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Author for correspondence:

Xavier Raick

e-mail: xavier.raick@cornell.edu

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Do sea lions fall silent when fish have something to say?

Xavier Raick^{1,2}, Claudia J. Hernández-Camacho³ and Damien Olivier^{4,5}

¹K. Lisa Yang Center for Conservation Bioacoustics, Cornell Lab of Ornithology, Cornell University, Ithaca, NY, USA

²Marine Mammal Research, Department of Ecoscience, Aarhus University, Roskilde, Denmark

³Centro Interdisciplinario de Ciencias Marinas (CICIMAR), La Paz, B.C.S., Mexico

⁴Departamento Académico de Ciencias Marinas y Costeras, Universidad Autónoma de Baja California Sur, La Paz, Baja California Sur, Mexico

⁵Secretaría de Ciencia, Humanidades, Tecnología e Innovación, Ciudad de Mexico, Mexico

XR, 0000-0002-1977-0289

Coastal soundscapes are complex systems composed of many biological sounds, among which fish often play a central role. Marine mammal vocalizations can also contribute substantially, either when animals pass through an area or because their loud calls can be heard from offshore. Sea lion colonies, known for their intense aerial vocalizations, may also represent a major sound source around breeding areas. However, how colonies shape the underwater acoustic environment remains poorly understood. This study focused on the barking of California sea lions (*Zalophus californianus*) at Los Islotes (Gulf of California), to quantify diel and seasonal patterns of vocal activity and its interaction with the surrounding biophony. We developed an AI-based detector trained on BirdNET to identify major biophony components. Barks dominated the diurnal soundscape, while fish sounds dominated just after the end of twilight. Their diel peak coincided with a reduction in sea lion vocalizations. Fish sound abundance increased from April–May to June–July. Bark abundance remained stable. The negative diel correlation between bark and fish sound abundance highlights temporal partitioning among taxa, illustrating the integration of aquatic–aerial soundscapes and demonstrating the potential of passive acoustics to study pinniped vocal behaviour and its interplay with reef biophony.

1. Introduction

California sea lions (*Zalophus californianus*) breed on islands along the eastern Pacific Ocean, from Southern California to the Baja California Peninsula, including the Gulf of California [1]. Sea lion presence begins to increase in May at the onset of the breeding season. From May through June, females give birth to a single pup and enter oestrus approximately four weeks postpartum, after which

mating occurs. The breeding season concludes in August. At the breeding sites, strong female mate choice and male–male competition [2] result in a highly polygynous lek-type mating system [3]. Aggressive behaviours used to defend territories increase in intensity when females are about to enter oestrus [4]. Territorial defence during this period is known to involve vocalizations, particularly barking [2].

Unlike other otariid species, which produce a wide variety of vocalizations during territory defence when reproductively active [5], breeding male California sea lions rely mainly on barking [6]. Barks are described as percussive sounds [6] characterized by a rich harmonic structure and an up-down-up frequency modulation [7]. Their bark is described as incessant and raucous, and can be produced both in air and underwater [7,8]. In addition to barks, they can emit clicks, although their function remains debated.

During the breeding season, aerial barking is used in territorial and sexual contexts. Barks and clicks produced with the head above water can also be recorded underwater [8] and are called ‘amphibious’ [7]. In addition, as bulls’ territories have both terrestrial and aquatic components, sounds can be emitted when males patrol in the water or on land. Underwater barks are more common at high tide, when a larger portion of the territory is submerged [7]. Aerial and underwater barks are acoustically very similar, although produced with the mouth open or closed, respectively [7]. A typical sequence may involve an animal barking amphibiously, then submerging to bark underwater, resurfacing to bark amphibiously again, and repeating the cycle [7].

Whether produced underwater or in air may be relevant from a terrestrial perspective, but from an aquatic ecoacoustic standpoint, all these sounds are part of the same underwater soundscape, since they can both be detected underwater. The concept of the soundscape, first called the ‘bio-spectrum’ [9], encompasses biological sounds, anthropogenic noise and geophysical sounds [10]. In the marine environment, soundscapes typically exhibit strong diel variation, driven by sounds emitted by fish [11–13], invertebrates [14–16], cetaceans [17,18] or humans [17–19]. The differential use of acoustic resources by species within an ecosystem forms the basis of the Acoustic Niche Hypothesis (ANH) [20]. Just as the ecological niche can be defined as a hypervolume in which each dimension represents a resource axis, the acoustic niche is a subset of this hypervolume that encompasses acoustic resources (e.g. temporal, spectral and diel features) [12,21]. In the Gulf of California, rocky reefs are dominated by a fish biophony primarily driven by a sound type referred to as ‘highFPT-1’ [22]. It is a ‘fast pulse train’ pulse series with no apparent frequency modulation, with most of the energy between 400 and 1400 Hz. This sound type shares a similar pulse period with Sciaenidae sounds reported in the northern Gulf of California [23], but differs in terms of frequency. However, the extent to which other taxa contribute locally to the soundscape remains poorly understood.

What does the soundscape near a California sea lion breeding colony sound like? Is it truly an incessant acoustic environment, and how does it interact with the rest of the underwater biophony? To try answering these questions, this study aims to characterize the diel cycle of California sea lion acoustic activity using underwater recordings from Los Islotes colony in the Gulf of California (Mexico), collected just before and during the breeding season. Los Islotes is the only reproductive colony in La Paz Bay region [24,25]. In addition to describing these soundscapes, this work represents a first attempt to apply passive acoustic monitoring (PAM), a non-intrusive monitoring technique [26], to track colony activity without the need for land-based observations during the breeding season.

2. Material and methods

2.1. Sites and recordings

The study was conducted at Los Islotes, an islet north of the Archipelago of Espiritu Santo-La Partida (La Paz Bay, Baja California Sur, Mexico), a Marine National Park part of a UNESCO Biosphere Reserve. It is known to host one of the few colonies in the Gulf of California with a healthy growing population [24]. Population size has increased from 195–209 individuals in 1978–1981 [27] to 874 individuals in 2023 [28]. By contrast, most colonies in Mexico are either declining or remaining stable [29–31]. Los Islotes is also the most visited colony by tourists in Mexico [24]. The birth period extends from the last week of May to the third week of July, with the peak of births occurring in the last week of June [32]. The peak of suckling at this site occurs in June and decreases progressively as the season advances [30,31,33].

