A “13-Hz” short call recorded off Elephant Island, Antarctica – By which species is it emitted?

Student Research Project in

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Abstract

Over the last years passive acoustic recording devices were used frequently to observe baleen whales acoustic presence in the Southern Ocean. During previous analyses a low frequency call was detected that had not been observed before in recordings from the passive acoustic recording device at 61°00.88' S and 55°58.53' W off Elephant Island, Antarctica, further referred to as "13-Hz" short call. The name was chosen on the basis of the frequency and duration of the call. Due to signal characteristics of the sound and known acoustic presence from previous studies, fin and blue whales were considered as potential producers of this call. Previous analysis detected the "13-Hz" short call in Austral fall, therefore, data from March to June of 2014 were analysed to associate the hourly presence of the "13-Hz" short call with the presence of either '20-Hz' fin whale pulses or Antarctic blue whale z-calls. Additionally, the "13-Hz" short call characteristics were investigated (n = 75). Furthermore, temporal distances between single "13-Hz" short calls to vocalizations of fin and blue whales were investigated (n = 518). The "13-Hz" short call had a frequency range of 11 ± 1 Hz to 14 ± 1 Hz and a mean duration of 2 ± 1 seconds. The temporal distribution analysis showed a positive correlation between the occurrence of fin whale pulses and "13-Hz" short calls and a negative correlation of blue whale z-calls and the "13-Hz" short call. The investigation of the temporal distances between the "13-Hz" short call and fin and blue whale calls showed a non-normal distribution of the data for both species, but a more normal distribution of the data for blue whale z-calls, suggesting an association with fin whale pulses. Overall, the results indicate that fin whales could be the producers of the "13-Hz" short call, but further investigation is necessary to confirm this hypothesis. Further investigation could include analysis of more data as well as the use of a continuous passive acoustic recording, or the use of different methods such as tagging, simultaneous visual surveys and the comparison with vocalizations of other fin whale populations in different regions.

Introduction

Mysticeti or baleen whales are present in all oceans. They are filter feeders and often migrate over large distances from their high latitude feeding areas to low latitude breeding grounds (e.g. Edds-Walton 1997). Many marine organisms, including baleen whales, use vocalizations for communication, due to the fact that in water, sound is the most effective form of communication, as it travels faster and further than for example light (Tyack and Miller 2002). Acoustic behavior of baleen whales is known to play an important role on feeding grounds as well as breeding grounds as different vocalizations are associated with both feeding and breeding behavior (e.g. Croll et al. 2002; Jaquet et al. 2001; Stimpert et al. 2007; Watkins 1981). Marine mammal distribution and behavior can therefore be observed through their vocalizations using passive acoustic monitoring. Over the last few years the method was used frequently in surveys on marine organisms, including baleen whales (Mellinger et al. 2007; Oleson et al. 2007; Rankin et al. 2005; Stafford et al. 1999).

Several studies based on passive acoustic data from acoustic recorders were conducted and provided information about marine mammal distribution and migratory behavior (Širović et al. 2004; Širović et al. 2009; Thomisch et al. 2016)

In the Weddell Sea, the Hybrid Antarctic Float Observation System (HAFOS), an oceanographic observing system, provides the infrastructure for passive acoustic recording devices and supports the investigation of marine acoustic behavior (Rettig et al. 2013). Therefore, the passive acoustic recorders deployed within the HAFOS array help to observe the baleen whales in an environment that is otherwise difficult to access and to conduct visual surveys, due to heavy sea ice coverage and adverse weather conditions (Mellinger et al. 2007). Fin whales (*Balaenoptera physalus*) have repeatedly been sighted during visual surveys off Elephant Island, Antarctica (Burkhardt and Lanfredi 2012; Joiris and Dochy 2013) as the waters around Elephant Island are known to be potential feeding grounds for baleen whales due to the high krill abundance (Siegel et al. 1998). Therefore, in 2012 a passive acoustic recording device was deployed off Elephant Island to provide information about marine mammal distribution and migratory behavior. During previous analyses a new low frequency short acoustic signature, located in the frequency band between 5 to 15 Hz, was observed in recordings by the passive acoustic recorder off Elephant Island, Antarctica, further referred to as 13-Hz call or "13-Hz" short call (Leroy 2018; Mattmüller and Burkhardt, personal communication).

Generally, in this area two baleen whales are known to vocalize at these low frequencies, fin whales and (Antarctic) blue whales (*Balaenoptera musculus (intermedia)*) (Mellinger et al. 2007). A previous study conducted off Elephant Island observed both baleen whales to be acoustically present yearround (Meister 2017) and therefore being potential candidates for the emission of the newly found call.

The most common vocalization of fin whales is the so called ‘20 Hz’ pulse (see Figure 1) (Watkins 1981), hereinafter referred to as fin whale pulse. It is described as a short downsweep of 0.5 – 1.5 seconds typically ranging from 15 – 31 Hz (Sirovic et al. 2006; Širović et al. 2004; Watkins et al. 1987). Additionally, a (seemingly) simultaneously produced pulse at 89 Hz is observed in the Southern Ocean (see Figure 1) (Širović et al. 2004). The frequency range of this additional pulse shows variation between regions (Širović et al. 2009). The mean intercall interval for fin whale pulses is reported to be around 9 to 12 seconds (Širović et al. 2004; Thompson et al. 1992) with an inter-pulse sequence interval of approximately 30 seconds (Širović et al. 2004). Additionally, in the northern hemisphere backbeats have been reported to be part of fin whale vocalizations (Figure 2) (Clark et al. 2002; Soule and Wilcock 2013). They are described as narrow-band and have a center-frequency of 16 to 17 Hz. They always occur associated with a so called 18 Hz pulse described by Soule and Wilcock (2013) as a downswept pulse with a center frequency of 17 to 20 Hz, which is identical to the 20 Hz pulse described by Watkins (1981). In the northern hemisphere Thompson et al. (1992) recorded additional sounds in the presence of fin whales such as short downsweeps or upsweeps occurring between 18 and 310 Hz.

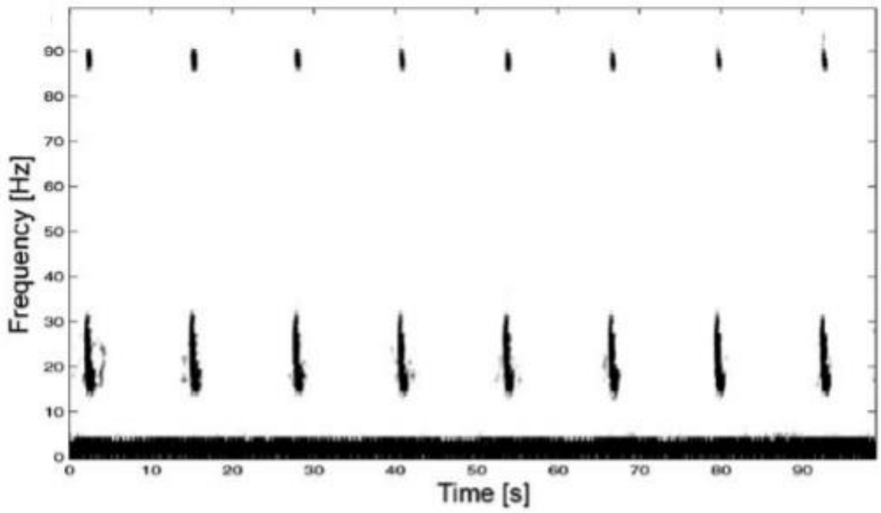


Figure 1: Spectrogram of fin whale pulses with upper 89 Hz component, modified after Širović et al. (2004)

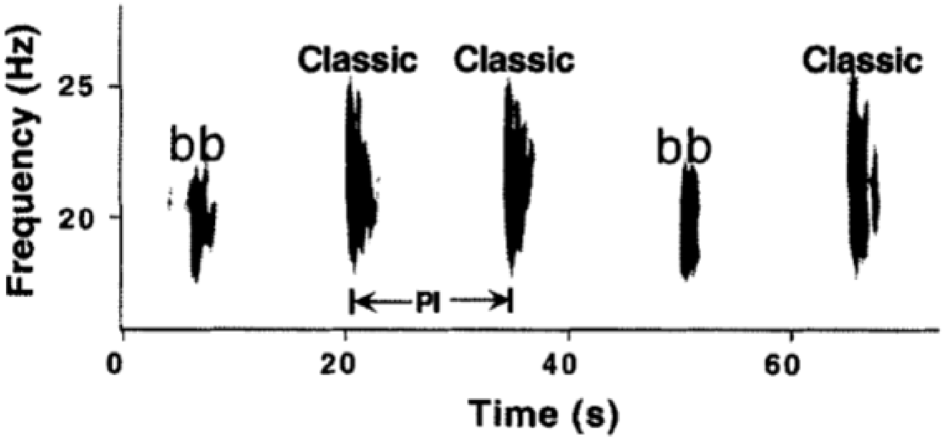


Figure 2: Spectrogram of classic ´20 Hz´ fin whale pulses and backbeats, modified after Clark et al. (2002).

The most common vocalization of Antarctic blue whales are the so called z-calls, hereinafter referred to as blue whale z-call (see Figure 3). Previous studies describe the sound as follows. Starting with a 8 – 9 second long sound between 26 – 29 Hz which is followed by a short downsweep to approximately 19 Hz and ending with a slight downsweep to 18 Hz (Rankin et al. 2005; Širović et al. 2004). The mean intercall interval is about 62 seconds (Širović et al. 2004).

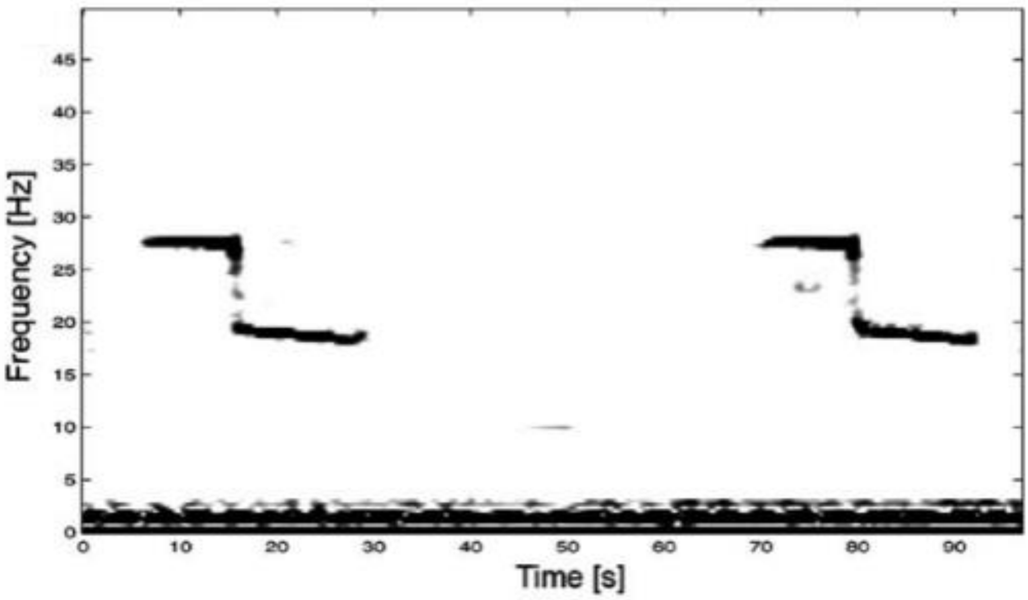


Figure 3: Spectrogram of Antarctic blue whale z-calls, modified after Širović et al. (2004).

Additionally, fin whales and blue whales, among other baleen whale species, are known to produce so called frequency-modulated downsweep calls (FM-calls) (see Figure 4). For fin and blue whales, they are located between 76 and 40 Hz and last about 3 seconds (Rankin et al. 2005; Širović et al. 2004).

