

Apparent Low Densities of Small Cetaceans in Okinawa May Be Due to Uncontrolled Local Hunting¹

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Abstract: From October 2011 to May 2012, we conducted the first marine mammal surveys of Okinawan waters, using line-transect vessel surveys and passive acoustic monitoring (PAM). We obtained 913 km of visual survey effort, and 1,039 cumulative hours of PAM data from around the island. Only a single on-effort sighting was made (of two common bottlenose dolphins [*Tursiops truncatus*]) during visual surveys, and acoustic detection rates were generally low, with the exception of humpback whale (*Megaptera novaeangliae*) observations during their winter/spring breeding season. The apparent low density of at least some marine mammals observed in Okinawan waters may be due to the depletion of coastal populations. We believe this could result from many decades of heavy and largely-uncontrolled hunting of small cetaceans in waters around the island.

Keywords: dolphin, fisheries impacts, marine mammal, pilot whale, tropical Pacific, whale

THE MARINE MAMMAL FAUNA OF OKINAWA is known primarily from old whaling and dugong-hunting records, as well as strandings, captures, and sightings documented by staff of the Okinawa Churami Aquarium (and its predecessor, the Okinawa Expo Aquarium). Until research on marine mammals in Okinawa began in the mid-1970s, very little was known about cetaceans or sirenians in the area. Today, due mostly to directed research conducted by staff from the Okinawa Churami Aquarium, the situation is much improved. However, most of the work has been opportunistic, associated with whale-watching activities, dolphin and small whale fisheries, or live-capture operations for the aquarium. A review of both published

and unpublished information indicated that 26 species of mostly-tropical marine mammals (four mysticetes, 21 odontocetes, and one sirenian) are known to occur around the island of Okinawa, making it an area with high marine mammal diversity (Jefferson and Sekiguchi 2011). However, there have been virtually no systematic sighting surveys, and estimates of density and abundance for marine mammals in the region are lacking.

Hunting of marine mammals has a long history in Okinawa, with whaling (Nishiwaki 1960, 1962) and hunting of dugongs (*Dugong dugon*) dating back many centuries (Welch et al. 2010). Fishermen based in Nago also hunt small cetaceans, with the primary target species being the short-finned pilot whale (*Globicephala macrorhynchus*). Between 1960 and 1982, 2,753 pilot whales were recorded as being taken in this fishery, and smaller numbers of other species of delphinids were taken on occasion as well (e.g., killer whale *Orcinus orca*, false killer whale *Pseudorca crassidens*, pygmy killer whale *Feresa attenuata*, melon-headed whale *Peponocephala electra*, rough-toothed dolphin *Steno bredanensis*, pan-tropical spotted dolphin *Stenella attenuata*, Risso's dolphin *Grampus griseus*, and bottle-nose dolphins *Tursiops* spp.). In the early years,

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the hunting was done by driving schools into shore, but beginning in 1975, harpoon hunting with crossbows began, and soon after replaced the drive fishery (Kishihiro and Kasuya 1993). The last two drives occurred in 1982 and 1989, and the drive fishery is today illegal and considered “extinct” in Okinawa (Kishihiro and Kasuya 1993). The harpoon fishery, in which steel projectiles are fired from crossbows at the bow of the ship, is still active. Therefore, thousands of small cetaceans have been taken by the combined drive and harpoon fisheries of Okinawa since 1960 (Nishiwaki and Uchida 1977, Nishiwaki 1982, Uchida 1982, 1985, Kishihiro and Kasuya 1993, Kasuya 2009), and the impacts of these catches on local populations are unknown.

In 2011 and 2012, the United States Marine Corps (USMC) funded a marine mammal survey of Okinawan waters, mainly covering four “water space areas” adjacent to USMC and US Navy installations in coastal waters on the eastern and northwestern sides of the island (Figures 1 and 2). Survey tracklines were drawn up to provide relatively even coverage of each of these four areas of interest. This represents the first such marine mammal survey of the region using systematic line-transect and passive acoustic monitoring (PAM) methods.

