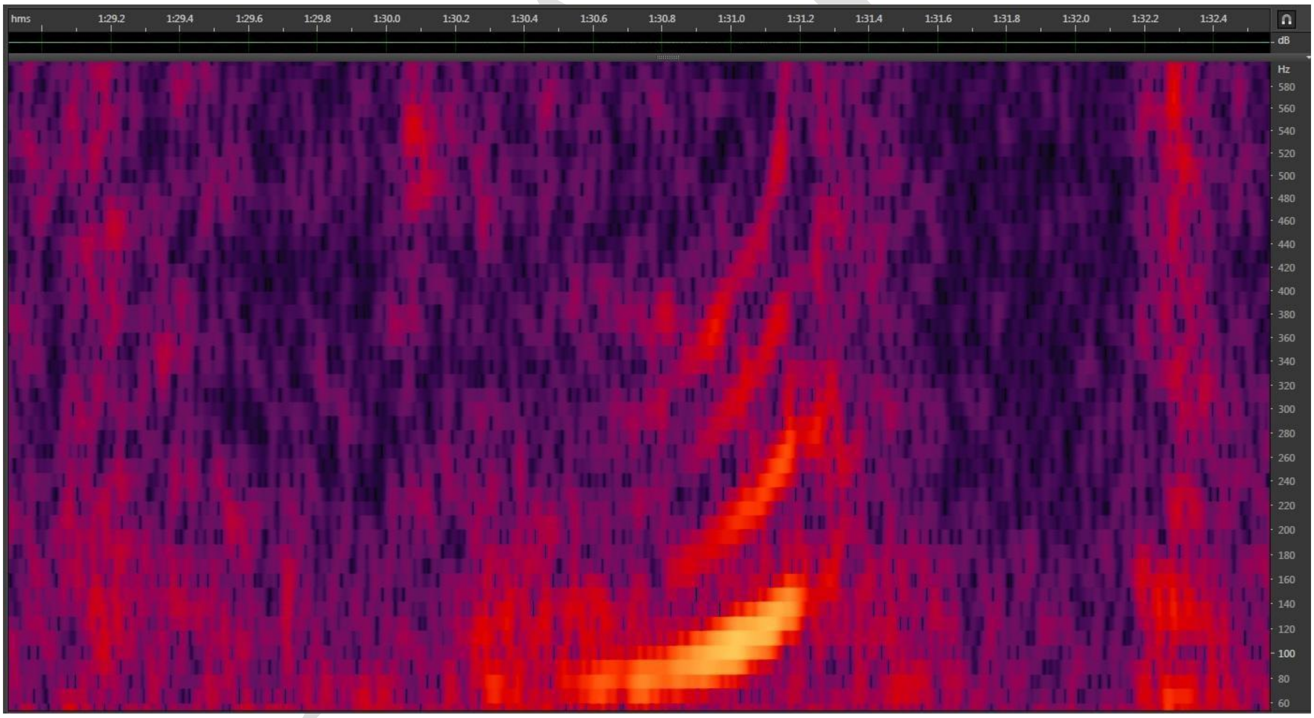


Figure 3: SRW Upcall

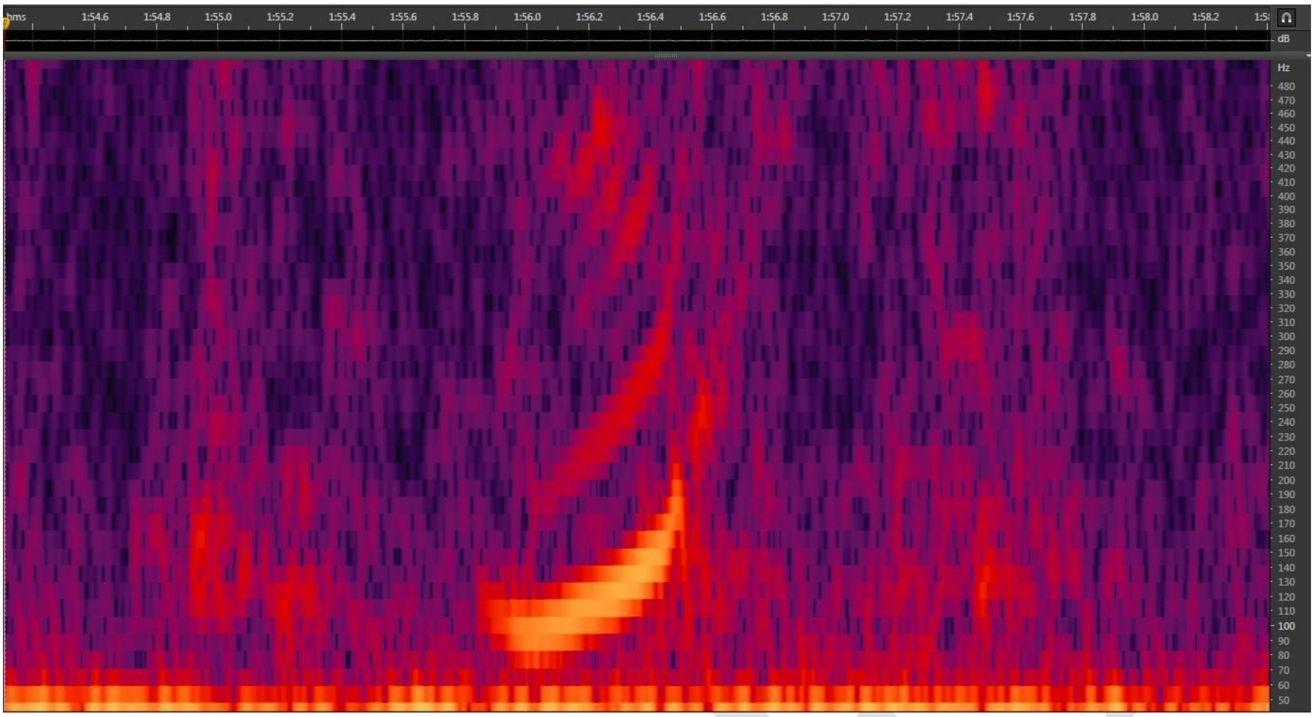


Figure 4: SRW Upcall

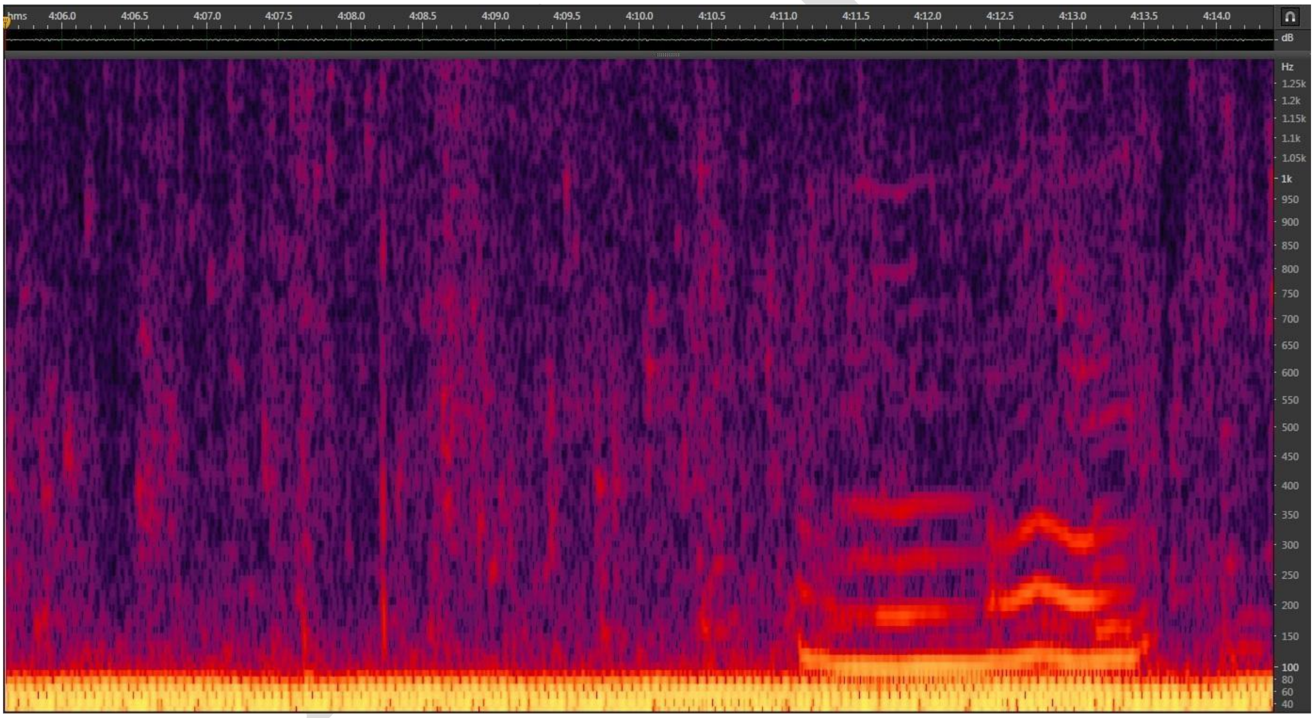


Figure 5: SRW Constant call

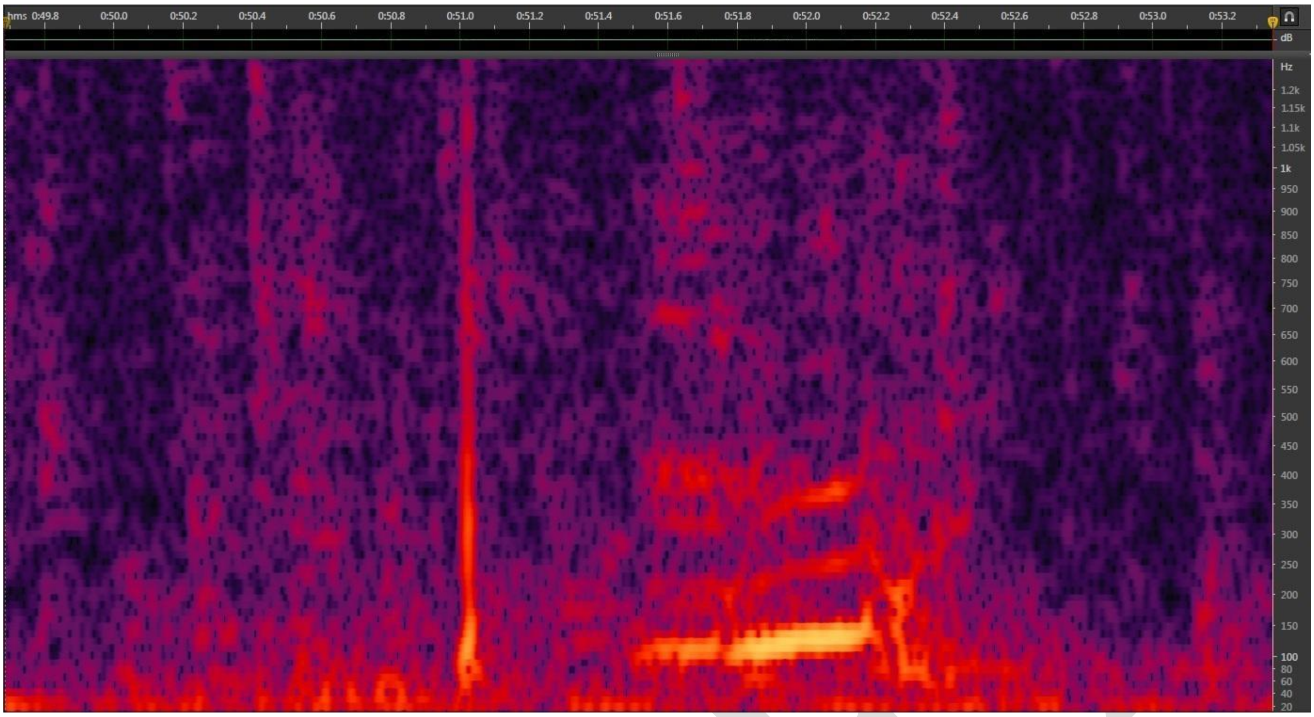