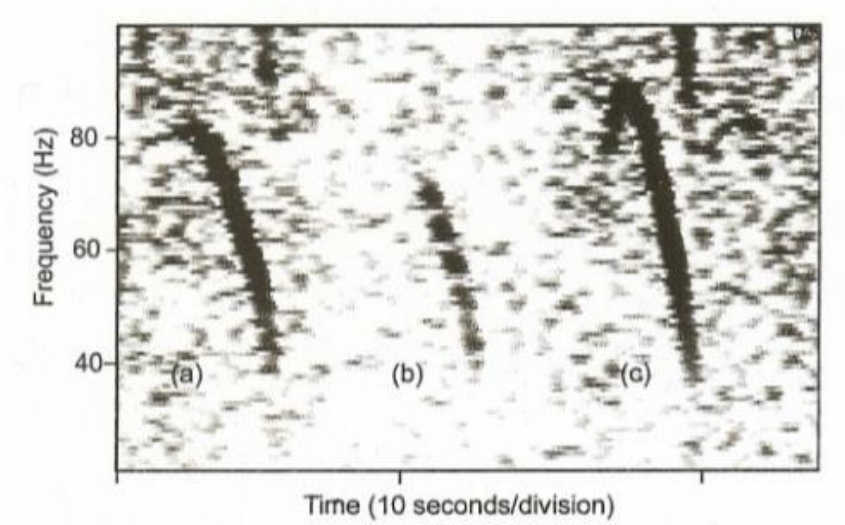


Figure 4: Spectrogram of 3 different blue whale FM-calls, (a) high-frequency downsweep, (b) amplitude-, modulated downsweep, (c) complex variation of the high frequency downsweep, modified after Rankin et al. (2005).

Due to the frequency characteristics of the "13-Hz" short call and the above described frequency characteristics of the blue whale and fin whale vocalization both species might be possible sources for the new call. The goal of this project was to describe the call and attribute it to a species.

Linking a sound in passive acoustic recordings to a certain species is essential for passive acoustic studies (Baumgartner et al. 2008; Stafford et al. 1999).

One method to assign an unknown sound to a certain species is tagging i.e. attaching a multi-sensor acoustic recording tag to an animal to record its vocalizations. Risch et al. (2014) used multi-sensor acoustic recording tags to attribute the bio-duck sound, which has been a sound with unknown origin for decades, to Antarctic minke whales. A study in the North Atlantic used recordings from tags to attribute sounds to certain behaviors of humpback whales (Stimpert et al. 2011).

Another approach was taken by a study in Mariana Trench Marine National Monument that recorded a complex baleen whale call of unknown origin (Nieukirk et al. 2016). By analyzing the characteristics of the new call and comparing it to known vocalizations of present baleen whale species, they found it to be most likely produced by minke whales. Similarly Heimlich et al. (2005) attributed sounds recorded in the eastern tropical Pacific to Bryde's whales based on the resemblance to known calls from this baleen whale species.

A further method is the application of a temporal correlation analysis with known presence of whale species through visual surveys and concurrent acoustic recordings. Gedamke et al. (2001) used simultaneous visual surveys and hydrophone arrays to confirm the dwarf minke whale as the origin of the "star-wars" sounds, recorded previously in the waters east off Australia. Similarly, Baumgartner et al. (2008) observed low frequency downsweep vocalizations east of Cape Cod of unknown origin. Through a correlation analysis with other present species the authors found sei whales to be most

likely emitting the calls. A similar approach will be taken here by counting the number of fin whale pulses and blue whale z-calls in relation to “13-Hz” short calls.
Additionally, time intervals between consecutive calls can be used to attribute an unknown call to a certain species. When describing baleen whale vocalization the intercall intervals or interpulse intervals often play a crucial role (Gedamke et al. 2001; Širović et al. 2004; Stafford et al. 1999). Stafford et al. (1999) used the interpulse spacing of the recorded sounds as one characteristic to highlight, that the potential origin of the recorded pulse series in the eastern tropical Pacific, might be fin whales, even though they have not been reported frequently in the study area. Similarly, a study conducted in the eastern tropical Pacific used the intercall or interphrase intervals as one characteristics to compare known Bryde’s whale sounds to sounds of unknown origin (Heimlich et al. 2005). Although no comparable sounds have been reported so far, the intervals between the unknown “13-Hz” short call and known blue whale vocalizations as well as known fin whale vocalizations will be measured to investigate temporal correlations between the known call types and the newly found call. Additionally, the results presented here might help in the future to identify similar calls in different recordings and therefore confirm the origin of the “13-Hz” short call.

In this project the frequency range and duration of the “13-Hz” short calls will be described. Additionally, the following hypotheses will be tested to investigate which species is responsible for the call: (1) The presence of “13-Hz” short calls is positively correlated with the presence of fin whale ‘20 Hz’ pulses. (2) The presence of “13-Hz” short calls is not positively correlated with the presence of blue whale z-calls. (3) The intervals of fin whale pulses to “13-Hz” short calls are not normally distributed. (4) The intervals of blue whale z-calls to “13-Hz” short calls are normally distributed.

Materials and Methods

Passive acoustic data collection

A recording device type AURAL (Multi-Électronique Inc., Canada) to gather passive acoustic data was attached to a deep-sea mooring. The mooring, which was deployed at a depth of 320 m, is located next to the Hybrid Antarctic Float Observation System (HAFOS) array, which collects oceanographic information of the pelagic waters in the Southern Ocean (see Figure 5). The recording device was attached to the deep-sea mooring at 61°00.88' S and 55°58.53' W at a depth of 210 m (see Figure 6). The recorder was deployed on 16th of January 2013 during Polarstern research cruise PS81 and recovered on the 10th of February 2016 during Polarstern research cruise PS96.

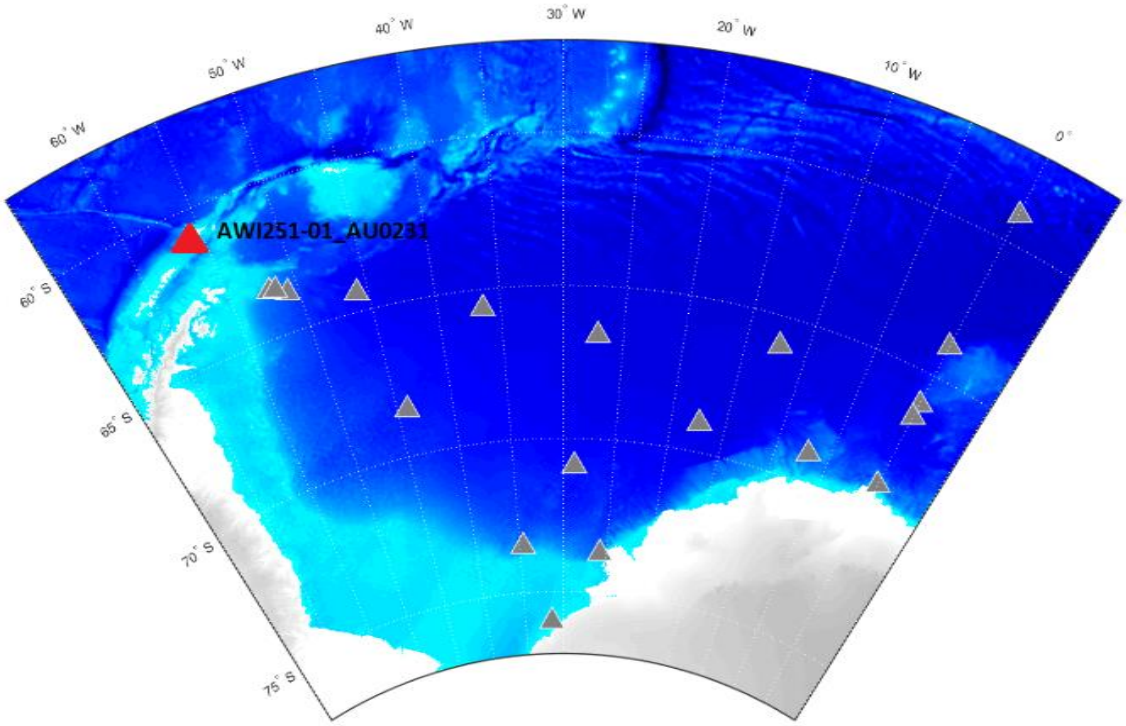


Figure 5: Locations of the autonomous passive acoustic recording devices within the HAFOS array in the Southern Ocean. Red triangle represents the position of the passive acoustic recorder, AWI 251-01 AU231, analysed during this study and grey triangles show the location of the other moorings within the HAFOS array © AWI.

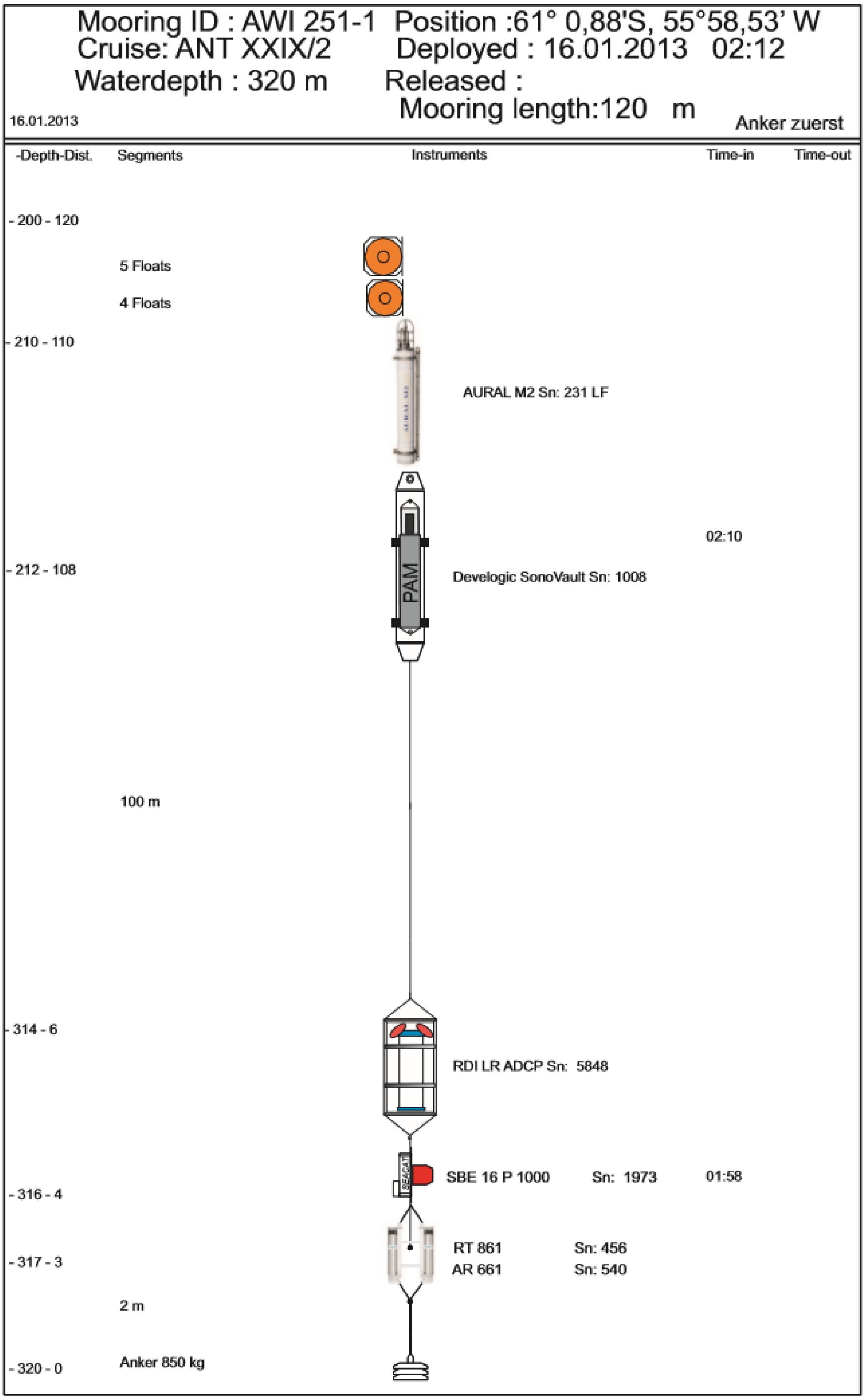


Figure 6: Mooring scheme of the mooring AWI251-1 deployed off Elephant Island on the 16th of January 2013 and retrieved on the 10th of February 2016. The recorder type AURAL was attached at 210 m. ©AWI.