MATERIALS AND METHODS

In October 2011, we conducted an 8-day small-vessel survey in the northwestern waters around Okinawa. A second 18-day survey was conducted in May 2012, covering both eastern and northwestern waters. Standard line-transect vessel searches were conducted from the *Blue Fin* (a 15-m local vessel used for sportfishing and diving trips), weather permitting (Beaufort Sea States [Beau] 0–5, no heavy rain, and visibility greater than 1 km). The observer team conducted searches and observations from the flying bridge area, about 4–5 m eye height above the water’s surface. Two observers made up the on-effort survey team. As the vessel transited the survey lines at a constant speed of 13–15 km/hr, the Primary Observer searched for marine mammals continuously through 7 × 35 marine binoculars. The other on-effort observer searched primarily with the naked eye,

to minimize the chance of missing groups on and near the trackline. A Data Recorder recorded data on a laptop computer in the pilothouse using specialized software (*VisSurvey* in 2011 and *Mysticetus* in 2012) and was not part of the searching team. On some days with poor weather, when we were unable to survey from the vessel (Beau 6 and above, or when the vessel transited from one side of the island to the other), we conducted shore-based surveys for marine mammals from one of several high vantage points on land. We also conducted an off-effort search in deep waters off the southeast part of the island on 25 May 2012 (Figure 2).

In addition to visual surveys, we also used passive acoustic monitoring to investigate the marine mammals of Okinawa (Figures 1 and 2). Three Ecological Acoustic Recorders (EARs—Lammers et al. 2008) were deployed initially in October 2011, recovered, refurbished and redeployed in February–March 2012, and finally recovered (without redeployment) in May 2012. The devices were deployed with acoustic releases so that a dive team was not required for retrieval (deployment depths ranged from 128 m to 455 m). A trip to refurbish the EARs was conducted in February 2012. The EARs were programmed to record with a sampling rate of 80 kHz and on a 10% duty cycle (30 sec every 300 sec). Dolphin whistles were analyzed using *Triton*, a MATLAB-based analysis tool developed at Scripps Institute of Oceanography (Wiggins 2003). Long-Term Spectral Averages (LTSA) were generated to look for periods when dolphins were present. Their whistles were categorized based on their frequency characteristics and echolocation signals were also noted. Additional classification analyses were conducted using the Real-time Odontocete Call Classification Algorithm (ROCCA) classifier (Oswald et al. 2007). Sounds from humpback whales (*Megaptera novaeangliae*), were analyzed using an automated baleen whale detector.

RESULTS

Overall, we completed 913 km of on-effort visual line-transect survey effort, and we surveyed the Camp Schwab, Kin Bay, and