An autonomous acoustic recorder was deployed twice on the north and south sides (24°35′57.28″ N, 110°24′6.53″ W; 24°35′55.17″ N, 110°24′6.48″ W; figure 1). Recorders were either SNAP or LS1 units

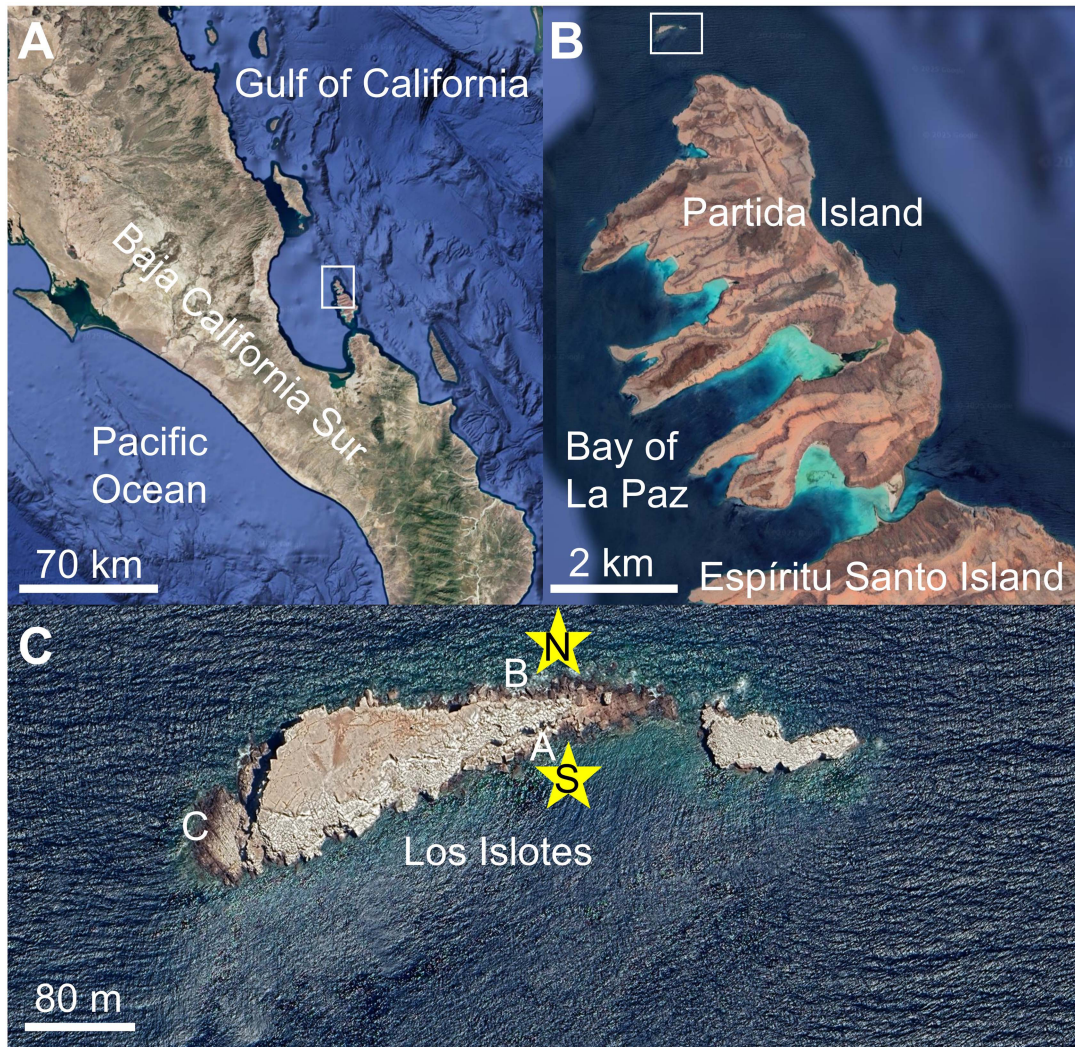


Figure 1. Study site. Panel B is a zoom-in of panel A, and panel C is a zoom-in of panel B. Yellow stars indicate recorder deployment locations. N = north, S = south, A = Zone A, B = Zone B and C = Zone C. Map attributions: (A) SIO, NOAA, U.S. Navy, NGA, GEBCO, Landsat / Copernicus, LDEO-Columbia, and NSF; (B) SIO, NOAA, U.S. Navy, NGA, GEBCO, LDEO-Columbia and NSF; (C) Airbus.

(Loggerhead Instruments; Sarasota, FL) connected to HTI-96-Min hydrophones (sensitivity ≈ -170 dB re $1 \text{ V}\mu\text{Pa}^{-1}$), recording at a sampling rate of 44.1 kHz with 16-bit resolution. The recording schedule was 1 min every 10 min, except for one deployment in which it was 1 min every 20 min. Because one deployment used a 20-min recording cycle instead of 10 min, all detections were rescaled to a common 20-min sampling interval to ensure comparability across deployments. Recorders were deployed at approximately 8–10 m depth on the north side and at approximately 10–12 m depth on the south side. For the second deployment, the recorder at the north site had to be positioned at 22 m owing to stability concerns. Sea lions are mainly concentrated in three zones: A (south), B (north) and C (west) versus intermediate zones (figure 1). Each zone functions as a breeding area, predominantly occupied by territorial males, females and their pups. Zones A and B are located within the public-use area, where recreational activities such as swimming, snorkeling and scuba diving are permitted throughout the year, with the exception of the breeding season (1 June to 31 August). By contrast, Zone C is situated in an area where all recreational activities are prohibited [34]. The three zones currently constitute the main breeding areas. The intermediate zones also function as breeding areas, as the colony has expanded to the point that the entire site is now occupied by breeding territories. Adult females exhibit strong site fidelity within the colony [35]. The south and north deployment sites are situated in the so-called zones A and B, respectively.

