# Humpback whale song occurrence in Ecological Acoustic Recorder (EAR) data from Pagan and Maug (Northern Mariana Islands), 2009-2010

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## Abstract

Since 2007, visual and acoustic cetacean monitoring efforts in the Mariana Islands have documented the occurrence of humpback whales (*Megaptera novaeangliae*) during winter months. However, these efforts have focused mainly around the southern portion of the archipelago, in particular Saipan and Tinian. This report presents an analysis of passive acoustic data for humpback whale song near the islands of Maug and Pagan in the northern portion of the archipelago.

Data were recorded using Ecological Acoustic Recorders (EARs) from April 2009 through February 2010 (Pagan) or October 2010 (Maug). EARs sampled for 30 seconds at 15-minute intervals with an effective recording bandwidth of 0-20 kHz. Analysts visually browsed spectrograms from the entire Pagan dataset and from the winter months (Nov-May) at Maug. Potential humpback whale detections were reviewed aurally and visually by experienced researchers. Humpback whale song was detected at Pagan on 8 days in February 2010, prior to the cessation of recording in late February.

No humpback whale song was detected in any recordings from Maug. The lack of detections at Maug was likely due to the location of the EAR inside the perimeter of the Maug islands, which acoustically shielded it from the open ocean. The occurrence of humpback whales at Pagan in February is consistent with the timing of occurrence at other islands in the Mariana archipelago; future monitoring effort for humpback whales (and other migratory baleen whales) should consider placement of instruments, duty cycle, and seasonality of recording in order to maximize the likelihood of detection.

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Since 2007, visual and acoustic cetacean monitoring efforts in the Mariana Islands have documented the occurrence of humpback whales (Megaptera novaeangliae) during winter months. However, these efforts have focused mainly around the southern portion of the archipelago, in particular Saipan and Tinian. This report presents an analysis of passive acoustic data for humpback whale song near the islands of Maug and Pagan in the northern portion of the archipelago.

Data were recorded using Ecological Acoustic Recorders (EARs) from April 2009 through February 2010 (Pagan) or October 2010 (Maug). EARs sampled for 30 seconds at 15-minute intervals with an effective recording bandwidth of 0-20 kHz. Analysts visually browsed spectrograms from the entire Pagan dataset and from the winter months (Nov-May) at Maug. Potential humpback whale detections were reviewed aurally and visually by experienced researchers. Humpback whale song was detected at Pagan on 8 days in February 2010, prior to the cessation of recording in late February.

No humpback whale song was detected in any recordings from Maug. The lack of detections at Maug was likely due to the location of the EAR inside the perimeter of the Maug islands, which acoustically shielded it from the open ocean. The occurrence of humpback whales at Pagan in February is consistent with the timing of occurrence at other islands in the Mariana archipelago; future monitoring effort for humpback whales (and other migratory baleen whales) should consider placement of instruments, duty cycle, and seasonality of recording in order to maximize the likelihood of detection.

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## Introduction

Humpback whales (*Megaptera novaeangliae*) are known to occur seasonally throughout portions of the tropical western North Pacific, with some areas representing possible wintering/breeding grounds for animals identified on summer foraging grounds in the Bering Sea and Gulf of Alaska. The winter occurrence of humpback whales (*Megaptera novaeangliae*) in some areas of the Commonwealth of the Northern Mariana Islands (CNMI) has been documented through visual observation as well as passive acoustic monitoring (PAM). The first systematic survey effort in recent years was the Mariana Islands Sea Turtle and Cetacean Survey (MISTCS), a vessel-based survey conducted in 2007, during which humpback whales were detected acoustically and visually in February, with most detections near the island of Saipan (DoN 2007; Fulling et al. 2011, Norris et al. 2012). Since 2010, cetacean survey effort and long-term PAM have been routinely conducted in the CNMI primarily by the National Oceanic and Atmospheric Administration (NOAA) Pacific Islands Fisheries Science Center (PIFSC) in partnership with the U.S. Navy, and other collaborators/partners. Efforts include ongoing annual shore-based observation, small-boat surveys, and long-term PAM deployments.

