Final Field Report

Guam Marine Species Monitoring Survey, Shore Station Study: May 2013 and March 2015

Prepared for:

Commander, U.S. Pacific Fleet

Submitted to:

Naval Facilities Engineering Command Pacific under
HDR Environmental, Operations and Construction, Inc.
Contract No. N62470-10-D-3011, CTO KB26

Prepared by:

Mark H. Deakos (HDR)
Robert K. Uyeyama (NAVFAC Pacific)
Morgan W. Richie (NAVFAC Pacific)
Michael F. Richlen (HDR)
Jessica M. Aschettino (HDR)

Submitted by:

HDR

Honolulu, HI

January 2016

Suggested Citation:

Deakos, M.H., R.K. Uyeyama, M.W. Richie, M.F. Richlen, and J.M. Aschettino. 2016. Guam Marine Species Monitoring Survey, Shore Station Study, May 2013 and March 2015. Final Field Report. Prepared for Commander, U.S. Pacific Fleet, Environmental Readiness Division, Pearl Harbor, Hawaii. Submitted to Naval Facilities Engineering Command (NAVFAC) Pacific, EV2 Environmental Planning, Pearl Harbor, Hawaii under Contract No. N62470-10-D-3011, Task Order KB26 issued to HDR, Inc., Honolulu, Hawaii. January 2016.

Cover Photo Credits:

Guam Shore Station with primary observers using high powered Big Eyes binoculars, theodolite, and camera with telephoto lens to survey for marine mammals and sea turtles. Photo taken by Mark Deakos.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
01-2016

2. REPORT TYPE
Monitoring report

3. DATES COVERED *(From - To)*
April 2013-December 2015

4. TITLE AND SUBTITLE
GUAM MARINE SPECIES MONITORING SURVEY, SHORE STATION STUDY: MAY 2013 AND MARCH 2015. FINAL FIELD REPORT

5a. CONTRACT NUMBER
N62470-10-D-3011

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Mark H. Deakos
Robert K. Uyeyama
Morgan W. Richie
Michael F. Richlen
Jessica M. Aschettino

5d. PROJECT NUMBER
KB26

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
HDR, Honolulu, 1132 Bishop Street, Suite 1200, Honolulu, HI

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Commander, U.S.Pacific Fleet, 250 Makalapa Dr., Pearl Harbor, HI

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSORING/MONITORING AGENCY REPORT NUMBER

12. DISTRIBUTION AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
A shore-based platform, incorporating two high-powered 25 × 150-millimeter binoculars ("Big Eyes"), was evaluated as an alternative approach for surveying marine areas for protected species (marine mammals and sea turtles). During a pilot study at a test site on Oahu (278-meter [m] elevation), humpback whale (Megaptera novaeangliae) blows were visible through Big Eyes at 37 kilometers (km) away in Beaufort Sea State (BSS) 2. This suggests the approach could be effective at detecting baleen and sperm whales from long distances, priority species under the United States Department of the Navy's Marine Species Monitoring Program. Systematic scans using Big Eyes were performed in Guam over 10 days in May 2013 and 10 days in March 2015 from a north-facing (193-m elevation) and a northeast-facing (143-m elevation) shore station, chosen for mostly unobstructed views of the ocean in areas that are difficult to access by small vessel due to strong winds and large waves. The horizon distance calculated from each elevation was 50 and 42 km, respectively. A SnapZoom digiscoping adapter, equipped with an iPhone or GoPro, was attached to the Big Eyes eyepiece allowing collection of photos and video, complementing super-telephoto (500- and 800-millimeter) photography on a Digital Single Lens Reflex camera to assist with species confirmation. Despite a mean BSS of 5 or greater obscuring the visual arena for 90 percent of the survey time, observers recorded 32 odontocete and 38 turtle sightings. No baleen or sperm whales were observed. Odontocete sightings consisted of four confirmed species: spinner dolphins (Stenella longirostris; 66 percent, n=21), bottlenose dolphins (Tursiops truncatus; 6 percent, n=2), pilot whales (Globicephala macrorhynchus; 3 percent, n=1) and melon-headed whales (Peponocephala electra; 3 percent, n=1) and 7 unconfirmed (unidentified small dolphin; 16 percent, n=5, unidentified small whale; 3 percent, n=1, unidentified medium whale; 3 percent, n=1). The marine mammal sighting rate of 0.11 sightings per hour in March 2015 was less than four