The passive acoustic device recorded at 32 kHz and 16 bit sampling with a subsampling scheme of the first 5 minutes of every hour, resulting in 2 hours of recording per day. The subsampling scheme was used to be able to bridge a three-year deployment given the device's limited battery life and storage capacity. For my project I analysed the data from March to June 2014, totalling 244 hours of recordings. March to June were selected for analysis, because a previous preliminary analysis of the entire year of 2014 showed a presence of the "13-Hz" short call in these months (Leroy 2018). Before analysing, the data were decimated[1] to 500Hz to increase the frequency resolution of low-frequency signals.

Data analysis

Temporal distribution

Spectrograms were analysed visually and aurally with the bioacoustics software Raven Pro 1.4 (Bioacoustic Research Program 2011). Spectrograms were scanned for fin whale pulses, blue whale z-calls and the "13-Hz" short call. The spectrogram settings (Hanning window, overlap: 90 %, FFT: 1025 points, Frequency range: 0 – 88 Hz, Interval: 3:45 minutes, time resolution: 2 seconds, frequency resolution: 0.5 Hz) were kept constant over the entire analysis. When detecting a potential short call, it was zoomed in to verify the selection.

Not all files could be analysed due to noise in the frequency band of interest from 0 Hz to 30 Hz. In total 2243 files out of the initial 2928 files could be analysed and 685 files had to be discarded due to noise or noise in the frequency band of the "13-Hz" short calls (see Appendix Table 6 for details).

The tags applied to the spectrograms are summarized in Table 1.

Table 1: Tags applied to spectrogram analyses in Raven Pro 1.4

Tag	**Description**
s	"13-Hz" short call
s!	very good quality short call, used for frequency and duration measurements
b	blue whale z-call
f	fin whale '20 Hz' pulse
noise	file could not be analysed due to noise over the entire visible frequency range
noise in s band	file was discarded due to noise in the frequency band of 5 to 15 Hz as the possibility of detecting short calls was not given
mooring	mooring clacks/ vertical lines (might overlay fin whale calls)
none	no other tag could be found in the file
for interval measurements for short calls to fin whales and blue whales (measured from center time to center time)	
pf , ef	intervals for fin whales f <--pf (previous fin)--> s <--ef (ensuing fin)--> f
pb, eb	intervals for blue whales b <--pb (previous blue)--> s <--eb (ensuing blue)--> b

[1] Decimating: Method from signal-processing, custom written Matlab routine using a low pass filter to reduce the noise of the signals above 500 Hz and therefore minimize the influence of the high frequency signals followed by a downsampling by factor 1/64 from 32 kHz to 500 Hz. (also see Thomisch et al. 2016)

“13-Hz” short call measurements

To describe the frequency range and the duration of the new call, 75 short calls of very good quality recorded in March, April and May were measured with the spectrogram settings of Hanning window, overlap: 0 %, FFT: 500 points, Frequency range: 0 – 31 Hz, Interval: 1.30 minutes resulting in a time resolution of 1 second and a frequency resolution of 1 Hz.

Interval measurements

Figure 7 illustrates interval length measurements for pf, ef, pb and eb which were measured from center time to center time of the respective calls (interval measurement error was ± 2 s).

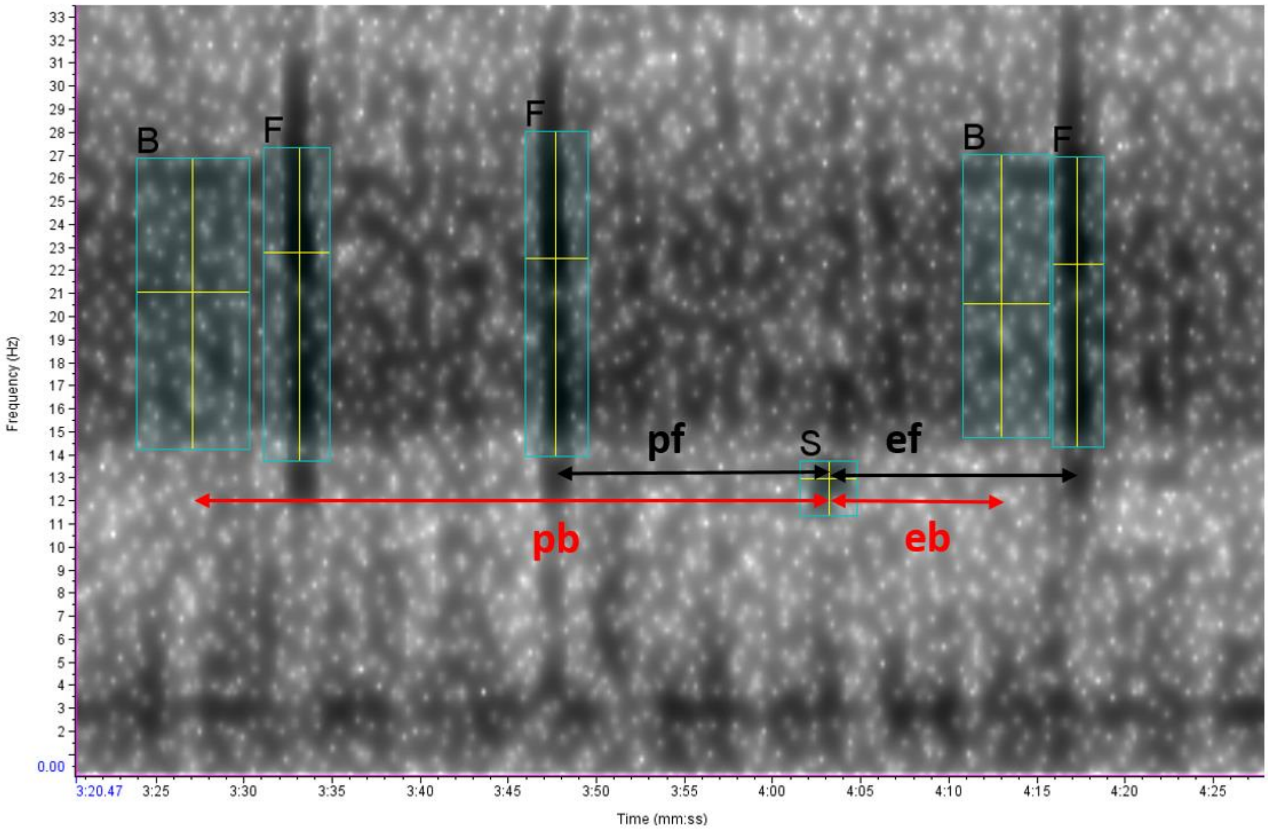


Figure 7: Spectrogram of May 12, 2014, 1 o'clock with selection of blue whale z-calls (B), fin whale pulses (F), "13-Hz" short calls (S) and interval measurements from center time to center time (vertical yellow line): pb = interval between “13-Hz” short call and the previous blue whale z-call, eb = interval between “13-Hz” short call and the ensuing blue whale z-call, pf = interval between “13-Hz” short call and the previous fin whale pulse, ef = interval between “13-Hz” short call and ensuing fin whale pulse. (Hanning window, overlap: 90 %, FFT: 1025, time resolution: 2 seconds, frequency resolution: 0.5 Hz)

Statistical analysis

The data were analysed statistically using R Studio Version 3.5.0 (R Core Team 2018). The graphs were generated using R Studio Version 3.5.0 and Microsoft Excel 2016.

Differences were accepted as statistically significant at $p < 0.05$ and all values were rounded to two digits if not stated otherwise.

“13-Hz” short call measurements

The means and the standard deviation of the “13-Hz” short call measurements were calculated using Microsoft Excel 2016. The values were rounded to zero digits, as the measurements time resolution and frequency resolution was 1 second and 1 Hz respectively. Values were further used to describe the frequency range and duration of the “13-Hz” short call.

Temporal distribution

The number of fin whale pulses, blue whale z-calls and “13-Hz” short calls were each plotted in a grouped bar plot using Microsoft Excel 2016 to analyse the frequency distribution of number of calls per file.

The mean number of calls per day were calculated and the weighted mean number of calls per day plotted over time (R package ‘graphics’, version 3.5.0). The weighted means were used for a better visualisation and comparison of the data. The means were weighted using the total mean number of calls per species. To display trends over time a cubic smoothed spline was fitted through the scatterplot with 20 degrees of freedom (R package ‘stats’, version 3.5.0).

Correlation analysis

To investigate the correlation of the occurrence of different call types the scatterplots of fin whale pulses versus “13-Hz” short calls and blue whale z-calls versus “13-Hz” short calls were plotted and a linear regression line (command lm from R package ‘stats’, version 3.5.0) was added to the plots (R package ‘graphics’, version 3.5.0) to display the relationship between the two call types. The R^2 value and the equation for the linear regression line were retrieved from the linear model (lm).

The temporal correlation of the fin whale pulse and the blue whale-z calls to the “13-Hz” short calls was investigated by cross-correlating (ccf in R package ‘stats’, version 3.5.0) the fin whale pulses and the blue whale z-calls with the “13-Hz” short calls. Additionally, Kendall’s rank correlation analysis was performed using cor.test (R package ‘stats’, version 3.5.0) to further investigate the results from the temporal correlation analysis. Kendall’s rank correlation analysis was used, as the data were not normally distributed.

To examine the dependency of fin whale pulse presence and 13-Hz call presence as well as the dependency of blue whale z-calls presence and 13-Hz call presence a Fisher’s exact test of independence was performed using fisher.test with alternative greater (R package ‘stats’, version 3.5.0) using the formula

$$p = \frac{(a + b)!\,(c + d)!\,(a + c)!\,(b + d)!}{a!\,b!\,c!\,d!\,n!}$$

where *a*, *b*, *c*, *d* and *n* are the number of observations of the two-way contingency Table 2 and *!* indicates the factorial operator. For my data, observation 1 equals presence or absence of “13-Hz” short call and observation 2 equals presence or absence of fin whale pulses or blue whale z-calls, respectively. Therefore *a* stands for both call types present and *d* for no call type present, whereas *c* equals only 13-Hz calls present, but absence of fin whale pulses or blue whale z-calls, respectively, and *b* equals presence of fin whale pulses or blue whale z-calls and absence of 13-Hz calls. All presence-absence data were on a file basis, therefore the maximum n equals the number of files analysed.

Table 2: Two-way contingency table for Fisher's exact test of independence and accompanying coefficient of association Φ. Observation 1: presence or absence of “13-Hz” short call and observation 2: presence or absence of fin whale pulses or blue whale z-calls.

		Observation 1		
		Present	**Absent**	**Total**
Observation 2	**Present**	a	b	a + b
	Absent	c	d	c + d
	Total	a + c	b + d	a + b + c + d = n

Additionally, to analyse the degree of association between fin whale pulses or blue whale z-calls and the “13-Hz” short call respectively, the accompanying coefficient of association Φ was calculated according to Sokal and Rohlf (1995) with the formula

$$\Phi = \frac{ad - bc}{\sqrt{(a + b)(c + d)(a + c)(b + d)}}$$

where *a*, *b*, *c* and *d* are the number of observations from the two-way contingency Table 2.

To analyse the influence of number of species calls on the presence of 13-Hz calls a generalised linear model (glm) (R package ‘stats’, version 3.5.0) with presence of 13-Hz calls as response variable and number of fin whale pulses and number of blue whale z-calls as fixed effects was used. For error distribution binomial was used as the response variable was either present or absent.

Masking effect of mooring noise on number of detections

To investigate the influence of mooring noise on the detectability of the different call types, the scatterplot of fin whale pulses, blue whale z-calls and “13-Hz” short calls were plotted against the presence or absence of mooring noise and a linear regression line (command lm from R package ‘stats’, version 3.5.0) for each comparison was added to the plot (R package ‘graphics’, version 3.5.0). The R^2 value and the equation for the linear regression line were retrieved from the linear model (lm).