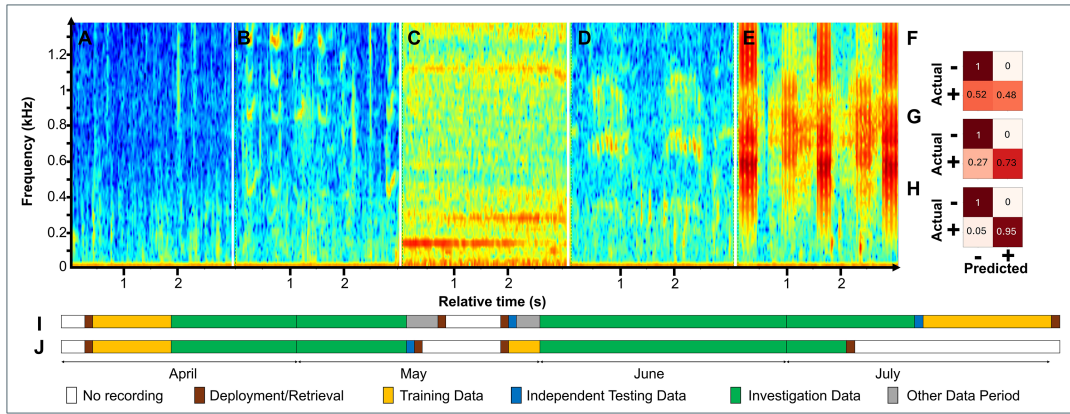


Figure 2. Spectrogram of (A) background ambient noise, (B) sea lion barks (dotted lines highlighting one bark), (C) boat noise, (D) two sea lion series of clicks, and (E) five nocturnal Sciaenidae sounds. Sampling frequency = 44.1 kHz. FFT size = 2 048; Hann window; 50% overlap. Confusion matrix for the sea lion bark detector after (F) the first independent test, (G) model improvement and second independent test, and (H) model improvement and third independent test. Timescale of the acoustic data collected between 1 April 2024 and 1 August 2024 at (I) the north site, and (J) the south site.

During the first deployment, recordings were collected from 4 April to 19 May 2024 at the north site, and from 4 April to 16 May 2024 on the south site. During the second deployment, recordings were collected from 27 May to 1 August 2024 on the north site, and from 27 May to 8 July 2024 on the south site. To put this into perspective, births are currently recorded from late April through September at Los Islotes, with females entering oestrus approximately 20 days after giving birth, at which point males begin to display territorial behaviour. The ecological investigation was conducted using data from 15 April to 14 May 2024 and from 1 June to 15 July 2024 (figure 2I,J). All remaining data were used for training or testing the automatic detectors (figure 2I,J, see §2.2).

2.2. Acoustic analysis

As manual analysis is highly time-consuming, we aimed to develop an AI-based automatic detector for sea lion barks. A custom detector for sea lion barks was developed using BirdNET software (model V2.4; Cornell University, Ithaca, NY, USA) based on a foundation model. A foundation model is a large artificial intelligence model trained on an extensive dataset, in this case, bird vocalizations, and adaptable to a wide range of applications. With a foundation model, the model is customized by modifying only the final neural layer, which is the output layer responsible for producing predictions or class probabilities specific to the new task [36].

2.2.1. Embeddings search

Embeddings are the lower-dimensional representations of acoustic data learned by a model [37,38]. This embedding search involved four steps: (step 1) presenting example vocalizations, (step 2) generating embeddings, (step 3) measuring similarity, and (step 4) validation by a human analyst [39]. For step 1, one high-signal-to-noise-ratio (SNR) example of a bark sound was selected from the data recorded on 16 July, along with examples of boat noise, background ambient noise and sea lion click sounds (figure 2). For step 2, training data included recordings from 5 to 14 April and 17 to 30 July at the north site, and from 5 to 14 April and 28 to 31 May at the south site. The selection was decided to maximize the independence of the training and testing datasets. Embeddings were searched independently on each recording day and independently at each site. For step 3, the embeddings were ranked in descending order of similarity. For step 4, a maximum of 100 bark, 20 boat and 80 background examples were manually validated and extracted per recording day and per site. It resulted in a total of 3350 bark examples, 1513 background examples and 404 boat examples (figure 3).

As nocturnal Sciaenidae-like fish sounds were a predominant component of the biophony, a detector was trained for them using the same methodology as for barks. These sounds were previously described as 'highFPT-1' [22]. They form a homogeneous sound type, but the emitting species is unknown. During

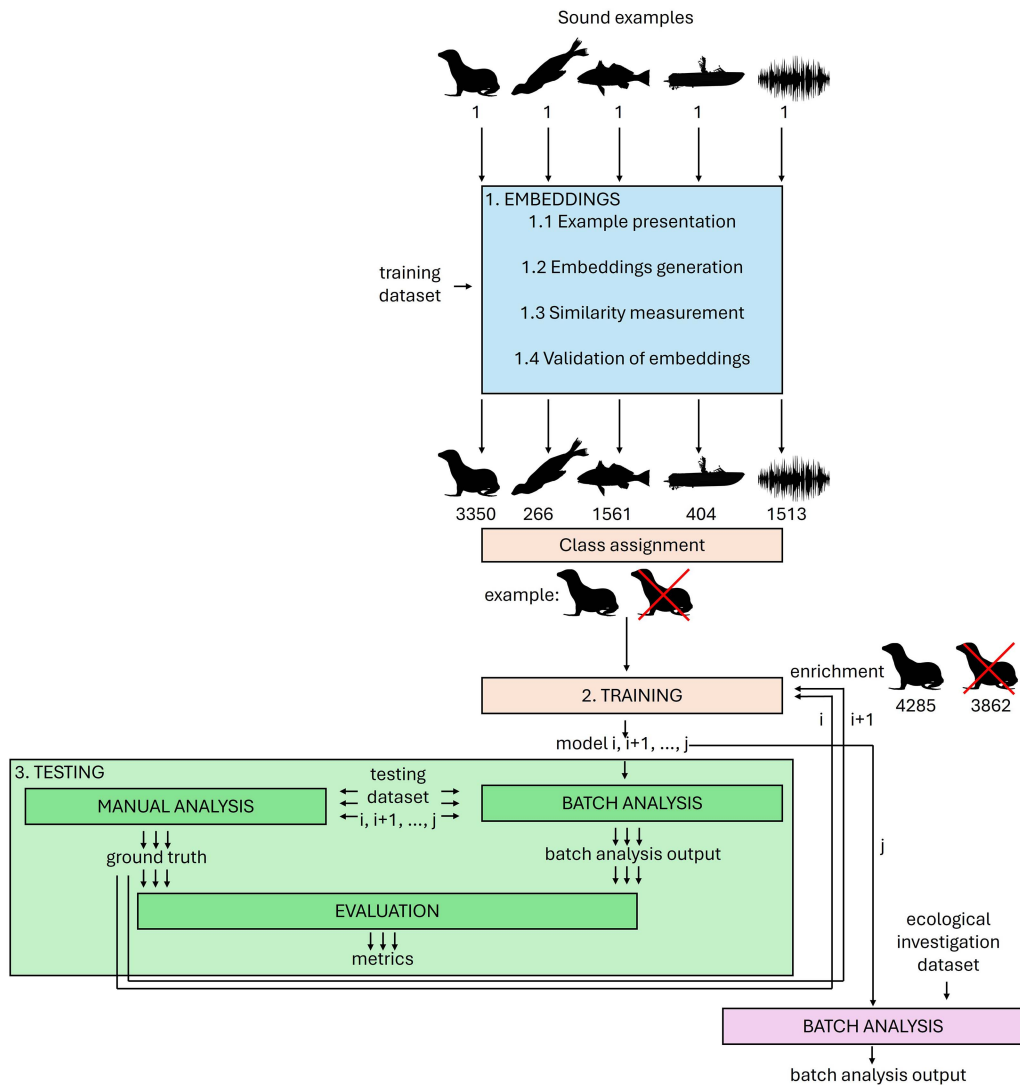


Figure 3. Design of the embeddings search, training and testing of the model illustrating the different steps of the AI model trained in BirdNet.

the embeddings search step, negative examples (i.e. 3 s segments without fish sounds, but considered similar in the embeddings search) were added to the noise class. A total of 1561 nocturnal Sciaenidae examples were used.

