Spatiotemporal Distribution of Rice's Whale Calls in the Northeastern Gulf of America
2025

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Executive Summary

The Rice's whale (*Balaenoptera ricei*; formerly Gulf of Mexico Bryde's whale) is estimated to have a population size of 51 individuals in U.S. waters (Garrison et al., 2020), and was listed as endangered under the ESA in 2019 (84 *Federal Register* 15446, 87 *Federal Register* 8981). The majority of modern sightings occur within waters between the 100 and 400 meter isobaths within an area near the De Soto Canyon off northwestern Florida (Rosel et al., 2021; Soldevilla et al., 2017), an area defined as the Rice's whale core distribution area (Rosel & Garrison, 2022). Occurrence patterns from long-term passive acoustic monitoring (PAM) over the 2010–2024 period and from summer and fall visual surveys during 2018 and 2019 indicate that the whales are found year-round within the core distribution area, but also suggest there may be seasonal movements throughout, and potentially out of, this area. High densities of anthropogenic activities occur throughout the Gulf of America (formerly Gulf of Mexico, hereafter GOA), including oil and gas exploration and extraction, fisheries, shipping, and military activities. Many of these activities, including U.S. Navy readiness activities, and Eglin Air Force Base activities, overlap with the whales' core distribution area. Understanding seasonal distribution and density of Rice's whales throughout this area will improve understanding of potential impact of human activities, improve the accuracy and precision of impact assessments, and assist in developing effective mitigation measures as needed.

To improve management of human-based activities in the core distribution area of these endangered whales, the SEFSC deployed a sparse array of 17 PAM units concurrent with one long-term High-frequency Acoustic Recording Package (HARP) from May 2021 to March 2023. The PAM moorings were deployed in two lines of nine units each to nearly completely cover the core distribution area over a nearly 2-year period to improve understanding of seasonal and interannual distribution, movement patterns, and habitat use. The moorings used SoundTrap ST500 or ST600 STDs, calibrated long-term recorders capable of continuously recording underwater sound in the 20 Hertz to 48 kHz frequency range, including Rice's whale calls and ambient noise, for up to 6 months. Additionally, the study leveraged a long-term HARP deployed by the SEFSC, Scripps Institution of Oceanography, and collaborators, at the De Soto Canyon site in the Rice's whale core distribution area over the August 2020 to July 2025 period. At this site, they have continuously recorded ambient noise and other acoustic events in the 10 Hertz to 100 kHz frequency range since 2010 to monitor the impacts of the *Deepwater Horizon* oil spill and subsequent restoration activities on cetaceans. Analyses from the combined DC HARP and sparse array of SoundTrap deployments over the 2021-2023 period suggested Rice's whale detections occurred at all PAM stations throughout the entire year, with detections occurring more commonly on the inshore line compared to the offshore line, and suggested call detections increased to the south in winter and to the north in summer. Additional data collection was recommended to determine whether these patterns were consistent over longer periods, as needed to understand seasonal distribution and density of Rice's whales.

To meet this need, a new 3-year project is being conducted from June 2025 to June 2028 that includes redeploying the PAM array for at least one more year, and conducting analyses of Rice's whale spatiotemporal occurrence across the new (2025-2026) and historic (2021-2023) datasets. The project objectives include 1) characterizing spatiotemporal distribution of calling Rice's whales throughout the CDA over three years to understand interannual variation in year-round occurrence patterns; 2) evaluating whether intra-annual habitat use patterns represent consistent seasonal cycles over time; and 3) evaluating longer-term trends in occurrence of calling Rice's whales as needed for monitoring population recovery. Results from 2021-2023 will be combined with the current effort to yield the three full years of broad coverage passive acoustic data collection. The project is off to a successful start. In June 2025, 17 SoundTrap ST600 STD recorders were deployed at the same study sites from the 2021-2023 period, along with the De Soto Canyon HARP. In January 2026, all 17 SoundTrap recorders were successfully retrieved. Upon initial inspection, acoustic recordings from each instrument were of high quality, yielding a total of 3,524 instrument-days of recording effort. The instruments recorded for a median of 6.9 months each, with most recordings ending in late December or early January. All 17 SoundTrap recorders were serviced and redeployed for another 6-month deployment. They will be retrieved, along with the HARP, in June 2026. Data analyses, including Rice's whale call detection, localization, and call density estimation will begin in fall 2026.