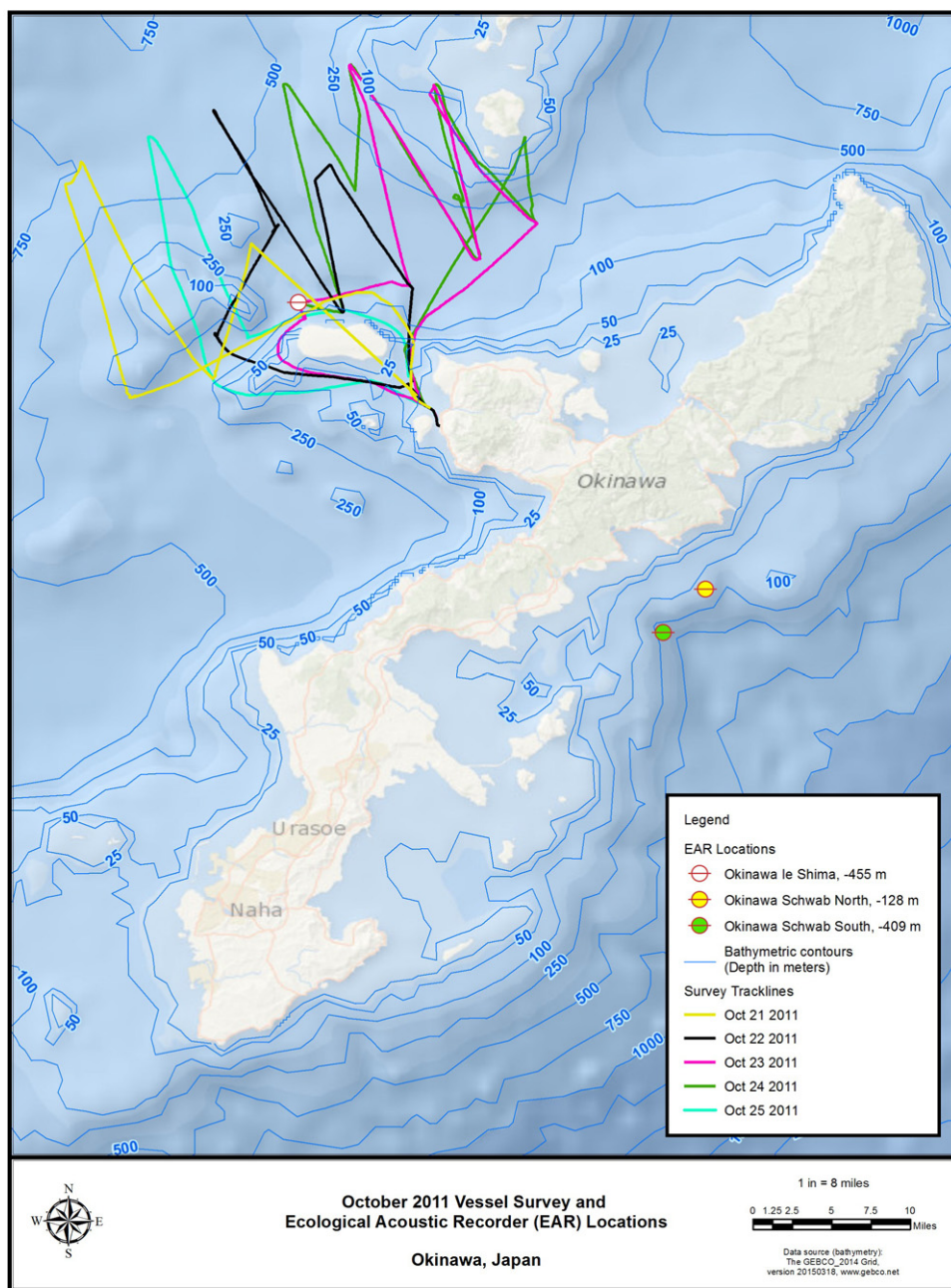


FIGURE 1. Study area showing the visual survey transect lines completed, and EAR locations, October 2011.

