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Seasonal acoustic presence of sei whales off the Juan Fernandez Archipelago, Chile

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ABSTRACT: This study examined the occurrence of sei whale upsweep and downsweep vocalisations in 3 yrs of acoustic data (2015–2017) from the Juan Fernandez Archipelago, Chile, to determine the seasonal presence of this species in this area. Acoustic data were obtained from a hydroacoustic station (HA03) maintained by the Comprehensive Test-Ban-Treaty Organization and analysed for target signals using automatic detectors in Raven Pro 2.0. Monthly upsweep call rates (ranging 0–1.2 calls h^{-1}) displayed a fairly consistent seasonal pattern, with none or very few detections from the austral summer to early winter and, overall, more detections in late winter and spring, peaking in September. Monthly downsweep call rates (ranging 0–0.69 calls h^{-1}) were higher in winter and spring. We discuss the implications of these results for understanding seasonal migration routes. Upsweeps had a duration of (mean ± SD) 1.5 ± 0.3 s with a peak frequency of (mean ± SD) 62.0 ± 8.3 Hz (n = 100), and downsweeps had a duration of 1.3 ± 0.1 s with a peak frequency of 56.3 ± 10.9 Hz (n = 100). Inter-note intervals (INIs) for upsweeps had modes at 7 s and 14 s; the dominant INIs mode for downsweeps was 4 s. This is the first multi-year passive acoustic monitoring study of sei whales in the Southeast Pacific and provides novel information on the distribution of a poorly-studied Endangered species in the southern hemisphere.

KEY WORDS: Sei whale · *Balaenoptera borealis* · Juan Fernandez · Chile · Southeast Pacific · Passive acoustic monitoring · Bioacoustics

1. INTRODUCTION

The sei whale *Balaenoptera borealis* is a cosmopolitan species which prefers offshore waters primarily in temperate habitats (Prieto et al. 2012). It is believed that sei whales migrate between low latitude winter zones and high latitude feeding grounds during summer (Mizroch et al. 1984, Prieto et al. 2014). However, of all large cetaceans, the sei whale remains one of the least studied; there is a lack of ecological information since the end of historical commercial whaling (Prieto et al. 2012). Presently, in Chile, the species is listed as critically endangered by the Chilean Ministry for the Environment (Ministerio del Medio Ambiente 2011) and as Endangered by the IUCN (Cooke 2018). Concern for sei whales was amplified by a mass stranding of over 300 individuals off southern Chile in 2015 (Häussermann et al. 2017); smaller stranding events have occurred since then (Olavarría et al. 2019).

In Chile, and the Southeast Pacific, there is little information about sei whale distribution and seasonal

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movements. Sei whale presence (sightings and some whaling data) has been documented along nearly the entire Chilean coast (Aguayo-Lobo et al. 1998a) from the north of Antofagasta (Findlay et al. 1998) to Antarctic waters (Aguayo & Torres 1967), including northern Chilean Patagonia (Buchan et al. 2021, 2022), southern Chilean Patagonia (Español-Jimenéz et al. 2019), and the Juan Fernandez Archipelago (JFA) (Aguayo-Lobo et al. 1998b). Feeding areas have been documented in southern Chile off the northwestern coast of Chiloé (Guzmán 2006), in the Magellan Strait (Acevedo et al. 2017), the Golfo de Penas (Reiss et al. 2020), and the Corcovado Gulf (Buchan et al. 2021).

Sei whale acoustic behaviour is poorly known. Vocalisations have been described from a number of widely spread geographic areas in the North Atlantic, North Pacific and Southern Oceans. However, until 2019, there were no records of sei whale acoustic signals in the Southeast Pacific (Español-Jiménez et al. 2019). Among the different types of acoustic signals that have been recorded for this species, there are mid-frequency vocalisations (Thompson et al. 1979, Knowlton et al. 1991, McDonald et al. 2005) including a mid-frequency song (200–5000 Hz), (Cerchio & Weir 2022), low-frequency vocalisations (<200 Hz) including downsweeps (Baumgartner et al. 2008, Español-Jiménez et al. 2019, Cerchio & Weir 2022), upsweeps, 'L' calls, low-frequency variable calls, and upsweep–downsweeps (Calderan et al. 2014, Cerchio & Weir 2022). In a recent study conducted by Cerchio & Weir (2022), with near-annual PAM coverage off the Falkland Islands/Islas Malvinas, the acoustic presence of low-frequency vocalizations was found throughout the year, with a higher occurrence in March and April. However, sei whale seasonal acoustic presence in the Southeast Pacific has not yet been examined.

The main objective of this study was to examine the temporal variability of sei whale upsweep and downsweep vocalisations from 3 yr of acoustic data obtained off the JFA and to determine sei whale seasonal presence in this area. Additionally, we present the frequency, duration, and internote interval (INI) characteristics of a small subset of sei whale calls. This is the first report of the seasonal acoustic presence of the sei whale in the Southeast Pacific.