Project Background

As one of the most endangered whale species on earth with an estimated population size of 51 individuals in U.S. waters (Garrison et al., 2020), the Rice's whale (*Balaenoptera ricei*; formerly Gulf of Mexico Bryde's whale) was listed as endangered under the ESA in 2019 (84 FR 15446; 87 FR 8981). The majority of modern sightings occur in waters between the 100 – 400 m water depths in an area, defined as the core distribution area (CDA), near the De Soto Canyon off northwestern Florida in the Gulf of America (GOA; formerly Gulf of Mexico; Soldevilla et al, 2017, Rosel et al 2021, Rosel and Garrison, 2022). Rice's whales have additionally been sighted and detected in the western Gulf, offshore of Louisiana and Texas, USA, and Tampico, Mexico (Rosel et al 2021, Soldevilla et al 2022, Soldevilla et al 2024), though sightings and detections occur less frequently compared to the CDA.

Analyses of twelve years of near-continuous passive acoustic recordings at one long-term mooring site near the center of the CDA show the whales occupy this region year-round, with decreased call detections during winter and early spring suggesting potential seasonal patterns in habitat use (Debich et al., in prep). High densities of anthropogenic activities occur throughout the GOA, including oil and gas exploration and extraction, fisheries, shipping, and military activities, which potentially pose threats to Rice's whales. Many of these activities, including effects from US Navy readiness activities, and Eglin Air Force base activities, overlap with the whales' CDA. Understanding the seasonal and interannual distribution and density of Rice's whales throughout the CDA is critically needed to understand potential impact of human activities and assist in developing effective mitigation measures as needed.

With support from the U.S. Navy, the Southeast Fisheries Science Center (SEFSC) developed a large-scale passive acoustic monitoring project to evaluate intra-annual distribution and density of calling Rice's whales in the core habitat over two years. Over the May 2021 to March 2023 period, the SEFSC deployed a sparse array of moored PAM units at 17 sites concurrent with one long-term moored HARP (funded separately under LISTEN GoMex project) to cover the Rice's whale core habitat and provide the necessary data to understand intra-annual distribution and habitat use (**Figure 1**). The 18 moorings were deployed along the shelf-break in two lines of nine units each that nearly completely covered the core habitat to evaluate potential inshore to offshore and north to south movement patterns throughout the year. Over the 2-year period, four five-month deployments of up to 17 SoundTrap ST500 or ST600 STD long-term recorders were completed. Analyses of recordings from the first three deployments, covering the May 2021 to September 2022 period were completed, with automated detectors of Rice's whale long-moan and downsweep sequence calls run and manually validated. Over these three deployment periods, there were a total of 5,475 site-days of recordings, 755,547 true Rice's whale long-moan calls validated from 1,306,692 detected, and 42,441 true Rice's whale downsweep sequences validated from 224,060 detected. During the May 2021 – September 2022 period, true Rice's whale long-moans were detected year-round at all sites, ranging from 4 to 110,887 calls per deployment-site, with calls present on 46 to 99 percent of days per site. Over this period, true Rice's whale downsweep sequences were less common than long moans, ranging from 0 to 7,450 calls per deployment-site, with calls present on 0 to 59 percent of days per site. Higher numbers of detections of both call types occurred at the inshore sites than offshore sites throughout the three deployments. Preliminary results suggest potential seasonal movements with higher occurrence and call detection rates at northern sites in summer compared to winter months, and higher occurrence and call detection rates at southern sites in fall to winter (**Figure 2**). Similar timing of these movement patterns were observed for both call types, though there was a slight spatial offset with few downsweep detections at the northernmost sites.

