# Caribbean Humpback Acoustic Monitoring Programme: 2016-2017 Report

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# Executive Summary

In September 2016, the West Indies distinct population segment (DPS) of humpback whales (*Megaptera novaeangliae*), was delisted under the US Endangered Species Act. This DPS covers all of the Caribbean breeding grounds. However, growing evidence suggests the West Indies DPS contains more than one breeding population. In response to these changes in the status of humpback whales and evidence supporting more than one breeding population in the West Indies, we formed the Caribbean Humpback Acoustic Monitoring Programme (CHAMP). This research program leverages and expands on networks already established in the Caribbean to promote and enhance collaborative research on the biology of humpback whales and establish a robust monitoring program, focusing first on passive acoustic monitoring. CHAMP is a multi-national program which includes researchers, government officials, non-governmental organizations, resource managers, and others in Aruba, Bonaire, the Dominican Republic, Guadeloupe, Martinique, Saint Martin, and the United States.

With the cooperation and assistance of this large network of partners and collaborators, we deployed nine passive acoustic recording devices at seven recording sites throughout the Caribbean from December 2016 to June 2017 (Fig. 1). To record humpback whale song and broadly characterize the acoustic environment, we used two different types of autonomous, bottom-mounted acoustic recorders: Marine Autonomous Recording Units (MARUs, Cornell University, Ithaca, New York) and SoundTraps (Ocean Instruments, Auckland, New Zealand). We deployed a single recorder at each study site, with the exception of the Bonaire and Guadeloupe East sites, where a MARU and SoundTrap were deployed together (Fig. 1). In addition to this broad-scale passive acoustic monitoring effort, we worked with the Sea Education Association to collect opportunistic recordings during their "Colonization to Conservation in the Caribbean" voyage in winter 2017.

To assess the occurrence and seasonality of humpback whale song across the Caribbean, we analyzed all recordings for the daily presence or absence of humpback whale song. Song was recorded at five of the seven monitoring sites, and was generally present from January through May, with variation in the seasonal timing of song presence across sites (Fig. 2). Other biological and anthropogenic sounds of interest were noted opportunistically during this analysis, and are described in the following sections of this report.

Future analyses of the acoustic data will focus on the content and structure of humpback whale song, quantifying temporal and spatial variation in song structure. Differences in song structure can be used to identify separate breeding populations, which may ultimately help inform management and policy decisions. Additional analyses will explore the soundscape at the recording sites including the acoustic footprint of human activities.