times the 0.47 sightings per hour during the May 2013 surveys, despite having one additional observer and a second pair of Big Eyes. These results suggest an even lower density of marine mammals during the later winter months. The long distance for which large whale blows can be observed, as evidenced at the Oahu test site, demonstrates the extended range capability for shore-based systematic surveys of large whales when Big Eyes are incorporated. The long distance at which unidentified small dolphins (15 km away in BSS 3) and melon-headed whales (13 km away in BSS 5) were observed, gives promise to shore-based surveys as an alternative means of surveying an area where the use of other research platforms are impractical or cost prohibitive. However, marine mammal species whose detection probability decreases drastically with increasing BSS such as beaked whales and rough-toothed dolphins (Steno bredanensis) are likely to go undetected in a BSS greater than 2.

15. SUBJECT TERMS
monitoring, marine mammal, toothed whales, visual survey, shore station, Mariana Islands Training and Testing

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**	UU	40	Department of the Navy
Unclassified	Unclassified	Unclassified			**19b. TELEPONE NUMBER (*Include area code)*** 808-471-6391

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Acronyms and Abbreviations

BSS	Beaufort Sea State
km	kilometer(s)
m	meter(s)
mm	millimeter(s)
MIRC	Mariana Islands Range Complex
RTDP	Relative trackline detection probability
U.S.	United States

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Abstract

A shore-based platform, incorporating two high-powered 25 × 150-millimeter binoculars ("Big Eyes"), was evaluated as an alternative approach for surveying marine areas for protected species (marine mammals and sea turtles). During a pilot study at a test site on Oahu (278-meter [m] elevation), humpback whale (*Megaptera novaeangliae*) blows were visible through Big Eyes at 37 kilometers (km) away in Beaufort Sea State (BSS) 2. This suggests the approach could be effective at detecting baleen and sperm whales from long distances, priority species under the United States Department of the Navy's Marine Species Monitoring Program. Systematic scans using Big Eyes were performed in Guam over 10 days in May 2013 and 10 days in March 2015 from a north-facing (193-m elevation) and a northeast-facing (143-m elevation) shore station, chosen for mostly unobstructed views of the ocean in areas that are difficult to access by small vessel due to strong winds and large waves. The horizon distance calculated from each elevation was 50 and 42 km, respectively. A SnapZoom[1] digiscoping adapter, equipped with an iPhone or GoPro, was attached to the Big Eyes eyepiece allowing collection of photos and video, complementing super-telephoto (500- and 800-millimeter) photography on a Digital Single Lens Reflex camera to assist with species confirmation. Despite a mean BSS of 5 or greater obscuring the visual arena for 90 percent of the survey time, observers recorded 32 odontocete and 38 turtle sightings. No baleen or sperm whales were observed. Odontocete sightings consisted of four confirmed species: spinner dolphins (*Stenella longirostris*; 66 percent, n=21), bottlenose dolphins (*Tursiops truncatus*; 6 percent, n=2), pilot whales (*Globicephala macrorhynchus*; 3 percent, n=1) and melon-headed whales (*Peponocephala electra*; 3 percent, n=1) and 7 unconfirmed (unidentified small dolphin; 16 percent, n=5, unidentified small whale; 3 percent, n=1, unidentified medium whale; 3 percent, n=1). The marine mammal sighting rate of 0.11 sightings per hour in March 2015 was less than four times the 0.47 sightings per hour during the May 2013 surveys, despite having one additional observer and a second pair of Big Eyes. These results suggest an even lower density of marine mammals during the later winter months. The long distance for which large whale blows can be observed, as evidenced at the Oahu test site, demonstrates the extended range capability for shore-based systematic surveys of large whales when Big Eyes are incorporated. The long distance at which unidentified small dolphins (15 km away in BSS 3) and melon-headed whales (13 km away in BSS 5) were observed, gives promise to shore-based surveys as an alternative means of surveying an area where the use of other research platforms are impractical or cost prohibitive. However, marine mammal species whose detection probability decreases drastically with increasing BSS such as beaked whales and rough-toothed dolphins (*Steno bredanensis*) are likely to go undetected in a BSS greater than 2.

[1] http://snapzooms.com

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1. Introduction

1.1 Background

As part of the regulatory compliance process associated with the Marine Mammal Protection Act and the Endangered Species Act, the United States (U.S.) Navy is responsible for meeting specific monitoring and reporting requirements for military training and testing. In support of these monitoring requirements associated with the Mariana Islands Range Complex (MIRC) Environmental Impact Statement (DoN 2010), a marine species monitoring program has been conducted in the MIRC since 2010 (DoN 2014).This monitoring has primarily involved small-vessel operations and passive acoustic monitoring.