Analyses of recordings from the fourth deployment (September 2022 to March 2023) were recently completed (NOAA-funded), however, hardware quality issues with the ST500 recorders that were built during staffing shortages during COVID shutdowns led to limited data collection at the inshore sites (only 3 of the 9 inshore sites had more than 6 weeks of data during the 6 month deployment). To understand whether the suggested movement patterns represent regular seasonal cycles, a minimum of three years of data collection are needed, including final statistical analyses to evaluate diel, seasonal, and spatial variation in call occurrence over the core habitat array, and to evaluate the impacts of varying ambient noise levels on call detection. Additional analyses of data from the first two deployments normalized call detection counts by accounting for seasonal sound propagation and noise level variation, and estimated call density via spatial capture-recapture methods. These analyses supported the observed patterns, but yielded higher call densities to the south compared to raw call counts, primarily due smaller detection ranges due to the higher noise levels at southern sites (Cook, 2025). Further, individual calls from animals were concurrently detected on multiple hydrophones within the array, and a framework was developed to time-synchronize the distinct instruments and acoustically track calling whales, providing preliminary information on call and swim behavior (Tenorio-Hallé et al., 2026). These ongoing analyses from the first 3 deployments will provide crucially important data for understanding how

Rice's whales are utilizing the habitat and whether they exhibit intra-annual movement patterns throughout the year, as needed to improve understanding of potential impact of human activities on these whales and assist in developing effective mitigation measures as needed.

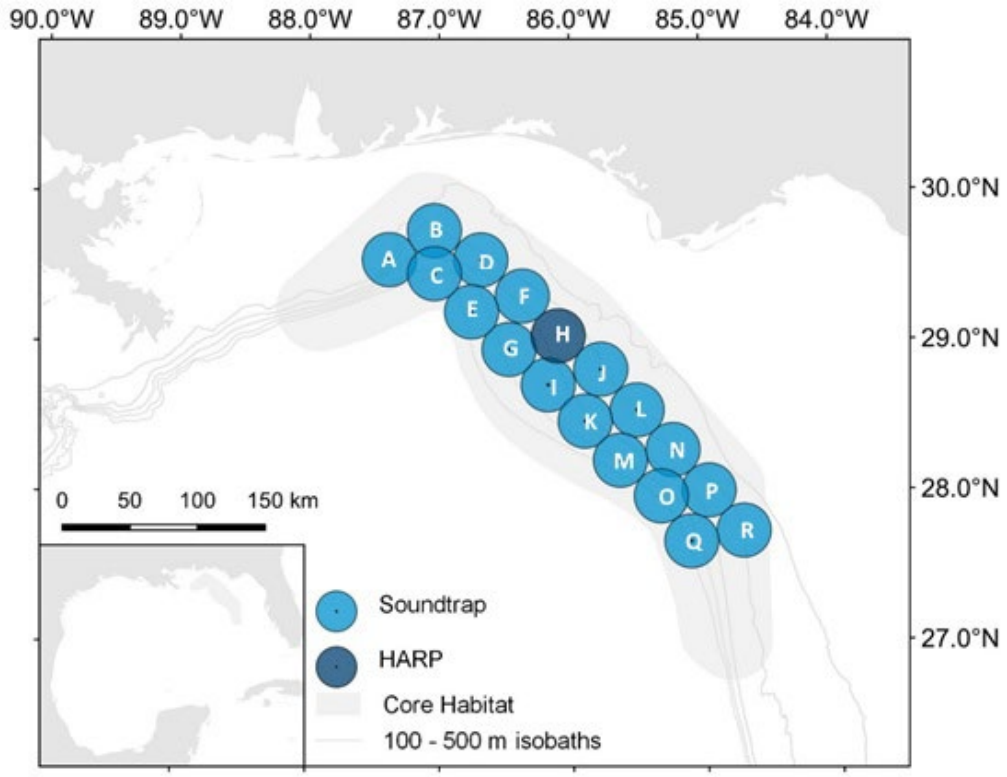

Figure 1. *Historic long-term passive acoustic monitoring station (HARP; dark blue) deployed in the Rice's whale core distribution area in the northeastern Gulf of America since 2010, and sparse array of passive acoustic monitoring stations (SoundTraps; light blue) deployed over the 2021-2023 and 2025-2026 periods. Circles around passive acoustic stations indicate the minimum expected acoustic coverage, assuming 20 km call detection distances. The NMFS core distribution area for Rice's whales is indicated as a shaded polygon. The long-term De Soto Canyon (DC) HARP site was deployed concurrent with the SoundTrap array under a Deepwater Horizon Restoration project.*