Humpback whale survey and PAM effort to date have been concentrated mainly around the islands of Saipan, Tinian, and Rota, in the southern portion of the archipelago (Figure 1); most sightings and acoustic detections have been reported off Saipan. Although no humpback whales were documented during PIFSC/Navy vessel surveys in the CNMI in 2010-2011 (Oleson and Hill 2010), acoustic detections of humpback whales off Saipan have been reported during December – April for every year of PAM data collection with recording during those months (Munger et al. 2015, Oleson et al. 2015, Hill et al. 2019). Humpback whales were also detected less frequently in recordings off Tinian in 2010-2013 (Oleson et al. 2015). Shore-based and small-boat efforts have been conducted each year since 2015 primarily around Saipan, but also in waters around Guam, Tinian and Rota; humpback whales have been visually detected during these efforts in February and April, with all detections taking place off Saipan (Hill et al. 2019).

Effort in the northern portion of the Mariana archipelago to date has been more limited. A moored high-frequency acoustic recording package (HARP) has been maintained by the NOAA PIFSC Cetacean Research Program off Pagan Island since 2015; data analyses are underway (Hill et al. 2019). This report presents the results of an analysis for humpback whale occurrence in archival passive acoustic monitoring data obtained using Ecological Acoustic Recorders (EARs) deployed off the islands of Maug and Pagan in the northern portion of the CNMI by the PIFSC Coral Reef Ecosystem Division from 2009 to 2010. This analysis and report were prepared by Oceanwide Science Institute (OSI).

## Methods

Acoustic data were recorded using bottom-mounted Ecological Acoustic Recorders (EARs) deployed at depths between 10-20 m from 2009-2010 off the islands of Maug and Pagan (Figures 1-2). The EARs sampled at 40 kHz for an effective bandwidth of 20 kHz, and recorded data for 30 s "on" at 15 m intervals (3.3% duty cycle) (Table 1). The Maug EAR recorded from 04/29/2009 - 10/17/2010, and the Pagan EAR recorded from 04/23/2009 - 02/23/2010. Data were searched manually by analysts who visually scanned spectrograms of each individual 30-s

recording using the Matlab program *Triton* (Wiggins et al. 2003). The search effort focused on winter months (January to March) when humpback whales were most likely to be detected, as well as adjacent months in late autumn and early spring when data were available. Two recording periods were analyzed from the Maug EAR: late April 2009 - May 2009, and November 2009 - May 2010 (Table 1). The entire Pagan dataset was analyzed, i.e. from late April 2009 through late February 2010 (Table 1). Potential humpback whale detections were logged by the analyst and reviewed by two additional experienced researchers (ML and LM).