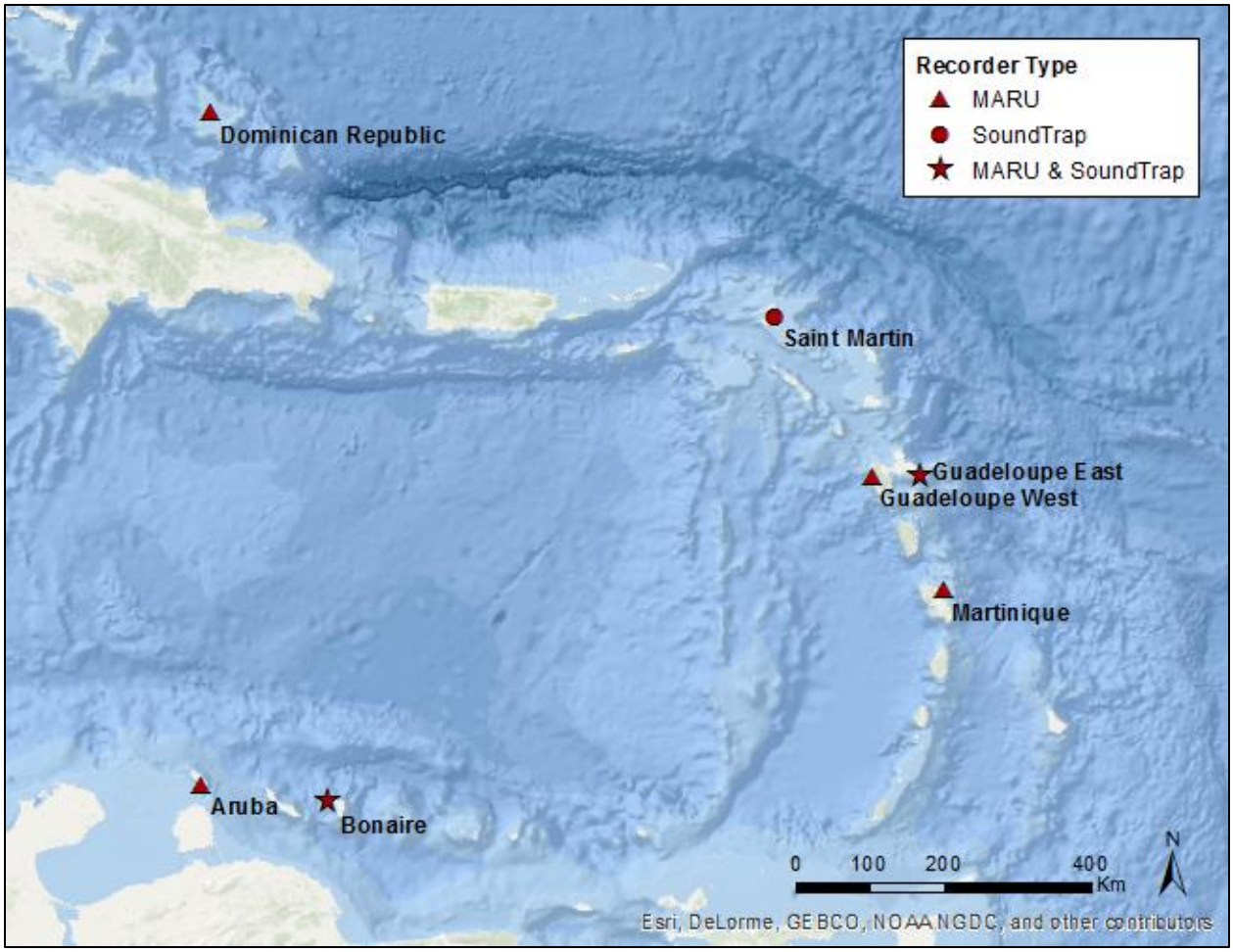


**Figure 1.** Map of passive acoustic recording sites in the Caribbean, December 2016 through June 2017.

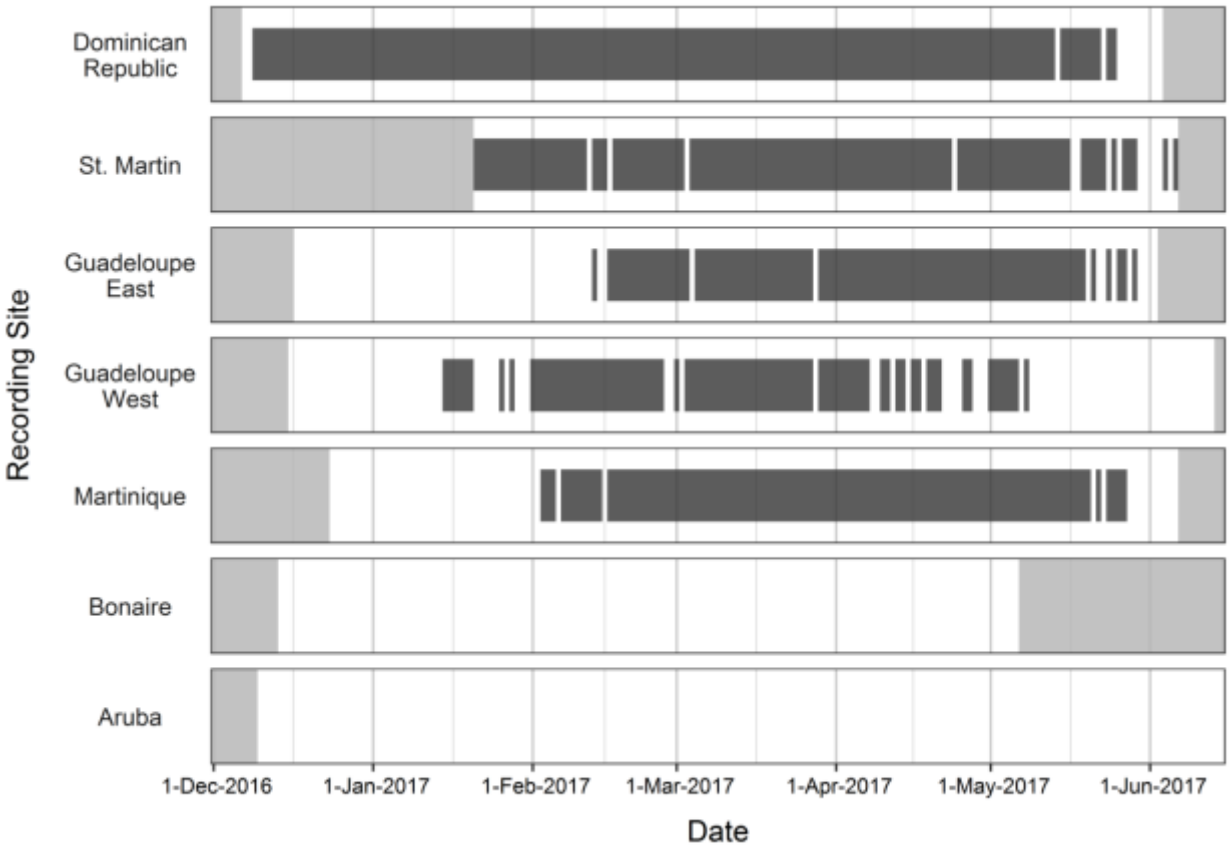


**Figure 2.** Seasonal occurrence of humpback whale song from December 2016 to June 2017 across all recording sites, shown from north (top) to south (bottom). Dark gray bars indicate recording dates with humpback song present; light gray shading indicates periods with no recording effort. Recordings were collected continuously at all sites except for St. Martin, where a 25% duty-cycled recording schedule (1 h/ 4 h) was used.

# General Methods

## Passive Acoustic Data Collection

We conducted passive acoustic monitoring using two types of autonomous, bottom-mounted recording devices: Marine Autonomous Recording Units (MARUs; Cornell University, Ithaca, New York) and SoundTraps (Ocean Instruments, Auckland, New Zealand). We deployed MARUs at six locations (Fig. 1, Table 1), and programmed each unit to collect continuous recordings at a sampling rate of 2 kHz, suitable for recording low-frequency sounds including baleen whale calls. We deployed SoundTraps at three locations (Fig. 1, Table 1), and programmed these instruments to record at a sampling rate of 48 kHz, allowing a broader characterization of the soundscape and the detection of higher-frequency sounds, such as dolphin whistles and sperm whale echolocation clicks. To obtain recordings across the full deployment period at this higher sampling rate, the SoundTrap recordings were collected using a duty-cycled recording schedule, with 1 hour of recording time occurring every 4 hours. A programming error resulted in one SoundTrap recording 1 hour every 4 days (Table 1). At the Bonaire and Guadeloupe East study sites, we deployed a MARU and SoundTrap together; at the remaining sites we used a single recorder (Table 1). We deployed all recording devices in December 2016 and January 2017, and recovered them in May and June 2017. All units were anchored at depths ranging from 16 to 59 m with the hydrophone suspended 1-2 m above the seafloor. Methods of deployment and recovery varied depending on local weather conditions, site characteristics such as depth and distance from shore, and other logistical considerations.

## Data Analysis

All MARU recordings were analyzed for the daily presence of humpback whale song. We used Raven Pro (Bioacoustics Research Program, Cornell University, Ithaca, New York) to view spectrograms across a frequency range of 0-600 Hz and a time window of 3 minutes. For each recording day, we scrolled through spectrograms until the first occurrence of humpback whale song was observed, then marked daily presence and moved ahead to the next day. In some cases, an automated detection system, the Low Frequency Detection and Classification System (LFDCS; Baumgartner & Mussoline 2011[1]), was also used to help identify hours with high numbers of detections of potential song units. Hours with automated detections were manually examined to verify humpback song presence on a daily basis, and days with no humpback song detections were visually scanned using spectrograms to ensure true absence of song. Other low frequency sounds, such as minke whale pulse trains, were noted opportunistically during the analysis of humpback whale song presence.

SoundTraps recorded at a higher sampling rate (48 kHz), providing an analysis bandwidth from 0 Hz to 24 kHz. To review these datasets for higher-frequency sounds, we created long-term spectral averages (LTSAs) using the Triton software (Scripps Whale Acoustic Lab, Scripps Institution of Oceanography, La

[1] Baumgartner, M. F., and S. E. Mussoline. 2011. A generalized baleen whale call detection and classification system. The Journal of the Acoustical Society of America 129:2889–2902.

Jolla, CA) developed in MATLAB (The Mathworks, Inc., Natick, MA). LTSAs provide a compressed spectrogram view with a 5 s time resolution and 100 Hz frequency resolution, and facilitate efficient visual review of large datasets. The prevalence of snapping shrimp in the high-frequency recordings complicated this analysis and tended to mask other sounds in the LTSAs, but we were able to identify some odontocete vocalizations including dolphin whistles and sperm whale clicks.

**Table 1.** Summary of passive acoustic recording effort in the Caribbean from December 2016 to June 2017.

| Site | Instrument Type | Sampling Rate, Recording Schedule | Location | Depth (m) | Recording Dates | No. of Recording Days |
|---|---|---|---|---|---|---|
| Aruba | MARU | 2 kHz, continuous | 12° 26.318 N<br>69° 56.387 W | 38.1 | 10 Dec 2016 - 15 Jun 2017 | 188 |
| Bonaire | SoundTrap<br>MARU | 48 kHz, 1 h/4 h<br>2 kHz, continuous | 12° 15.635 N<br>68° 25.265 W | 35 | 14 Dec 2016 - 06 May 2017 | 144 |
| Dominican Republic | MARU | 2 kHz, continuous | 20° 36.514 N<br>69° 49.168 W | 29.9 | 07 Dec 2016 - 03 Jun 2017 | 179 |
| Guadeloupe East | SoundTrap<br>MARU | 48 kHz, 1 h/4 d*<br>2 kHz, continuous | 16° 12.749 N<br>61° 12.360 W | 29.5 | 17 Dec 2016 - 02 Jun 2017 | 168 |
| Guadeloupe West | MARU | 2 kHz, continuous | 16° 11.537 N<br>61° 47.292 W | 28 | 16 Dec 2016 - 13 Jun 2017 | 180 |
| Martinique | MARU | 2 kHz, continuous | 14° 48.627 N<br>60° 55.383 W | 59.2 | 24 Dec 2016 - 06 Jun 2017 | 165 |
| Saint Martin | SoundTrap | 48 kHz, 1 h/4 h | 18° 07.301 N<br>62° 58.106 W | 16 | 21 Jan 2017 - 06 Jun 2017 | 137 |

*A programming error resulted in a reduced recording schedule on this SoundTrap

# Aruba

## Study Site & Data Collection

In Aruba, we deployed a single MARU along the southwestern coast of the island, just offshore of Savaneta. The study site was located at a depth of 38.1 m in a flat, sandy-bottom area. We deployed the MARU on 9 December 2016, with assistance from divers to position the unit on the seafloor and measure the depth. The MARU was recovered on 15 June 2017, and recorded continuously throughout the deployment, resulting in 188 full recording days.