Interval measurements

To investigate the temporal patterns of the intervals from single 13-Hz calls to consecutive fin whale pulses and blue whale z-calls the data were processed as follows. The length of the intervals from previous fin whale pulse or previous blue whale z-call to the next 13-Hz call were converted into negative numbers for a better visualisation of the data. Additionally, the values were also rounded to zero digits as for the measurements of the “13-Hz” short call, because the measurements were not calculated but measured manually, with an error of ± 1 seconds. Thereafter, the density distribution of the length of the intervals was graphically presented in a histogram (package ‘graphics’, version 3.5.0). Additionally, a density distribution curve was fitted to the plot (R package ‘stats’, version 3.5.0) to display the distribution of the data. The Shapiro-test (package ‘stats’, version 3.5.0) was applied to test for normal distribution of the data. The mean and standard deviation were also calculated with R (R package ‘base’ and ‘stats’, version 3.5.0). They were further used to describe the interval length.

Results

“13-Hz” short call characteristics

The “13-Hz” short call is a low-frequency upsweep ranging from 11 ± 1 Hz to 14 ± 1 Hz a mean duration of 2 ± 1 seconds (see Figure 8 and Figure 9). The lowest frequency measured was 9 Hz and the highest 16 Hz. The duration of the shortest 13-Hz call was 1 second whereas the longest lasted for 4 seconds (see Table 3).

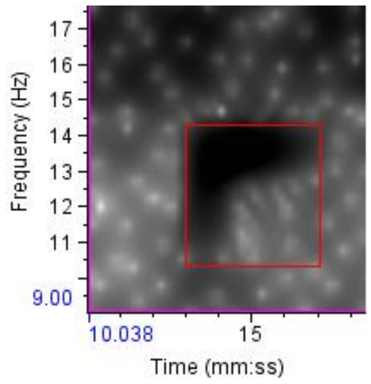


Figure 8: Spectrogram of "13-Hz" short call with measurement box. (Image from March 11 2014, 08:00 a.m., Hanning window, overlap: 90 %, FFT: 1025, time resolution: 2 seconds, frequency resolution: 0.5 Hz)

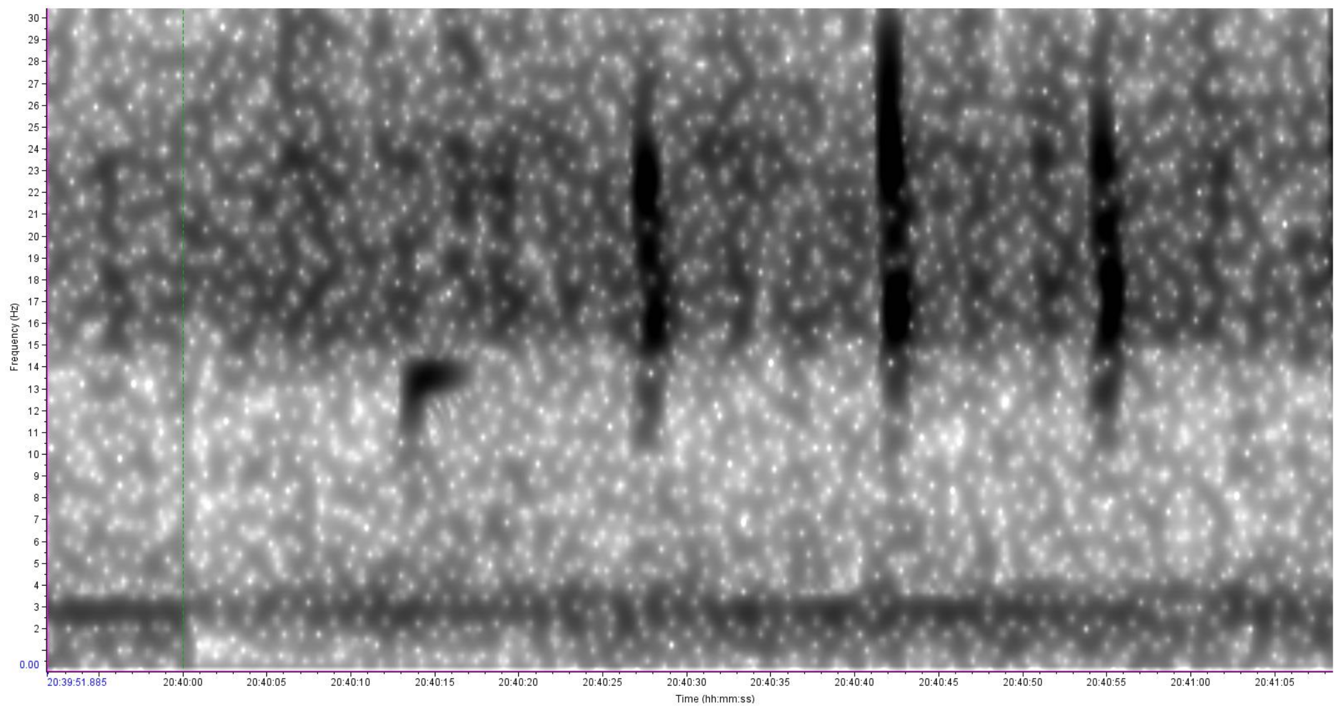


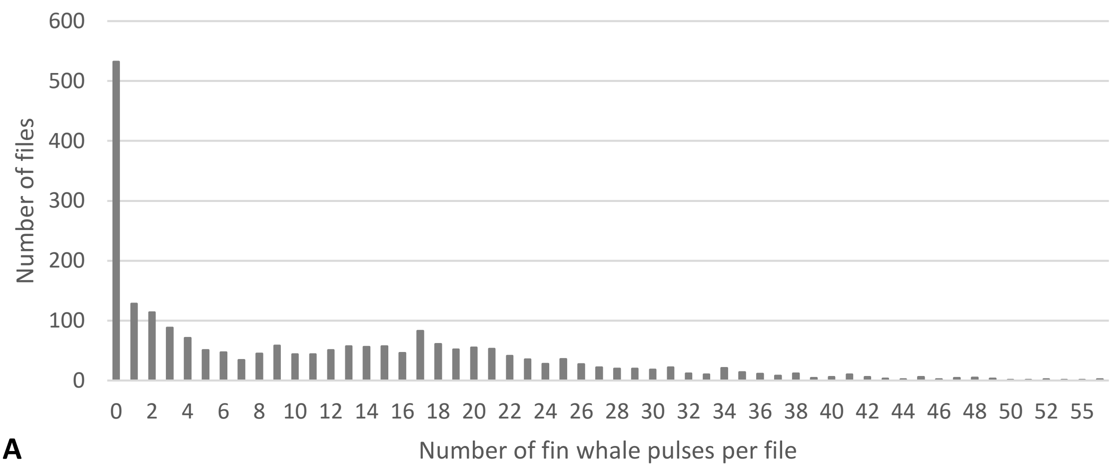
Figure 9: "13-Hz" short call with 3 fin whale pulses. (Image from March 11 2014, 08:00 a.m., Hanning window, overlap: 90 %, FFT: 1025, time resolution: 2 seconds, frequency resolution: 0.5 Hz)

Table 3: Measurements of the "13-Hz" short call with mean, minimum and maximum of frequency and duration.

	Low frequency	High frequency	Duration
Mean	11 ± 1 Hz	14 ± 1 Hz	2 ± 1 seconds
Minimum	9 Hz	14 Hz	1 second
Maximum	13 Hz	16 Hz	4 seconds

Temporal distribution

In total, 25,568 fin whale ’20-Hz’ pulses, 7,102 blue whale z-calls and 518 “13-Hz” short calls were detected in the analysed time period. In most 5-min files, the number of fin whale pulses was between 1 and 8 with a maximum of 58 pulses in 5 minutes of recording, occurring once on the 25 April and once on 10 May 2014. The maximum number of blue whale z-calls within 5 minutes was 23, occurring on the 19 June, whereas blue whale-z calls generally occurred between 1 or 3 times in 5 minutes. 13-Hz calls occurred mostly only once in 5 minutes and the maximum number of 13-Hz calls within 5 minutes was 13, on the 10 May. Overall, fin whale pulses were most frequent with only 532 files of 2243 in total without any fin whale pulses in contrast to 769 files without blue whale z-calls and 1948 files without 13-Hz calls.



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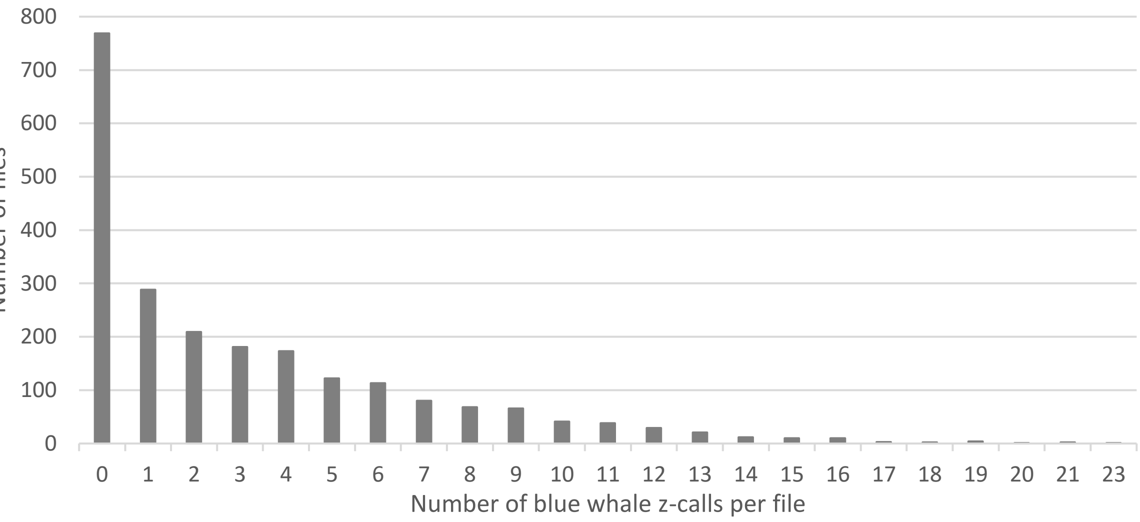

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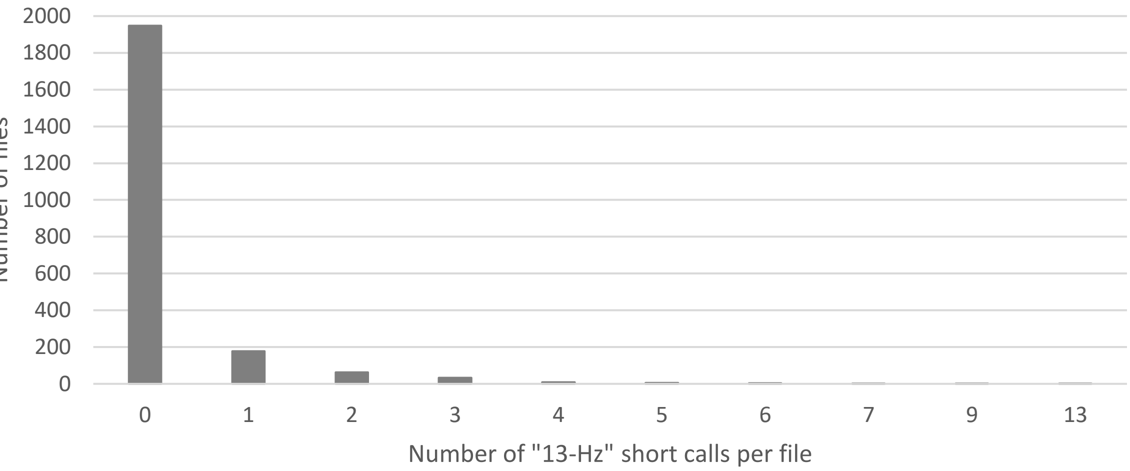


C

Figure 10: Grouped bar plots for number of calls per file for the three call types (A) Fin whale pulses (n = 25568), (B) Blue whale z-calls (n = 7102) and (C) "13-Hz" short calls (n = 518).