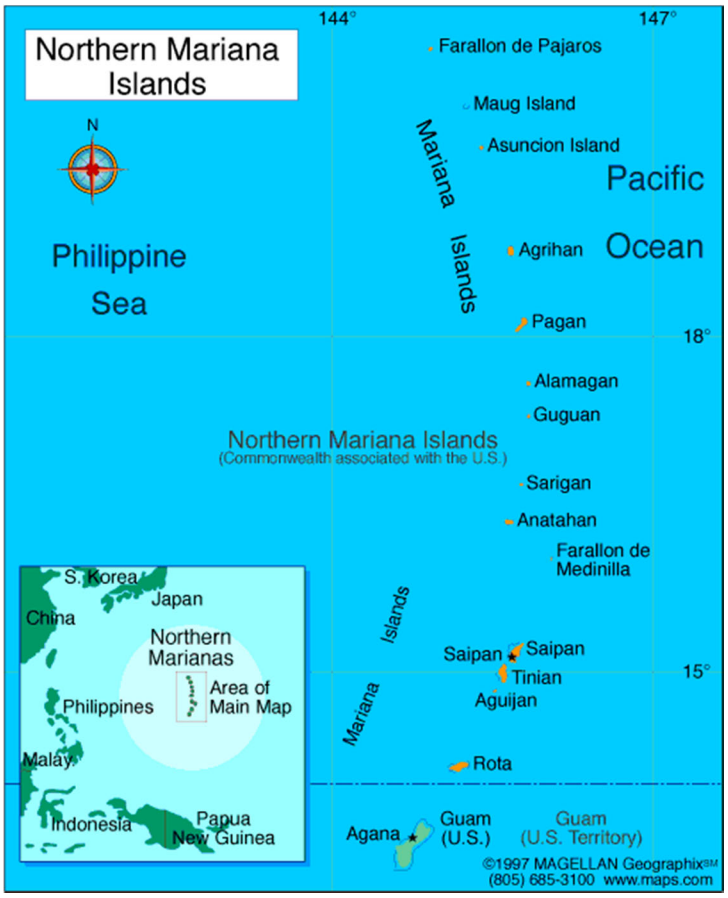


Figure 1. Location of the study area.


Figure 2. Satellite images of Maug (top) and Pagan (bottom) showing the deployment locations of the EARs (yellow pins).

Table 1. EAR deployment locations and recording parameters.

| Sample rate<br>Duration<br>Interval | Recording dates | Location | Latitude (°N) | Longitude (°E) | Depth (m) | Analyst Search Effort |
|---|---|---|---|---|---|---|
| 40 kHz<br>30 s on<br>900 s interval | 4/29/2009 – 10/17/2010 | Maug | 20.01395 | 145.22728 | 13.4 | 4/29/09 – 5/31/09<br>11/1/09 – 5/31/10 |
| 40 kHz<br>30 s on<br>900 s interval | 4/23/2009 – 02/23/2010 | Pagan | 18.12018 | 145.75465 | 17.4 | 4/23/09 – 2/23/10 |

**Results**

No evidence of humpback whale singing was detected at Maug in the months searched (late April-May 2009 and November 2009 through May 2010).

At Pagan, humpback whale song was detected with high confidence on 8 days in February 2010 (35% of days with recording effort that month), but not in any other months (Figure 3). Humpback whale song was detected at Pagan from February 9 through February 21, 2010, with the greatest detection rates noted on Feb 11-12 in approximately 30% of recordings each day (a "recording" being one 30 s sound file) (Figure 4). For the entire analysis period, a total of 123 recordings with humpback song were documented. Humpback song was detected during all hours of the day, with slightly greater numbers of detections during evening and pre-dawn hours (Figure 5).

Most of the song observed was at relatively low signal to noise ratio (SNR) with few harmonics, indicating that the singer(s) were likely several kilometers away, but in a few recordings the singing was relatively strong (e.g., Figure 6). The results showing all confirmed detections for Pagan are presented in Table 2.