2.2.2. Training

Using the training data (i.e. labelled classes obtained from the embedding search), separate models were trained for barks and clicks. For barks, boat and background ambient noise were combined into a single noise category. Autotune was used to search for the best hyperparameters of the model, with 50 trials (i.e. the number of training runs for hyperparameter tuning) and a bandwidth of 0–15 000 Hz.

2.2.3. Independent testing

Data from 28 May at the north site, 15 May at the south site, and 16 July from the north site were used for several independent testing rounds. In total, 38 days (19.9%) were used for training, 3 days for independent testing (1.6%) and 150 days for the ecological investigation (78.5%).

The model was tested on independent data by comparing its batch analysis outputs with the ground truth data obtained through manual analyses (figure 3). The detection threshold (i.e. threshold for

classifying a prediction as positive) was set to 0.1. The detection threshold is the cut-off value to decide if a prediction is positive. Higher thresholds increase precision but reduce recall [40]. Improving recall is particularly important when predictions are used to analyse vocal activity patterns over time. The minimum overlap (i.e. overlap needed to assign an annotation to a sample) was set to 0.5 s, and the sample duration (i.e. audio sample length) to 3 s. Ground truth was established by visually and aurally inspecting 1440 3-s sections in Raven Pro 1.6. (FFT = 2048, Hann window, 50% overlap; Cornell University, Ithaca, NY, USA). For barks, the testing datasets contained between 272 and 1287 3-s segments with barks and between 153 and 1168 segments without. For clicks, which were naturally much less abundant, the testing datasets contained a maximum of 264 segments with clicks and between 1176 and 1440 negative examples. Batch analysis was performed with minimum confidence = 0.25, sensitivity = 1 (default value), no overlap, no audio speed modification and the same bandwidth used previously. After each testing round, newly annotated detections were added to the training dataset, resulting in a final total of 4285 bark examples and 3862 'noise' examples. Across testing rounds, precision increased from 0.91 to 0.94 and recall from 0.74 to 0.97, with accuracy remaining greater than or equal to 0.99 (figure 2F–H). A total of 266 222 3-s periods containing barks and 19 859 3-s periods containing nocturnal Sciaenidae sounds were used for the ecological analysis. Precision measures the proportion of correct positive predictions, recall quantifies the proportion of actual positives correctly identified and accuracy reflects the overall percentage of correct predictions.

2.2.4. Clicks

Finally, for sea lion clicks, the same process was applied. A total of 266 click examples were used (figure 3). Because the pulsed nature of fish sounds could potentially lead to false detections by the detector, pulse series from nocturnal Sciaenidae (see previous paragraph) were included in the noise class. Model recall ranged from 0.82 to 0.99, precision ranged from 0.51 to 0.82 and accuracy remained greater than 0.90. This model was therefore suboptimal compared with the bark detector, and its outputs should be interpreted with caution. A total of 6512 detections were used for the ecological analysis.

2.3. Statistical analysis

Graphs and calculations were performed in R [41]. All abundance data presented in this study are expressed as the number of 3-s segments per 20-min interval. The maximum possible abundance is therefore 400, corresponding to the number of segments within the interval. Sunset and twilight data were retrieved from timeanddate.com. Pearson correlation and associated p -values ($\alpha = 0.05$) were calculated between bark and Sciaenidae-like sound abundances. A Student's t -test was used to compare bark abundance between the two sites for April–May and again for June–July. The same test was used to compare bark abundance between the two periods. The same comparisons were made for clicks.

3. Results

3.1. General abundance between April–May and June–July

In April–May, the number of 3-s segments containing barks was 290 ± 71.6 per 20-min interval at the south site (range: 171–371) and 347 ± 25.2 at the north site (range: 281–380). Thus, when subdividing the biophony into 3-s segments, bark sounds were detected 72.5–87% of the time in April–May. In June–July, the number of 3-s segments containing barks was 289 ± 81.3 per 20-min interval at the south site (range: 111–378) and 343 ± 69.3 at the north site (range: 74–384). Accordingly, bark sounds were detected 72.2–85.8% of the time in June–July. The number of barks was consistently higher at the north site than at the south site in both April–May (347 versus 290, $t = 6.39$, $df = 88.38$, $p < 0.0001$) and June–July (343 versus 289, $t = 4.28$, $df = 138.51$, $p < 0.0001$). No monthly difference was observed at either site, with similar totals in April–May and June–July (north: 347 versus 343, $t = -0.45$, $df = 90$, $p = 0.66$; south: 290 versus 289, $t = -0.049$, $df = 140$, $p = 0.96$).

Segments containing clicks were also consistently more abundant at the north site than at the south site, both in April–May (14.6 ± 8.05 versus 9.21 ± 5.94 per 20-min interval; $t = 4.61$, $df = 130.63$, $p < 0.0001$) and in June–July (74.6 ± 26.2 versus 11.7 ± 7.06 per 20-min interval; $t = 19.68$, $df = 81.29$, $p < 0.0001$). When subdividing the biophony into 3-s segments, click sounds were detected 2.3–3.6% of the time in