Figure 6: SRW Constant call

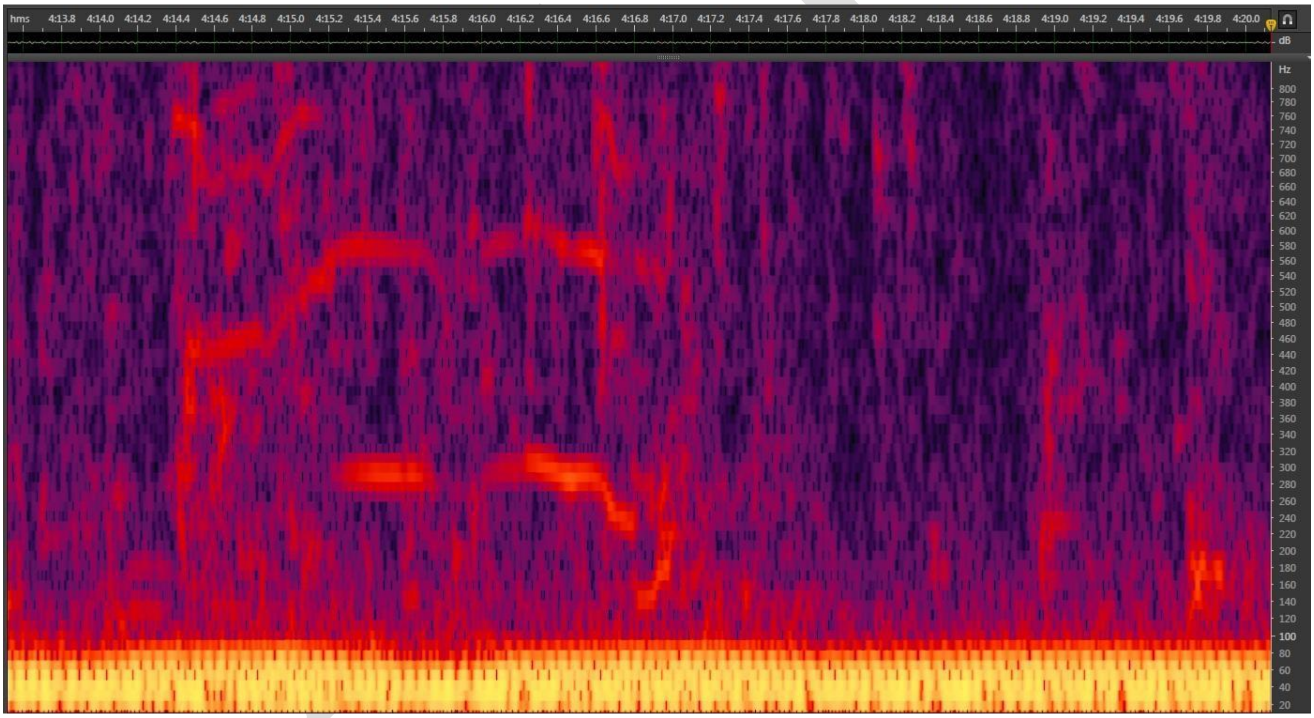


Figure 7: SRW Unknown call

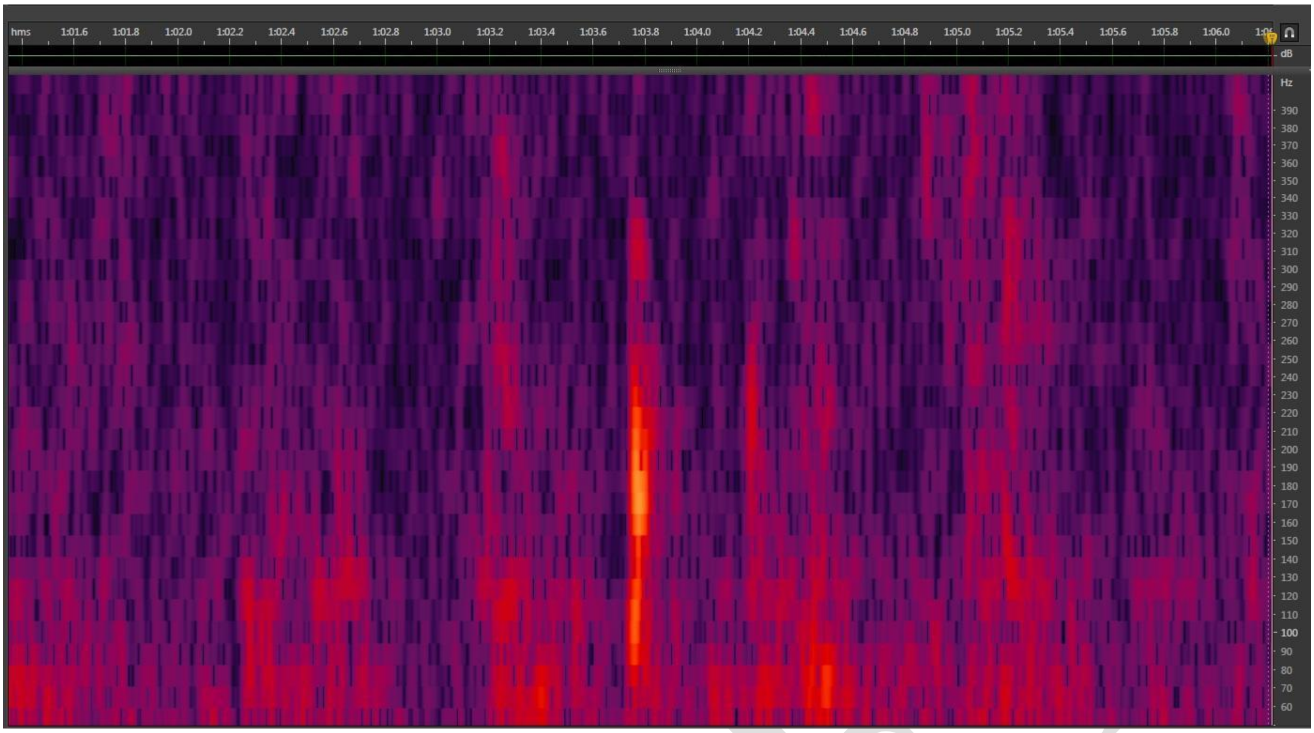


Figure 8: SRW Pec slap

4.2.2 Bottlenose dolphin