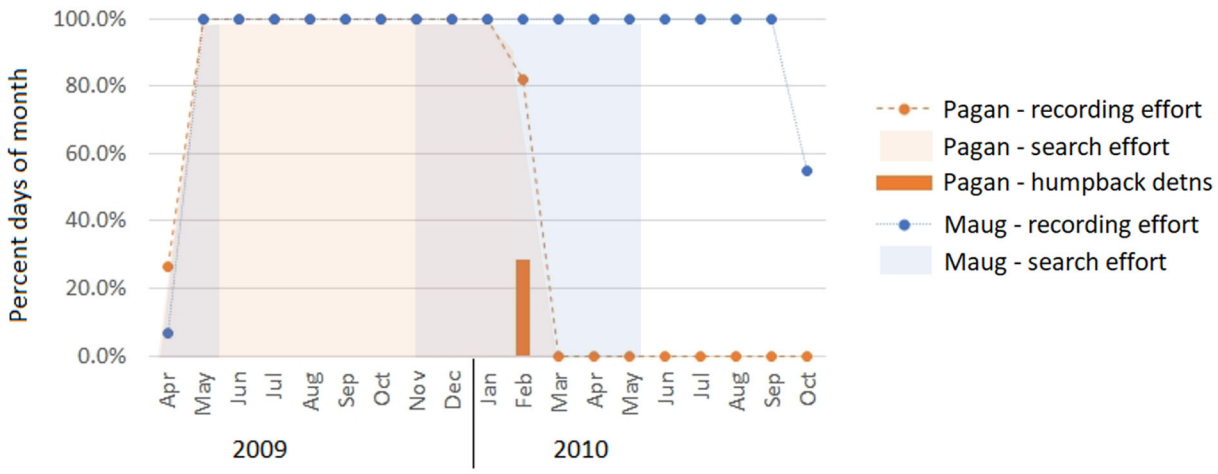


Figure 3. Timeline of recording effort (filled circles), analyst search effort (shaded areas), and humpback song detections (solid vertical bar), expressed as a percentage of days of each month. Pagan = orange markers and shading, Maug = blue markers and shading.

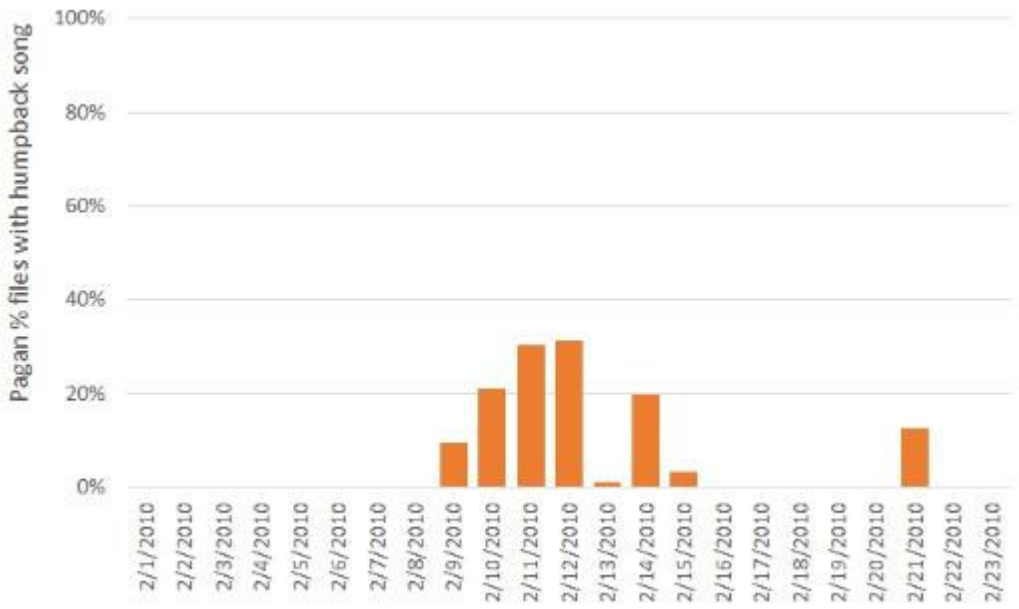


Figure 4. February 2010 detections of humpback whale song at Pagan, expressed as a percentage of 30-s recordings ("files") per day.