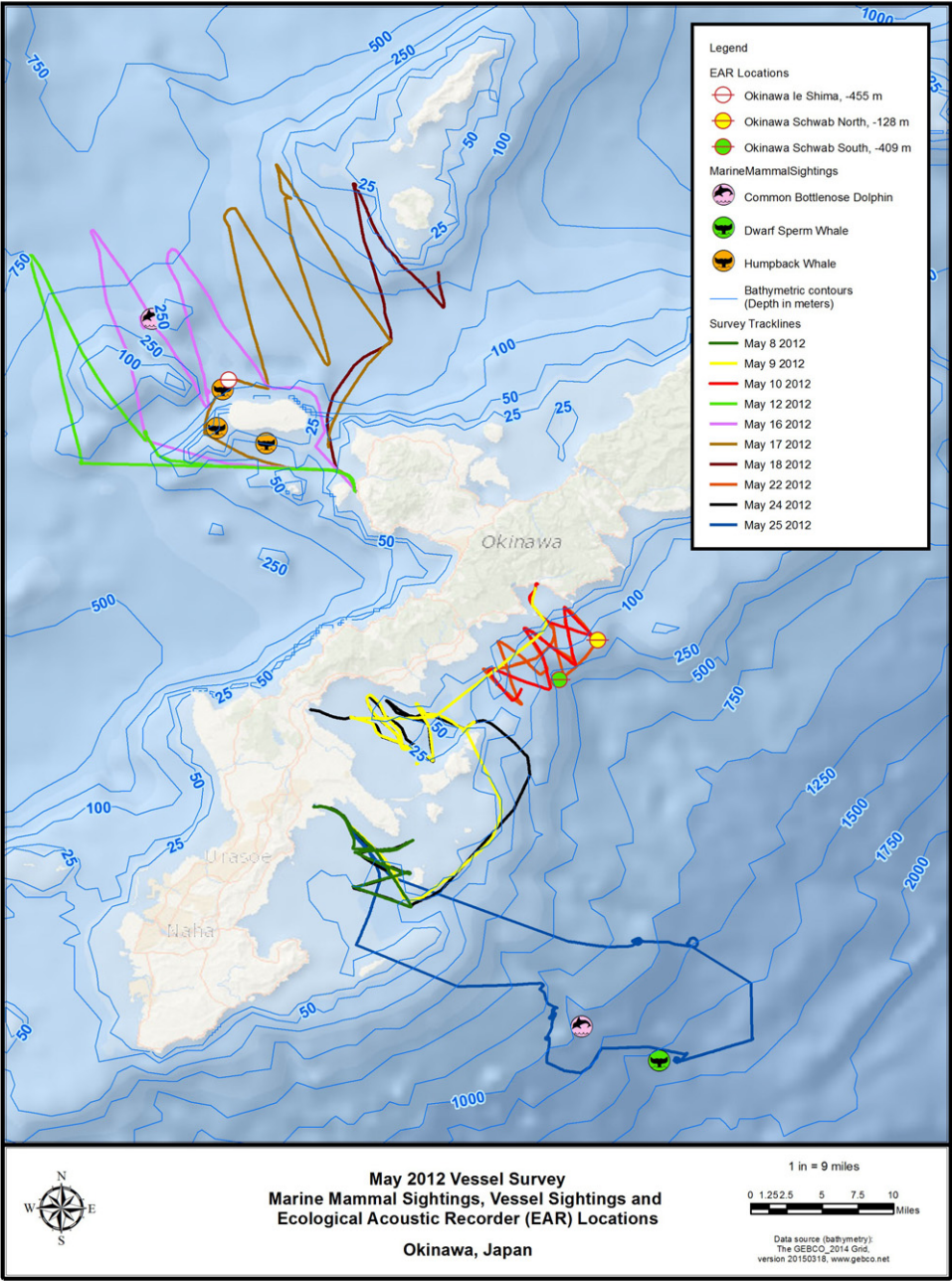


FIGURE 2. Study area showing the transect lines completed, EAR locations, and locations of marine mammal sightings, May 2012. The humpback whale sightings occurred in February 2012.

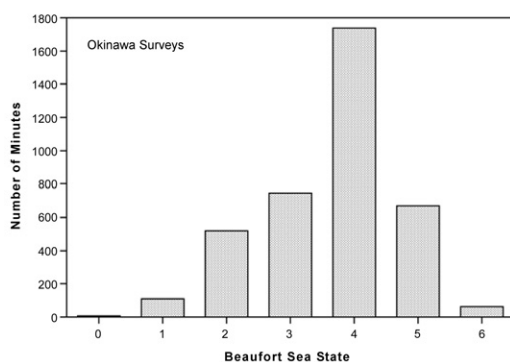


FIGURE 3. Distribution of line-transect vessel survey effort by Beaufort Sea State categories.

Tsukun survey areas twice each (no line-transect effort was conducted during EAR refurbishment trips). Ie Shima was surveyed a total of three times (see Figure 1). Most line-transect effort was conducted during moderate to poor conditions of Beau 3–6 (84%), but a smaller amount was conducted in good conditions of Beau 0–2 (16%) (Figure 3). In total (including opportunistic sightings made on the EAR refurbishment trip), we had six marine mammal sightings—three groups of humpback whales, two groups of common bottlenose dolphins, and one group of dwarf sperm whales *Kogia sima* (Figures 1 and 2; Table 1). However, only one of these was an on-effort sighting (a group of two common bottlenose dolphins).

The Ie Shima EAR malfunctioned during the first deployment, and therefore only data from the second deployment were available for analysis. Acoustic data from both Camp Schwab deployments and the second Ie Shima deployment were analyzed for various species (Figure 4).