2. METHODS

2.1. Data collection

The study used 3 consecutive years of passive acoustic data (2015, 2016, and 2017) provided by the Comprehensive Test-Ban-Treaty Organization (CTBTO; https://www.ctbto.org/) through the Chilean Nuclear Energy Commission. These data were collected at Station HA03 off the JFA (Fig. 1), continuously recorded without interruption at a sample rate of 250 Hz with a hydrophone deployed on a cabled array suspended at 813 m depth in a total water column depth of 1538 m, with a sensitivity of 558.9 µPa per digital count.

This station collects low-frequency passive acoustic data with the primary objective of detecting underwater nuclear explosions globally (Bondár & North 1999). However, these data also serve to study large whale species vocalizing at frequencies of up to ~115 Hz (e.g. Stafford et al. 2011, Buchan et al. 2019, 2020, Miksis-Olds et al. 2019, Leroy et al. 2021). Acoustic data from a single hydrophone (node 1 from the north triad) at 33° 27′ 28.8′′ S, 78° 56′ 2.8′′ W were used for the analysis. Detection range was not estimated in this study due to analytical time constraints.

2.2. Data analysis

To determine the temporal acoustic presence of sei whales, we focused on the following target signals: sei whale downsweep (primarily based on Español-

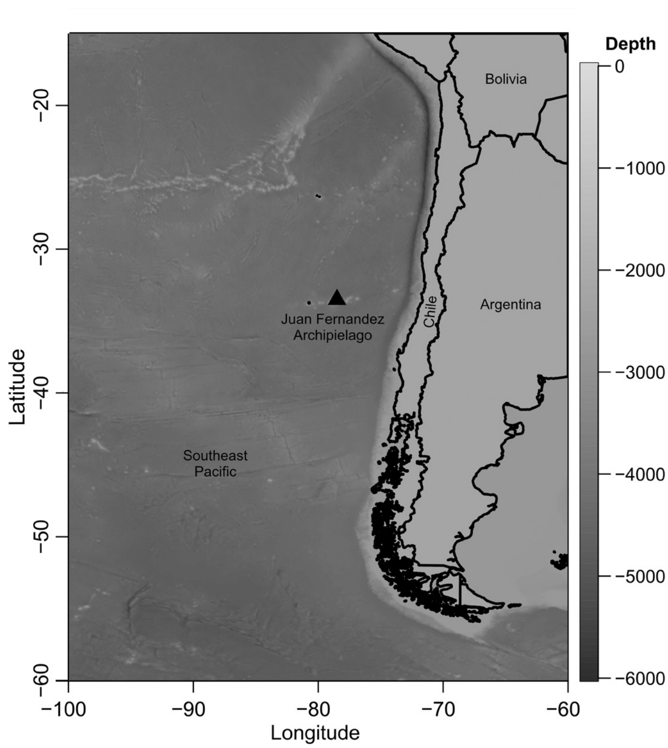

Fig. 1. Study area and location (black triangle) of CTBTO HA03 station off the Juan Fernandez Archipelago (JFA). Revised from Buchan et al. (2019)

Jiménez et al. 2019, Cerchio & Weir 2022) and upsweep calls (per Calderan et al. 2014, Cerchio & Weir 2022). Other call types and subtypes recently described by Cerchio & Weir (2022) were not considered given time constraints in analysis and because their very detailed characterization of call types and subtypes is beyond the scope of this study. We consider that the broad categories of downsweep and upsweep call types are sufficient for examining trends in the temporal presence of sei whales.

Moreover, given that sei whale downsweeps may resemble downsweeps produced by other whale species in this study area, such as fin whale *B. physalus* and blue whale *B. musculus* (Buchan et al. 2020), and visual confirmation of species was not feasible, we applied a criterion to remove downsweeps that could be confused with other species. Since doublets and triplets (or series of more), and upsweeps are stereotyped and considered indicative of sei whales in multiple regions (e.g. Baumgartner et al. 2008, Newhall et al. 2012, Español-Jiménez et al. 2019, Tremblay et al. 2019, Davis et al. 2020, Nieukirk et al. 2020, Cerchio & Weir 2022, Macklin et al. 2024), downsweeps were only included in our analysis if they occurred as doublets, triplets, or more (Fig. S1 in the Supplement at www.int-res.com/articles/suppl/n055p043_supp.pdf), or were adjacent (<60s) to a series of 2 or more downsweeps or an upsweep (Fig. S1). Any solitary downsweep that did not meet this criterion was excluded from data analysis (Fig. S2).

2.2.1. Development of an automatic detector with 1 month of data

Two automatic detectors were developed to target sei whale acoustic signals. The first was for upsweeps (Fig. 2A); this detector also occasionally detected some upsweep—downsweep vocalisations (Fig. 2B) due to their similarity. The second detected downsweeps (Fig. 2C). The 'Template Detector' tool of the Raven Pro 2.0 software (K Lisa Yang Center for Conservation Bioacoustics 2023) was used, which detects a signal of interest by means of spectrogram cross-correlation with a data template or kernel.