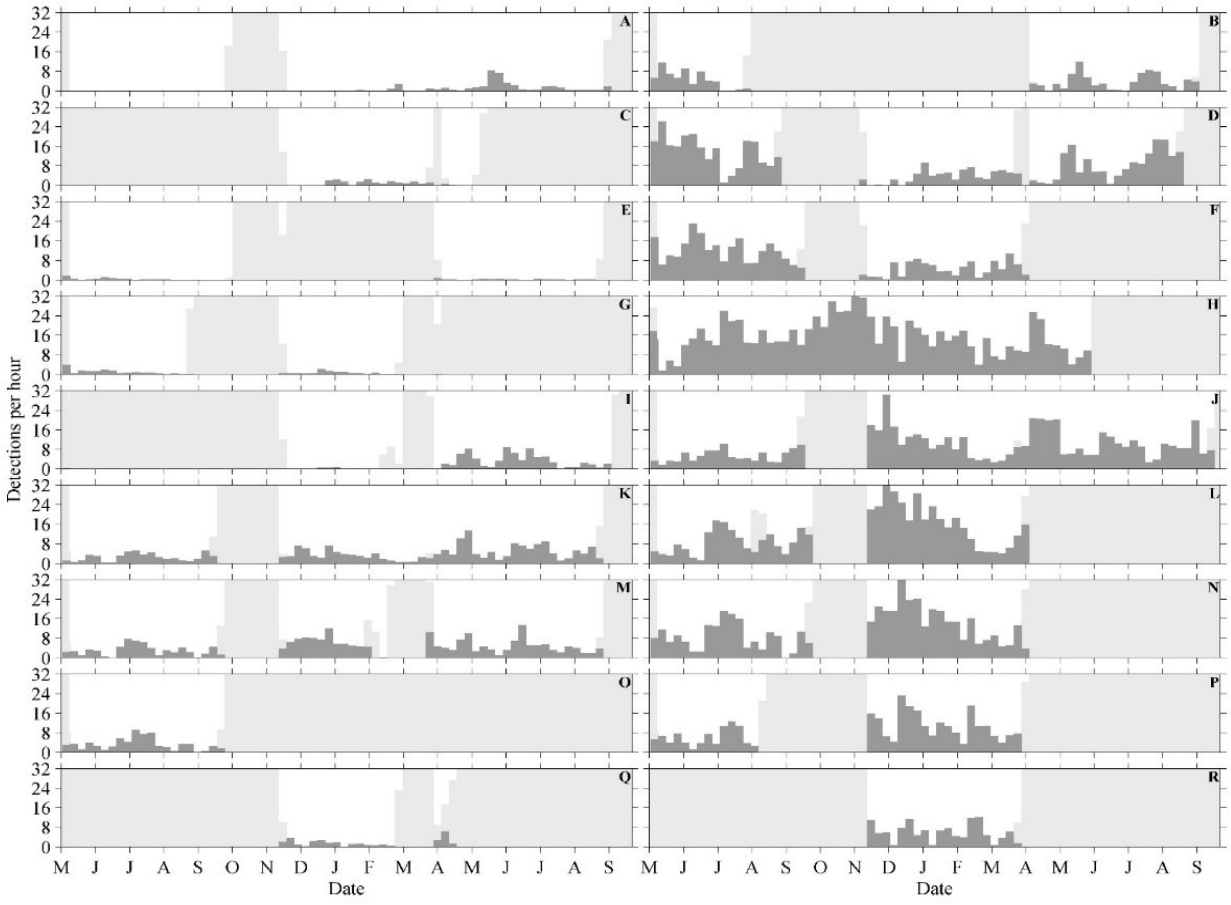

Figure 2. *Rice's whale long-moan call detection rates at 18 passive acoustic monitoring sites in the De Soto Canyon sparse array from May 2021 to October 2022. Dark gray bars represents average hourly call rates per week. Light gray shading indicates periods with no data. Call detections have not been corrected for detection ranges that vary with ambient noise and seasonal oceanographic conditions.*

Project Objectives

To provide a more robust dataset to understand seasonal movement patterns of endangered Rice's whales in the CDA, where they overlap with numerous human activities, this project will continue passive acoustic monitoring of Rice's whales throughout the core habitat for at least one additional year, beginning in June 2025. Data collection over a minimum of three years is needed to determine whether intra-annual variation Rice's whale occurrence and distribution represents seasonal movement patterns or a more nuanced response to oceanographic conditions, including the position of the Loop Current and its eddies and variation in Mississippi River outflow. Further, long-term monitoring of this critically endangered population is needed in their CDA to quickly identify potential population-level changes to adaptively manage human impacts to maximize chances for recovery. To address both of these needs, we will collect and analyze at least one additional year of data, from approximately June 2025 through June 2026, for Rice's whale occurrence using the same 18-mooring sparse array study design.