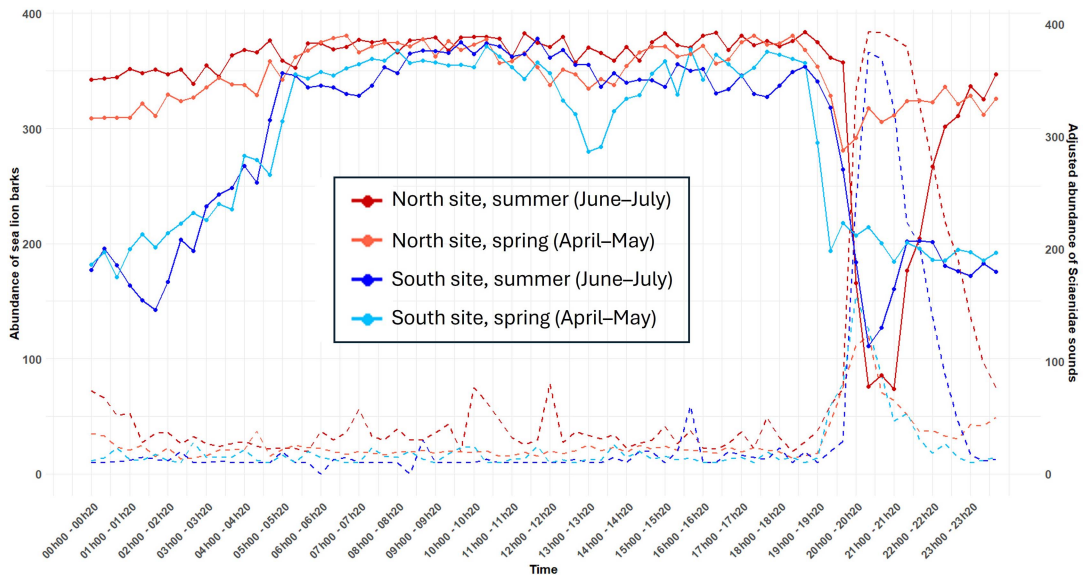


Figure 4. Diel cycle of sea lion bark emission (plain lines) and Sciaenidae-like sounds (dotted lines) for the North site (red lines) and the south site (blue lines) at Los Islotes. April–May is represented with light lines, and June–July is represented with dark lines. Bark values are expressed as the abundance of 3-s segments per 20-min interval, while Sciaenidae sounds are shown on a relative scale in order to be presented in the same graph.

April–May and 2.9–18.6% of the time in June–July. In contrast to barks, a marked seasonal difference was observed at the north site, with substantially higher values in June–July than in April–May (74.6 versus 14.6; $t = 18.58$, $df = 84.32$, $p < 0.0001$).

Besides sea lion vocalizations, which were the most abundant source of biophony, nocturnal Sciaenidae-like sounds were the second most abundant contributors. In April–May, the number of 3-s segments containing such fish sounds was 22.4 ± 25.3 per 20-min interval at the south site (range: 10–158) and 28.3 ± 20 on the north site (range: 13.3–123). When subdividing the biophony into 3-s segments, such fish sounds were detected 5.6–7.1% of the time in April–May. In June–July, the number of 3-s segments containing such fish sounds was 39.8 ± 80.7 per 20-min interval at the south site (range: 0–375) and 75.4 ± 100 at the north site (range: 20–393). Accordingly, fish sounds were detected 10–18.8% of the time in June–July. An increase was observed at both sites from April–May to June–July, more pronounced at the north site (28.3 versus 75.4) than at the south site (22.4 versus 39.8).

3.2. Diel differences between April–May and June–July

When examining the abundance of barks as a function of time of day, clear patterns emerged (figure 4). Barking was consistently more abundant during daytime. In April–May, a 25–50% decrease was observed between 19:00 and 20:00 (local time), followed by a recovery that occurred more rapidly at the north site than at the south site. This drop coincided with the period just after sunset (occurring between 18:37 and 19:05) and before the end of nautical twilight (between 19:27 and 20:00). Night-time is also a known foraging period for female California sea lion [42,43]. Abundance increased around 01:00, reaching daytime levels by 05:00–06:00. In June–July, the pattern differed: the number of barks also declined at the beginning of the night, but with a sharper reduction of 60–80%, reaching minimum values between 20:20 and 21:00. This period followed the end of the nautical twilight (between 19:57 and 20:09). After this low point, barking increased at both sites, reaching levels similar to those observed during April–May.

Clicks produced by sea lions were scarce in April–May but became much more abundant in June–July at the north site (the open-ocean side of the islet). A marked decrease was observed between 20:00 and 21:40, occasionally dropping to zero, whereas the preceding period showed 75–125 segments containing click trains per 20-min interval (Supplementary materials). This decrease occurred during the same period in which bark emissions were reduced.

The abundance of Sciaenidae-like sounds was also quantified by counting the number of 3-s segments containing them. These sounds were generally absent or low throughout the day, except at the

beginning of the night when a peak was observed at 20:00–20:30 in April–May and between 20:30 and 21:00 in June–July. This peak reached its maximum approximately 30 min after the end of the nautical twilight (April–May: 19:27–20:00, in June–July: 19:57–20:09). Peak abundance was 2.2–3.2 times higher in June–July than in April–May and lasted slightly longer on the north side. This increase in Sciaenidae-like sounds coincided with the decrease in sea lion vocalizations (figure 4). Bark abundance and Sciaenidae-like abundance were significantly negatively correlated (Pearson correlation = -0.50 , $p < 0.0001$) when considering all sites and seasons together. A more detailed analysis showed that this negative correlation was evident at all sites during June–July, but not in April–May. The strongest correlation was observed at the north site in June–July (Pearson correlation = -0.68 , $p < 0.0001$, Supplementary materials).

4. Discussion

4.1. Site differences

Two main patterns were observed in the diel pattern of bark emission. First, a larger proportion of time was occupied by bark vocalizations at the north site than at the south site.

This may reflect a higher number of individuals using this offshore area of the islet. We did not record the number of males present at each site at the time of the vocalization recordings. However, previous observations indicate that the north site generally hosts slightly more males than the south one (CJ Hernández-Camacho 2025, personal communication). During the summer seasons from 2020 to 2024, an average of 5.5 ± 3.07 males were recorded at the north site, compared with 3.75 ± 1.83 at the south site. As the number of individuals has varied over the years, differences are observed compared with older literature, which reported that the south site (Zone A, the most sheltered from waves) has the highest number of adult females during the breeding season [33,44].

In addition, there are males vocalizing all around the island, so it is likely that some recordings include calls from the males located there, as well as from those on the small islet adjacent to the island and from the intermediate B–C site. In ecology, low abundance of individuals and narrow niches (e.g. activities restricted to precise time windows) are often considered positively correlated [45,46]. This relationship may also apply to acoustic niches [12,21]. Thus, the higher abundance of sea lions at the north site could explain why bark vocalizations spanned longer than at the south site.