Although much has been learned about species presence, abundance, distribution, and group dynamics in MIRC, marine species monitoring in the region presents some challenges. Small-vessel visual surveys have been one of the most productive survey methods for determining the presence and absence of protected species in MIRC, but these surveys can be difficult to conduct on the windward side of the islands where strong winds and large waves typically make it extremely difficult. The ability to visually monitor MIRC waters for large whales during times of the year when they are most likely to occur has great value given their high priority for occurrence as Endangered Species Act-listed species. Shore-based surveys can provide a low-cost platform for measuring the distribution and relative abundance of animals over time (e.g., Gailey et al. 2007) and for multiple cetacean species at once (Shelden and Rugh 2010).

During May 2013, a pilot study was conducted from two locations on Guam to determine the effectiveness/feasibility of a shore-based observation platform as a substitute for visually surveying marine mammals and sea turtles (HDR 2014). The cliffs of Guam offered an elevated vantage point for shore-based surveys. The pilot study utilizing theodolite and Big Eyes demonstrated that odontocetes could be detected at distances of 15 kilometers (km), but since no large baleen whales or sperm whales were observed, it is difficult to know the furthest distance at which a large whale blow would have likely been detected with Big Eyes. To the authors' knowledge, this was the first shore-based survey using Big Eyes to investigate the occurrence of multiple cetacean species over a wide visual arena. Although Shelden and Rugh (2010) used Big Eyes to search a migration corridor for gray whales and other cetaceans, the Big Eyes were static and could not be rotated, limiting the area surveyed.

To help quantify the maximum detection range of Big Eyes for sighting large whales, Big Eyes were set up on three different shore-based platforms in Hawaii during the peak of humpback whale (*Megaptera novaeangliae*) season. Hawaii has the largest concentration of humpback whales in the North Pacific during the winter breeding season (Calambokidis et al. 2008) and therefore provides an ideal location for sighting distant humpback whales. By determining the distance at which a baleen whale blow can be observed using Big Eyes from a known elevation, this information can be used to approximate the furthest distance a large whale could be observed from a different elevation.

Following the Hawaii calibration work, a second 10-day survey of marine mammals and sea turtles was conducted similar to the 2013 surveys except a second set of Big Eyes was used and an additional observer to provide better coverage of the offshore, visual arena. Both Guam surveys and the Hawaii calibration work are reported here to help determine the effectiveness of Big Eyes for shore-based visual surveys when monitoring for protected marine species.

2. Methods

2.1 Shore Stations

The shore station platform sites selected for Hawaii included the Pali Lookout on Maui (elevation of 39 meters [m] and visual horizon at 24 km), Kapalua Airport on Maui (elevation of 65 m and visual horizon of 29 km) and Kaena Point on Oahu (elevation 278 m and a visual horizon of 60 km). These locations provide a clear view of the ocean with portions of the visual arena in protected areas with a low Beaufort Sea State (BSS) and exposed waters with high BSS. These locations also overlook shallow waters where humpback whales are most likely to congregate and that are long distances away from the shore station.

Both Guam shore stations (**Figure 1**) used in this study were located on Andersen Air Force Base and chosen based on high elevations that provide a large visual arena for monitoring and overlooking waters that are difficult to survey by small vessel (HDR 2014). The NE Station[2] is on the northeastern corner of Guam facing the windward side (elevation of 143 m and visual horizon at 42 km) with a horizontal viewshed of 149 degrees. The N Station[3] was on the northeastern corner of Guam, facing north towards the island of Rota (elevation 193 m and a visual horizon of 50 km) and a horizontal viewshed of 126 degrees.

Figure 1. **Map of Guam Showing the N and NE Shore Stations.**

[2] This site is also known as Installation Restoration Program site 9.
[3] This site is adjacent to what is also known as Installation Restoration Program site 12.