Our primary objectives are to: 1) characterize spatiotemporal distribution of calling Rice's whales throughout the CDA over a full three years to understand interannual variation in year-round occurrence patterns; 2) evaluate whether intra-annual habitat use patterns represent consistent seasonal cycles over time; and 3) evaluate longer-term trends in occurrence of calling Rice's whales as needed for monitoring population recovery. The three full years of broad coverage passive acoustic data collection with analyses of diel, seasonal, interannual, and spatial variation in occurrence of Rice's whale call detections over the CDA will be analyzed to assess generality of the 2021-2022 intra-annual results and will additionally yield a robust dataset for developing predictive habitat models to understand factors driving Rice's whale occurrence. These monitoring data are crucial for implementing conservation and management plans, including developing mitigation measures for potential anthropogenic threats, in this area that is important to both Rice's whales and the US military.

Methods

Rice's Whale Calls

Long-term, broad-coverage passive acoustic monitoring is a highly effective tool for investigating whale seasonal and interannual occurrence patterns. In the GOA, three call types (downsweep sequence calls, long-moan calls, and tonal-sequence calls) have been identified and definitively attributed to free-ranging Rice's whales (Rice et al., 2014; Širović et al., 2014; Soldevilla et al., 2022b), and one additional call type (high-frequency downsweep pulses) has been proposed as a likely candidate (Širović et al., 2014, **Figure 3**). Rice's whale downsweep sequence calls are made up of series of two or more short-duration downsweep pulses (mean: 8 downsweeps, range: 2-25) ranging from 110 ± 4 to 78 ± 7 Hz, with a mean duration of 0.4 ± 0.1 s, an inter-pulse interval of 1.3 ± 0.1 s, and source levels of 155 ± 14 dB re: 1 µPa at 1 m (Rice et al., 2014; Širović et al., 2014; Soldevilla et al., 2022b). The long-moan call type is a long-duration, amplitude-modulated tonal call that sweeps from 150 to 75 Hz with a mean center frequency of 107 Hz, mean 22.2 s duration, and 3.4 pulse/s amplitude pulse rate (Rice et al., 2014; Soldevilla et al., 2022a). Stereotyped variants of the long-moan that are common in the western Gulf are occasionally detected in the CDA as well (Soldevilla et al., 2022b). The second tonal call type, the tonal-sequence, consists of 1-6 narrow-band constant-frequency tones in sequence following some long-moans, with individual tonals having a mean center frequency of 103 Hz and mean 3.6 s duration (Rice et al., 2014).