The cubic smoothed spline in Figure 11 revealed similar temporal trends for the mean number of calls per day of fin whale pulses and of “13-Hz” short calls. Both exhibited the maximum in the beginning of May and decreased towards the end of May whereas the mean number of blue whale calls increased in June, peaking in late June.

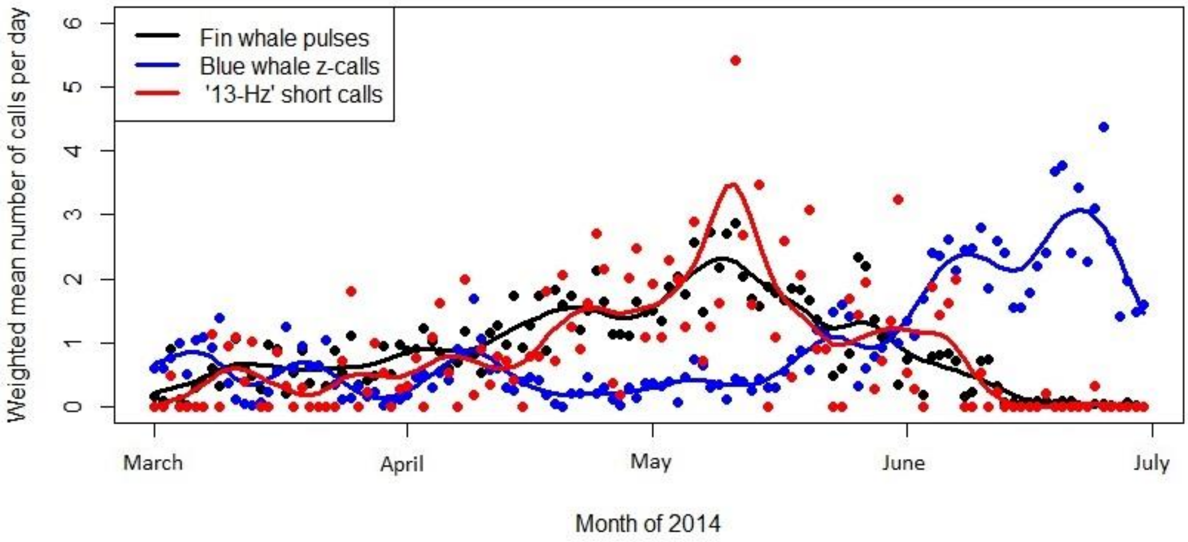
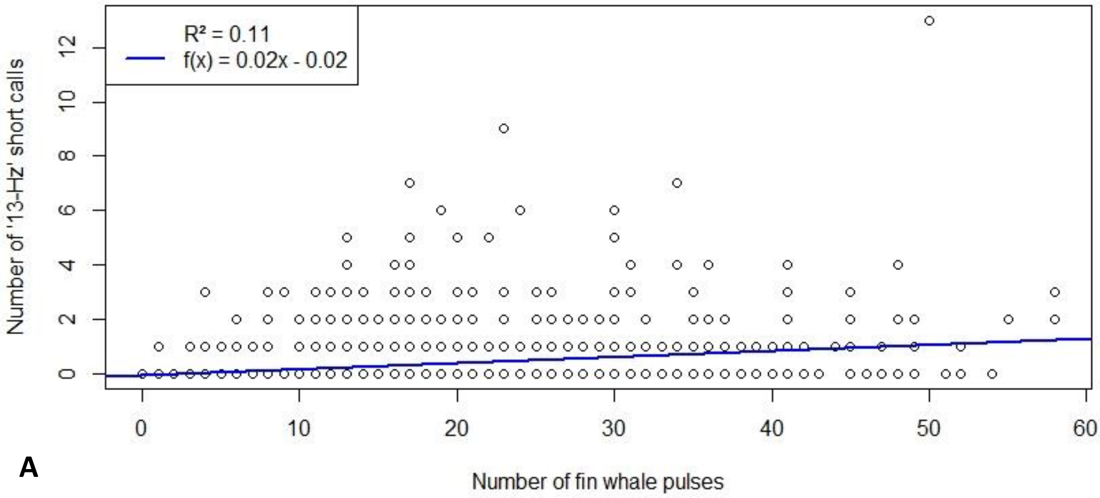


Figure 11: Weighted mean number of calls per day over time with cubic smoothed spline (df = 20). The mean number of calls per day was weighted with the total mean number of calls per species. Fin whale pulses are displayed in black, blue whale z-calls in blue and "13-Hz" short calls in red.

Correlation analysis

The scatterplot in Figure 12 A shows a slightly positive correlation of number of fin whale pulses and number of 13-Hz calls per file with a R^2 value of 0.11. The scatterplot in Figure 12 B shows a slightly negative correlation of number of blue whale z-calls and number of 13-Hz calls per file with a R^2 value of 0.02.

Overall, the number of 13-Hz calls at first increased with increasing number of fin whale pulses until 23 fin whale pulses per file. Thereafter the number of 13-Hz calls decreased with increasing number of fin whale pulses with one exceptional value. On 10 May 50 fin whale pulses were observed with 13 13-Hz calls and no blue whale z-calls present. The second highest number of 13-Hz calls (9) is associated with 23 fin whale pulses and 4 blue whale z-calls at 11 May.



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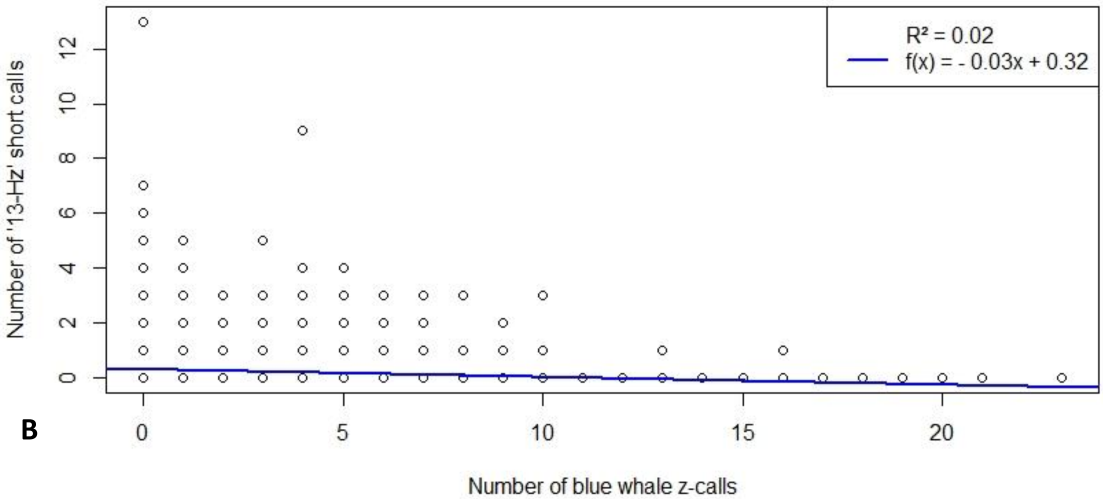

B

Figure 12: Scatterplots with linear regression line for (A) number of fin whale pulses versus number of "13-Hz" short calls and (B) number of blue whale z-calls versus number of "13-Hz" short calls per file.

The temporal cross correlation analysis showed a positive correlation between fin whale pulses and “13-Hz” short calls at lag[2] zero of 0.67 (see Figure 13). A further Kendall’s rank correlation test revealed a significant p-value of $2.2*10^{-16}$ and a correlation coefficient τ of 0.55, showing a moderate positive correlation between fin whale pulses and “13-Hz” short calls over time.

[2] Lag: temporal shifting of the data to investigate temporal cross correlation.

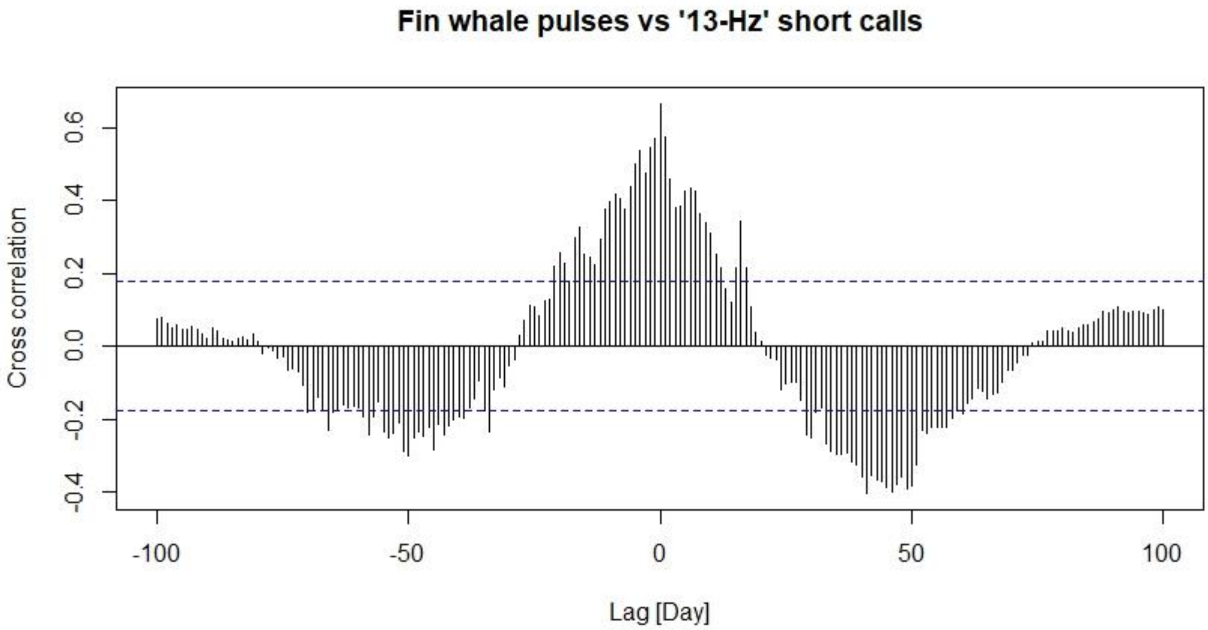

Figure 13: Temporal cross correlation analysis of fin whale pulses versus "13-Hz" short calls over time with maximum lag of 100.

The temporal cross correlation between blue whale z-calls and “13-Hz” short calls in Figure 14 shows a negative cross correlation of -0.30 at lag 0. A further Kendall’s rank correlation analysis showed a significant p-value of $2.2*10^{-5}$ and a correlation coefficient τ of -0.27, revealing a weak negative correlation of blue whale z-calls over time.

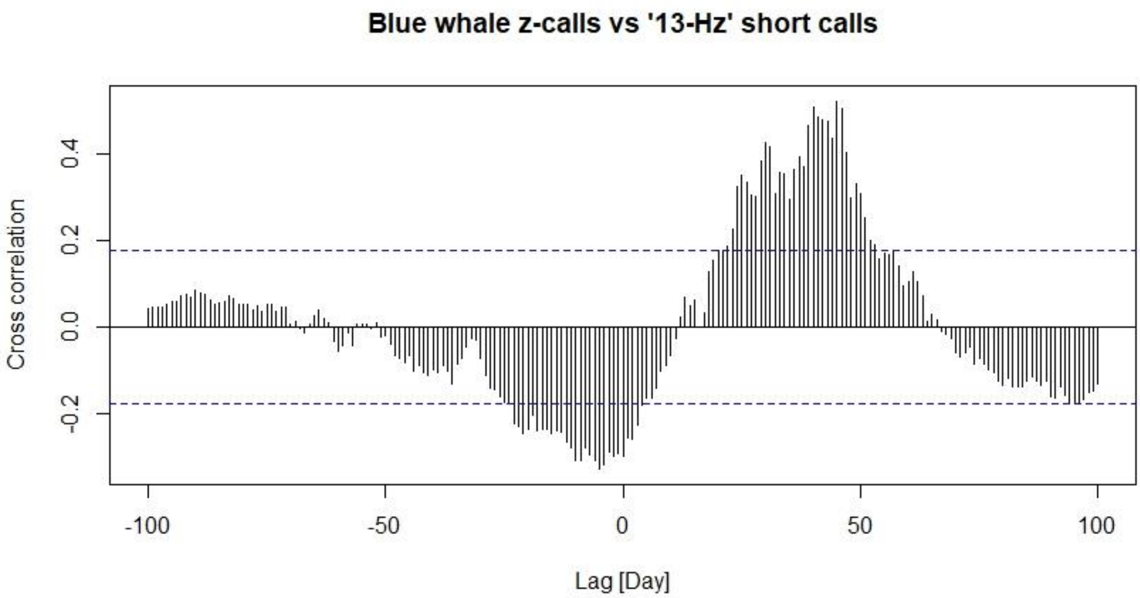

Figure 14: Temporal cross correlation analysis of blue whale z-calls versus "13-Hz" short calls over time with maximum lag of 100.