Alternatively, differences in vocal activity among males could also explain part of the observed patterns, as submissive males are known to be less vocal or even almost silent [47]. A higher proportion of highly vocal males at one site would, therefore, produce a similar result. Behavioural context may also influence vocal output. For example, the number of barks per series increases when a bull is locomoting compared with when it is stationary [6], although this is further complicated by differences in the proportion of aerial versus underwater calls during movement versus when stationary. Repetition rate is also more rapid when bulls are at their territorial boundaries than when they are in the centre of their territories [6], suggesting that territory size could affect the overall abundance of calls recorded. The system is further complicated by the dual medium of bark production, both aerial and underwater, with repetition rates differing by up to a factor of two between the two media [7]. Finally, barking occurs in multiple behavioural contexts, including chasing male intruders, herding females, self-advertisement and patrolling territorial borders [6], which complicates the interpretation of function, especially when compared with species possessing a broader vocal repertoire [5]. To determine whether call abundance is related to the rate of agonistic interactions, it would be necessary to record male behaviour simultaneously with vocalizations.

The configuration of the site could explain differences in the positioning of individuals and, consequently, in the recording of sounds underwater. Previous research highlighted that in zone A (south site), the rocks prevented sea lions from seeing or hearing the researchers upon their arrival. However, it is difficult to understand why differences would be observed at night but not during the daytime, since abundances were equivalent between sites during the day. More research is therefore necessary at night, a period when foraging is known to occur and during which mating is presumed, as copulations have not been observed during daylight hours [42].

Finally, it is not surprising that the proportion of time spent barking during the daytime is similar between April–May and June–July, as the number of adult males is not known to vary during this period (15–34 individuals during the breeding season, based on data from 2010 to 2024), with peak values in January for males and in February–March for subadults [27,48]. In the cold season, subadult males arrive

at Los Islotes from the western coast of the Baja California Peninsula, which explains the increase in this age class [27,48].

4.2. Diel and seasonal differences

The second observation is the sharp reduction in sea lion acoustic activity (both barks and clicks) that coincides with the peak of Sciaenidae sound production. While this represents a correlation rather than a causal relationship, it remains highly intriguing. Several hypotheses may be proposed to explain this pattern.

There is a substantial overlap in the frequencies produced by the two taxa, and according to theories such as the ANH, temporal partitioning may occur to optimize the use of the soundscape. Such patterns are known in marine biophonies where many fish species emit sounds simultaneously [12,21,49]. Partitioning can also take forms other than diel separation. For example, in marine mammals, sound modulation has been shown as a possible adaptation to exploit a new acoustic niche; killer whales adjust their vocalizations when leopard seals, another predator vocalizing at similar frequencies, are acoustically present during certain periods of the year [50]. A limitation of this hypothesis is that while barks are readily detected underwater, partly owing to their amphibious production, the reverse is not necessarily true; fish sounds may not be effectively perceived in air. Thus, competition for acoustic space could occur only underwater. One possibility is that the proportion of barks emitted in underwater versus in air changes during this specific time window, but this cannot be assessed with the current dataset. However, unlike barks, clicks, which also decreased during the peak of Sciaenidae sounds, appear to be purely underwater vocalizations [8].

The second hypothesis builds on the first: sea lions may engage in alternative activities that involve reduced barking during this specific time window (e.g. leaving the islet for foraging). Because the identity of the fish species producing the sounds is currently unknown [22], it is not possible to determine whether these are of interest to sea lions, especially as sea lions are known to travel more than 60 km away from the colony to forage [43,51], and this hypothesis cannot be explored further at present. However, it is important to note that such patterns of Sciaenidae-like sounds also appear at sites without sea lions, indicating a correlation rather than causation. Nevertheless, the sounds of both taxa fall within each other's hearing range, making the theoretical use of these communication sounds for interception possible.

A final possibility is that the two phenomena are independent, despite the observed correlation. Low-frequency sounds propagate efficiently underwater, and the convergence of signals to optimize communication is a central idea of the Acoustic Adaptation Hypothesis. While a detection bias could be considered, masking is unlikely to explain the pattern, as barks would have remained clearly visible in spectrograms during nocturnal sound emission.

4.3. Conservation bioacoustics

Sea lion watching is one of the main tourist activities in La Paz. Zones A and B are the two primary anchorage areas at Los Islotes, where sea lion watching ranks as the most popular activity, followed by snorkeling and scuba diving [24]. Protection measures include restrictions, such as the prohibition of scuba diving and snorkeling during the breeding season. Although sea lions appear to be habituated to the presence of boats, continued monitoring of the population is recommended to detect any potential changes in colony size and to understand potential impacts of tourism-related activities [34]. In this context, PAM appears as a potentially valuable tool for tracking both underwater and aerial sea lion activities, as well as anthropogenic disturbances such as boat traffic and the presence of divers [26,52]. However, further research is needed both to track anthropogenic disturbances at the breeding site with PAM and to establish a cue rate linking the number of individuals to the effective number of (distinct) vocalizations.

Ethics. The data consist of underwater acoustic recordings made near the island where sea lions reside (not on the island itself). No animals were used in this study. Therefore, no ethics statement is required according to both university and Mexican standards, as passive acoustic monitoring of pinnipeds does not require an ethics permit. Additionally, the recorders were deployed before the beginning of the breeding season and retrieved afterward. We did not visit the site during the breeding season, so no additional authorization was necessary.

Data accessibility. Data are openly accessible at [53].

Supplementary material is available online [54].

Declaration of AI use. The convolutional neural networks employed in BirdNET Analyzer constitutes AI methods.

Authors' contributions. X.R.: conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, resources, software, supervision, validation, visualization, writing—original draft, writing—review and editing; C.J.H.-C.: writing—review and editing; D.O.: resources, writing—review and editing.

All authors gave final approval for publication and agreed to be held accountable for the work performed therein.

Conflict of interest declaration. We declare we have no competing interests.

