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Citation
Kok, A. C. M., Soderstjerna, C., Kim, E. B., Joseph, J. E., Margolina, T., Peavey Reeves, L. E., … Baumann-Pickering, S. (2026). Acoustic behavior and diversity of fish calling in the Channel Islands. *Jasa Express Letters*, *6*(1). doi:10.1121/10.0042167

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Note: To cite this publication please use the final published version (if applicable).

JASA Express Letters

JANUARY 21 2026

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JASA Express Lett. 6, 011202 (2026)
https://doi.org/10.1121/10.0042167

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Acoustic behavior and diversity of fish calling in the Channel Islands

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Abstract: Many fish species are suspected to produce sound, but the variety of sounds they produce is still largely undocumented. This study investigated the presence and diversity of fish sounds in the Channel Islands National Marine Sanctuary. Besides regular sounds from three known species—bocaccio (*Sebastes paucispinis*), plainfin midshipman (*Porichthys notatus*), and white seabass (*Atractoscion nobilis*)—two unusual sound types were observed that require further analyses and for which the species is still unknown: Unidentified Fish or UF200 and UF450. Sound types had distinct acoustic signatures and varied in diel presence. Monitoring fish sounds is a promising technique for non-invasive monitoring of fish presence with conservation applications. © *2026 Author(s). All article content, except where otherwise noted, is licensed under a Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC) license (https://creativecommons.org/licenses/by-nc/4.0/).*

[Editor: JoAnn McGee]] https://doi.org/10.1121/10.0042167

Received: 11 September 2025 **Accepted:** 11 December 2025 **Published Online:** 21 January 2026

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1. Introduction

Acoustic soundscapes are valuable in understanding the dynamics of ocean ecosystems. Although extensive research has been performed on cetacean acoustics (e.g., Refs. 1–3) the acoustic repertoire of fish in natural environments remains less well characterized.[4] Fishes are known to produce sound during courtship, spawning, parental care, feeding, and aggression or territorialism.[5] Courtship and spawning calls often occur at specific times of the day (e.g., Refs. 6 and 7) Fishes may produce sound by vibrating their swim bladders with a pair of contracting vocal muscles that are attached to the outer walls of the gas-filled bladder[8] and through rubbing bones or teeth together,[5] among other mechanisms. Fish sounds are species specific and most are low frequency (<3 kHz), with variation depending on the species.[9] These differences in acoustic repertoire allow for the discrimination of fish from other species through passive acoustic monitoring (e.g., Ref. 10), which has previously been used in identifying, describing, and monitoring disturbance and advertisement calls (e.g., Ref. 11).

Sounds from various fishes have previously been reported in the Southern California Bight.[12–15] In all four studies, plainfin midshipman (*Porichthys notatus*) and white seabass (*Atractoscion nobilis*) calls were detected,[8,16] with vocal presence ranging from the southern coastline near San Diego,[12,15] in the Channel Islands Marine Sanctuary,[13,14] to Monterey Bay National Marine Sanctuary[13] in the north. The Channel Islands and Monterey Bay further harbored bocaccio rockfish (*Sebastes paucispinis*),[13] and possible vocal activity of giant seabass (*Stereolepis gigas*) was detected in the Channel Islands.[14] Additionally, three unknown fish choruses were reported: UF (Unidentified Fish) 440,[12,13] UF310,[13] and Chorus I.[12] However, all four studies focused on fish calls that formed choruses—many fish calling at the same time—that

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were detectable in long-term spectral averages (LTSAs) of recordings. As a result, other, less prevalent sound types were not captured.

We aim to contribute to the knowledge of fish acoustic biodiversity by documenting the acoustic repertoire of fish calling at one site within the Channel Islands National Marine Sanctuary. We investigated the sounds produced by fish at this location and how their sounds varied temporally and seasonally. By focusing on individual calls, we uncovered two previously undescribed sound types. Through analyzing fish calling behavior, we can improve our understanding of spawning seasons, species distribution, and essential habitats throughout the Channel Islands. Improved knowledge on fish acoustic ecology will assist in improved conservation and management practices for fishes in this region and beyond.