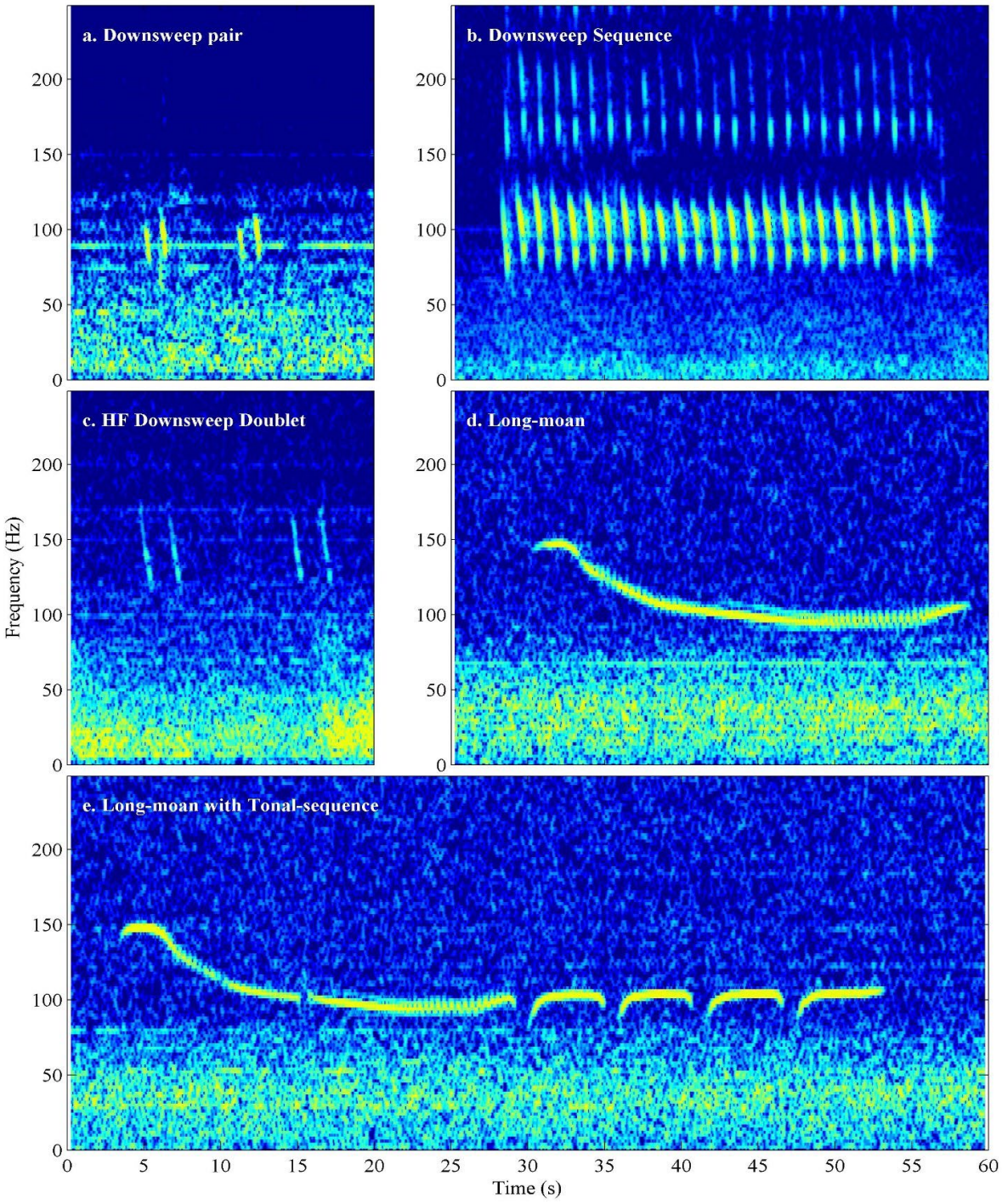

Figure 3. *Spectrograms of Rice's whale calls and potential calls.*

Acoustic Recording Instrumentation

High-frequency Acoustic Recording Package (HARP)

HARPs have been used to record marine mammal sounds and characterize the low-frequency ambient soundscape in the GOA at the De Soto Canyon (DC) HARP site from 2010 through 2025. HARPs can autonomously record underwater sounds from 10 Hz up to 160 kHz and are capable of over 365 days of continuous data storage. The HARPs can be deployed in either a seafloor mooring or a seafloor package configuration with the hydrophones suspended 10 m above the seafloor (**Figure 4a**). Each HARP is calibrated in the laboratory to provide a quantitative analysis of the received sound field. Representative data loggers and hydrophones are also calibrated at the Navy's TRANSDEC facility to verify the laboratory calibrations (Wiggins & Hildebrand, 2007).