Bottlenose dolphin whistles were heard offshore from Fowlers Bay along the migration parth into the bay on 25 August 2013. These whistles were high frequency in the range of 1.2 – 1.4 kHz (Figure 9).

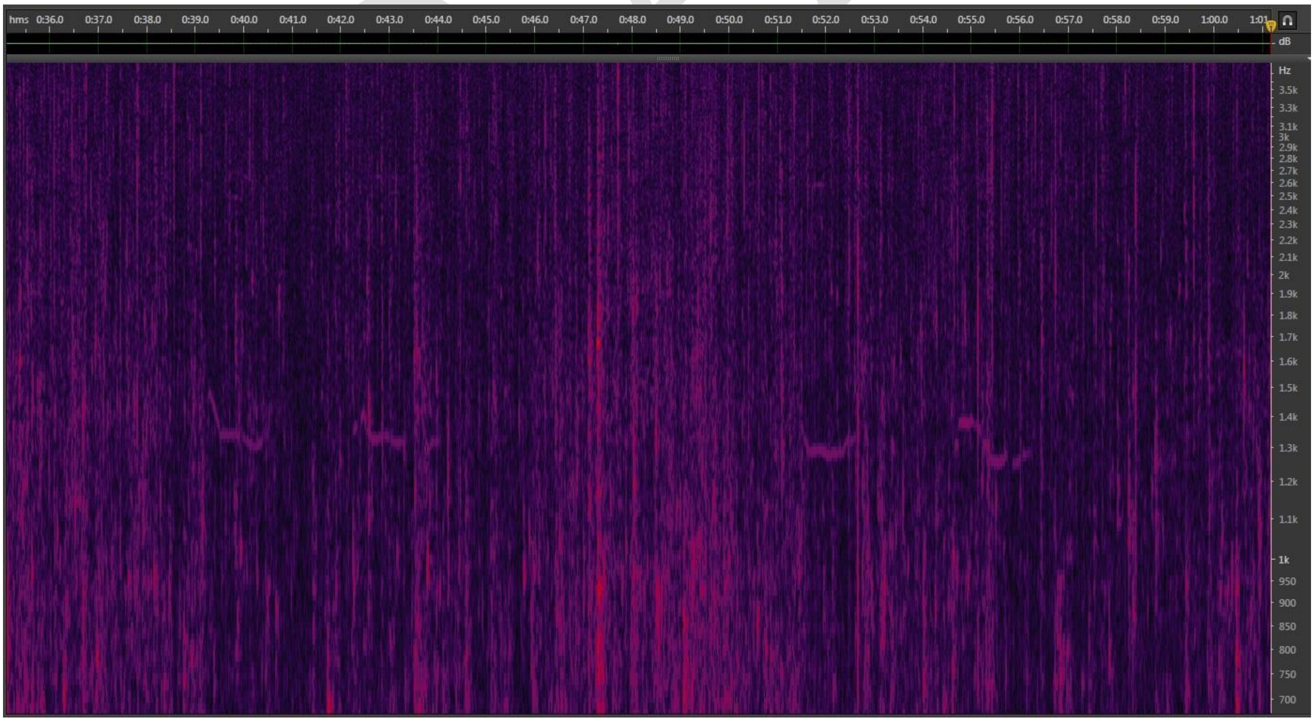


Figure 9: Dolphin whistles

4.2.3 Unknown whale

Seven calls were heard offshore from Fowlers Bay along the migration path into the bay on 25 August 2013. The call (Figure 10) looks similar to the down-up call described for North Pacific right whales (Clapham *et al.* 2009) with a slightly different frequency band. However, the call also looks and sounds similar to a humpback whale ‘wop’ call. Sighting records have shown humpback whales do frequent the Fowlers Bay area throughout the season.