The EARs recorded 1,039 cumulative hours of data across the five deployments containing data, spread over a range of 207 days from October 2011 to May 2012 (Table 2). Odontocete whistles and echolocation signals were observed on all datasets (Table 3) and throughout the deployment period. Overall, detection rates were low. The spring period did have significantly more acoustic activity at both of the Schwab sites (comparison at Ie Shima was not available due to the EAR malfunction). The majority of the detections (approximately 77%) were between 1800 and 0600 hours (local time) at all sites, suggesting that there is a diel pattern of occurrence, consistent with nighttime foraging behavior (Benoit-Bird and Au 2003). However, it is also possible that there is animal movement toward the EARs at night.

For odontocete whistles categorized by frequency bin, low-frequency (LF < 10 kHz) are generally the larger delphinids including the “blackfish” (pilot whales, false killer whales, pygmy killer whales, killer whales, and melon-headed whales). The high-frequency whistlers (HF > 10 kHz) are generally

TABLE 1
Summary of Marine Mammal Sightings Made During Okinawa Surveys

Date	Time	Species	Grp Sz.	PSD	Position	Effort	Photos	Notes
29 February 2012	A.M.	<i>Megaptera novaeangliae</i>	5	n/d	26° 42' 32" N, 127° 44' 17" E	Off	Yes	While refurbishing EAR
29 February 2012	A.M.	<i>Megaptera novaeangliae</i>	2	n/d	26° 44' 54" N, 127° 44' 38" E	Off	Yes	While refurbishing EAR
29 February 2012	A.M.	<i>Megaptera novaeangliae</i>	2	n/d	26° 41' 36" N, 127° 47' 17" E	Off	Yes	While refurbishing EAR, cow/calf
16 May 2012	1029	<i>Tursiops truncatus</i>	2	0.13 km	26° 49' 12" N, 127° 40' 20" E	On	No	Brief sighting
25 May 2012	1244	<i>Kogia sima</i>	18	0 km	26° 03' 58" N, 128° 11' 13" E	Off	Yes	Very large group
25 May 2012	1456	<i>Tursiops truncatus</i>	120	3.33 km	26° 06' 03" N, 128° 06' 29" E	Off	Yes	Acoustic recordings obtained

PSD = Perpendicular Sighting Distance.

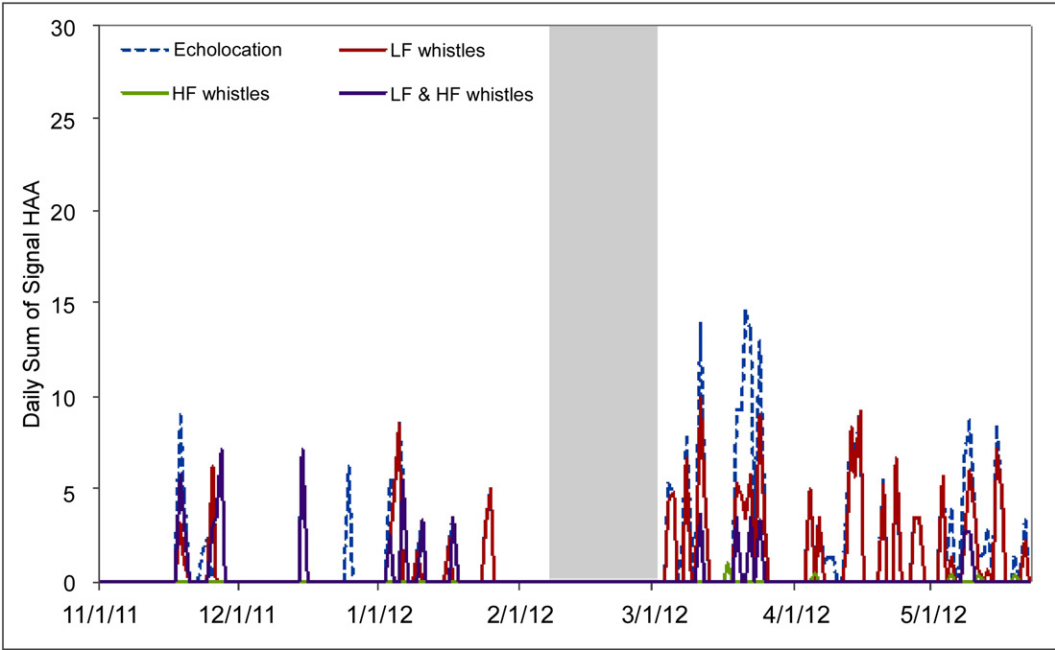


FIGURE 4. Compiled plot of acoustic detections on the EAR deployed at Schwab North between 1 November 2011 and 22 May 2012. Lines of different color represent sound category. The gray area represents the time when an EAR was not deployed and recording.