A visual scan performed by an experienced analyst (S. Alvarez Abarzua) of data from 2016 was carried out in Raven Pro 2.0, and it was determined that September was the month with the highest presence of calls. Data from September were visualised in spectrograms (FFT of 128 samples, 70% overlap, Hann window). Upsweeps and downsweeps were identified based on literature (Calderan et al. 2014, Español-Jiménez et al. 2019, Cerchio and Weir 2022), annotated and compiled with the 'Selection Table' function in Raven Pro 2.0. From 846 annotated upsweeps and 557 annotated downsweeps from September, the 30 highest-quality upsweeps and 30 highest-quality downsweeps were selected to build the detector (Fig. S3). Quality was determined using the 'SNR NIST Quick' metric of Raven Pro 2.0, which is an approximation of the signal-to-noise ratio. All signals used in the data template had an SNR NIST Quick >20 dB.

For the upsweeps, based on the standard deviation of the low (43.6 ± 5.5 Hz) and high (67.1 ± 6.4 Hz) frequencies of all annotated calls (n = 846) in September 2016, the detector was configured with a 'detection frequency range' of 7 Hz (i.e. maximum allowable frequency shift). The performance of the upsweep detector was evaluated based on 6 correlation thresholds between 0.75 and 0.80. The Raven 2.0 'Compare Tables' tool was used to compare the detections obtained at each correlation threshold with the annotated subsample and quantifying true positives, false positives, and false negatives. From this, 4 types of performance metrics were calculated: recall, precision, false detection rate, and missed detection rate (according to Baumgartner et al. 2019) for each threshold and ultimately a correlation threshold of 0.75 was chosen (Fig. S4).

With the objective of reducing the number of false positives for the upsweep detector (improving precision and false detection rate), a post-processing filter based on INIs was applied. INIs were calculated as the time period(s) between the beginning of 2 consecutive signals (Fig. 2A) (after Buchan et al. 2019). Several INI filters were evaluated, and ultimately, the 420 s filter was chosen, because it greatly improved precision and false detection rate, with only a small decrease in recall (Fig. S5).

The lower end of sei whale downsweeps overlap in frequency with the downsweep vocalisations of other whale species, such as fin and blue whales (Ou et al. 2015), also known to occur in the study area (Buchan et al. 2020). To reduce potential false positives, the detector was configured with a 'detection frequency range' of 0 Hz. As for the upsweeps, the detector's performance was evaluated based on 6 correlation thresholds between 0.73 and 0.78, and optimal performance was determined with a correlation threshold of 0.73 (Fig. S4). No post-processing filter was applied for the downsweep detector because it had no impact on performance.