2. Methods

2.1 Study site

The Channel Islands consist of an island chain that is approximately 240 km long and is located approximately 20–115 km off the Pacific coast of southern California. Because of the region being an eastern boundary upwelling system, there is rich biodiversity, making it an ideal location for research. Nearshore subtidal habitats around the islands consist of mud or hard substrates with kelp forests and reefs, whereas the deeper waters contain soft bottom, sandy habitats. The recording location was in a shallow reef within the no-take zone of the marine reserve. The favorability of this habitat for fish makes it a prime location for research and may be informative in the determination of specific fish species' sounds in future studies.

2.2 Data collection

We collected passive acoustic recordings at the Channel Islands National Marine Sanctuary using bottom-deployed SoundTrap ST500 acoustic recorders (Ocean Instruments, Auckland, New Zealand) with a sampling rate of 48 kHz. This study was part of the Sanctuary Soundscape Monitoring Project (SanctSound), a collaboration between the U.S. National Oceanic and Atmospheric Administration (NOAA) and the U.S. Navy to monitor underwater sound within shallow water national marine sanctuaries.

One site in the Channel Islands National Marine Sanctuary was analyzed as part of this study, site CI01 (18–21 m depth, Fig. 1). Recording occurred between November 2018 and September 2019. Gaps in recording were because

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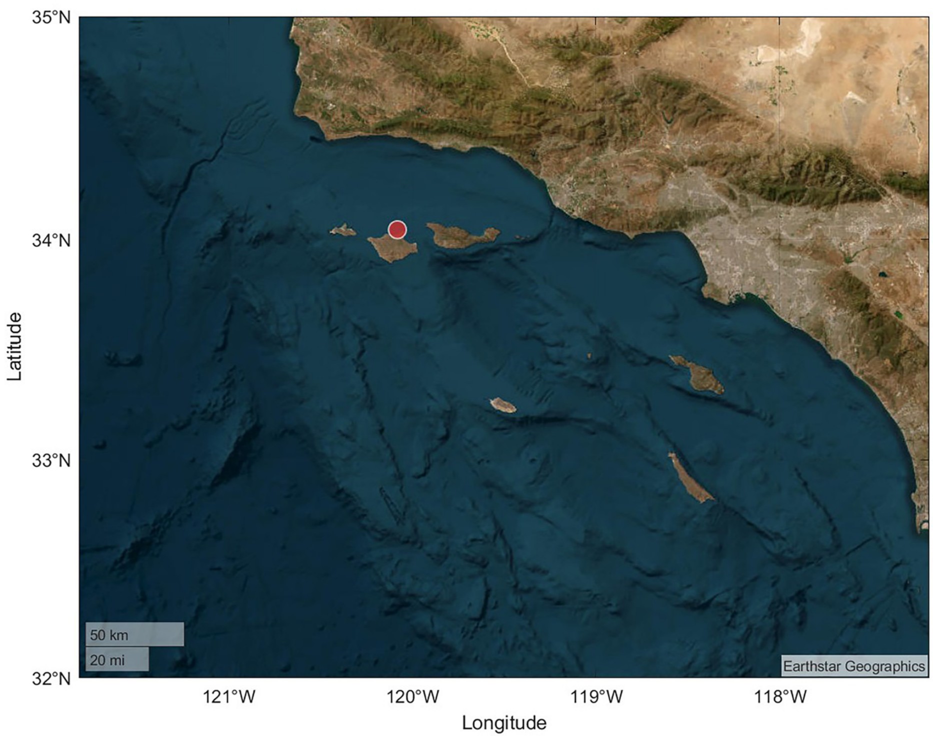

Fig. 1. The recorder was placed in the Channel Islands National Marine Sanctuary on the southwest coast of the United States. Recordings were collected through the SanctSound project, in which the site is referred to as CI01. The map was created in MATLAB 2022b. Satellite imaging was hosted by the Environmental Systems Research Institute (Esri). N, North; W, West.

of turn-around of hydrophones and malfunctioning of equipment (Table S1). After collection, data were down sampled to a sample rate of 2 kHz to improve spectrogram resolution.

The recordings were analyzed in MATLAB (version 2016b, MathWorks, Natick, MA) using the TRITON software package.[17,18] LTSAs with 5 s/1 Hz bins were used to visualize acoustic signals throughout the deployment. LTSA viewing length was 8 h, 40 dB brightness, and contrast of 120%.