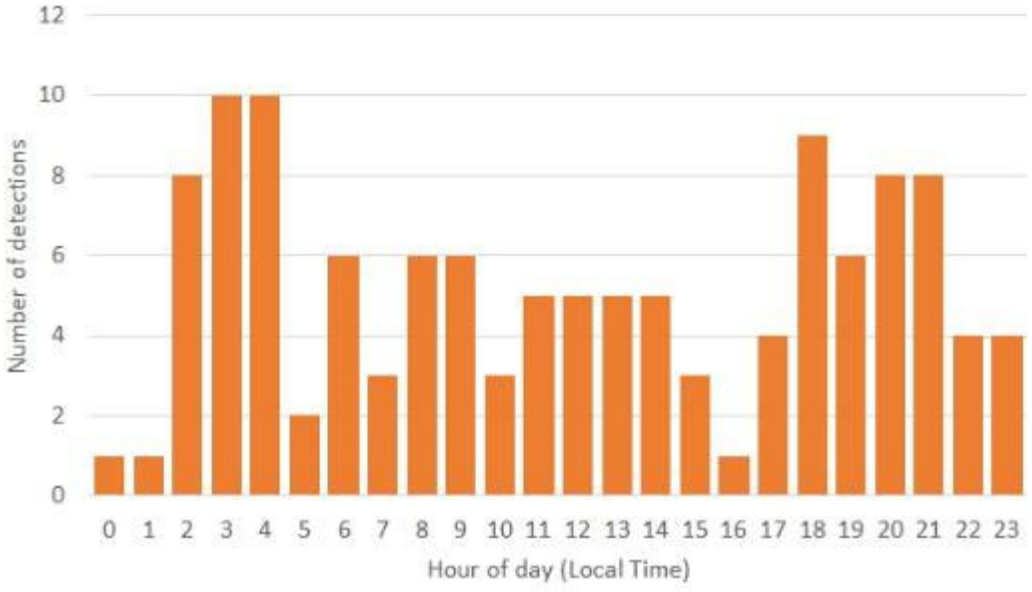


Figure 5. Humpback whale detections ("detection" = 30-s recording with song present) at Pagan by hour of day, local time.

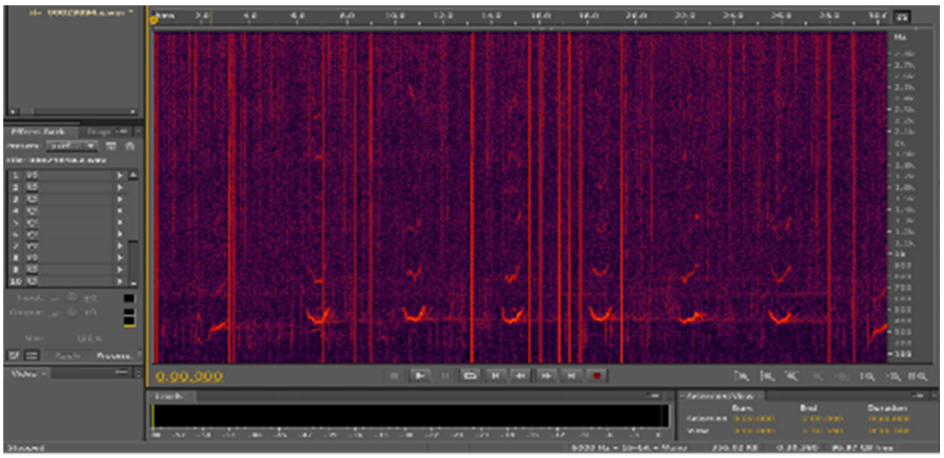

Figure 6. Spectrogram of file 00029894.e.wav recorded on 2/21/2010 at Pagan, showing evidence of humpback whale singing.

Table 2 – Log of humpback whale song detections at Pagan showing recording in which the detection was made, the date and the time in Coordinated Universal Time (UTC)