TABLE 2
Deployment Sites for EARs

Site	Recording Period	Latitude	Longitude	Depth
Ie Shima	23 October 2011–17 May 2012	26° 45.480' N	127° 45.011' E	455 m
Schwab North	1 November 2011–22 May 2012	26° 29.611' N	128° 07.464' E	128 m
Schwab South	1 November 2011–22 May 2012	26° 27.224' N	128° 05.130' E	409 m

TABLE 3
Detection Summary for All EAR Deployments

Site	Signal Type Detections				Total Encounters
	HF	LF	HF&LF	Echolocation Only	
Ie Shima – 1st	NA	NA	NA	NA	NA
Schwab North – 1st	0	16	10	4	15
Schwab South – 1st	31	20	16	9	43
Ie Shima – 2nd	3	37	0	83	79
Schwab North – 2nd	6	73	6	50	72
Schwab – 2nd	10	108	8	53	73

HF = high frequency (>10 kHz) whistles; LF = low frequency (<10 kHz) whistles.

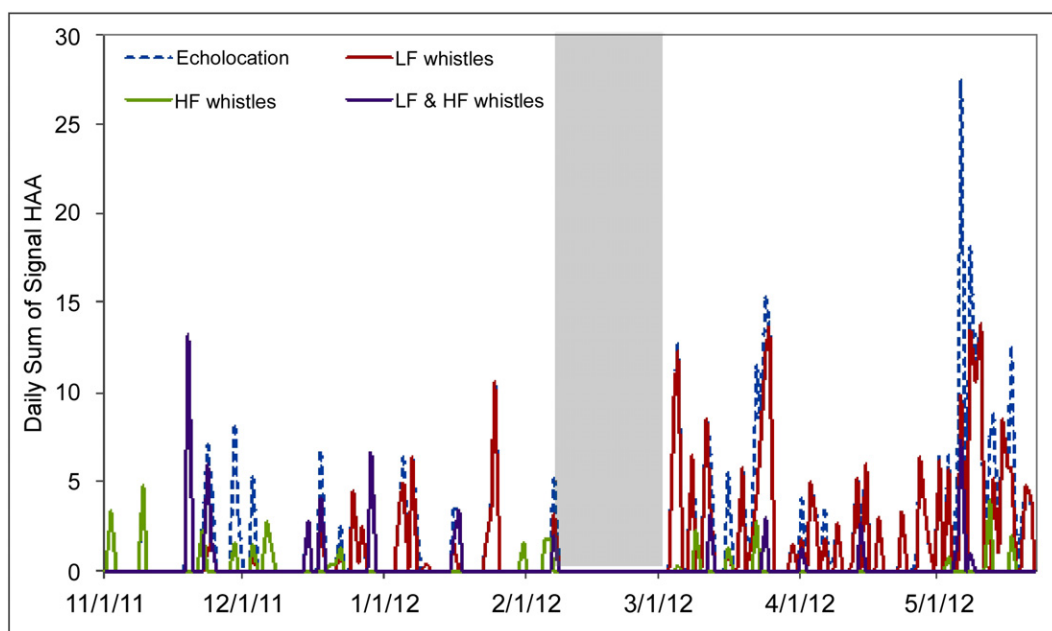


FIGURE 5. Compiled plot of acoustic detections on the EAR deployed at Schwab South between 1 November 2011 and 22 May 2012. Lines of different color represent signal detection type. The gray area represents the time that the EAR was not recording.

smaller dolphins, primarily those in the genus *Stenella*, that occur in the North Pacific. The two bottlenose dolphin species, as well as rough-toothed dolphins produce whistles that can be HF, LF, or both. The ROCCA results did not identify the presence of species other than those caught when the fisheries were active. The detection of more LF whistles may be indicative of short-finned pilot whales occurring relatively close to shore more regularly than the visual surveys would suggest (Figures 4–6).