## Humpback Song Presence

No humpback song was present in the Aruba MARU recordings. Low-frequency noise from vessel traffic was prevalent at this site, and frequently masked the recordings, making it difficult or impossible to identify other sounds present for periods from minutes to hours at a time (Fig. 3). We did note a variety of fish sounds present throughout the dataset; these have not been quantitatively analyzed or identified to species.

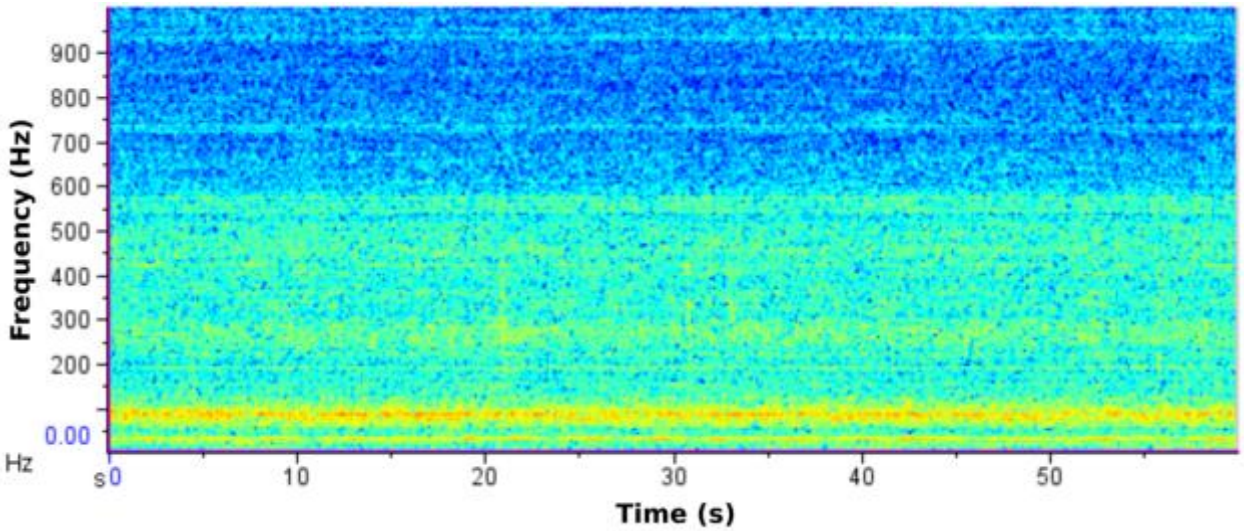


**Figure 3.** Example spectrogram of recordings masked by ship noise at Aruba.

# Bonaire

## Study Site & Data Collection

The Bonaire study site was located off the northwestern coast of the island, in a pristine reef environment within the Bonaire National Marine Park. This region features a fringing reef and steeply sloping bathymetry, reaching a depth greater than 1000 m less than 2 km offshore. We deployed a MARU and SoundTrap along the reef approximately 100 m offshore at a depth of 35 m. Both recorders were deployed on 13 December 2016, and recovered on 7 May 2017, resulting in 144 full recording days on the MARU and 864 hour-long files on the SoundTrap, which recorded for 1 hour every 4 hours throughout the deployment period.

## Humpback Song Presence

No humpback song was present in the MARU or SoundTrap recordings from Bonaire.

## Other Sounds

A diverse array of fish sounds were recorded in both datasets, which have not been quantitatively analyzed or identified to species. In the higher-frequency SoundTrap recordings, we identified sounds from sperm whales (*Physeter macrocephalus*) and unknown delphinid species; both were detected sporadically throughout the dataset (Fig 4). Dolphin sounds usually consisted of whistles (Fig. 5). Sperm whale detections included echolocation clicks as well as sounds used in social communication, including slow clicks and a trumpet-like sound (Fig. 6).

**Figure 4.** Daily presence of odontocetes (top: unidentified dolphins, bottom: sperm whales) based on SoundTrap recordings collected in Bonaire between 14 Dec 2016 and 6 May 2017. Recordings were collected on a duty-cycled recording schedule of 1 h/4 h.