2.3 Acoustic data analysis

The LTSAs were manually scanned for potential fish sounds (each sound type by a single reviewer). Potential sounds were chosen based on frequency contour, temporal pattern, and vocalization sound type (repetitive pulsing, growling, grunts). A library of potential sounds was created, and sounds that had recurring detections throughout the deployment (>10 occasions) and deemed likely to be fish based on frequency and temporal pattern were selected for logging.

Chosen sounds were logged using LOGGER, an add-on package (termed "REMORA") included within TRITON. The start and end times of each call/chorus were selected manually in the LTSA. Sound types that were not visible from the LTSA window were detected by scanning the data in 50 s spectrograms (Fast Fourier Transform length = 700, 0–1000 Hz, 90% overlap). Call bouts were deemed separate events if a ∼10 min gap occurred between them. After logging, peak frequency was measured for a subsample of 12 sounds distributed across seasons.

In contrast to the other sound types, bocaccio calls were detected automatically using the Fish Detector in TRITON. Recordings were decimated to a sample rate of 2000 Hz before running through the detector. The fish detector first filtered the time series between 100 and 950 Hz (10th order Butterworth filter). Then it computed cross correlation between the envelope of a filtered example call (3 s, Hann windowed) and 75 s of the envelope of the filtered time series (i.e.,Hilbert transform low pass filter). To enhance peaks in the signal, the cross correlation was squared.

To account for detecting signals within background noise, we used a floating threshold of the median cross correlation value over the current 75 s of data, with a threshold offset of 2e-9 above the median of the cross correlation. Detections were evaluated if they exceeded this threshold. Consecutive calls were required to have a minimum time gap of 0.5 s to be detected separately. Root mean square (RMS) received levels were computed over the potential detection period and a period corresponding to the length of the bocaccio call template before and after the detection. Detections were considered false and discarded if the signal-to-noise ratio between the detection period and the time series before and after the detection was <0.01. The threshold was chosen in favor of fewer missed detections rather than many true detections (recall > precision) and evaluated based on the distribution of histograms of manually verified true and false detections. After running the detector, a trained analyst verified the detections as true or false.

3. Results

Five sound types were present (presence >10 occasions) throughout deployments and were logged for the purpose of this study. The following three sound types could be matched to fish species: white seabass,[1] bocaccio rockfish,[2] and plainfin midshipman.[3,4] Two sound types were named for their spectral characteristics—UF200, a growl with predominant energy at 200 Hz, and UF450, a repetitive sound with main energy at 450 Hz (Fig. 2).

3.1 Sound type 1—white seabass

Sound type 1 (Fig. 2) was a sound type that had varied characteristics throughout the deployments. It consisted of two similar but visually distinctive subtypes that on occasion morphed into each other. Sound type 1A was characterized as a repetitive pulse train followed by zero to three separate pulses. The frequency of the call typically ranged from ∼90 to 400 Hz, with some variation across calls, and a peak frequency at 147 ± 30 Hz (mean ± s.d., Table 1). The time between calls was approximately 5 s. Sound type 1B (Fig. 2) consisted of a series of 1–4 pulses, with each subsequent pulse series decreasing in duration. The call's frequency typically ranged from ∼65 to 450 Hz, with variation across calls and peak frequency at 142 ± 19 Hz (mean ± s.d.).

Sound types 1A and 1B have previously been identified as white seabass[13,16] and will from now on be referred to as white seabass A and white seabass B. White seabass calls were present throughout spring and most of summer, from March to mid-September (Fig. S1; Note that calling could have commenced before March, as that period was not recorded.). For sound type white seabass A, the majority of the calls occurred during daylight hours, from 10:00–19:00 Coordinated Universal Time (UTC)-8 (Fig. 3). Although calling did occur during the night, it was much less frequent than during daytime. Sound type white seabass B interchanged with sound type A (Fig. S1). Sound type B had a slightly higher calling presence at night, whereas calling still peaked during daytime (Fig. 3).

3.2 Sound type 2—bocaccio

Sound type 2 was a two-part drumming sound between 150 and 850 Hz, with a peak frequency at 187 ± 18 Hz (mean ± s.d., Table 1). The sound type was matched to calls produced by bocaccio rockfish.[19] Bocaccio calls were present in all deployments, although the number of calls diminished in summer and early fall (Fig. S1). Bocaccio calls were mostly present at night, with a peak at dusk prevalent in fall (Fig. 3).