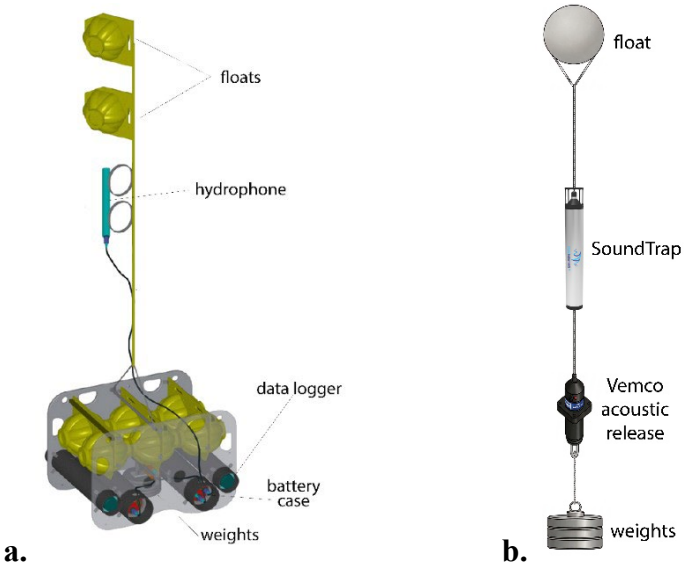

Figure 4. *Schematic diagrams of a HARP seafloor package (a) and a SoundTrap mooring (b).*

SoundTrap ST600 (SoundTrap)

SoundTrap ST600 STD recorders (Ocean Instruments Inc.) have been deployed as a sparse array to record marine mammal sounds and characterize the low-frequency ambient soundscape throughout the Rice's whale CDA in the northeastern GOA since 2021. The SoundTrap ST600 STDs are calibrated long-term recorders capable of continuously recording underwater sound in the 20 Hz – 60 kHz frequency range, including Rice's whale calls and ambient noise, for at least six months. The SoundTraps are deployed in a small mooring configuration with the hydrophones suspended 3 m above the seafloor (**Figure 4b**). The ST600 STD recorders are factory calibrated at 250 Hz. The SoundTrap moorings use a Vemco VR2AR acoustic release that allows opportunistic collection of transmissions from Vemco-acoustic-tagged fish and reptiles that pass by the mooring.

Data Collection

In June 2025, 17 SoundTrap ST600 STD recorders were deployed by SEFSC from the NOAA Ship Gordon Gunter, representing the 5th deployment since 2021. These moorings were deployed at depths ranging from 192 to 468 m in two lines that nearly completely covered the Rice's whale core habitat (**Figure 1**) and sampled continuously at 24 kHz. In January 2026, the SEFSC recovered all 17 SoundTrap moorings from the fifth deployment, and redeployed 17 SoundTrap moorings for a sixth deployment from Florida Institute of Oceanography's R/V W.T. Hogarth. The acoustic recordings from the fifth deployment yielded a total of 3,943 instrument-days of recordings over the June 2025 to January 2026 period with recording durations ranging from 187-229 days, and a median of 210 days (**Table 1**). Preliminary QA/QC spot checks indicate the data retrieved from the fifth deployment are high quality throughout each recording, with signals from Rice's whales, dolphins, airguns, and vessel noise present in the data, and no apparent corrupt data were observed. The sixth deployment will be retrieved in June 2026, and the instruments will be serviced and re-deployed for a seventh deployment (supported by a FL RACEP-funded project).

The DC HARP was concurrently deployed by Scripps and SEFSC in June 2025 (270 m depth) from the R/V Pelican under funding from a *Deepwater Horizon* Restoration project. This is the 18th deployment at this historic site, which is located approximately in the center of the Rice's whale CDA (**Figure 1**). This recorder is sampling continuously at 200 kHz, and will be retrieved, serviced, and redeployed in June 2026.

Future Analytical Opportunities

Acoustic detection, classification, localization, and density estimation analyses are planned to meet the project objectives to: 1) characterize spatiotemporal distribution of calling Rice's whales throughout the CDA over a full three years to understand interannual variation in year-round occurrence patterns; 2) evaluate whether intra-annual habitat use patterns represent consistent seasonal cycles over time; and 3) evaluate longer-term trends in occurrence of calling Rice's whales as needed for monitoring population recovery. These include running automated detectors and classifiers and validating call detections for Rice's whale call presence and call detection rates on the 2025-2026 datasets to use in cross-site and time-series analyses of spatiotemporal occurrence patterns across the 2021-2023 and 2025-2026 datasets.