The “13-Hz” short call could be observed in 154 files with only fin whale pulses present, in 141 with both, fin whale pulses and blue whale z-calls present but in zero files with only blue whales present.

The results of the one-tailed Fisher’s exact test of independence showed a significant dependency of fin whale pulses present and short calls present (see Table 4). Nevertheless, the accompanying coefficient of association was low with 0.22 showing a weak correlation. Additionally, the test for the dependency of blue whale z-calls present and short calls present showed a negative accompanying coefficient of association with -0.15 and a non-significant p-value of 1.

Table 4: Two-way contingency tables for fin whale pulses and blue whale z-calls versus presence of “13-Hz” short calls, comparing occurrence of call type per file. The results of one-tailed Fisher's exact test of independence and the accompanying coefficient of association Φ (Sokal and Rohlf 1995) are provided.

	“13-Hz” short call				
Fin whale pulse	**Present**	**Absent**	**Total**	**Φ**	**p-value**
Present	295	1416	1711	0.22	$2.2*10^{-16}$
Absent	0	532	532		
Total	295	1948	2243		
	“13-Hz” short call				
Blue whale z-call	**Present**	**Absent**	**Total**	**Φ**	**p-value**
Present	141	1333	1474	-0.15	1
Absent	154	615	769		
Total	295	1948	2243		

The general linear model (glm) showed a statistically significant correlation between presence of 13-Hz calls and number of fin whale pulses as well as number of blue whale z-calls. The number of fin whale pulses influenced the presence of 13-Hz calls positively while the number of blue whale z-calls had a negative influence on the presence of 13-Hz calls (see Table 5).

Table 5: Generalised linear model with presence of "13-Hz" short calls as response variable and number of fin whale pulses and number of blue whale z-calls as fixed effects. Error distribution: binomial.

Presence of “13-Hz” short calls				
Fixed effects:				
	Estimate	SE	z-value	p-value
(Intercept)	-3.02	0.16	-19.14	$< 2*10^{-16}$
Fin whale pulses	0.08	0.01	13.68	$< 2*10^{-16}$
Blue whale z-calls	-0.07	0.03	-2.52	0.01

Masking effect of mooring noise on number of detections

The linear models revealed a low influence of the presence of the mooring noise on the number of calls detected for each call type as the R^2 values are all below 0.05 suggesting a minor influence of mooring on the detectability (see Figure 15).

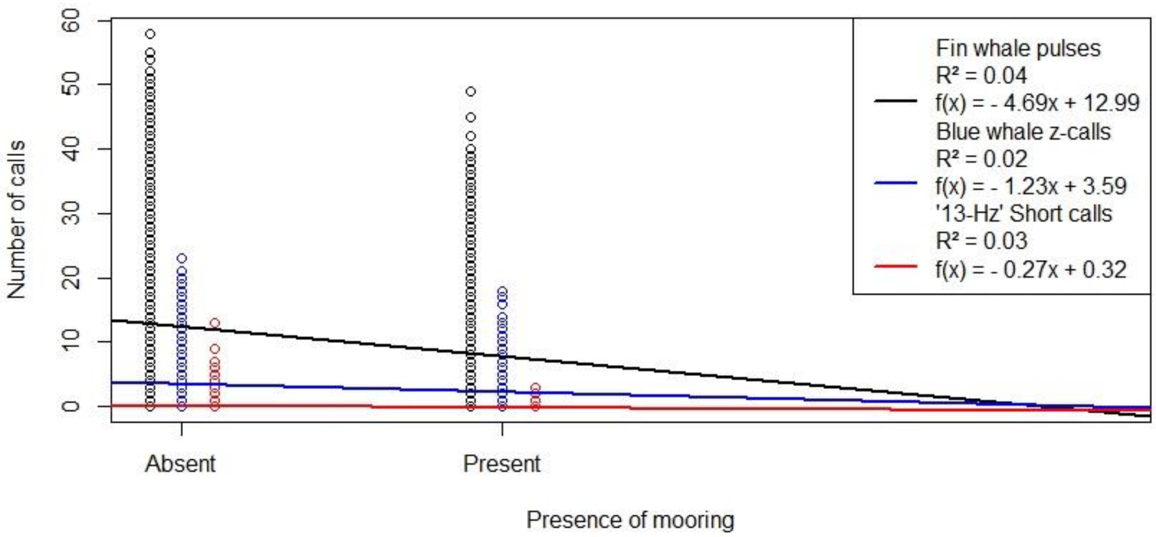

Figure 15: Scatterplot of presence of mooring noise versus number of calls for fin whale pulses (black), blue whale z-calls (blue) and "13-Hz" short calls (red) with linear regression line, n = 2243 for all.

Interval measurements

Figure 16 shows the density distribution of interval lengths from the previous fin whale pulses to the next 13-Hz calls and 13-Hz calls to the ensuing fin whale pulses. The red line showing the density distribution displayed the non-normal distribution of the interval lengths. The Shapiro-test for normality revealed a significant p-value of $2.2*10^{-16}$ and therefore confirmed the non-normal distribution. Additionally, the plot showed a maximum in density at 13 seconds and -16 seconds of interval length and a density of 0.05 and 0.06, respectively, revealing that a large proportion of 13-Hz calls were either located 16 seconds behind the previous fin whale pulse of 13 seconds before the ensuing fin whale pulse. The mean interval length from fin whale pulse to the next “13-Hz” short call was 12 ± 13 seconds and the mean interval length ± standard deviation from the “13-Hz” short call to the next fin whale pulse was 12 ± 16 seconds.

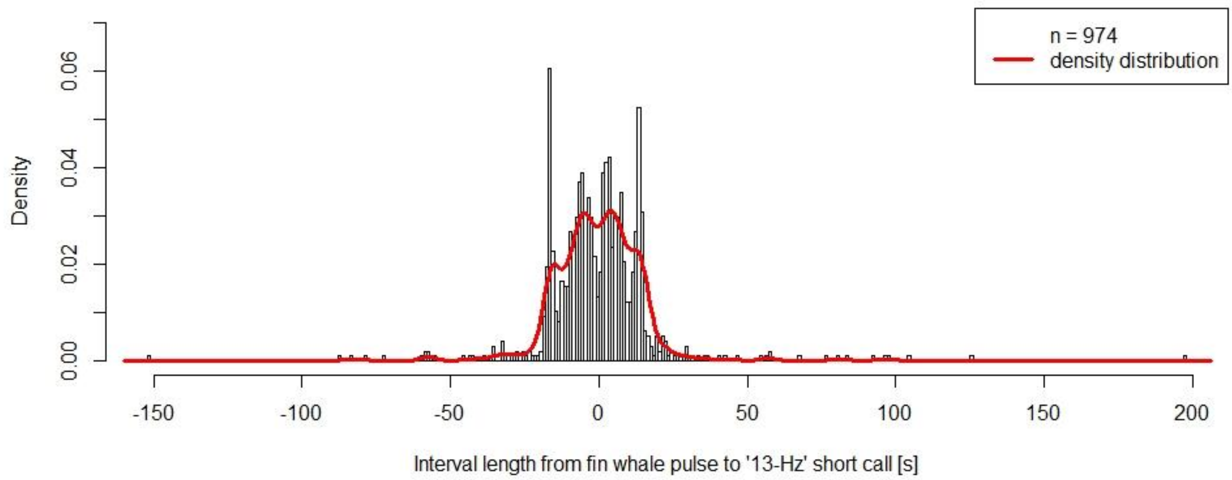

Figure 16: Density distribution of interval length from the previous fin whale pulse to the next "13-Hz" short call for negative x-values and interval length of the "13-Hz" short call to the ensuing fin whale pulse for positive x-values. The red line shows the density distribution of the interval length.

The density distribution of intervals of blue whale z-call to 13-Hz calls showed a more normal distribution (see Figure 17) compared to the density distribution of the intervals associated with fin whale pulses (see Figure 16). Nevertheless, a Shapiro-test for normality revealed a significant p-value of $2.69*10^{-6}$ which indicates a non-normal distribution of the data. The highest density of 0.02 occurred at -1 seconds and 6 seconds, revealing that a large proportion of 13-Hz calls were either located 1 second after the previous blue whale z-call or 6 seconds before the ensuing blue whale z-call. The mean interval length from blue whale z-call to the next "13-Hz" short call was 40 ± 42 seconds and the mean interval length ± standard deviation from the 13-Hz call to the next blue whale z-call was 47± 46 seconds.

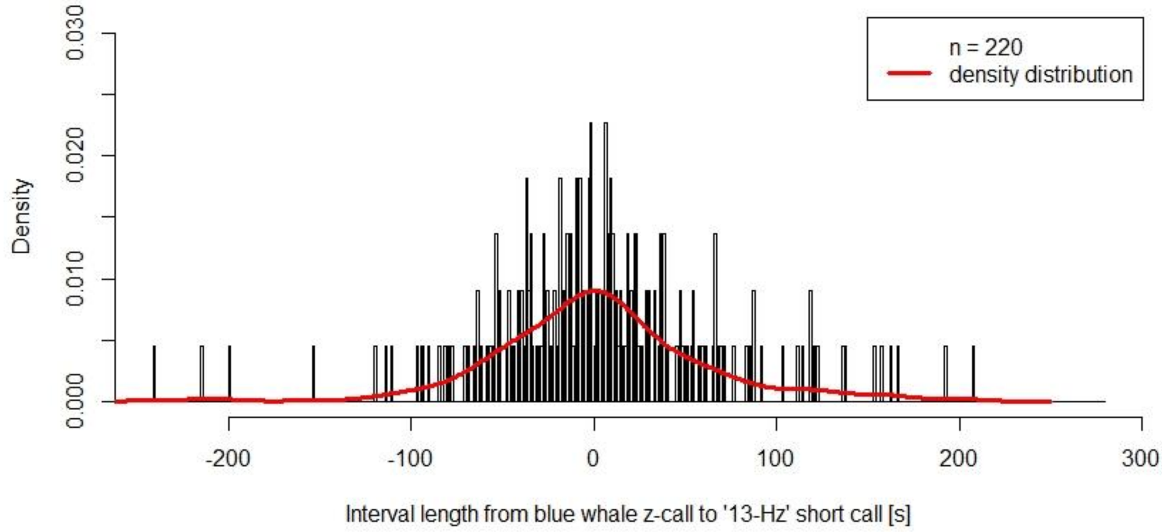

Figure 17: Density distribution of interval length from the previous blue whale z-call to the next "13-Hz" short call for negative x-values and interval length of "13-Hz" short call to the ensuing blue whale z-call for positive x-values. The red line shows the density distribution of the interval length.

Discussion

"13-Hz" short call characteristics

The acoustic description of the "13-Hz" short call was based on a relatively poor resolution, as the call is of low frequency, narrow band and short in duration. These characteristics are leading to a poor time and frequency resolution for measurement purposes. The existing trade-off between frequency resolution and time resolution, as time resolution is FFT/sample rate and frequency resolution the inverse function, therefore sample rate/FFT leads to the fact that with a better time resolution the frequency resolution declines and otherwise. Measuring the short call in two different settings was not possible due to the nature of the call.