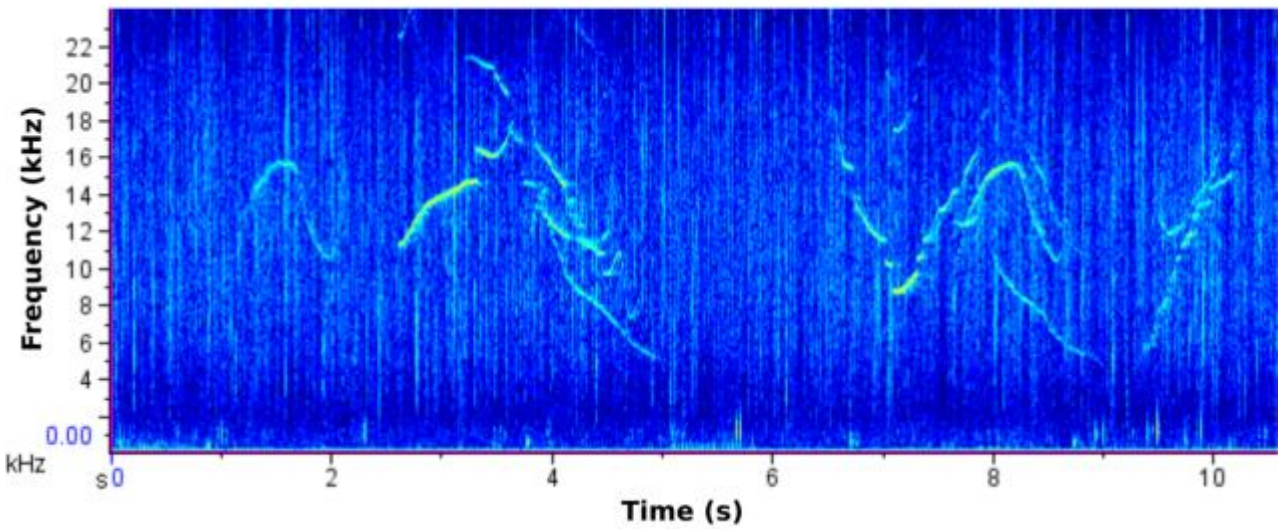


**Figure 5.** Example spectrogram of dolphin whistles recorded at Bonaire on 18 Jan 2017.

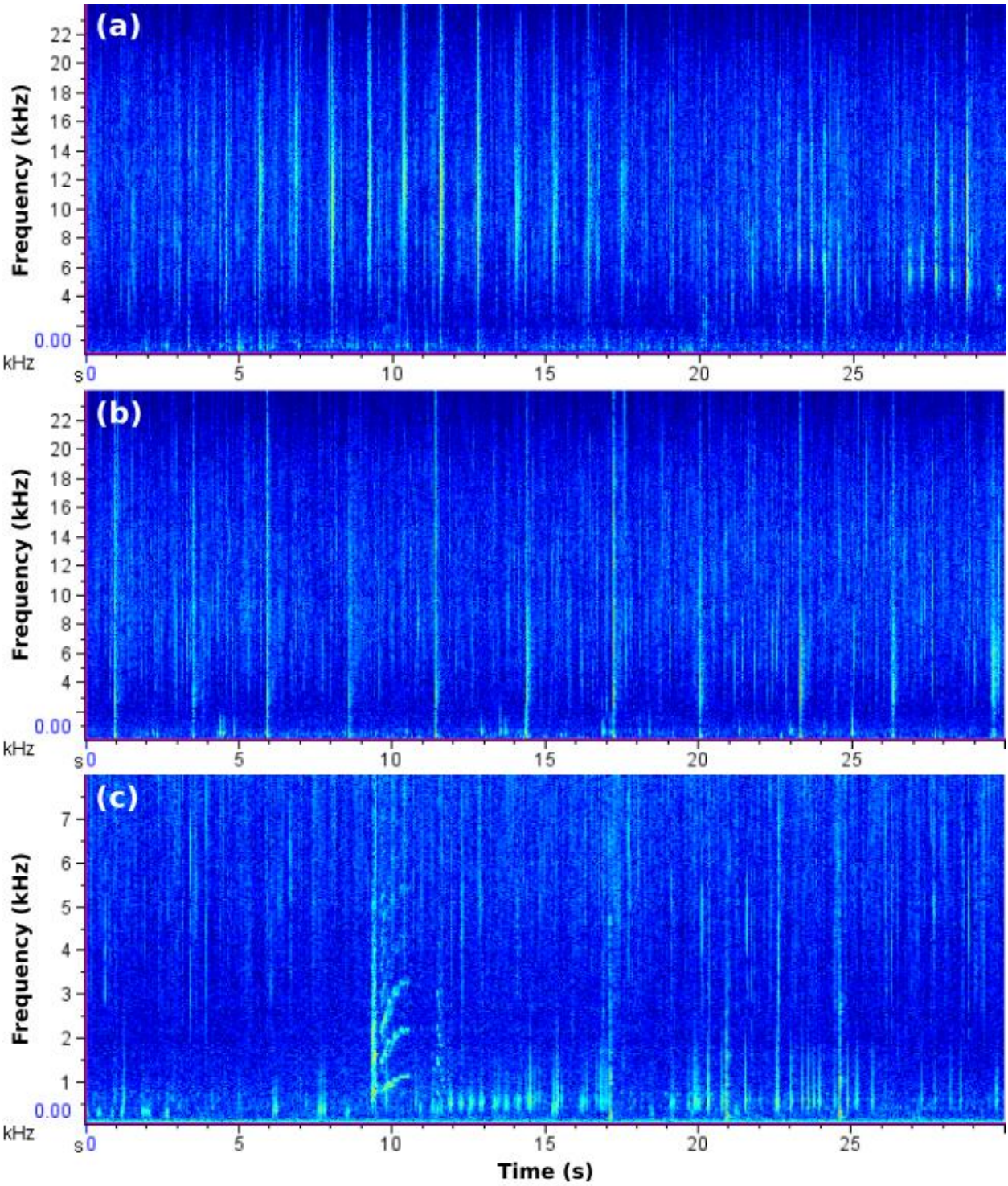


**Figure 6.** Example spectrograms of (a) sperm whale echolocation clicks, (b) slow clicks, and (c) a trumpet-like sound recorded at Bonaire on 9 Feb 2017. Note that frequency ranges differ across panels.

# Dominican Republic

## Study Site & Data Collection

In the Dominican Republic, our study site was located on Silver Bank, approximately 125 km north of Puerto Plata. Silver Bank is a relatively flat, shallow bathymetric feature, with an area of approximately 2,400 $km^2$ and an average depth of 30 m. The warm, shallow waters of Silver Bank are known to be a preferred breeding and calving ground for humpback whales. We deployed a MARU on 6 December 2016 at a depth of 29.9 m with the assistance of divers to guide the unit to the seafloor and document its position and depth. We recovered this unit on 4 June 2017, using the built-in acoustic release mechanism, and collected 179 full days of recordings.

## Humpback Song Presence

Humpback whale song was present on 166 (93%) of the 179 recording days. Song was present in the recordings every day from 9 December 2017 to 13 May 2017, then continued more sporadically until 25 May 2017. This site had the longest seasonal presence of humpback whale song (see Fig. 2), and singing activity was often intense, with multiple singers recorded simultaneously (Figs. 7 and 8.).

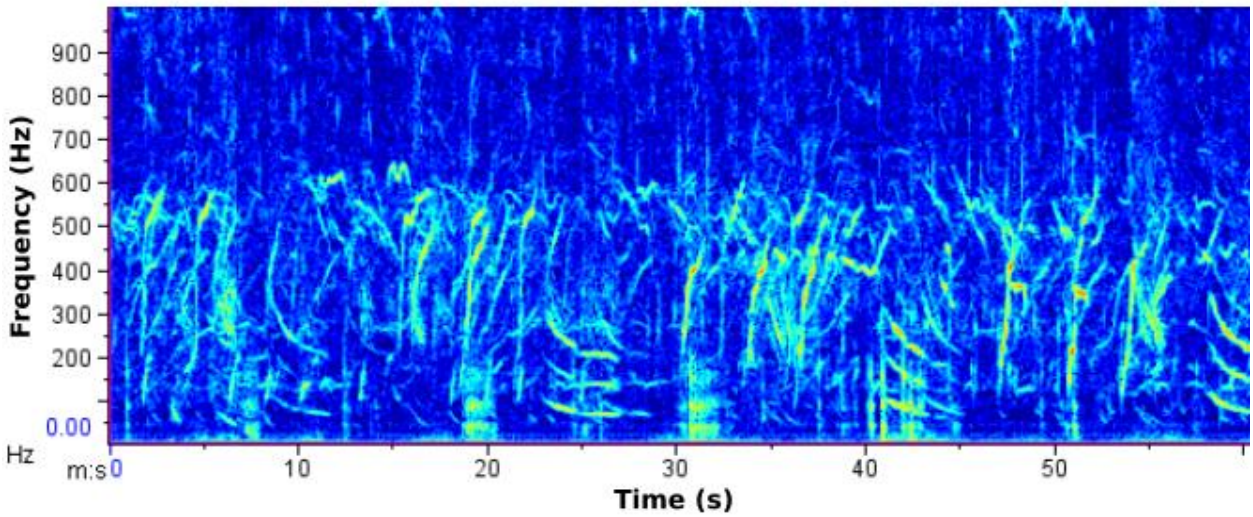


**Figure 7.** Example spectrogram of humpback whale song recorded on Silver Bank on 25 Feb 2017 with multiple singers present.