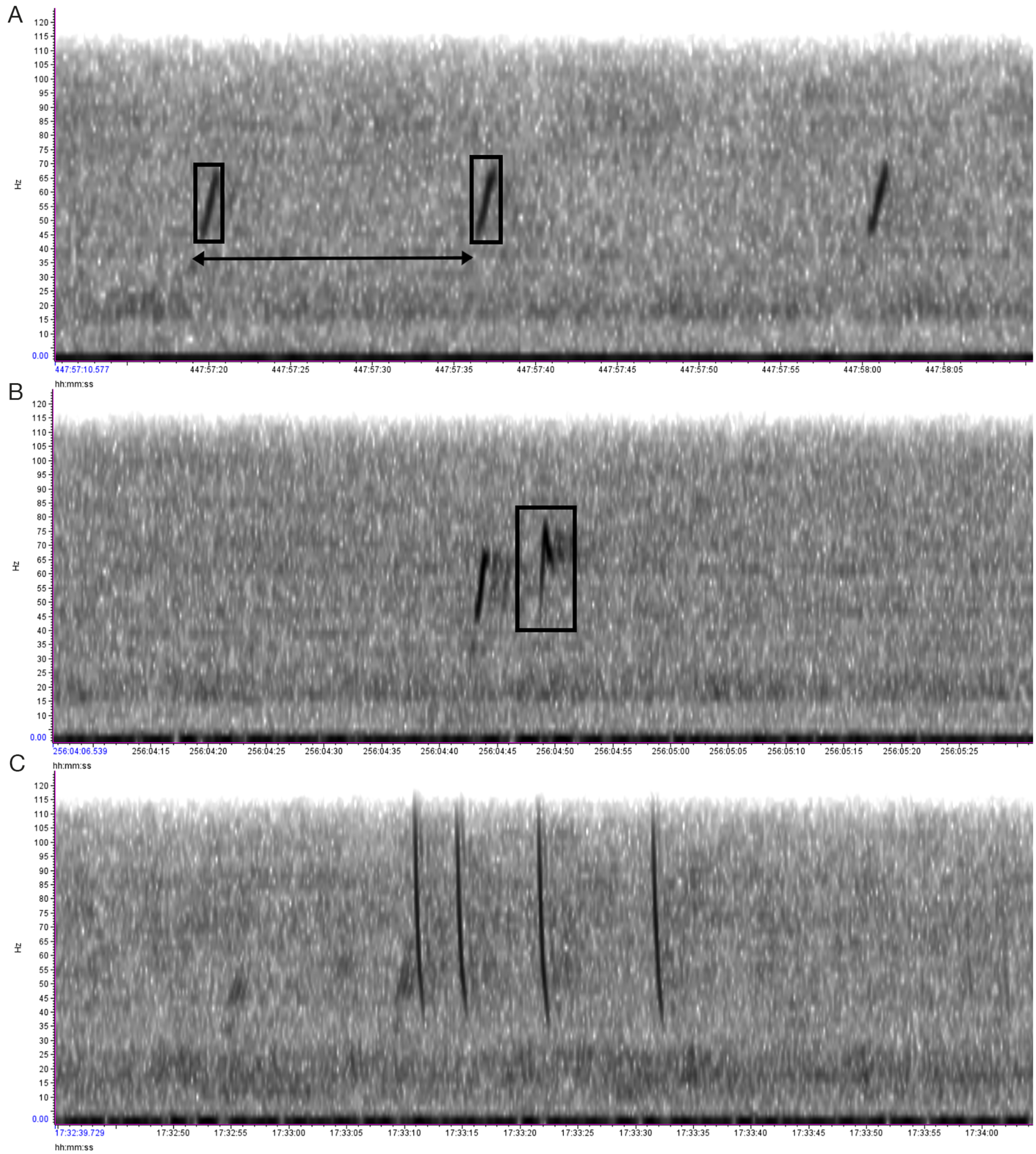

Fig. 2. Spectrogram (128 pt FFT, 70% overlap, Hann window, 250 Hz sample rate) of (A) upsweep vocalisations, (B) upsweep–downsweep vocalisations (black rectangle), and (C) downsweep vocalisations of sei whale off the JFA, September 2016. (A) The double arrow indicates how the inter-note interval (INI) between two consecutive signals (black boxes) was determined

2.2.2. Assessment of automatic detector performance

The performance of both detectors was assessed on a subset of data which included the entire month of September 2016 and a random subset of approximately 722 h yr^{-1} (~8.3% yr^{-1}) from July–December in 2015 and 2017. This provided a subset of 1787 annotated upsweeps and 1035 annotated downsweeps to test detector performance. This subset was manually annotated in Raven Pro 2.0 using the same method used for developing the detectors. Using this annotated subset, the following metrics were calculated per year per detector: false detection rate, missed detection rate, precision and recall (according to Baumgartner et al. 2019) (Table 1).

2.2.3. Monthly call rate analysis

To determine monthly call rates, the upsweep detector and post-processing filter were applied to the entire 2015–2017 dataset. The downsweep detector, which had a high false detection rate, was only applied to a random 50% subsample of the entire 2015–2017 dataset. All detections were reviewed by an experienced analyst (S. Alvarez Abarzua) to manually delete false detections or calls that did not meet the criteria for species identification (see first paragraph of Section 2.2).

With only the filtered true positive detections, a monthly call rate (calls h^{-1}) was calculated by normalising total monthly calls by total hours of PAM recording effort. Monthly call rates were then plotted as a time series to examine acoustic presence per season (spring: September–November; summer: December–February; autumn: March–May; winter: June–August).

2.2.4. Sei whale call characterization

For the characterization of sei whale vocalisations, the top 100 highest-quality upsweep and downsweep calls (>20 dB), determined using SNR NIST Quick, were selected from the manual annotations from all 3 yr of acoustic data. Mean ± SD of peak frequency, high and low frequency, and duration of calls were calculated. Given the upper limit of the frequency bandwidth of our dataset, it was not possible to make measurements above 115 Hz, thus possibly underestimating the high frequency measurements of downsweeps. This is an inherent limitation of our dataset.

To provide an approximation of the INIs for upsweeps and downsweeps, these were calculated for all true positive detections from the entire study period (2015–2017) and values were rounded to the nearest second. Results were plotted as a frequency histogram to examine INI distribution per year.

Table 1. Performance evaluation metrics of the detector on subsamples from the years 2015, 2016, and 2017. Rates do not have specific units. Note that false detections were eliminated manually for final results in Fig. 3

Year	Vocalisation	False detection rate	Missed detection rate	Precision	Recall
2015 (730 h, Jul–Dec)	Upsweeps	0.45	0.30	0.55	0.70
	Downsweeps	0.91	0.30	0.09	0.70
2016 (722 h, Sep)	Upsweeps	0.39	0.25	0.61	0.75
	Downsweeps	0.89	0.29	0.11	0.71
2017 (722 h, Jul–Dec)	Upsweeps	0.70	0.29	0.30	0.71
	Downsweeps	0.96	0.21	0.04	0.79

3. RESULTS

3.1. Seasonal variation

A total of 1590 upsweeps were detected in 2015, 1026 in 2016, 1182 in 2017, and a total of 652 downsweeps were detected in 2015, 388 in 2016, and 600 in 2017. Monthly upsweep call rates ranged between 0 and 1.2 calls h^{-1} (Fig. 3) with a relatively consistent seasonal pattern for all years: none or very few detections in the months of December to July (except for June 2017), and overall, more detections in late winter and spring (between August and November), with a peak in September. Monthly downsweep call rates varied from 0 and 0.69 calls h^{-1} (Fig.3) and higher rates were seen in winter (June–August) and spring (September–November), with some occurrences in autumn (March–May) and almost none in summer (December–February).