Beyond these spatio-temporal occurrence patterns, advanced analytical projects will use the data collected from the large-scale sparse PAM array to further improve our understanding of Rice's whale seasonal and interannual density patterns and the oceanographic and anthropogenic factors driving them. To convert occurrence and distribution results into call or animal density, more information is needed on call detection ranges and how they change over time and space due to varying sound propagation conditions and ambient noise levels. Prior analyses found calls from individual whales are commonly detected at multiple sites, and used time-difference-of-arrival (TDOA) methods to localize and track over 400 whale-detection-events, with typical detection distances of 40-50 km and some detections out to 75 km. These TDOA-based localization methods are yielding statistically robust information on call detection distances, source levels, and dive

behavior, and may yield important information about swim behavior and movement patterns in the CDA. Additionally, the occurrence of the same call on multiple instruments is being used in a pilot study testing spatially-explicit capture-recapture methods to estimate density and detection distances, providing complementary results to evaluate detection distances and how they change over time along with call density estimates. Automated analytical tools for TDOA-based tracking and SECR density estimation are in development, making these methods more accessible for analyses of future array-deployment datasets.

*Table 1. Acoustic monitoring effort at 18 sites near De Soto Canyon during two deployments over the June 2025 to January 2026 period. SoundTraps from Deployment 6 are scheduled for June 2026 recovery, and will be redeployed as part of a FL-RACEP project. * DC_H is the LISTEN project HARP site, which is deployed for 1-year durations, is scheduled for recovery and redeployment in June 2026.*

Site	Latitude (°N)	Longitude (°W)	Deployment 5				Deployment 6			
			Start Time	End Time	Effort (Days)	Effort (Hours)	Start Time	End Time	Effort (Days)	Effort (Hours)
DC_A	29.57	-87.32	6/7/2025 19:45	1/5/2026 15:46	211.8	5,084	1/12/2026 20:00	--	--	--
DC_B	29.76	-87.04	6/7/2025 18:07	1/6/2026 11:08	212.7	5,105	1/12/2026 17:57	--	--	--
DC_C	29.49	-87.04	6/7/2025 20:47	1/18/2026 16:19	224.8	5,396	1/12/2026 22:18	--	--	--
DC_D	29.56	-86.68	6/7/2025 20:58	12/23/2025 15:59	198.8	4,771	1/12/2026 22:39	--	--	--
DC_E	29.22	-86.76	6/7/2025 21:28	12/28/2025 19:29	203.9	4,894	1/12/2026 22:59	--	--	--
DC_F	29.32	-86.37	6/7/2025 19:28	12/30/2025 12:29	205.7	4,937	1/12/2026 22:39	--	--	--
DC_G	28.97	-86.47	6/7/2025 17:56	1/4/2026 1:57	210.3	5,048	1/15/2026 23:18	--	--	--
DC_H*	29.05	-86.10	6/17/2025 13:00	--	--	--	--	--	--	--
DC_I	28.73	-86.18	6/7/2025 21:16	12/29/2025 5:17	204.3	4,904	1/15/2026 23:49	--	--	--
DC_J	28.83	-85.78	6/7/2025 20:30	1/5/2026 17:31	211.9	5,085	1/18/2026 17:14	--	--	--
DC_K	28.48	-85.90	6/7/2025 19:55	1/10/2026 16:56	216.9	5,205	1/18/2026 15:52	--	--	--
DC_L	28.55	-85.50	6/7/2025 15:54	12/12/2025 20:54	188.2	4,517	1/18/2026 21:30	--	--	--
DC_M	28.22	-85.63	6/7/2025 15:07	1/22/2026 19:31	229.2	5,500	1/18/2026 22:31	--	--	--
DC_N	28.29	-85.24	6/7/2025 15:20	1/3/2026 5:21	209.6	5,030	1/18/2026 23:29	--	--	--
DC_O	27.98	-85.33	6/7/2025 18:15	1/8/2026 18:16	215.0	5,160	1/12/2026 21:12	--	--	--
DC_P	28.01	-84.97	6/7/2025 17:30	12/18/2025 21:31	194.2	4,660	1/19/2026 2:25	--	--	--
DC_Q	27.68	-85.11	6/7/2025 17:40	12/24/2025 8:41	199.6	4,791	1/12/2026 16:57	--	--	--
DC_R	27.74	-84.71	6/7/2025 19:13	12/11/2025 18:14	187.0	4,487	1/12/2026 16:42	--	--	--

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