2.2 Equipment

The equipment used for the MIRC shore-station surveys included one high-powered Fujinon 25 × 150-millimeter (mm) MTM Big Eyes binoculars in year 2013 and two units in year 2015 as the primary means for scanning waters from 3 km out to the horizon. The angle of view for the Big Eyes is 2.7 degrees. The right ocular contains reticles inscribed by Baker Marine with each reticle representing 0.0779 degrees. In 2013, the single pair of Big Eyes was mounted into a yoke and onto a stanchion used for bolting to the deck of a ship; a suitably flat area of bare ground was located and the stanchions were weighted with concrete blocks (HDR, 2014). In 2015, the Big Eyes and yokes were mounted onto a Fujinon tripod (model #781130) (**Figure 2**). Two pairs of Fujinon 7 × 50-mm FMTRC-SX Polaris handheld reticle binoculars (0.2943 degrees per reticle) with a magnetic compass bearing and monopod mount were used to scan waters primarily from approximately 1 to 5 km offshore. A Sokkia DT5 theodolite with a 30 × 4.5-mm singular ocular was used as a backup means for getting precise azimuth and bearing information for a sighting but its small field of view is not practical for searching for animals. The theodolite interfaced with a Lenovo laptop computer running the Pythagoras[4] software. An iPad ran a customized Filemaker Pro database as the primary data collection tool. Pythagoras was used as a backup recording system for theodolite fixes. A tripod-mounted Canon 7D Mark II[5] APS-C camera equipped with a Canon fixed 500-mm lens (Canon f/4L IS II USM) or a Canon fixed 800-mm lens (Canon f/5.6L IS USM) was used to document sightings and confirm species identification. A SnapZoom adaptor, in conjunction with an iPhone or GoPro camera, was also mounted onto the ocular piece of the Big Eyes during sightings to capture images from these high power optics (**Figure 3**).

(Photo by M. Deakos).

Figure 2. **Big Eyes on tripod mount.**

[4] http://www.tamug.edu/mmbeg/pythagoras.htm

[5] A Canon 7D was used in the 2013 survey; a Canon 7D Mark II was used in the 2015 survey

(Photo by M. Deakos).

Figure 3. SnapZoom ocular mount for taking photos or video with an: iPhone (a) or GoPro (b and c) using the 25× magnification from the Big Eyes.

2.3 Hawaii Survey Big Eyes Range Estimation

At both the Maui and the Oahu shore station sites, a single pair of Big Eyes was mounted on a tripod and referenced to a known landmark to calibrate the horizontal bearing relative to true north. A data recorder entered whale and dolphin sighting information into an iPad running a customized Filemaker Pro database program that converted bearing and reticle information into a geographic position. During the Maui survey, a small vessel motoring offshore in front of the site provided GPS positions of the vessel to validate the formulas, and provide a target for field comparisons of photographic equipment tests.

2.4 Guam Marine Mammal and Sea Turtle Surveys

A distant reference landmark with a known position and bearing was used to calibrate both the theodolite and Big Eyes in the horizontal plane to reference true north. During the 2013 survey, one set of Big Eyes scanned the entire visual area, and during the 2015 surveys, one set was orientated to scan the left side of the visual arena while the other was orientated to scan the right visual arena, with an overlap of approximately 20 degrees in the center.

In 2013, a team of four observers scanned the waters continuously from approximately 0730 until 1600. The same team was used during the 2015 surveys with the addition of one more observer to accommodate the additional Big Eyes station. Observers rotated between four stations every 30 minutes: 1) Big Eyes; 2) theodolite operator; 3) handheld binocular scans; and 4) data recorder. During the 2015 surveys, an additional Big Eyes station was included in the rotation as well as an additional Big Eyes observer. Surveying ceased for about 1 hour each day for lunch.

In 2013, in order to quantify the precision error between the theodolite, Big Eyes and handheld binoculars, GPS coordinates were taken at the shoreline from six locations visible from the N Station (HDR 2014). These locations ranged from 6.0 km to 8.5 km away from the N Station (**Table 1**).

Table 1. Estimated distance and percent error of theodolite (TH), Big Eye (BE), and handheld binocular (HH) fixes on six known locations at sea level visible from the N Station (taken from HDR 2014).

Shoreline Waypoint	Actual Distance from TH (km)	Calculated Distance to Target (km)			Percent Error		
		TH	BE	HH	TH	BE	HH
1	6.23	6.25	6.26	6.13	0.21	0.42	1.59
2	6.43	6.45	6.32	6.40	0.25	1.78	0.49
3	6.83	6.81	6.65	6.81	0.31	2.64	0.20
4	7.09	7.10	6.91	7.51	0.13	2.49	5.94
5	7.64	7.63	7.43	7.67	0.04	2.72	0.39
6	8.81	8.79	8.58	8.77	0.28	2.59	0.45
Mean					**0.20**	**2.11**	**1.51**

All three methods of estimating position of targets proved to be very accurate with the theodolite being most accurate to within 0.20 percent error at distances of 8 km to the target, whereas Big Eyes and handheld binoculars had a mean error below 3 percent (HDR 2014).