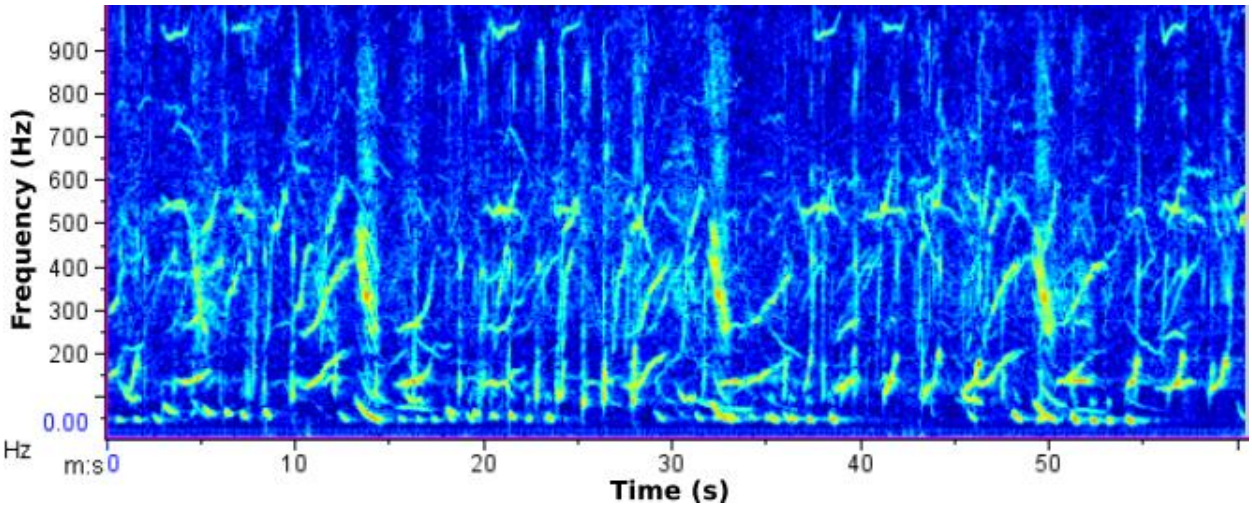


**Figure 8.** Example spectrogram of humpback whale song recorded on Silver Bank on 3 Mar 2017 with multiple singers present.

# Guadeloupe East

## Study Site & Data Collection

On the east coast of Guadeloupe, our study site was located just south of the far eastern point of Grande-Terre island. We deployed a MARU and a SoundTrap together at a depth of 29.5 m on 16 December 2016. Both recorders were recovered on 2 June 2017, resulting in 168 full recording days on the MARU, and 43 hour-long files on the SoundTrap. Due to a programming error, this SoundTrap recorded for 1 hour every 4 days throughout the deployment period instead of the intended schedule of 1 hour every 4 hours.

## Humpback Song Presence

Humpback whale song was present on 97 (58%) of the 168 recording days, beginning in mid-February and continuing until late May. Across this period, we observed gradual change in recurring song themes (Fig. 9). A full analysis of song structure has not yet been completed.

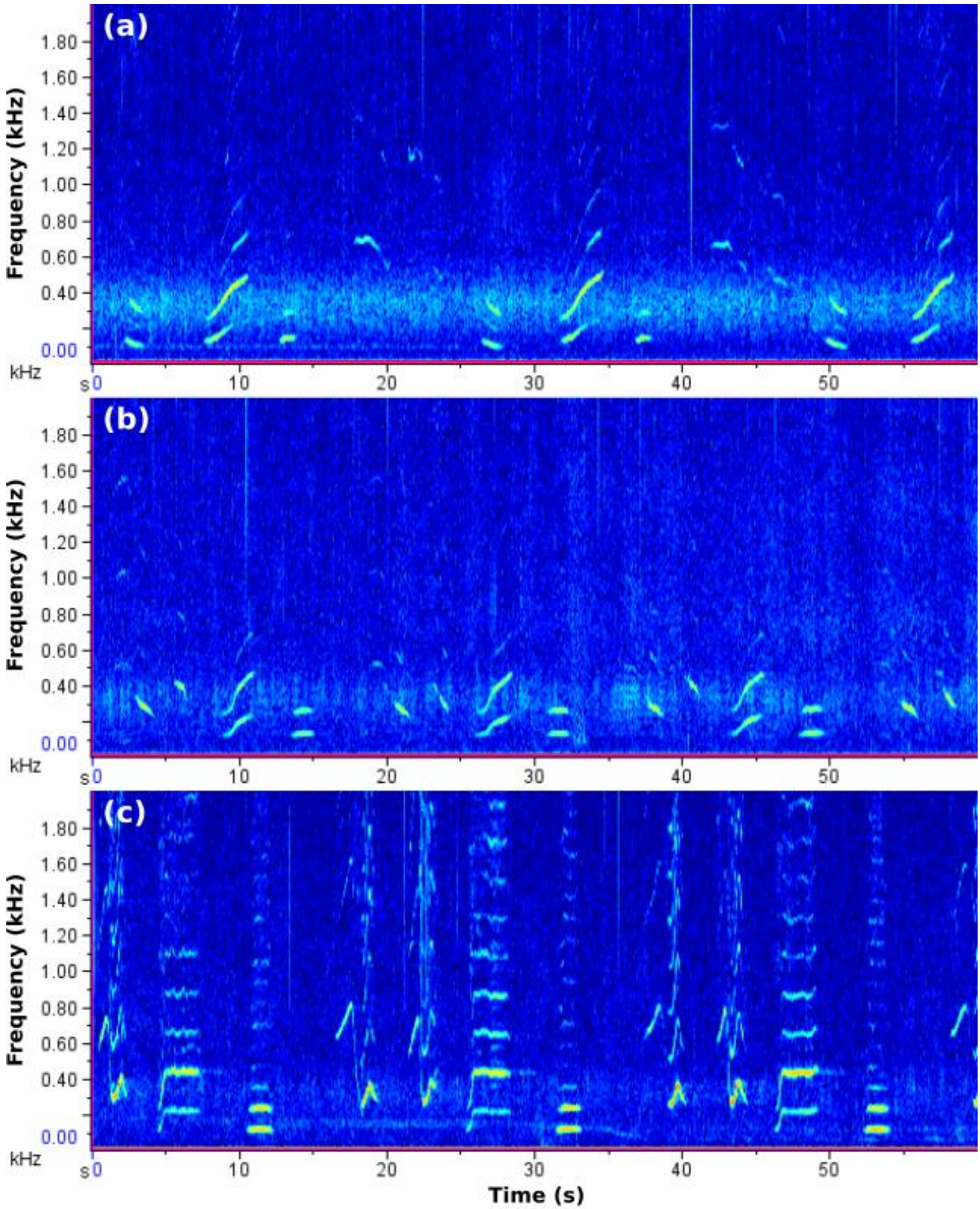


**Figure 9.** Example spectrogram of humpback whale song recorded on 22 Feb 2017 (a), 26 Mar 2017 (b) and 17 May 2017 (c) showing seasonal change in a recurring song theme.

# Guadeloupe West

## Study Site & Data Collection

On the west coast of Guadeloupe, we deployed a MARU just off the western coast of Basse-Terre island, within the National Parc of Guadeloupe and close to Pigeon Island. This unit was deployed on 15 December 2017 at a depth of 28 m, and recovered on 14 June 2017, resulting in 180 full recording days.

## Humpback Song Presence

Humpback whale song was present on 88 (49%) of the 180 recording days, from mid-January to early May. Song was detected on the west coast of Guadeloupe a full month earlier than the first detection on the east coast, and was present more intermittently at this site (see Fig. 2).

## Other Sounds

Seismic airgun pulses were noted during the analysis of the MARU data for humpback whale song (Fig. 10). These occurred on several days in late May and June, fading in and out of the recordings.