3.2. Sei whale vocalisation characterization

Upsweeps varied in frequency, ranging from an average minimum of (mean ± SD) 41.3 ± 5 .2 Hz to an average maximum of 72.2 ± 4.1 Hz over (mean ± SD) 1.5 ± 0.3 s, with a peak frequency of 62.0 ± 8.3 Hz (Table 2). The downsweeps varied in frequency, ranging from an average maximum of 102.3 ± 13.2 Hz to an average minimum of 35.3 ± 6.1 Hz during 1.3 ± 0.1 s with a peak frequency of 56.3 ± 10.9 Hz (Table 2).

The distribution of INIs for upsweeps (Fig. 4; data only shown up to INI = 40s) showed a bimodal distribution over all years, with the first peak at 7 s and a second at 14 s (i.e. exactly double the first peak). Examining years separately, the dominant INI in 2015 and 2016 was 7 s and 14 s in 2017. The dominant INI for downsweeps was 4 s for all 3 years (Fig. 5).

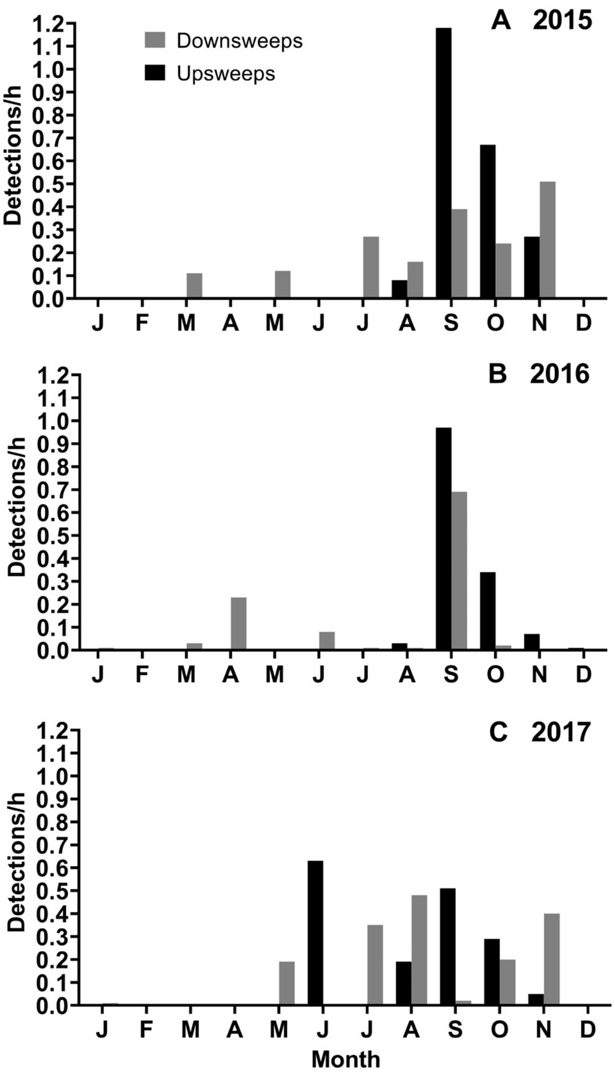

Fig. 3. Monthly rates of validated detections of sei whale vocalisations off the JFA from automatic detection of upsweeps and downsweeps (detections per hour of passive acoustic monitoring effort) from 3 consecutive years of acoustic data: (A) 2015; (B) 2016; and (C) 2017

4. DISCUSSION

4.1. Seasonal distribution of the sei whale off the JFA

The results from this study confirm the annual acoustic presence of sei whales off the JFA, with higher presence in winter and spring months. This seasonal pattern is not as marked as the pattern reported for fin whales, which have much higher overall acoustic presence off the JFA (Buchan et al. 2019). Based on detector performance, we can say that at least 70% of sei whale calls in the dataset were detected, however the 30% missed detection rate means that we are most likely underestimating the total number of calls recorded. Nevertheless, this is unlikely to change the overall seasonal pattern observed, which is consistent in all 3 years. We cannot rule out the presence of sei whales in other months of the year because animals may be present but silent (Baumgartner et al. 2008).

The acoustic data used in this investigation were collected without simultaneous visual sighting data, nonetheless, based on the available literature (Calderan et al. 2014, Español-Jiménez et al. 2019, Cerchio & Weir 2022), we are confident that the calls described here come from sei whales. The likelihood of confusion with other species is low since all detections were reviewed manually and checked using conservative criteria to make sure they did not resemble other baleen whales in the study area (e.g. Buchan et al. 2020).

In this study, although we did not estimate the detection range of sei whale vocalisations, this has been done previously for fin whale calls off the JFA (Buchan et al. 2019), whose detection range was 97 to 324 km, depending on whale calling depth. Given that sei whales have a lower source level (Romagosa et al. 2015) than fin whales (Širović et al. 2007), it is reasonable to assume that the detection range will be smaller for sei whales off the JFA than that reported for fin whales.