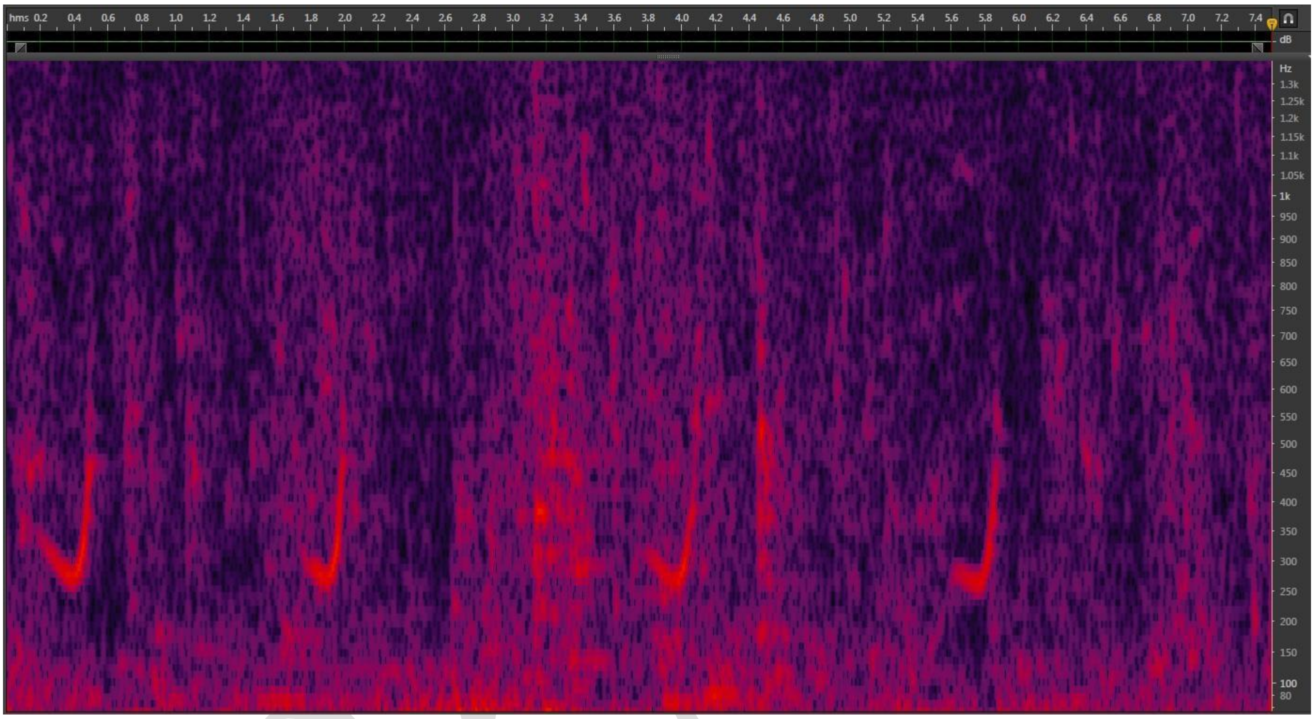


Figure 10: Unknown whale call

5. Conclusion

The 2013 pilot study and acoustic data collection and analysis shows that southern right whales vocalisations can successfully be collected from Fowlers Bay, South Australia. The data collection and analysis methods are appropriate for a characterisation study of southern right whale sound repertoire. The 2013 sample size of acoustics limited the detection of a range in call types, however 32 calls were successfully characterised including 23 upcalls, 8 constant calls and 1 unknown call. A 2014 vessel based acoustic study at Fowlers Bay run by the Great Australian Bight Right Whale Study Team will expand this research and increase sample size to publish the sound repertoire of southern right whales in South Australia. The 2014 study will include opportunistic recordings using a hand held hydrophone and acoustic logger recordings from 13km offshore in 45m of water. The study aims to characterise inshore social calls and offshore long range calls of SRW for future use in passive acoustic monitoring to better understand SRW movements outside of known aggregation grounds.

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