| Input file | Call type | Date | Time (UTC) |
|---|---|---|---|
| 00028704.e.wav | humpback | 02/09/10 | 1:42:22 PM |
| 00028705.e.wav | humpback | 02/09/10 | 1:57:25 PM |
| 00028706.e.wav | humpback | 02/09/10 | 2:12:32 PM |
| 00028714.e.wav | humpback | 02/09/10 | 4:12:41 PM |
| 00028716.e.wav | humpback | 02/09/10 | 4:42:22 PM |
| 00028717.e.wav | humpback | 02/09/10 | 4:57:25 PM |
| 00028718.e.wav | humpback | 02/09/10 | 5:12:26 PM |
| 00028719.e.wav | humpback | 02/09/10 | 5:27:24 PM |
| 00028720.e.wav | humpback | 02/09/10 | 5:42:34 PM |
| 00028753.e.wav | humpback | 02/10/10 | 1:57:44 AM |
| 00028755.e.wav | humpback | 02/10/10 | 2:27:26 AM |
| 00028756.e.wav | humpback | 02/10/10 | 2:42:31 AM |
| 00028757.e.wav | humpback | 02/10/10 | 2:57:32 AM |
| 00028780.e.wav | humpback | 02/10/10 | 8:42:40 AM |
| 00028781.e.wav | humpback | 02/10/10 | 8:57:25 AM |
| 00028785.e.wav | humpback | 02/10/10 | 9:42:20 AM |
| 00028787.e.wav | humpback | 02/10/10 | 10:12:38 AM |
| 00028789.e.wav | humpback | 02/10/10 | 10:42:23 AM |
| 00028791.e.wav | humpback | 02/10/10 | 11:12:26 AM |
| 00028792.e.wav | humpback | 02/10/10 | 11:27:48 AM |
| 00028818.e.wav | humpback | 02/10/10 | 5:57:36 PM |
| 00028819.e.wav | humpback | 02/10/10 | 6:12:35 PM |
| 00028820.e.wav | humpback | 02/10/10 | 6:27:22 PM |
| 00028821.e.wav | humpback | 02/10/10 | 6:42:39 PM |
| 00028822.e.wav | humpback | 02/10/10 | 6:57:39 PM |
| 00028838.e.wav | humpback | 02/10/10 | 10:57:43 PM |

| | | | |
|---|---|---|---|
| 00028840.e.wav | humpback | 02/10/10 | 11:27:27 PM |
| 00028841.e.wav | humpback | 02/10/10 | 11:42:26 PM |
| 00028842.e.wav | humpback | 02/10/10 | 11:57:28 PM |
| 00028843.e.wav | humpback | 02/11/10 | 12:12:23 AM |
| 00028861.e.wav | humpback | 02/11/10 | 4:42:41 AM |
| 00028864.e.wav | humpback | 02/11/10 | 5:27:37 AM |
| 00028865.e.wav | humpback | 02/11/10 | 5:42:18 AM |
| 00028870.e.wav | humpback | 02/11/10 | 6:57:37 AM |
| 00028871.e.wav | humpback | 02/11/10 | 7:12:47 AM |
| 00028873.e.wav | humpback | 02/11/10 | 7:42:21 AM |
| 00028874.e.wav | humpback | 02/11/10 | 7:57:24 AM |
| 00028876.e.wav | humpback | 02/11/10 | 8:27:19 AM |
| 00028877.e.wav | humpback | 02/11/10 | 8:42:17 AM |
| 00028884.e.wav | humpback | 02/11/10 | 10:27:31 AM |
| 00028885.e.wav | humpback | 02/11/10 | 10:42:25 AM |
| 00028886.e.wav | humpback | 02/11/10 | 10:57:26 AM |
| 00028888.e.wav | humpback | 02/11/10 | 11:27:30 AM |
| 00028889.e.wav | humpback | 02/11/10 | 11:42:36 AM |
| 00028892.e.wav | humpback | 02/11/10 | 12:27:22 PM |
| 00028896.e.wav | humpback | 02/11/10 | 1:27:20 PM |
| 00028906.e.wav | humpback | 02/11/10 | 3:57:22 PM |
| 00028908.e.wav | humpback | 02/11/10 | 4:27:23 PM |
| 00028910.e.wav | humpback | 02/11/10 | 4:57:34 PM |
| 00028911.e.wav | humpback | 02/11/10 | 5:12:24 PM |
| 00028912.e.wav | humpback | 02/11/10 | 5:27:21 PM |
| 00028917.e.wav | humpback | 02/11/10 | 6:42:33 PM |
| 00028926.e.wav | humpback | 02/11/10 | 8:42:46 PM |
| 00028927.e.wav | humpback | 02/11/10 | 8:57:44 PM |
| 00028929.e.wav | humpback | 02/11/10 | 9:27:43 PM |
| 00028930.e.wav | humpback | 02/11/10 | 9:42:27 PM |
| 00028932.e.wav | humpback | 02/11/10 | 10:12:31 PM |
| 00028933.e.wav | humpback | 02/11/10 | 10:27:38 PM |
| 00028943.e.wav | humpback | 02/12/10 | 12:42:18 AM |
| 00028945.e.wav | humpback | 02/12/10 | 1:12:32 AM |
| 00028946.e.wav | humpback | 02/12/10 | 1:27:30 AM |
| 00028947.e.wav | humpback | 02/12/10 | 1:42:26 AM |
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| 00028960.e.wav | humpback | 02/12/10 | 4:57:28 AM |
| 00028963.e.wav | humpback | 02/12/10 | 5:42:32 AM |
| 00028972.e.wav | humpback | 02/12/10 | 7:57:43 AM |
| 00028973.e.wav | humpback | 02/12/10 | 8:12:20 AM |
| 00028974.e.wav | humpback | 02/12/10 | 8:27:27 AM |
| 00028975.e.wav | humpback | 02/12/10 | 8:42:44 AM |
| 00028976.e.wav | humpback | 02/12/10 | 8:57:36 AM |
| 00028979.e.wav | humpback | 02/12/10 | 9:27:38 AM |