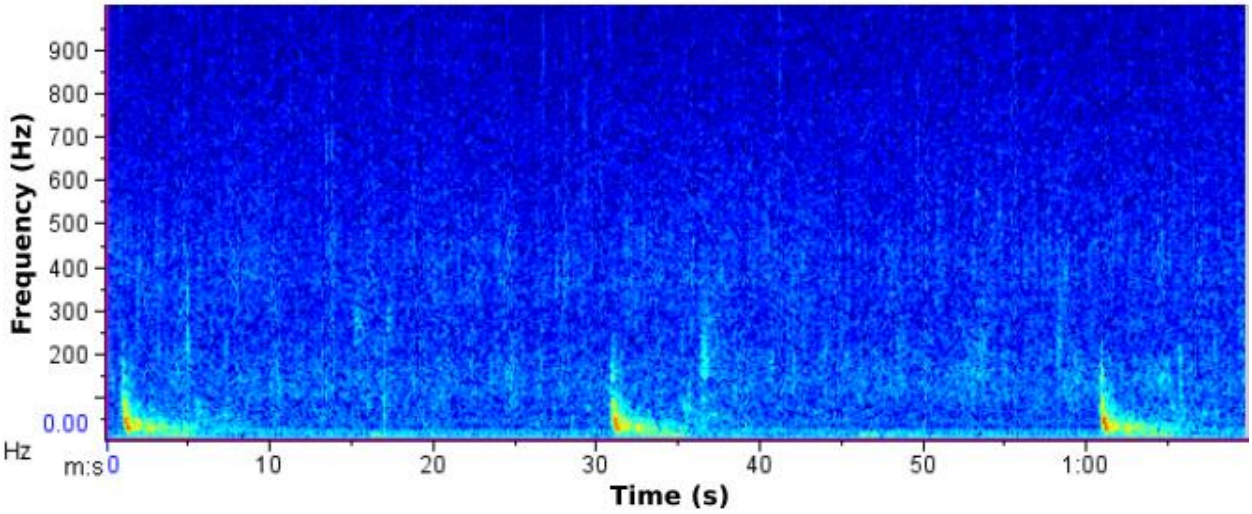


**Figure 10.** Example spectrogram of seismic airgun pulses recorded at Guadeloupe West on 3 June 2017.

# Martinique

## Study Site & Data Collection

In Martinique, our study site was located off the northeastern coast of the island, approximately 9 km offshore of La Trinité and just north of the Caravelle Peninsula. On 24 December 2016, we deployed a MARU at a depth of 59.2 m, which represents the deepest recording site in the study. We recovered this unit on 7 June 2017, using the built-in acoustic release mechanism, resulting in 165 full recording days.

## Humpback Song Presence

Humpback whale song was present in 110 (67%) of the 165 recording days, beginning in early February and continuing until late May. Fig. 11 provides an example of three distinct song themes recorded from a single singer on 14 April 2017.

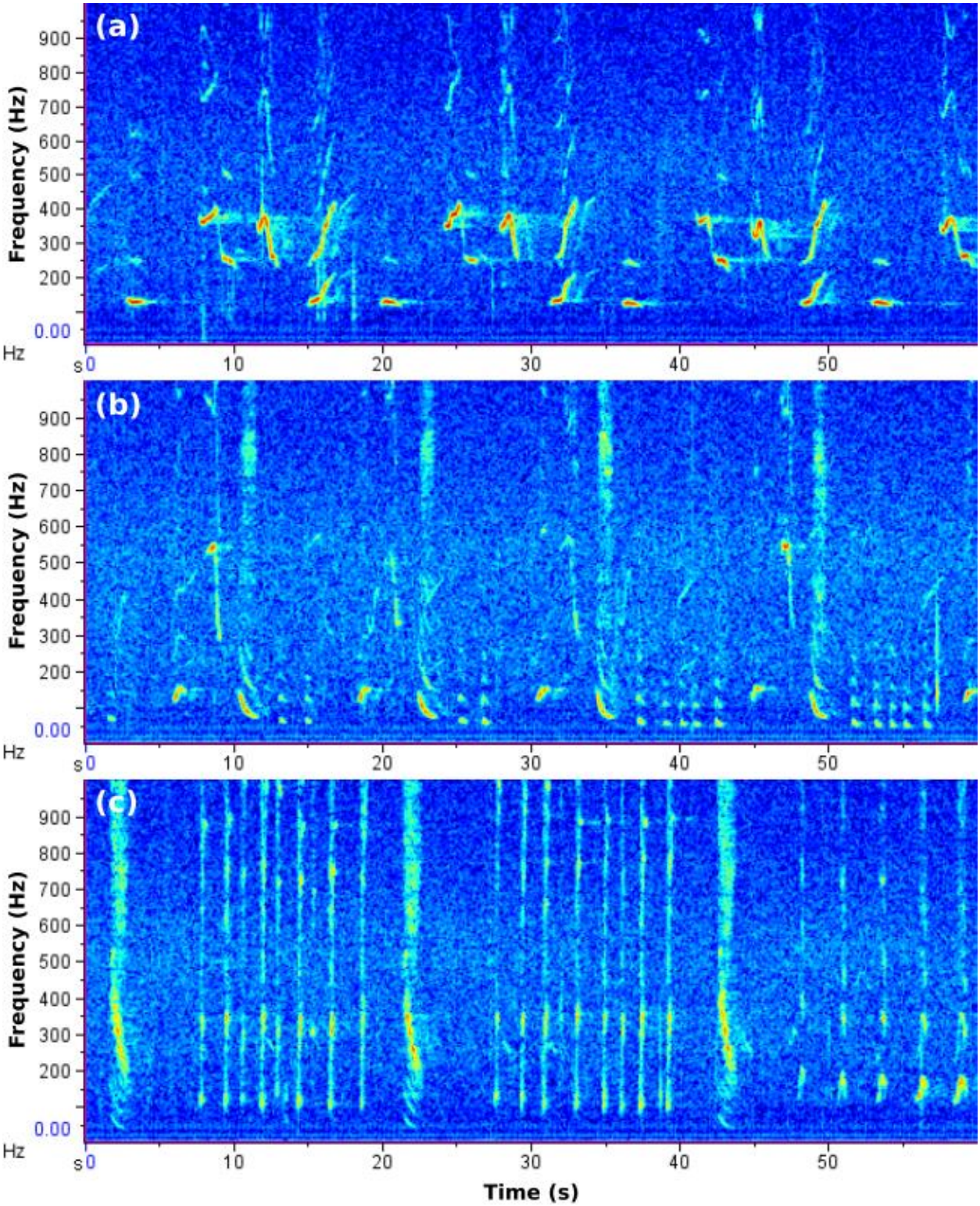


**Figure 11.** Example spectrograms of three different song themes recorded on 14 Apr 2017.

## Other Sounds

During the analysis for humpback whale song, we opportunistically observed pulse trains produced by minke whales (*Balaenoptera acutorostrata*). We did not analyze the full dataset for minke whale calls, but noted that pulse trains were frequently present at this site at least through January and February 2017. We observed two different types of minke whale pulse trains: speed-up trains in which the inter-pulse-interval decreases across the duration of the pulse train (Fig. 12), and constant trains with no clear change in inter-pulse-interval (Fig. 13).