There are several non-mutually exclusive explanations for higher sei whale presence off the JFA in austral winter and spring. First, the JFA could be an area of transit along the sei whale migratory route, given that this species is thought to migrate between wintering grounds at lower latitudes and summer feeding grounds at higher latitudes (Mizroch et al. 1984). Presence of sei whales based on visual sightings (Pastene & Shimada 1999, Aguayo-Lobo et al. 2006, Guzmán 2006, Acevedo et al. 2017, Cisterna-Concha et al. 2022), strandings (Häussermann et al. 2017, Reiss et al. 2020), and acoustic monitoring (Español-Jiménez et al. 2019, Buchan et al. 2022), has been reported off coastal feeding grounds in southern Chile between November and May (austral spring through autumn), which coincides with the period that the acoustic presence of sei whales decreases off the JFA. This might suggest spring/winter presence offshore at mid-latitudes (like the JFA) and spring, summer, and autumn presence of animals off feeding grounds of mainland southern Chile. This would indicate an onshore/southern migration during spring and an offshore/northern migration during late autumn. We do not know, however, that whales sighted or acoustically de-

Table 2. Characterization of sei whale calls. Note that the 250 Hz sample rate of the data does not allow measurements above 115 Hz.

Call type	High frequency (Hz)	Low frequency (Hz)	Peak frequency (Hz)	Duration (s)	SNR NIST Quick (dB)
Upsweeps (n = 100)					
Mean	72.2	41.3	62.0	1.5	23.7
SD	4.1	5.2	8.3	0.3	2.0
Downsweeps (n = 100)					
Mean	102.3	35.3	56.3	1.3	25.4
SD	13.2	6.1	10.9	0.1	1.8

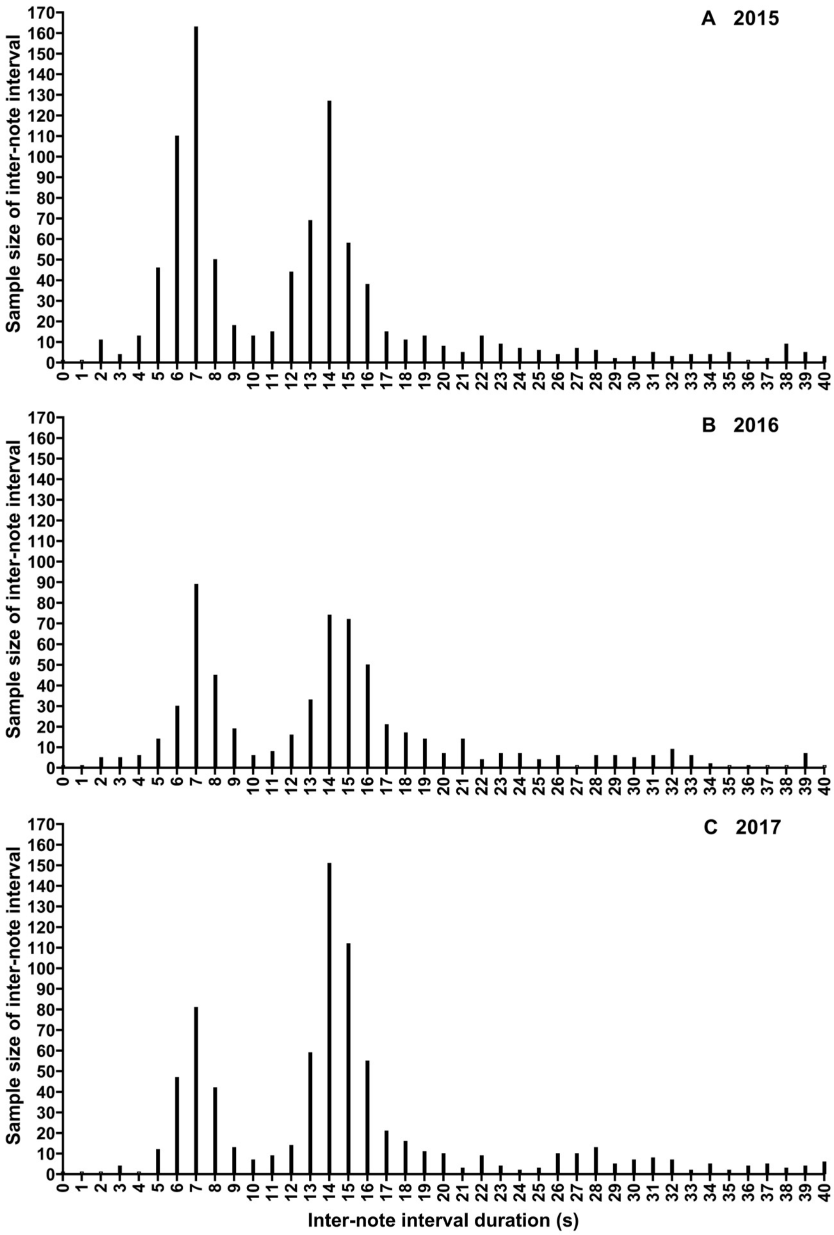

Fig. 4. Inter-note interval (INI) of sei whale upsweeps off the JFA from 3 consecutive years of passive acoustic data: (A) 2015, (B) 2016, and (C) 2017. INI was calculated from validated detections for each year as the duration in seconds between 2 consecutive upsweep detections. Values were rounded to the nearest second

tected off mainland Chile are the same animals that are heard off the JFA.