Big Eyes observers focused primarily on waters further than 1 km from shore while the handheld observer focused on waters from the shoreline out to about 5 km offshore. The unaided eye observers (recorder and theodolite operator) focused along the shoreline. Bearing and reticle information were input into the iPad software. For every sighting, the data recorded included the reticle and bearing to the sighting, (if the sighting was obtained with the unaided eye, then one of the other observers would located the sighting to provide a reticle and bearing), the initial sighting cue (splash, body or blow), the species and the estimated group size, if available. Estimated sighting locations calculated from the reticle and bearing were imported as a shapefile layer into ArcGIS and the “intersect” tool was used to extract depth values from a bathymetry data layer[6] from multibeam soundings for this area. A Guam shoreline shapefile[7] was created using the “polygon to line” tool and the “nearest” tool was used to obtain the closest distance from of each sighting to the shoreline.

The theodolite operator attempted to fix all marine mammal and sea turtle sightings, even if a measurement was obtained using Big Eyes. During a sighting, observers would opportunistically take photos using the telephoto lens or take video using the SnapZoom adapter. One of the Big Eyes observers always kept track of the sighting while others attempted photos and video opportunistically. To facilitate locating a sighting by another observer, it was important to be able to translate the horizontal and azimuth readings quickly from one optical instrument to another. The bearing of a sighting was used by all observers to try and locate the sighting in the horizontal plane. For vertical angle, in 2013, a table of conversions between number of Big Eyes reticles and the theodolite’s vertical angle was printed for use by the theodolite operator. This table was created by manual calibration on-site using comparisons of the locations of fixed features (e.g., a sea cliff) sighted and fixed in both devices. In 2015, this conversion table was

[6] http://www.soest.hawaii.edu/pibhmc; http://www.soest.hawaii.edu/pibhmc/pibhmc_cruise-catalog.htm
[7] http://biogeo.nos.noaa.gov/projects/mapping/pacific/territories/data/

replaced by an automated conversion displayed in the data recording software. Similarly, the photographer was also able to utilize the horizontal angle indicated on the Big Eyes yoke because the camera body (in 2013 Canon 7D with Canon GP-E2 GPS receiver; in 2015 Canon 7D Mark II with built-in GPS and compass) was set to display horizontal angle.

At the start and end of each day and following each observer rotation, the computer operator entered the Big Eyes observers' environmental conditions into the survey software. Environmental conditions consisted of: 1) BSS for both left and right Big Eyes observers, 2) the percentage of their respective visual field hindered by severe glare, 3) the furthest distance they believed they could observe (an estimation based on how far they could detect 20 dolphins and calculated as Big Eyes reticles from the horizon) and 4) the percentage of the overall visual arena covered by clouds. On occasion, during survey scans for marine mammals and turtles, observers obtained positions of boats and floating objects from each optical device at the same time to ensure that the fixes were calculated correctly. For details on theodolite setup and observer protocols, see HDR 2014.

3. Results

3.1 Hawaii Survey Big Eyes Range Estimation

Two days on Maui and 1 day on Oahu were spent examining the distance at which whales could be observed using Big Eyes binoculars.

On January 15, 2015, a shore station was setup on the west facing shore of Maui near the Pali Lookout (N20.78422, W156.54975) to measure the location of a small vessel offshore (with known GPS positions) to validate the plotting software. On January 16, 2015, a shore station was setup adjacent to the Kapalua Airport on Maui at an elevation of 65 m and a visual horizon at 29 km. The furthest humpback whale blow was estimated as being 23 km from the shore station in a BSS 2 (**Figure 4)**. On May 12, 2015, from the Kaena Point Satellite Tracking Station on Oahu, at an elevation of 278 m and a visual horizon at 60 km, the furthest humpback whale blow was seen at a distance of 39 km (**Figure 4**). Sea conditions were also BSS 2.