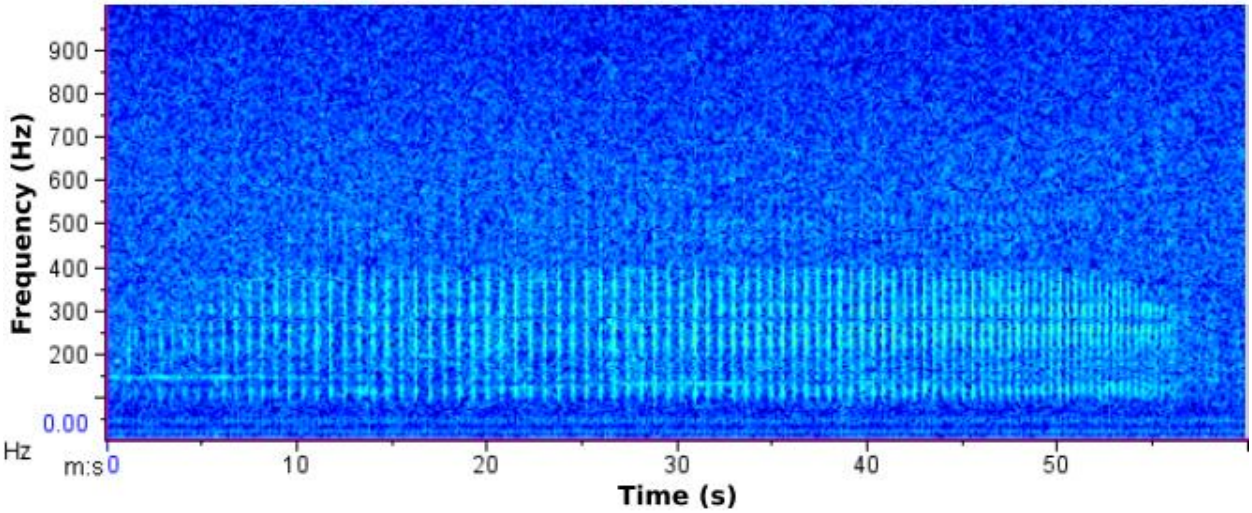


**Figure 12.** Example spectrogram of a minke whale pulse train with increasing inter-pulse-interval, recorded at Martinique on 22 Jan 2017.

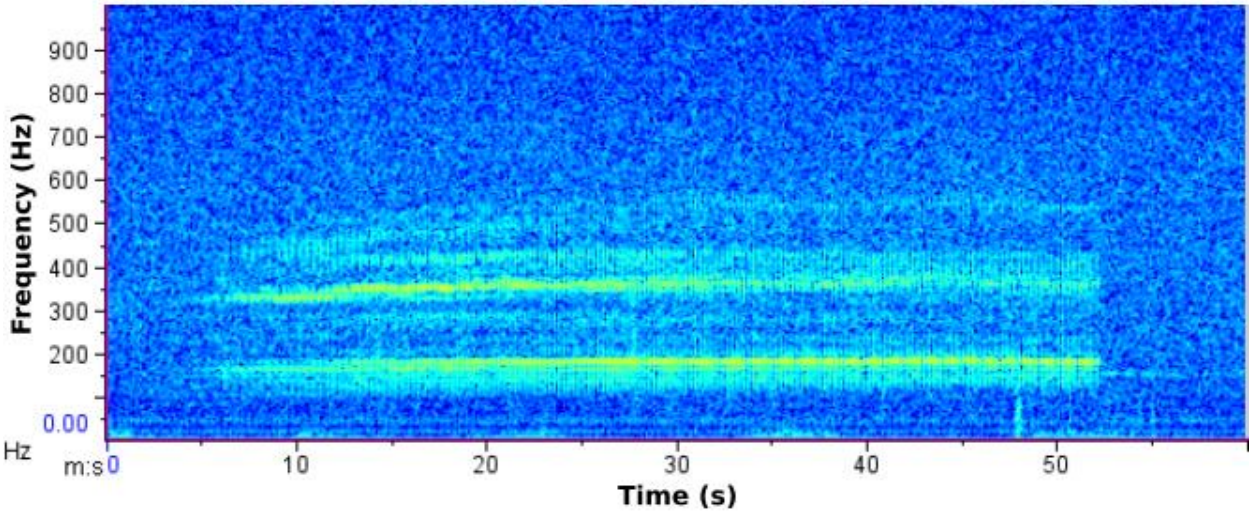


**Figure 13.** Example spectrogram of a minke whale pulse train with constant inter-pulse-interval, recorded at Martinique on 23 Jan 2017.

# Saint Martin

## Study Site & Data Collection

In Saint Martin, our study site was located northeast of the main island, along the eastern side of the small, uninhabited Île Tintamarre. We deployed a SoundTrap recorder at a depth of 16 m, representing the shallowest recording site in the study. This deployment occurred on 21 January 2017, several weeks later than planned due to unfavorable weather conditions in December. The SoundTrap was recovered on 6 June 2017. Using a recording schedule of 1 h/ 4 h, the SoundTrap collected 810 hour-long files across a recording period of 137 full days.

## Humpback Song Presence

Humpback whale song was present on 123 (90%) of the 137 (duty-cycled) recording days. Song was recorded throughout the deployment period including the first and last recording days (see Fig. 2). It is therefore likely that the deployment period of this recorder did not fully capture the seasonal occurrence of humpback whales at this site. Song was present sporadically in June, which was the latest occurrence of song recorded anywhere in the study. It is important to note that this was the only site at which we relied solely on duty-cycled SoundTrap data to characterize humpback song presence.

## Other Analyses

Possible dolphin sounds were noted once in the SoundTrap recordings on 30 April 2017. These chirp-like sounds appeared at frequencies of 1-3 kHz, and were present in the recordings for a few minutes (Fig. 14).

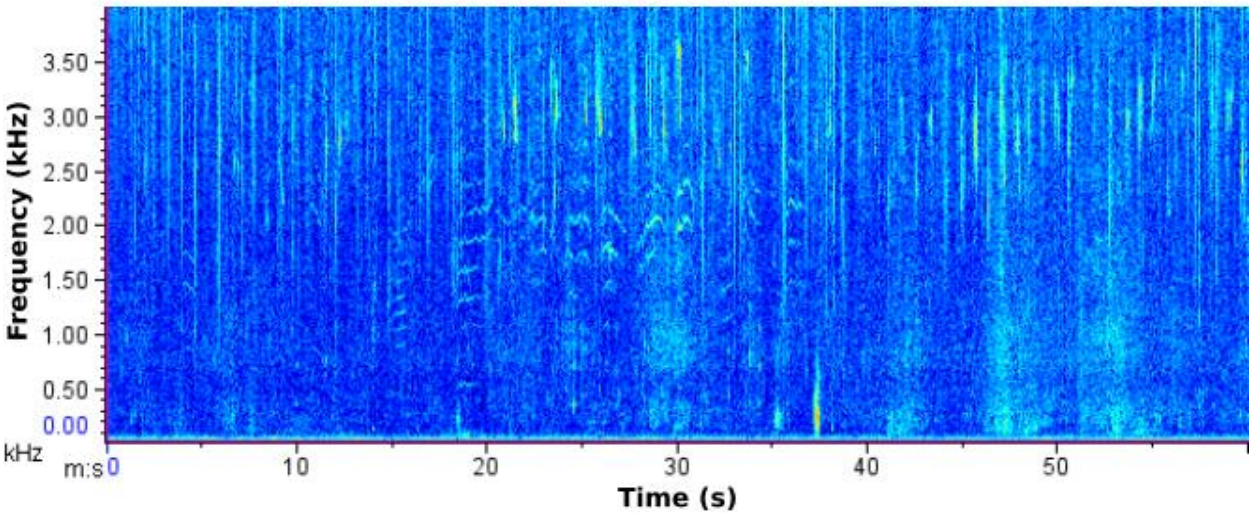


**Figure 14.** Spectrogram of possible dolphin sounds recorded at St. Martin on 30 April 2017.

# Sea Education Association Voyage

## Data Collection

In addition to the long-term passive acoustic monitoring described earlier in this report, we collected opportunistic passive acoustic recordings from the *SSV Corwith Cramer* in February and March 2017 during the Sea Education Association's "Colonization to Conservation in the Caribbean" program. We collected passive acoustic recordings at 14 different sites between 16 February 2017 and 5 March 2017 (Fig. 15, Table 2). This recording effort typically occurred during morning science stations using either an HTI-96-Min hydrophone connected to a TASCAM Recorder or a SoundTrap. Recordings were made at a sampling rate of 48 kHz with each recording period lasting approximately 30 minutes. In addition, we collected 7.5 hours of continuous recordings on Silver Bank using the TASCAM recorder and hydrophone, and 2 days of continuous recordings in Samana Bay using the SoundTrap.