A second explanation is that the high biological productivity of the JFA (Andrade et al. 2012, Ernst et al. 2020) could provide feeding habitat for sei whales. Archipelagos and seamounts are recognized for playing a crucial role as feeding habitats for large whales (Kaschner 2007, Morato et al. 2008, Visser et al. 2011). For example, several species of baleen whale have been observed feeding seasonally in the Azores, which is considered a transit area along their migratory routes (Visser et al. 2011).

Additionally, the JFA could provide a habitat for possible reproductive behaviours and/or calving, although no breeding areas or times of year have been identified for sei whales in the southeast Pacific. However, in Brazilian waters, off the Vitória-Trindade Chain (latitude ~ 20°S) 3 sightings of mother—calf pairs were made in May and June 2015, suggesting a winter calving ground in the southwest Atlantic (Heissler et al. 2016).

Lastly, it has been proposed that downsweeps are contact calls between sei whales (McDonald et al. 2005) and could suggest the presence of an aggregation of animals during foraging or social behaviours (Baumgartner et al. 2008). Clearly, many questions remain open regarding the function of sei whale calls in Chile and globally.

4.2. Characteristics of sei whale vocalisations off the JFA

The downsweeps of the sei whales characterised in this study had frequencies of ~102.3 to ~35.3 Hz with a

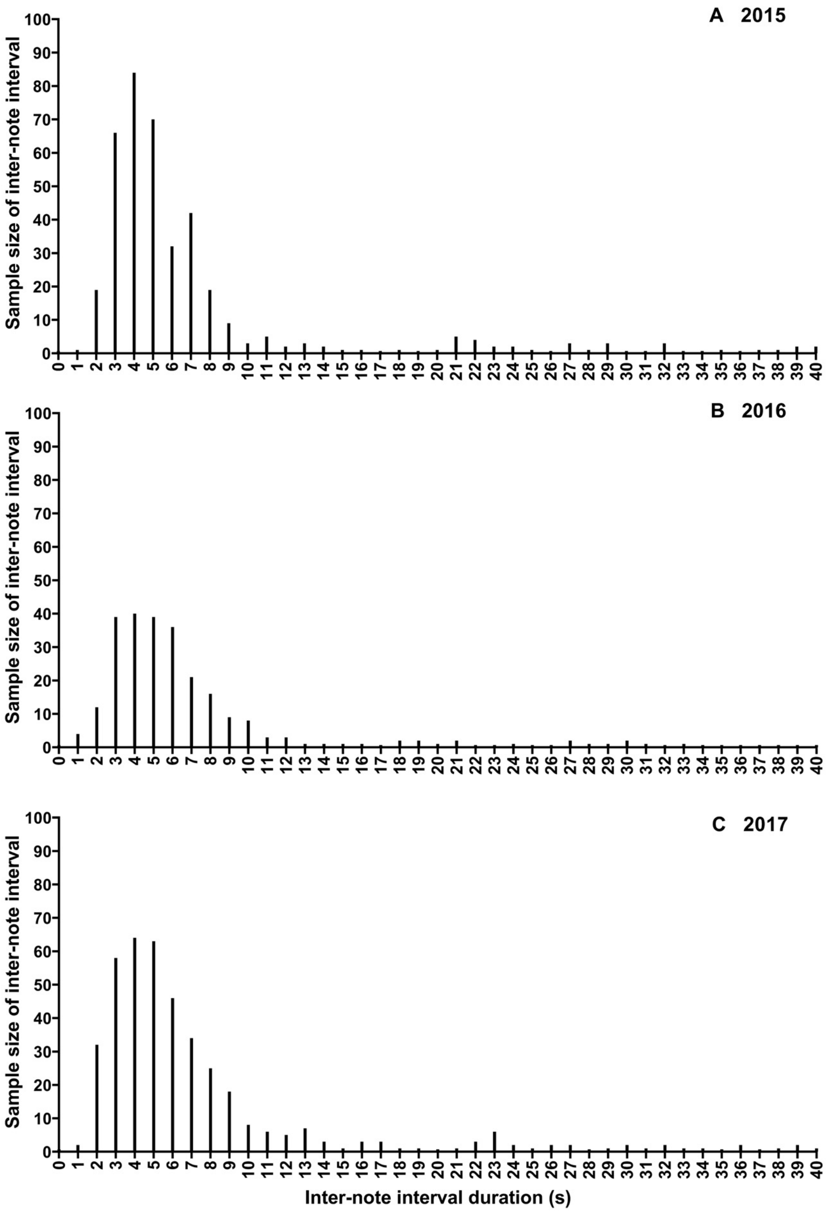

Fig. 5. Inter-note interval (INI) of sei whale downsweeps off the JFA from 3 consecutive years of passive acoustic data: (A) 2015, (B) 2016, and (C) 2017. INI was calculated from validated detections for each year as the duration in seconds between 2 consecutive downsweep detections. Values were rounded to the nearest second