Temporal distribution and correlation analysis

The hypothesis, that the presence of "13-Hz" short calls is positively correlated with the acoustic presence of fin whales is supported by the data analysis. The temporal distribution plots suggested a correlation of fin whale pulses with "13-Hz" short calls over time. Both have their maximum around mid of May, whereas the presence of blue whales is still low and the peak in occurrence of blue whale z-calls was in late June. These pattern was supported by the results of the linear correlation analysis showing a slightly positive correlation of fin whale pulses and "13-Hz" short calls as well as the cross correlation analysis and the Kendall's rank correlation analysis. Similarly, in a study conducted east off Australia visual sightings of dwarf minke whales and recordings of the "star-wars" sound also occurred over the same time, which lead, together with additional evidence, to the conclusion, that dwarf minke whales are responsible for the "star-wars" sound (Gedamke et al. 2001). Even though, no visual observations were made simultaneously in this study, the acoustic presence of fin whales together with the occurrence of the 13-Hz calls might indicate that the new call is emitted by fin whales.

Additionally, the Fisher's exact test for independence showed a correlation between fin whale acoustic presence and "13-Hz" short call presence but no correlation between blue whale acoustic presence and "13-Hz" short call. Nevertheless, the accompanying coefficient of association suggested a low correlation. Results from Baumgartner et al. (2008) found a slightly higher coefficient of correlation and therefore assigned their unknown call to sei whales. The data for the Fisher's exact test of independence also highlight that the 13-Hz call was never observed with only blue whales being acoustically present, but several times with only fin whales being acoustically present. This also implies that fin whales could be the species producing the sound.

Furthermore, the generalized linear model showed, that an unit increase in number of fin whale pulses increased the odds to observe a "13-Hz" short call by 0.08, whereas an unit increase in number of blue whale z-calls reduced the odds to observe a "13-Hz" short call by -0.07. This also indicates an association of fin whale pulses with "13-Hz" short calls rather than an association of blue whale z-calls with the "13-Hz" short call.

Supporting the hypothesis, that the presence of 13-Hz calls is not positively correlated to the presence of blue whale z-calls, the temporal distribution from blue whale z-calls and 13-Hz calls suggested a negative correlation. During June the number of blue whale z-calls increases whereas the number of 13-Hz calls decreases as well as the number of fin whale pulses. The linear regression line showing a slightly negative correlation, the cross correlation analysis of blue whale z-calls and 13-Hz calls with negative values at lag 0 as well as the significant Kendall's rank correlation analysis with a negative correlation coefficient confirmed this trend and indicates, that the occurrence of blue whale z-calls is negatively correlated with the occurrence of 13-Hz calls, suggesting that blue whales are not responsible for the new call.

The negative correlation of 13-Hz calls with blue whale z-call presence displayed in all tests, is not caused by masking, as the 13-Hz call is located in the frequency band of 9 Hz up to 16 Hz and the blue whale z-calls are located in the frequency band of 18 Hz up to 29 Hz (Širović et al. 2004) Therefore, the negative correlation of blue whale z-calls and 13-Hz calls is a true trend.

Fin whale pulses on the other hand might mask the 13-Hz calls as they can extend down to 15 Hz (Sirovic et al. 2006), whereas the 13-Hz calls were observed up to 16 Hz. This trend could be observed in the scatterplot in Figure 12A, showing a decline in 13-Hz calls after the number of fin whale pulses exceeded the 23, with one exceptional value at 50 fin whale pulses with 13 13-Hz calls. Nevertheless, the correlation between fin whale pulses and 13-Hz calls was positive for all tests. One could conclude, that the true correlation is even more significant, when taking into account the masking effect of fin whale pulses on 13-Hz calls.

Another explanation for the relatively low correlation coefficients suggesting a weak positive correlation for fin whale pulses and 13-Hz calls might be a masking effect of mooring noise as mooring noise might overlay fin whale pulses or interfere with 13-Hz calls. Nevertheless, the linear model showed only a weak influence of the presence of mooring on the number of calls detected.

Overall, the statistical analysis showed a positive correlation of fin whale pulses and 13-Hz calls and a negative correlation of blue whale z-calls and 13-Hz calls.

Interval measurements

Both interval lengths showed a non-normal distribution, indicating a correlation between blue whale z-calls and 13-Hz calls as well as between fin whale pulses and 13-Hz calls. Nevertheless, the distribution for the interval lengths associated with blue whales appear more normally distributed compared to the distribution for the interval lengths associated with fin whales. A normal distribution of the intervals would indicate no association of 13-Hz calls to the other call type. Additionally, the intervals associated with fin whale pulses displayed a peak at around 15 seconds, which is in the middle of the intersequence interval of 30 seconds reported by Širović et al. (2004). This could indicate an association of the 13-Hz call with fin whale song. The relatively low peak might become more prominent when analysing only single animal sequences, continuous data and more "13-Hz" short calls. The not very prominent peak for blue whale associated intervals is located at -1 and 6 seconds. Therefore, the data appear more normally distributed even though the test showed a non-normal distribution. With a larger sample size and the analysis of a continuous data set the data might become normally distributed.

Additionally, the distribution of the intervals associated with blue whales and the intervals associated with fin whales showed a large standard deviation. In previous studies the interpulse intervals or intercall intervals were less variable. Širović et al. (2004) described the intercall intervals with 12.9 ± 0.5 seconds and an intersequence interval with 29.7 ± 6.5 seconds for fin whales and an intercall interval of 62.3 ± 5.2 seconds for blue whale z-calls. In contrast, the intervals measured between fin whale pulses and 13-Hz calls have a standard deviation of 13 and 16 seconds with a mean of 12 seconds, whereas the intervals between blue whale z-calls and 13-Hz calls was 42 and 46 seconds with a mean of 40 and 47 seconds, respectively. These results could indicate, that the 13-Hz call is not associated with neither fin whale pulses nor blue whale z-calls, or at least is not a part of fin whale or blue whale song. Nevertheless, the intervals described by Širović et al. (2004) were measurements between the same call type, whereas in this study the intervals were measured between 2 different call types, the 13-Hz call and the known fin whale or blue whale vocalization. If the 13-Hz call is not produced as part of a song but randomly, the interval measurements cannot be used to attribute the new call to a certain species.

Overall, the analysis of the intervals showed no clear temporal distribution or association with neither one of the other call types.

Conclusion and Outlook

The hypothesis that the presence of “13-Hz” short calls is positively correlated with the presence of fin whale 20 Hz pulses could be confirmed.

Additionally, the presence of “13-Hz” short calls is not positively correlated with the presence of blue whale z-calls, the statistical analysis in fact showed a negative correlation of blue whale z-calls and “13-Hz” short calls. Therefore the second hypothesis, that the presence of “13-Hz” short calls is not positively correlated with the presence of blue whale z-calls could be confirmed.

The hypothesis that the intervals of fin whale pulses to “13-Hz” short calls are not normally distributed could also be confirmed, indicating a potential attribution of the “13-Hz” short calls to fin whales.

Finally, the hypothesis that the intervals of blue whale z-calls to “13-Hz” short calls are normally distributed had to be rejected. The data also showed a non-normal distribution of the intervals associated with blue whale z-calls.

Overall, the results indicated that fin whales could be the species producing the “13-Hz” short call but further analysis is necessary to confirm this hypothesis.

One possibility is to investigate the “13-Hz” short call in continuous data, recordings showing the entire day and therefore, displaying temporal patterns missed by the analysis of the subsampled data. With continuous data, the intervals between the short calls could be measured and investigated further to reveal the context of the “13-Hz” short call. Additionally, recordings from different recorders should be analysed to investigate if the “13-Hz” short call can be identified at other sites or if the call is a characteristic part of the vocalizations of a baleen whale species in the Antarctic regions.

Another approach to confirm fin whales as producer of the “13-Hz” short call could be tagging. Risch et al. (2014) confirmed with multi-sensor acoustic recording tags the minke whales as producer of the former mysterious bio-duck sound. Additionally, visual surveys together with acoustic observations could be conducted to confirm the species emitting the call, similarly done by Gedamke et al. (2001) for the “star-wars” sound of minke whales or Baumgartner et al. (2008) for sei whale vocalizations. Nevertheless, the results from tagging or simultaneous visual surveys might not be able to confirm the trends observed in this study as the “13-Hz” short call is relatively rare and it might not be produced during the recording time.

In conclusion, this project serves as a first description of a previously unknown call and gives a first idea of the animal producing the “13-Hz” short call.

References

Baumgartner, M. F., Van Parijs, S. M., Wenzel, F. W., Tremblay, C. J., Carter Esch, H., & Warde, A. M. (2008). Low frequency vocalizations attributed to sei whales (Balaenoptera borealis). *The Journal of the Acoustical Society of America, 124*(2), 1339-1349.

Bioacoustic Research Program. (2011). Raven Pro: Interactive Sound Analysis Software (Version 1.4) [Computer Software]. The Cornell Lab of Ornithology, Ithaca, NY. URL http://www.birds.cornell.edu/raven

Burkhardt, E., & Lanfredi, C. (2012). Fall feeding aggregations of fin whales off Elephant Island (Antarctica): Internatonal Whaling Commission.

Clark, C. W., Borsani, J., & Notarbartolo-Di-sciara, G. (2002). Vocal activity of fin whales, Balaenoptera physalus, in the Ligurian Sea. *Marine mammal science, 18*(1), 286-295.

Croll, D. A., Clark, C. W., Acevedo, A., Tershy, B., Flores, S., Gedamke, J., & Urban, J. (2002). Bioacoustics: Only male fin whales sing loud songs. *Nature, 417*(6891), 809.

Edds-Walton, P. L. (1997). Acoustic communication signals of mysticete whales. *Bioacoustics, 8*(1-2), 47-60.

Gedamke, J., Costa, D. P., & Dunstan, A. (2001). Localization and visual verification of a complex minke whale vocalization. *The Journal of the Acoustical Society of America, 109*(6), 3038-3047.

Heimlich, S. L., Mellinger, D. K., Nieukirk, S. L., & Fox, C. G. (2005). Types, distribution, and seasonal occurrence of sounds attributed to Bryde's whales (Balaenoptera edeni) recorded in the eastern tropical Pacific, 1999–2001. *The Journal of the Acoustical Society of America, 118*(3), 1830-1837.

Jaquet, N., Dawson, S., & Douglas, L. (2001). Vocal behavior of male sperm whales: Why do they click? *The Journal of the Acoustical Society of America, 109*(5), 2254-2259.

Joiris, C. R., & Dochy, O. (2013). A major autumn feeding ground for fin whales, southern fulmars and grey-headed albatrosses around the South Shetland Islands, Antarctica. *Polar Biology, 36*(11), 1649-1658.

Leroy, E. (2018). [Annotation of Elephant Island data for the SORP Annotated Library of Antarctic recordings].

Meister, M. (2017). *Temporal patterns in the acoustic presence of marine mammals off Elephant Island, Antarctica.* (Bachelor thesis), University Bremen.

Mellinger, D. K., Stafford, K. M., Moore, S. E., Dziak, R. P., & Matsumoto, H. (2007). An overview of fixed passive acoustic observation methods for cetaceans. *Oceanography, 20*(4), 36-45.

Nieukirk, S. L., Fregosi, S., Mellinger, D. K., & Klinck, H. (2016). A complex baleen whale call recorded in the Mariana Trench Marine National Monument. *The Journal of the Acoustical Society of America, 140*(3), EL274-EL279.

Oleson, E. M., Wiggins, S. M., & Hildebrand, J. A. (2007). Temporal separation of blue whale call types on a southern California feeding ground. *Animal Behaviour, 74*(4), 881-894.

R Core Team. (2018). R: A language and environment fo statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/

Rankin, S., Ljungblad, D., Clark, C., & Kato+, H. (2005). Vocalisations of Antarctic blue whales, Balaenoptera musculus intermedia, recorded during the 2001/2002 and 2002/2003 IWC/SOWER circumpolar cruises, Area V, Antarctica. *J. Cetacean Res. Manage, 7*(1), 13-20.