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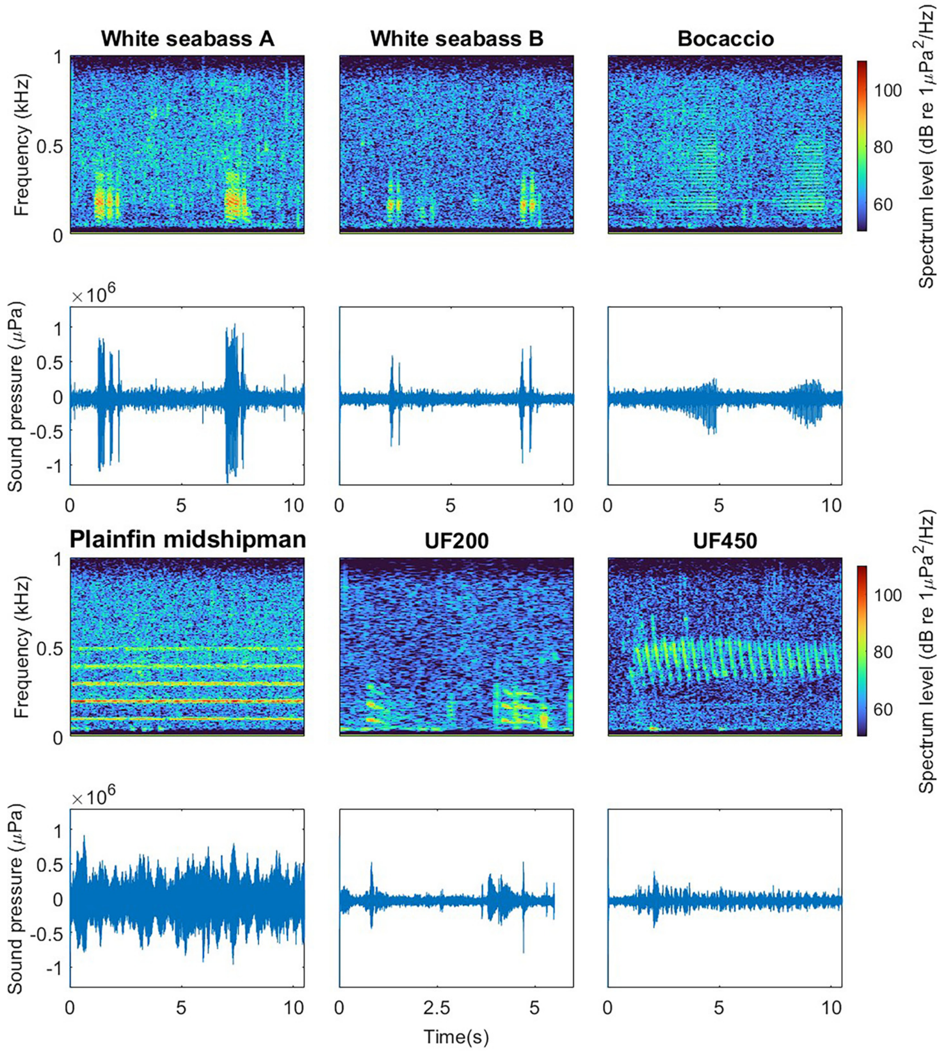

Fig. 2. Six call types were initially documented in the Channel Island recordings, which were later reduced to five by the merger of white seabass A and white seabass B. Both white seabass call types and the bocaccio call had a pulsed structure, while UF200 was a growl, and UF450 a modulating tonal sound. For plainfin midshipman, no individual calls could be distinguished, so this type was logged as a chorus. Note that the *x* axis for UF200 is shorter than for the other panels (10 s vs 1–2 s). The recordings were high-pass filtered at 50 Hz for visualization purposes.

3.3 Sound type 3—plainfin midshipman

A dominant part of the marine soundscape at the recording site was the hum of the plainfin midshipman.[8] Hums were characterized by several harmonics between 90 and 500 Hz, with a peak frequency at 177 ± 27 Hz (mean ± s.d., Table 1). Because individual hums could not be distinguished, this sound type was logged as a chorus. Chorusing commenced at the

Table. 1. Peak frequency of sound types found in this study, measured manually from a subsample of 12 calls spread across seasons (where possible) to account for seasonal variation in call frequency.