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References

1. Le Boeuf BJ, Aurioles D, Condit R, Foly C, Gisner R, Romero R, Sinsal F. 1983 Size and distribution of the California sea lion population in Mexico. *Calif. Acad. Sci. Proc.* **43**, 77–85.
2. Heath CB, Perrin WF. 2009 California, Galapagos, and Japanese Sea Lions. In *Encyclopedia of marine mammals*, pp. 170–176, Cham, Switzerland: Elsevier. ([doi:10.1016/B978-0-12-373553-9.00046-8](https://doi.org/10.1016/B978-0-12-373553-9.00046-8))
3. Heath CB. 1989 *The behavioral ecology of the California sea lion*. p. 510. Santa Cruz, CA: University of California.
4. Peterson RS, Bartholomew GA. 1967 The natural history and behavior of the California sea lion. *Am. Soc. Mammal* 1–79.
5. Stirling I. 1971 Studies on the behavior of the South Australian fur seal, *Arotocephalus forsteri* (Lesson). I. Annual cycle, postures and calls, and adult males during the breeding season. *Aust. J. Zool.* **19**, 243–266. ([doi:10.1071/Z09710243](https://doi.org/10.1071/Z09710243))
6. Schusterman RJ. 1977 Temporal patterning in sea lion barking (*Zalophus californianus*). *Behav. Biol.* **20**, 404–408. ([doi:10.1016/S0091-6773\(77\)90964-6](https://doi.org/10.1016/S0091-6773(77)90964-6))
7. Schusterman RJ, Balliet RF. 1969 Underwater barking by male Sea lions (*Zalophus californianus*). *Nature* **222**, 1179–1181. ([doi:10.1038/2221179a0](https://doi.org/10.1038/2221179a0))
8. Schevill WE, Watkins WA, Ray C. 1963 Underwater sounds of pinnipeds. *Science* **141**, 50–53. ([doi:10.1126/science.141.3575.50](https://doi.org/10.1126/science.141.3575.50))
9. Schafer RM. 1977 *The tuning of the world*. p. 322. New York, NY: Knopf.
10. Krause B. 1987 Bioacoustics: habitat ambience & ecological balance. *Whole Earth Rev.* **57**, 14–16.
11. Raick X, Collet P, Under The Pole C, Lecchini D, Bertucci F, Parmentier E. 2023 Diel cycle of two recurrent fish sounds from mesophotic coral reefs. *Sci. Mar.* **87**, e078. ([doi:10.3989/scimar.05395.078](https://doi.org/10.3989/scimar.05395.078))
12. Raick X *et al.* 2025 Depth-dependent dynamics and acoustic niche partitioning of fish sounds in mesophotic coral reefs. *Estuar. Coast. Shelf Sci.* 109 336. ([doi:10.1016/j.ecss.2025.109336](https://doi.org/10.1016/j.ecss.2025.109336))
13. Di Iorio L, Raick X, Parmentier E, Boissery P, Valentini-Poirier C-AA, Gervaise C. 2018 ‘Posidonia meadows calling’: a ubiquitous fish sound with monitoring potential. *Remote Sens. Ecol. Conserv.* **4**, 248–263. ([doi:10.1002/rse2.72](https://doi.org/10.1002/rse2.72))
14. Raick X, Parmentier É, Gervaise C, Lecchini D, Under The Pole C, Pérez-Rosales G, Rouzé H, Bertucci F, Di Iorio L. 2024 Invertebrate sounds from photic to mesophotic coral reefs reveal vertical stratification and diel diversity. *Oecologia* **205**, 307–322. ([doi:10.1007/s00442-024-05572-5](https://doi.org/10.1007/s00442-024-05572-5))
15. Lillis A, Mooney TA. 2018 Snapping shrimp sound production patterns on Caribbean coral reefs: relationships with celestial cycles and environmental variables. *Coral Reefs* **37**, 597–607. ([doi:10.1007/s00338-018-1684-z](https://doi.org/10.1007/s00338-018-1684-z))
16. Staatterman E, Paris CB, DeFerrari HA, Mann DA, Rice AN, D'Alessandro EK. 2014 Celestial patterns in marine soundscapes. *Mar. Ecol. Prog. Ser.* **508**, 17–32. ([doi:10.3354/meps10911](https://doi.org/10.3354/meps10911))
17. Lin TH, Kawagucci S. 2024 Acoustic twilight: A year-long seafloor monitoring unveils phenological patterns in the abyssal soundscape. *Limnol. Oceanogr. Lett.* **9**, 23–32. ([doi:10.1002/lol2.10358](https://doi.org/10.1002/lol2.10358))
18. Raick X, Vendrame M, Lecchini D, Parmentier É 2025 Evidence of vertical stratification in marine environments: insights from passive acoustic monitoring in French Polynesia. *Deep Sea Res. Part I Oceanogr. Res. Pap* **223**, 104 548. ([doi:10.1016/j.dsr.2025.104548](https://doi.org/10.1016/j.dsr.2025.104548))
19. Weilgart LS. 2007 The impacts of anthropogenic ocean noise on cetaceans and implications for management. *Can. J. Zool.* **85**, 1091–1116. ([doi:10.1139/Z07-101](https://doi.org/10.1139/Z07-101))
20. Krause B. 1993 The Niche Hypothesis: A virtual symphony of animal sounds, the origins of musical expression and the health of habitats. *Soundscape Newslett.* **6**, 6–10.
21. Bolgan M, Di Iorio L, Dailianis T, Catalan IA, Lejeune P, Picciulin M, Parmentier E. 2022 Fish acoustic community structure in Neptune seagrass meadows across the Mediterranean basin. *Aquat. Conserv. Mar. Freshw. Ecosyst.* **32**, 329–347. ([doi:10.1002/aqc.3764](https://doi.org/10.1002/aqc.3764))