Humpback whales were detected at all three deployment sites, and not surprisingly, only during winter through spring. There were only 29 days with detections at the Schwab North site and 12 at the Schwab South site. For the Schwab sites, the earliest detection was 2 November 2011, shortly after the EARS were deployed and humpback signals were observed as late as 22 May 2012. Due to the EAR malfunction at the Ie Shima site, we were not able to determine when the humpback whales were first observed, however they were

detected daily from 2 March 2012 (date of deployment) through mid-April 2012. The detections on the east side of Okinawa were very spread out spatially and may signify that animals do not consistently remain in the area and are perhaps in transit. However, the near-steady presence at Ie Shima indicates that it is an important habitat for the whales, presumably for breeding (see Kobayashi et al. 2016).

DISCUSSION

The current study provides some useful information on the status of marine mammal populations in Okinawa, something which has remained poorly known. We were not able to develop line-transect estimates of abundance or density, due to the fact that there was only a single on-effort sighting. Although 84% of the survey effort was undertaken during poor sighting conditions of Beau 3 or above, we did have a significant amount of data collected during fair to good conditions (16% in Beau 0–2), and overall sightings were still very rare.

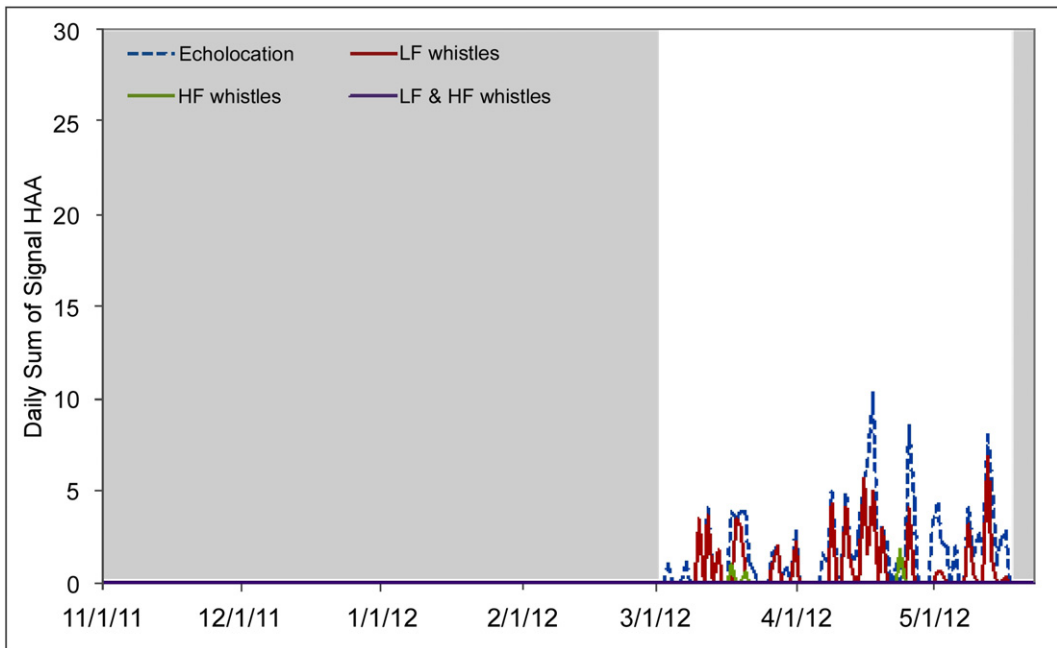


FIGURE 6. Compiled plot of acoustic detections on the EAR deployed at Ie Shima between 23 October 2011 and 17 May 2012. Lines of different color represent signal detection type. The gray area represents the period without an operational EAR.