## Humpback Song Presence

We recorded humpback whales at 11 of the 14 sampling stations: Saba Bank, Saba Offshore, Montserrat Offshore, St. Croix Offshore, Puerto Rico Offshore, Mona Passage, Samana Bay, Whale Hole, South of Silver Bank, Silver Bank, and Hispaniola Offshore (Fig. 15, Table 2). Humpback whales were also visually observed at three sites during this trip: Mona Passage, Silver Bank, and Hispaniola Offshore (Fig. 15, Table 2). Multiple whales could be heard singing at each of these sites.

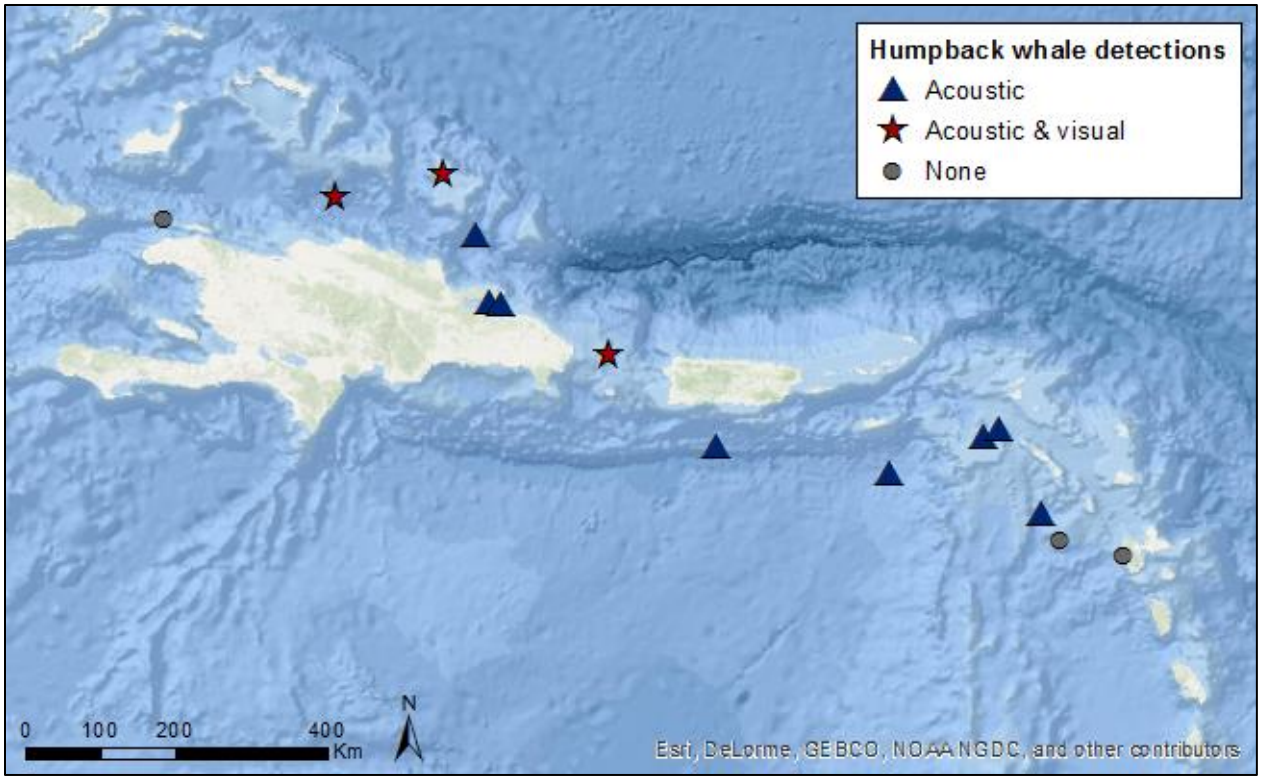


**Figure 17.** Map of recording stations during the 2017 Sea Education Association voyage in the Caribbean on the *SSV Corwith Cramer*. Blue triangles indicate stations where humpback whales were acoustically detected, red stars indicate stations where whales were both acoustically detected and visually sighted, and gray circles indicate stations where whales were neither heard nor seen.

**Table 2.** Locations of passive acoustic recording stations during the 2017 Sea Education Association voyage on the *SSV Corwith Cramer*.

| Area | Recording Location | Date | Humpback Whale Detections |
|---|---|---|---|
| Saba Bank | 17° 34.663 N<br>63° 27.387 W | 16 Feb 2017 | Acoustic |
| Saba Offshore | 17° 40.169 N<br>63° 17.670 W | 17 Feb 2017 | Acoustic |
| Montserrat Offshore | 16° 20.848 N<br>62° 32.747 W | 18 Feb 2017 | None |
| Pigeon Island | 16° 09.506 N<br>61° 47.970 W | 22 Feb 2017 | None |
| Montserrat Offshore | 16° 40.541 N<br>62° 46.395 W | 23 Feb 2017 | Acoustic |
| St. Croix Offshore | 17° 09.400 N<br>64° 34.800 W | 24 Feb 2017 | Acoustic |
| Puerto Rico Offshore | 17° 27.683 N<br>66° 38.311 W | 25 Feb 2017 | Acoustic |
| Mona Passage | 18° 34.700 N<br>67° 54.792 W | 26 Feb 2017 | Acoustic & Visual |
| Samana Bay | 19° 11.600 N<br>69° 19.900 W | 27 Feb 2017 | Acoustic |
| Whale Hole | 19° 09.400 N<br>69° 12.700 W | 01 Mar 2017 | Acoustic |
| South of Silver Bank | 19° 59.300 N<br>69° 30.100 W | 02 Mar 2017 | Acoustic |
| Silver Bank | 20° 43.700 N<br>69° 52.800 W | 03 Mar 2017 | Acoustic & Visual |
| Hispaniola Offshore | 20° 26.600 N<br>71° 09.900 W | 04 Mar 2017 | Acoustic & Visual |
| Hispaniola Offshore | 20° 10.000 N<br>73° 11.900 W | 05 Mar 2017 | None |

# Research Partners

## Aruba

Angiolina Henriquez (Aruba Marine Mammal Foundation), Luciano Mazzeo, Castro Perez

## Bonaire

Wijnand de Wolf, Kernza Rannou, and Sabine Engel (Bonaire National Marine Park)

Paul Hoetjes (National Office for the Caribbean Netherlands)

## Dominican Republic

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Jeremy Kiszka (Florida International University)

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(Natural Reserve of St. Martin)

## Sea Education Association

Jeff Schell and Paul Joyce

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