| | | | |
|---|---|---|---|
| 00028981.e.wav | humpback | 02/12/10 | 9:57:24 AM |
| 00028983.e.wav | humpback | 02/12/10 | 10:27:18 AM |
| 00028985.e.wav | humpback | 02/12/10 | 10:57:47 AM |
| 00028986.e.wav | humpback | 02/12/10 | 11:12:17 AM |
| 00028987.e.wav | humpback | 02/12/10 | 11:27:22 AM |
| 00028988.e.wav | humpback | 02/12/10 | 11:42:21 AM |
| 00028989.e.wav | humpback | 02/12/10 | 11:57:18 AM |
| 00028991.e.wav | humpback | 02/12/10 | 12:27:28 PM |
| 00028992.e.wav | humpback | 02/12/10 | 12:42:28 PM |
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| 00028994.e.wav | humpback | 02/12/10 | 1:12:18 PM |
| 00029134.e.wav | humpback | 02/13/10 | 11:27:46 PM |
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| 00029152.e.wav | humpback | 02/14/10 | 3:57:42 AM |
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| 00029226.e.wav | humpback | 02/14/10 | 10:27:29 PM |
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| 00029903.e.wav | humpback | 02/21/10 | 9:12:33 PM |

## Discussion

Clear evidence of humpback whale singing was found at Pagan. Most of the song observed was faint, suggesting that the singers were several kilometers away, but in a few recordings the singing was relatively strong and may indicate whales within a few kilometers. Song at Pagan was detected from February 9 through February 21, 2010; the data set ended two days later (23 Feb), so it cannot be concluded with certainty when singing ended for the season. However, no additional song was found in late April through May of the year before (2009), suggesting that the whale season may end between late February and the end of April, or whales may transition to another area outside of the Pagan detection range.

No humpback whale song was detected in recordings made by the Maug EAR; however, the location of the EAR inside of the Maug islands limited its acoustic exposure to offshore waters (see Figure 2), which may have greatly reduced the likelihood of detection. These EARs were originally deployed with the primary goal of recording shallow reef soundscapes and vessel traffic, not monitoring cetaceans, so placement inside the channel was deliberate. The 3.3% duty cycle of the EARs (i.e. for 30 seconds on every 15 minutes) may also have influenced the likelihood of detection, with the short recording duration and long interval most likely increasing the probability of missing distant singers and song fragments.

Future PAM for large cetaceans in the northern portion of the CNMI would be optimized by siting instruments for good acoustic propagation, e.g. at greater depths and on outer slopes of islands with more exposure to the open ocean, by deploying archival moorings close to the start of whale season (e.g. in autumn) to maximize battery life and hence data collection throughout an entire season, and by increasing the recording duration to at least a few minutes of continuous sampling to increase the probability of picking up song fragments or distant song. Placement of multiple recorders at several islands may provide more detailed information on the movements, habitat use, and relative abundance of humpback whales within the CNMI during the winter season.

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