Sound type	Peak frequency Hz (mean ± s.d.)
White seabass A	147 ± 30
White seabass B	142 ± 19
Bocaccio	187 ± 18
Plainfin midshipman	177 ± 27
UF200	208 ± 20
UF450[a]	453 ± 44

[a]Note that all measurements for UF450 were taken from March because of low overall presence and interference from plainfin midshipman chorusing.

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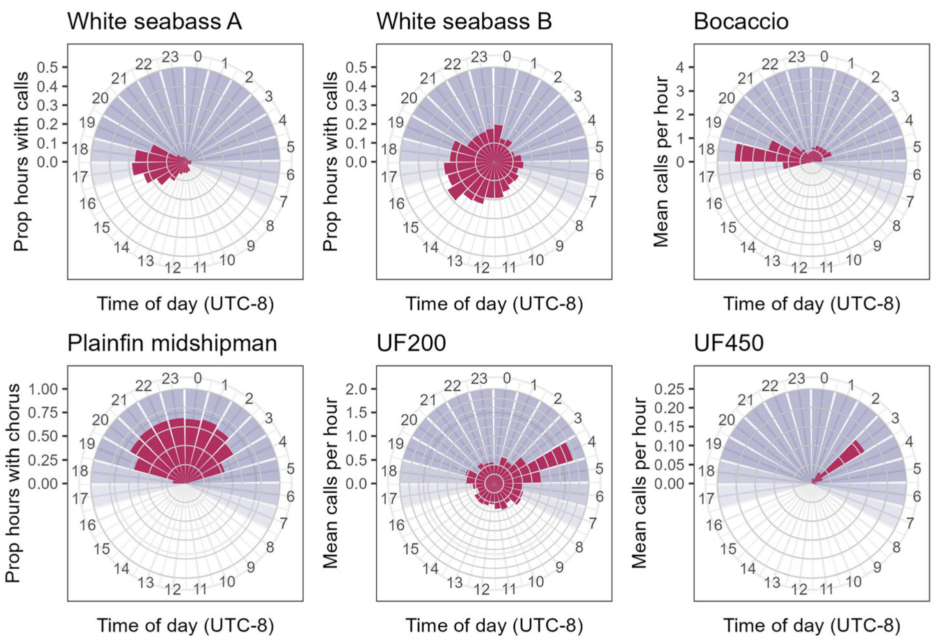

Fig. 3. Diel patterns of vocal activity varied between species. Although most call/chorus types peaked in presence at night, white seabass B calls occurred at all hours with a slight peak in daytime. UF200 was present throughout the day but peaked at dawn. Both plainfin midshipman and UF450 were restricted to nighttime, whereas bocaccio peaked at dusk. Blue shading = nighttime (average over the year), maroon bars = proportion of hours with chorus presence (white seabass A/B, plainfin midshipman) or average number of calls per hour (bocaccio, UF200, UF450).

25 March 2026 08:30:44

beginning of April and continued until mid-November (Fig. S1). Midshipman chorusing typically lasted the full night, starting right after dusk and finishing just before dawn (Fig. 3).

3.4 Sound type 4—UF200

Sound type UF200 (Fig. 2) was only analyzed for one deployment (March 25–August 4, 2019) because the call was only visible in 50 s spectrograms. The call consisted of a growling sound, often followed by a short burst of rapid pulsing. The duration of UF200 typically ranged from 3 to 15 s. Unlike white seabass calls, which were characterized by long periods of calling, UF200 was largely characterized by individual sounds often separated by minutes between occurrences. The call typically consisted of three harmonics, with main energy either in the first harmonic (208 ± 20 Hz, mean $\pm$ s.d.), or in the fundamental frequency (104 ± 13 Hz, mean $\pm$ s.d., Table 1). As only one deployment was analyzed, we were not able to determine seasonality. UF200 calls were present throughout the 24 h period, but there was an increase in call presence at dawn, from hours 4 to 6 UTC-8 (Fig. 3).

3.5 Sound type 5—UF450

Sound type UF450 (Fig. 2) was characterized by a higher frequency (peak frequency 453 ± 44 Hz, mean $\pm$ s.d.) highly repetitive sound. It was not of a pulse or growl nature. The call was much less frequent throughout the deployment compared to white seabass and UF200. UF450 was also only visible from 50 s spectrograms and not in the LTSA, and calling occurred for shorter, approximately 20 s, periods at a time. UF450 had very little presence overall, so it was not possible to determine seasonality. From what was recorded, we observed that the call was present during the nighttime hours (Fig. 3).