Detection rates from the PAM devices were also relatively low. The daily detection rates for each EAR ranged from 0.15 (first deployment at Schwab North) to 1.04 (Ie Shima) with a mean rate for all deployments of 0.69 detections per day. Compared to other PAM deployments elsewhere in the tropical Pacific, this detection rate is much lower. EARs were also deployed at three different sites around the Mariana Islands (Guam, Saipan, and Tinian) during a similar time span (September 2011 to September 2012) and the detection rates ranged from 0.67 to 4.61, with a mean for all three sites of 2.98 detections/day (Lammers et al. 2015). These are the most comparable to data recorded around Okinawa, as the PAM devices, specifications, and recording parameters were identical (EARs sampling at 80 kHz 10% duty cycle). However, the deployment depths for the Mariana Islands' EARs ranged from 778 m to 952 m and could result in higher detection rates, increased detection ranges, and/or greater species diversity including deep diving cetaceans.

Our surveys, while limited to certain portions of the island, did include a variety of habitats, from nearshore, shallow waters to more offshore, deep waters. The east coast survey areas were almost exclusively inshore of the shelf break, but the Ie Shima survey area off the west coast contained a significant amount of deep water beyond the shelf break. Similarly, our visual surveys only covered two seasons, autumn and spring, though most small cetacean species around this tropical island would be expected to occur there year-round. Despite the limitations of our surveys listed above, the low detection rates from both visual survey and passive acoustic monitoring data imply low densities for most cetacean species during the survey periods (humpback whales in winter and spring appear to be the lone exception) (Kobayashi et al. 2016).

The only species of marine mammal sighted during our on-effort surveys was a single group of bottlenose dolphins. It is difficult to do direct comparisons to other areas, due to a number of methodological and

geographic differences, but we can do an approximate comparison to Hawaiian waters, an area of known low density for most small cetaceans (Baird et al. 2013). After converting data to the common metric of sighting rate in conditions of Beau 3 or less in waters <500 m, we find similar sighting rates (0.0049 sightings/km for Hawai'i vs. 0.0068 sightings/km for Okinawa).

The apparent low density of cetaceans in the Okinawa survey area may seem surprising at first. However, when one considers the extensive hunting that has occurred in Okinawan waters over the past 50+ years, it becomes somewhat easier to understand. At least 6,210 small cetaceans of at least 10 species have been killed intentionally in Okinawa since 1960 using drive and crossbow fishery methods (Nishiwaki and Uchida 1977, Uchida 1985, Kishiro and Kasuya 1993, Kasuya 2017; see Jefferson et al. 2013 for a recent review). The vast majority of these have been short-finned pilot whales. Between the years of 1960 and 2009, at least 4,937 pilot whales were killed by Nago fishermen in the area around Okinawa, representing an average annual take of 101 whales (80% of the total reported take).

Assuming a maximum sustainable harvest of 4% and no mortality from other sources, this means that the affected pilot whale population(s) would have to number at least 2,525 individuals for the take to be sustainable. Work in other areas of the Pacific suggests that pilot whales near islands often have a high degree of residency—for instance around the island of Hawai'i (Shane and McSweeney 1990) and around Kaua'i and Ni'ihau (Baird 2016). If this was the case around Okinawa as well, then it seems possible that the population was depleted by the high levels of mortality caused by hunting, with additional contributions from local bycatch.

All of these kills have occurred with no known stock assessment research, and no known measures to ensure that they are sustainable. It appears to us that pilot whale (and possibly some other small cetacean) densities around the island may have been substantially reduced by this uncontrolled take. Our initial review of records (Jefferson and Sekiguchi 2011) suggested that eight species of small cetaceans could be considered common around the island, based

on previous records, and all eight of these species are among those hunted.

Although densities of most cetaceans appear to be low within the study area, the one exception may be for humpback whales in the winter to early spring months, when there seems to be significant numbers present in the Ie Shima survey area, and elsewhere along the southwestern part of Okinawa (see Uchida 2007, Kobayashi et al. 2016). Available data show that cetacean detections are generally lower in Okinawa than in Hawai'i or the Mariana Islands, other isolated tropical island chains with a similar assemblage of species (Baird et al. 2013, Lammers et al. 2015). Acoustically, the initial results from the analysis of the two Schwab EARs support the findings from the visual survey. While EAR acoustic detections cannot be used to estimate abundance *per se*, they do provide additional evidence, when combined with visual survey data, to support our findings of what appears to be low densities of marine mammals in the near-shore environment of Okinawa.

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