22. Rabasco F, Munguia-Vega A, Raick X, Parmentier E, Hernández L, Huato-Soberanis L, Reyes-Bonilla H, Sánchez-Ortiz C, Olivier D. 2025 Black coral patches and reef fish diversity: an integrative multidisciplinary approach. *Mar. Environ. Res.* **211**, 107 401. (doi:10.1016/j.marenvres.2025107401)
23. Erisman BE, Rowell TJ. 2017 A sound worth saving: acoustic characteristics of a massive fish spawning aggregation. *Biol. Lett.* **13**, 20170656. (doi:10.1098/rsbl.20170656)
24. Hernández-Camacho CJ, González-López I, Pelayo-González L, Aurióles-Gamboa D, López-Greene E, Rosas-Hernández MP. 2020 Effective management of the National Park Espíritu Santo, through the governance, planning, and design of an integral strategy for Los Islotes. In *Socio-ecological studies in natural protected areas*, 679–704. Cham, Switzerland: Springer International Publishing. (doi:10.1007/978-3-030-47264-1)
25. Burgoin-Díaz IM. 2020 *Distribución del lobo marino de california Zalophus californianus en la bahía de la paz y áreas aledañas, B.C.S., México*, México: Tesis Licenciatura. Univ. Autónoma Baja Calif. Sur. La Paz, B.C.S.
26. Darras KFA *et al.* 2025 Worldwide soundscapes: A synthesis of passive acoustic monitoring across realms. *Glob. Ecol. Biogeogr.* **34**, e70021. (doi:10.1111/geb.70021)
27. Aurióles D, Sinsal F, Fox C, Alvarado E, Maravilla O. 1983 Winter migration of subadult male California sea lions (*Zalophus californianus*) in the southern part of Baja California. *J. Mammal* **64**, 513–518. (doi:10.2307/1380369)
28. Galindo Romo DO. 2024 *Manejo del islote san rafaelito y estado de conservación de la población del lobo marino de california (Zalophus californianus) en la bahía de la paz y zonas aledañas, b. C. S., México*. Mexico: Universidad Autónoma de Baja California Sur. México.
29. Hernández-Camacho CJ, Pelayo-González L, Rosas-Hernández MP. 2021 California sea lion (*Zalophus californianus*, Lesson 1828). In *Ecology and conservation of pinnipeds in latin America* (eds G Heckel, Y Schramm), pp. 119–143. Cham, Switzerland: Springer.
30. Pelayo-González L *et al.* 2021 Effect of environmental variables on the number of births at California sea lion (*Zalophus californianus*) rookeries throughout the Gulf of California, Mexico. *Aquat. Conserv. Mar. Freshw. Ecosyst.* **31**, 1730–1748. (doi:10.1002/aqc.3545)
31. Pelayo-González L, González-Rodríguez E, Ramos-Rodríguez A, Hernández-Camacho CJ. 2021 California sea lion population decline at the southern limit of its distribution during warm regimes in the Pacific Ocean. *Reg. Stud. Mar. Sci.* **48**, 102 040. (doi:10.1016/j.rsma.2021102040)
32. García-Aguilar MC, Aurióles-Gambo D. 2003 Breeding season of the California sea lion (*Zalophus californianus*) in the Gulf of California, Mexico. *Aquat. Mamm.* **29**, 67–76. (doi:10.1578/016754203101024086)
33. Labrada-Martagón V, Aurióles-Gamboa D, Martínez-Díaz SF. 2005 Natural and human disturbance in a rookery of the California sea lion (*Zalophus californianus californianus*) in the Gulf of California, Mexico. *Lat. Am. J. Aquat. Mamm.* **4**. (doi:10.5597/lajam00080)
34. Pelayo-González L, Burciaga LM, González-López I, Hernández-Camacho CJ. 2024 Maternal behavior of California sea lions in different abundance and tourist activity scenarios. *Hydrobiologia* **851**, 1385–1395. (doi:10.1007/s10750-023-05371-8)
35. Rayas-Estrada A, Hernández-Camacho CJ. 2019 Fine-scale site fidelity in California sea lions, *zalophus californianus*, in the colony at Los Islotes, La Paz Bay, Mexico. *Ciencias Mar.* **45**. (doi:10.7773/cm.v45i4.3019)
36. Kahl S, Wood CM, Eibl M, Klinck H. 2021 BirdNET: A deep learning solution for avian diversity monitoring. *Ecol. Inform.* **61**, 101 236. (doi:10.1016/j.ecoinf.2021101236)
37. Stowell D. 2022 Computational bioacoustics with deep learning: a review and roadmap. *PeerJ* **10**, e13152. (doi:10.7717/peerj.13152)
38. Ghani B, Denton T, Kahl S, Klinck H. 2023 Global birdsong embeddings enable superior transfer learning for bioacoustic classification. *Sci. Rep.* **13**, 22 876. (doi:10.1038/s41598-023-49989-z)
39. Allen-Ankins S, Hoefer S, Bartholomew J, Brodie S, Schwarzkopf L. 2025 The use of BirdNET embeddings as a fast solution to find novel sound classes in audio recordings. *Front. Ecol. Evol.* **12**. (doi:10.3389/fevo.2024.1409407)
40. Tseng S, Hodder DP, Otter KA. 2025 Setting BirdNET confidence thresholds: species-specific vs. universal approaches. *J. Ornithol.* **166**, 1123–1135. (doi:10.1007/s10336-025-02260-w)
41. R Core Team. 2023 *R: a language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing.
42. Aurióles-Gamboa D, García-Rodríguez F, Ramírez-Rodríguez M, Hernández-Camacho C. 2003 Interacción entre el lobo marino de California y la pesquería artesanal en la Bahía de La Paz, Golfo de California, México. *Ciencias Mar.* **29**, 357–370. (doi:10.7773/cm.v29i3.151)
43. Molina-Chávez VG. 2022 *Caracterización de los movimientos en el mar de hembras de lobo marino de California (Zalophus californianus)*. Mexico: CICIMAR-IPN.
44. Young JK, Gerber LR. 2008 The influence of social composition on reproductive behavior of territorial male California sea lions. *Aquat. Mamm* **34**, 102–108. (doi:10.1578/AM.34.1.2008102)
45. Polechová J, Storch D. 2008 Ecological niche. In *Encyclopedia of ecology*, pp. 1088–1097, Oxford, UK: Elsevier.
46. Hanski I, Koskela H. 1978 Stability, abundance, and niche width in the beetle community inhabiting cow dung. *Oikos* **31**, 290. (doi:10.2307/3543653)
47. Schusterman RJ, Dawson RG. 1968 Barking, dominance, and territoriality in male sea lions. *Science* **160**, 434–436. (doi:10.1126/science.160.3826.434)
48. Elorriaga-Verplancken FR, Sandoval-Sierra J, Paniagua-Mendoza A, Robles-Hernández R. 2018 Seasonality and potential foraging grounds of migratory California sea lions from La Paz Bay, Southern Gulf of California, Mexico. *Aquat. Mamm* **44**, 56–61. (doi:10.1578/AM.44.1.201856)
49. Bertucci F, Maratrat K, Berthe C, Besson M, Guerra AS, Raick X, Lerouvreur F, Lecchini D, Parmentier E. 2020 Local sonic activity reveals potential partitioning in a coral reef fish community. *Oecologia* **193**, 125–134. (doi:10.1007/s00442-020-04647-3)

50. Mossbridge JA, Thomas JA. 1999 An 'acoustic niche' for antarctic killer whale and leopard seal sounds. *Mar. Mammal Sci.* **15**, 1351–1357. (doi:10.1111/j.17487692.1999.tb00897.x)
51. Kuhn CE, Costa DP. 2014 Interannual variation in the at-sea behavior of California sea lions (*Zalophus californianus*). *Mar. Mammal Sci.* **30**, 1297–1319. (doi:10.1111/mms.12110)
52. Rice AN, Garcia ML, Symes LB, Klinck H. 2023 Conservation bioacoustics: listening to the heartbeat of the earth. *Acoust. Today* **19**, 46. (doi:10.1121/AT.2023.19.3.46)
53. Raick X. 2025 DATASET Do sea lions fall silent when fish have something to say? [Dataset]. Zenodo. (doi:10.5281/zenodo.17410409)
54. Raick X, Hernández-Camacho CJ, Olivier D. 2026 Supplementary material from: Do sea lions fall silent when fish have something to say? Figshare. (doi:10.6084/m9.figshare.c.8598471)