4. Discussion

In this study, we identified two new sound types present at our Channel Islands recording site, along with three previously described sound types. The two new sound types, UF200 and UF450, could not be linked to species, whereas the other three sound types belonged to white seabass, bocaccio rockfish, and plainfin midshipman. White seabass calls consisted of two subtypes with similar acoustic features and closely related temporal and seasonal patterns.

Most sound types peaked in presence during the night, although the exact timing of the peak varied between sound types. Diel timing of peaks in calling activity of white seabass, bocaccio, and plainfin midshipman was similar to what was previously reported.[12,15,19,20] White seabass calls peaked in early twilight (sound type A) or even during the day (sound type B). UF200, characterized by its short-duration, individual growl-type sound, was present throughout the full 24-h period, with a heavier calling presence observed at dawn. UF450, characterized by its higher frequency, repetitive sound, was less commonly observed. When present, it occurred strictly during night hours. Bocaccio calls could be recorded day or night but predominantly at night and peaked at dusk, especially in fall. Plainfin midshipman chorusing was exclusively present at night. All sound types could be found in spring and most continued in summer. Although white seabass was restricted to spring and summer, both plainfin midshipman and bocaccio continued until late fall. UF200 and UF450 did not have enough data to draw conclusions on seasonality.

4.1 Origin of new call types

At present the source of UF200 and UF450 are unknown. Although we cannot be certain they were produced by fish, frequency range and temporal characteristics point to this conclusion.[5] Many of the fishes in the Channel Islands National Marine Sanctuary are potentially soniferous[21] but have not been recorded before. These include multiple species of rockfish, croakers, and scorpionfish, all of which have at least the morphological potential of sound production.[22,23] Confirming the sources of both UF200 and UF450 will require further research. Fish calls can be recorded in captivity, such as has been done for bocaccio rockfish.[19] Alternatively, the source of the sounds could be confirmed through audio-video arrays,[24,25] as the vocal behavior of fish may differ between captive environments and the wild.[26] Finally, more extensive recordings in the Channel Islands National Marine Sanctuary will help pinpoint when and where UF200 and UF450 are produced, which may reduce the number of possible source species.

4.2 Variation in diel calling patterns

The nightly calling peak in our study mirrors that of fish calling around the world. Many species display nocturnal calling activity, both in temperate and tropical regions.[27–29] Fish calling is often related to spawning activity, which tends to take place at night to avoid predation by egg-predators.[30] Even so, only plainfin midshipman and UF450 were completely restricted to nighttime, whereas the others maintained some presence during the day. This begs the question why this temporal variation occurs. Perhaps exposure to predators is higher for those species that restrict their calling to nighttime. Plainfin midshipman nest in tidal pools, which may be exposed to both aquatic and terrestrial predators during the day.[31] Alternatively, nighttime calling may optimize foraging time during the day as individual plainfin midshipman hums can last for long periods at a time (up to 14 min.[31]), whereas many other species produce short calls (e.g., a typical bocaccio call is 3 s), leaving more time to forage. Future experimental studies could help elucidate the drivers underlying this variability in calling activity.

5. Conclusion

This study characterized multiple putative fish sounds present at the Channel Islands, in relation to temporal and seasonal variability. Because this study collected only acoustic data, sound types that did not match previously reported sounds could not be linked to species. In future studies, combining passive acoustic monitoring techniques with other monitoring systems, such as an *in situ* camera or environmental deoxyribose nucleic acid (eDNA), could link observed sound types with fish presence in the area. Increased knowledge of the Channel Islands' acoustic soundscape and dynamics among species can strengthen future conservation and management efforts.

Supplementary Material

See the supplementary material for Fig. S1 and sound clips of the call types.

Acknowledgments

The authors would like to acknowledge the science staff, vessel crews, and coordinators of R/V Shearwater for their assistance with data collection and archiving. This work was completed as part of the SanctSound project, which is a collaboration between the National Oceanic and Atmospheric Administration and the U.S. Navy to better understand underwater sound within the National Marine Sanctuary System.

Author Declarations

Conflict of Interest

The authors have no conflicts to disclose.

Data Availability

The data that support the findings of this study are openly available in the National Centers for Environmental Information at https://doi.org/10.25921/saca-sp25.

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