duration of ~1.3 s and a modal INI of 4 s. The downsweeps reported here are within the range of frequency and duration reported by Español-Jiménez et al. (2019) for the Gulf of Penas and Tres Montes (Chilean Patagonia); they also present very similar characteristics to downsweeps described in the Falkland Islands/Islas Malvinas by Cerchio & Weir (2022), albeit with lower maximum frequencies. This difference may be due to an underestimation of the high-frequency measurement of downsweeps (due to the 250 Hz sample rate in this study). Although there are some similarities in the frequencies and durations reported in this study and in other studies in the Southern Hemisphere (Español-Jiménez et al. 2019, Cerchio & Weir 2022), the high frequencies are, on average, slightly higher that reports for the Northern Hemisphere (Rankin & Barlow 2007, Baumgartner et al. 2008, Romagosa et al. 2015, Ou et al. 2015, Tremblay et al. 2019, Macklin et al. 2024).

The dominant INI (4 s) of downsweeps in this study fit the general range (mean ± SD: 3.5 ± 0.36 s) reported by Baumgartner et al. (2008) off New England. The only other report for INI comes from sei whales in the northeast Atlantic (Macklin et al. 2024). This is the first INI report for this species in the southeast Pacific and is over 1 s longer than the average INI from the northeast Atlantic, which was reported as 2.2 s. This may be due to the method used to calculate the INI (Buchan et al. 2019), which was obtained by calculating the interval between consecutive true positive detections which could include the time between 2 calls in a doublet or between a singlet and the next singlet. Any false negatives could introduce bias in the form of greater values in the INI calculation, and any overlapping sequences of calls (produced by 2 or more animals at the same time), could introduce bias as smaller values in the INI calculation. This analysis was done to offer a first approximation of the INI of sei whale downsweeps in this region, based on a reasonable sample size (>400 calls yr^{-1}; 1984 total).

The frequency of upsweeps reported in this study ranged from ~41.3 to ~72.2 Hz, with a duration of ~1.5 s and a bimodal INI of 7 s and 14 s. The upsweep detector also detected upsweep–downsweep calls; however in our data, the vast majority of calls detected by this detector were upsweeps, not upsweep–downsweeps, which appear to occur less often. Upsweeps have been less studied than downsweeps. The upsweeps found in this study fit the general range reported for the Southern Ocean south of New Zealand (Calderan et al. 2014). Similar signals were found in the Falkland Islands/Islas Malvinas (Cerchio & Weir 2022) but with a lower average minimum frequency (25.4 Hz) and a slightly longer duration (2.0 s) compared to the upsweeps found in this study and Calderan et al. (2014). Differences between upsweeps in different studies may be due to geographical variation, but it is also possible that differences in the proximity of whales to hydrophones and variations in sampling equipment may have affected frequency and duration measurements. The dominant INI of upsweeps recorded in this study also fit the general range informed by Calderan et al. (2014) (mean ± SD: 10.3 ± 2.3 s; range: 1.1–13.5 s). Currently, there are no other reports of sei whale upsweep INIs in the literature.

To date, sei whale upsweep calls have only been reported in the Southern Hemisphere (McDonald et al. 2005, Calderan et al. 2014, Cerchio & Weir 2022, this study). This may indicate that upsweep calls are indicative of Southern Hemisphere sei whales. Like downsweep differences, variation in upsweep characteristics may indicate differences between acoustic groups. In effect, similarities between upsweeps reported in Calderan et al. (2014) and this study may indicate an acoustic group in the South Pacific and the adjacent Southern Ocean, with a distinct acoustic group in the South Atlantic (Cerchio & Weir 2022). It is important to note that acoustic groups do not necessarily correspond to distinct populations; a recent study of sei whale genetics from Chile, the Southern Ocean, Australia, and Northern Hemisphere sites has proposed a single genetic population for the Southern Hemisphere (Pérez-Álvarez et al. 2021).

Higher-frequency (>170 Hz) sei whale vocalisations have been reported in other parts of the world (Thompson et al. 1979, Knowlton et al. 1991, McDonald et al. 2005, Gedamke & Robinson 2010, Cerchio & Weir 2022), but these could not be examined in this study given the sample rate of this study (250 Hz). Additionally, new low-frequency sei whale vocalisations were described in a recent study (Cerchio & Weir 2022) but were not targeted in this study. Therefore, future acoustic studies for this species in the Southeast Pacific should look for these newly described signals and collect data at a higher sample rate to search for higher frequency vocalisations.

This study provides new information on the spatial–temporal distribution of this endangered species in winter and spring off JFA. Understanding the distribution and movements of this species is all the more important in light of the mass strandings of sei whales off the coast of Chile in recent years (Olavarría et al. 2019). This is the first report of sei whale vocalisations off oceanic islands in the southeast Pacific and further confirms the JFA as an Important Marine Mammal Area (IUCN-MMPATF 2023). To improve the understanding of the distribution, seasonal movements, and social structure of this poorly studied species, future research should be focused on a wider spatial and temporal PAM coverage in the southeast Pacific, with higher sample rates for recording the full range of sei whale vocalisations and detection range estimations as well as visual sighting efforts in Chilean waters.

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