Rettig, S., Boebel, O., Menze, S., Kindermann, L., Thomisch, K., & van Opzeeland, I. (2013). Local to basin scale arrays for passive acoustic monitoring in the Atlantic sector of the Southern Ocean.

Risch, D., Gales, N. J., Gedamke, J., Kindermann, L., Nowacek, D. P., Read, A. J., . . . Friedlaender, A. S. (2014). Mysterious bio-duck sound attributed to the Antarctic minke whale (Balaenoptera bonaerensis). *Biology letters, 10*(4), 20140175.

Siegel, V., Loeb, V., & Gröger, J. (1998). Krill (Euphausia superba) density, proportional and absolute recruitment and biomass in the Elephant Island region (Antarctic Peninsula) during the period 1977 to 1997. *Polar Biology, 19*(6), 393-398.

Sirovic, A., Hildebrand, J. A., & Thiele, D. (2006). Baleen whale spatial patterns in the Scotia Sea during January and February 2003.

Širović, A., Hildebrand, J. A., Wiggins, S. M., McDonald, M. A., Moore, S. E., & Thiele, D. (2004). Seasonality of blue and fin whale calls and the influence of sea ice in the Western Antarctic Peninsula. *Deep Sea Research Part II: Topical Studies in Oceanography, 51*(17-19), 2327-2344.

Širović, A., Hildebrand, J. A., Wiggins, S. M., & Thiele, D. (2009). Blue and fin whale acoustic presence around Antarctica during 2003 and 2004. *Marine mammal science, 25*(1), 125-136.

Sokal, R. R., & Rohlf, F. J. (1995). The principles and practice of statistics in biological research. *New York: Edition, 3*.

Soule, D. C., & Wilcock, W. S. (2013). Fin whale tracks recorded by a seismic network on the Juan de Fuca Ridge, Northeast Pacific Ocean. *The Journal of the Acoustical Society of America, 133*(3), 1751-1761.

Stafford, K. M., Nieukirk, S. L., & Fox, C. G. (1999). Low-frequency whale sounds recorded on hydrophones moored in the eastern tropical Pacific. *The Journal of the Acoustical Society of America, 106*(6), 3687-3698.

Stimpert, A. K., Au, W. W., Parks, S. E., Hurst, T., & Wiley, D. N. (2011). Common humpback whale (Megaptera novaeangliae) sound types for passive acoustic monitoring. *The Journal of the Acoustical Society of America, 129*(1), 476-482.

Stimpert, A. K., Wiley, D. N., Au, W. W., Johnson, M. P., & Arsenault, R. (2007). 'Megapclicks': acoustic click trains and buzzes produced during night-time foraging of humpback whales (Megaptera novaeangliae). *Biology letters, 3*(5), 467-470.

Thomisch, K., Boebel, O., Clark, C. W., Hagen, W., Spiesecke, S., Zitterbart, D. P., & Van Opzeeland, I. (2016). Spatio-temporal patterns in acoustic presence and distribution of Antarctic blue whales Balaenoptera musculus intermedia in the Weddell Sea. *Endangered Species Research, 30*, 239-253.

Thompson, P. O., Findley, L. T., & Vidal, O. (1992). 20-Hz pulses and other vocalizations of fin whales, B alaenopteraphysalus, in the Gulf of California, Mexico. *The Journal of the Acoustical Society of America, 92*(6), 3051-3057.

Tyack, P. L., & Miller, E. H. (2002). Vocal anatomy, acoustic communication and echolocation. *Marine mammal biology: An evolutionary approach*, 142-184.

Watkins, W. A. (1981). Activities and underwater sounds of fin whales. *Sci. Rep. Whales Res. Inst, 33*, 83-117.

Watkins, W. A., Tyack, P., Moore, K. E., & Bird, J. E. (1987). The 20-Hz signals of finback whales (Balaenoptera physalus). *The Journal of the Acoustical Society of America, 82*(6), 1901-1912.

Appendix

Table 6: Summary table of number of files and number of detected calls per month for analysed time period from March to June 2014.

	March	April	May	June	Sum
Number of files	744	720	744	720	2928
Number of files with noise	282	108	144	151	685
Number of files analysed	462	612	600	569	2243
Number of fin whale pulses	3156	8544	11939	1929	25568
Number of blue whale z-calls	732	856	1223	4291	7102
Number of "13-Hz" short calls	47	148	277	46	518
Number of files with mooring	155	224	169	214	762
Number of intervals for fin whales	88	282	523	81	974
Number of intervals for blue whales	9	49	96	66	220
Number of "13-Hz" short calls measured	9	20	46	0	75

Table 7: Summary of number of calls, number of files with mooring, number of files with noise or noise in "13-Hz" short call frequency band and number of files analysed per day.

Year	Month	Day	Number of fin whale pulses	Number of "13-Hz" short calls	Number of blue whale z-calls	Number of files with mooring noise	Number of files with noise	Number of files with noise in "13-Hz" short call frequency band	Number of files analysed
2014	03	01	21	0	21	7	13	0	11
2014	03	02	13	0	21	7	13	0	11
2014	03	03	93	1	22	5	15	0	9
2014	03	04	9	0	19	2	14	4	6
2014	03	05	2	0	8	0	17	2	5
2014	03	06	36	0	33	0	10	4	10
2014	03	07	68	0	52	2	6	3	15
2014	03	08	161	6	67	4	0	1	23
2014	03	09	89	0	101	0	0	1	23
2014	03	10	247	5	28	0	1	0	23
2014	03	11	242	5	7	3	3	1	20
2014	03	12	80	1	2	2	8	5	11
2014	03	13	95	4	2	5	6	1	17
2014	03	14	32	0	2	4	9	5	10
2014	03	15	77	0	5	2	14	3	7
2014	03	16	102	2	18	2	12	2	10
2014	03	17	33	1	52	5	4	7	13
2014	03	18	81	0	25	5	7	4	13
2014	03	19	142	1	42	5	6	4	14
2014	03	20	70	0	32	8	3	5	16
2014	03	21	148	0	43	12	2	1	21
2014	03	22	48	0	43	4	4	7	13
2014	03	23	132	0	14	3	6	5	13
2014	03	24	148	4	9	12	0	0	24

Year	Month	Day	Number of fin whale pulses	Number of "13-Hz" short calls	Number of blue whale z-calls	Number of files with mooring noise	Number of files with noise	Number of files with noise in "13-Hz" short call frequency band	Number of files analysed
2014	03	25	305	10	11	4	0	0	24
2014	03	26	88	0	23	12	0	2	22
2014	03	27	85	1	9	6	6	0	18
2014	03	28	74	3	10	7	6	5	13
2014	03	29	172	2	1	11	7	1	16
2014	03	30	87	0	4	10	8	1	15
2014	03	31	176	1	6	6	6	2	16
2014	04	01	131	1	8	2	9	2	13
2014	04	02	174	3	25	7	4	3	17
2014	04	03	280	0	33	11	1	3	20
2014	04	04	282	6	24	1	0	0	24
2014	04	05	235	9	40	2	0	0	24
2014	04	06	165	3	32	5	0	0	24
2014	04	07	189	0	68	7	0	0	24
2014	04	08	323	11	63	0	0	0	24
2014	04	09	224	1	129	0	0	0	24
2014	04	10	148	5	82	0	0	0	24
2014	04	11	315	2	44	4	0	0	24
2014	04	12	320	4	42	9	2	0	22
2014	04	13	200	3	18	11	6	0	18
2014	04	14	415	2	17	17	2	1	21
2014	04	15	158	0	19	10	8	1	15
2014	04	16	160	2	16	5	12	1	11
2014	04	17	219	2	15	3	11	2	11
2014	04	18	121	5	7	5	10	2	12

Year	Month	Day	Number of fin whale pulses	Number of "13-Hz" short calls	Number of blue whale z-calls	Number of files with mooring noise	Number of files with noise	Number of files with noise in "13-Hz" short call frequency band	Number of files analysed
2014	04	19	249	2	2	7	8	4	12
2014	04	20	417	11	1	14	1	0	23
2014	04	21	478	7	16	7	0	0	24
2014	04	22	327	5	16	10	0	0	24
2014	04	23	412	9	36	7	0	0	24
2014	04	24	582	15	16	9	0	0	24
2014	04	25	449	12	24	6	0	0	24
2014	04	26	296	2	9	15	1	0	23
2014	04	27	285	1	2	15	1	1	22
2014	04	28	189	7	14	5	8	1	15
2014	04	29	396	12	10	17	2	1	21
2014	04	30	405	6	28	13	0	0	24
2014	05	01	309	8	21	8	6	0	18
2014	05	02	305	5	21	10	4	0	20
2014	05	03	364	9	22	6	4	3	17
2014	05	04	558	11	5	2	0	0	24
2014	05	05	484	7	35	1	0	0	24
2014	05	06	700	16	56	0	0	0	24
2014	05	07	403	4	50	5	0	0	24
2014	05	08	746	7	24	5	0	0	24
2014	05	09	594	9	26	2	0	0	24
2014	05	10	744	50	10	1	0	0	24
2014	05	11	788	30	34	0	0	0	24
2014	05	12	490	13	27	6	3	0	21
2014	05	13	365	7	16	9	5	0	19

Year	Month	Day	Number of fin whale pulses	Number of "13-Hz" short calls	Number of blue whale z-calls	Number of files with mooring noise	Number of files with noise	Number of files with noise in "13-Hz" short call frequency band	Number of files analysed
2014	05	14	270	12	21	3	9	0	15
2014	05	15	234	0	11	7	13	0	11
2014	05	16	245	3	12	6	12	0	12
2014	05	17	379	12	35	7	3	1	20
2014	05	18	399	2	45	8	5	0	19
2014	05	19	440	10	58	11	3	0	21
2014	05	20	455	17	44	9	0	0	24
2014	05	21	374	5	91	1	0	0	24
2014	05	22	264	4	67	6	5	0	19
2014	05	23	134	0	112	14	0	0	24
2014	05	24	119	0	86	9	7	0	17
2014	05	25	171	7	80	9	6	0	18
2014	05	26	482	6	19	6	6	0	18
2014	05	27	504	9	38	4	4	0	20
2014	05	28	234	1	37	5	9	0	15
2014	05	29	150	2	35	3	11	1	12
2014	05	30	203	5	60	3	6	2	16
2014	05	31	32	6	25	3	16	0	8
2014	06	01	68	1	34	1	16	0	8
2014	06	02	205	1	57	6	8	0	16
2014	06	03	34	0	86	11	8	0	16
2014	06	04	208	10	176	6	1	0	23
2014	06	05	225	8	179	0	0	0	24
2014	06	06	227	9	198	0	0	0	24
2014	06	07	197	11	162	0	0	0	24

Year	Month	Day	Number of fin whale pulses	Number of "13-Hz" short calls	Number of blue whale z-calls	Number of files with mooring noise	Number of files with noise	Number of files with noise in "13-Hz" short call frequency band	Number of files analysed
2014	06	08	39	0	171	7	2	0	22
2014	06	09	52	0	157	8	4	0	20
2014	06	10	198	3	213	5	0	0	24
2014	06	11	197	0	135	12	1	0	23
2014	06	12	69	1	148	6	6	0	18
2014	06	13	15	0	122	9	7	1	16
2014	06	14	8	0	49	5	13	1	10
2014	06	15	5	0	54	8	13	0	11
2014	06	16	16	0	108	13	5	0	19
2014	06	17	28	0	160	9	1	0	23
2014	06	18	20	1	153	9	3	1	20
2014	06	19	11	0	280	4	0	0	24
2014	06	20	29	0	287	2	0	0	24
2014	06	21	25	0	183	0	0	0	24
2014	06	22	9	0	260	5	0	0	24
2014	06	23	2	0	143	12	4	0	20
2014	06	24	7	1	128	4	10	2	13
2014	06	25	5	0	152	2	9	4	11
2014	06	26	4	0	123	9	4	5	15
2014	06	27	3	0	85	18	2	3	19
2014	06	28	14	0	112	13	6	0	18
2014	06	29	6	0	80	13	5	2	17
2014	06	30	3	0	96	17	0	5	19