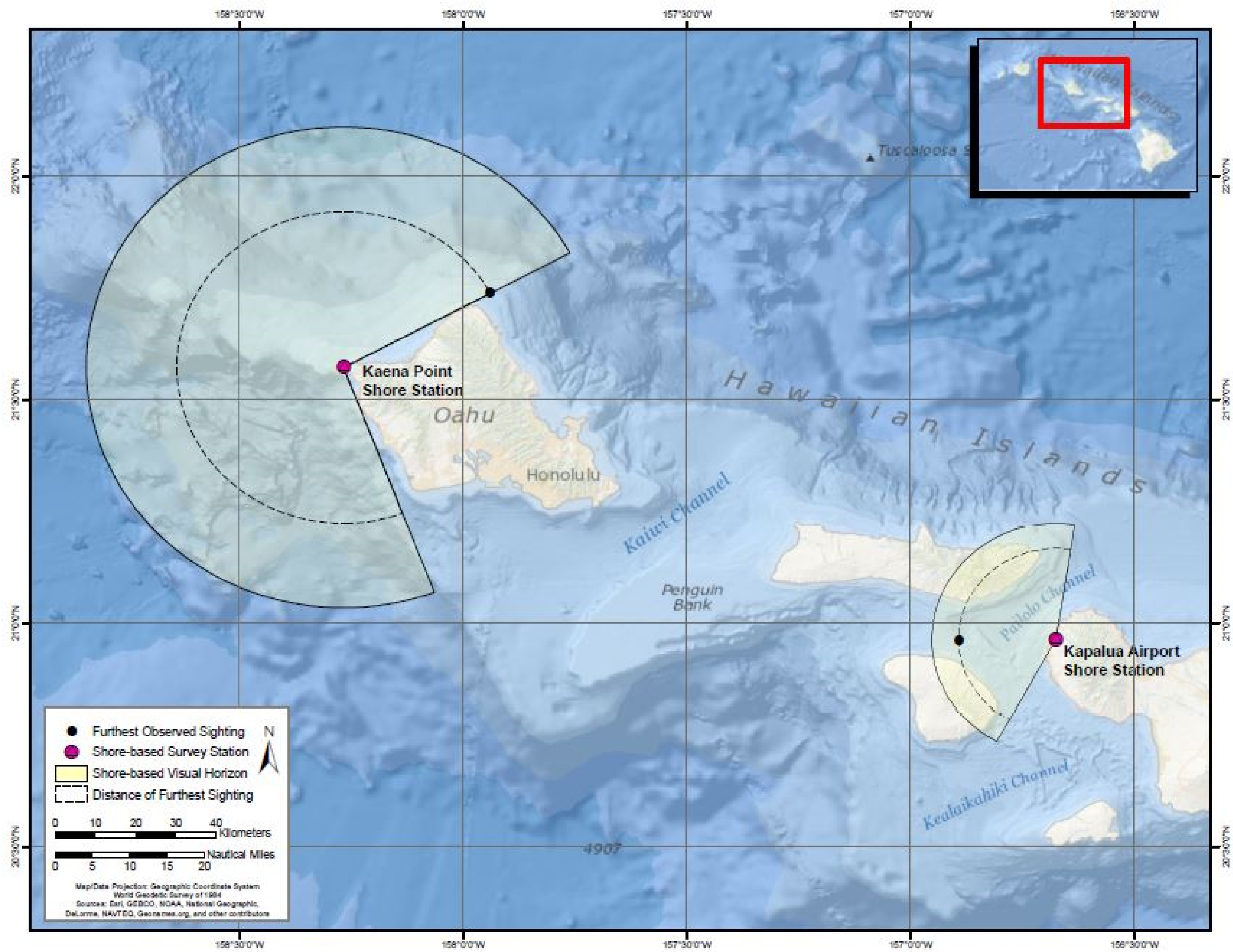


Figure 4. **Map of the Kapalua Airport shore station (65-m elevation, 29-km visual horizon) and Kaena Point shore station (278-m elevation, 60-km horizon) showing the furthest humpback whale blow sighting observed with Big Eyes binoculars at 23 km and 39 km from the shore station, respectively.**

3.2 Photography Comparison

Field comparisons of photographic equipment were also conducted at the Maui site, and included utilizing a small vessel on the water as a photographic target at a distance of several kilometers. The primary goals were comparing photographs resulting from: 1) 500-mm and 800-mm ultra-telephoto lenses; 2) use or omission of a 1.4x teleconverter; 3) a body with full-frame or APS-C sensor; 4) disabling or enabling on-lens image stabilization (IS); and 5) stepping down from maximum aperture.

Comparisons #4 and #5 yielded no difference. Although it was considered that enabling IS on a stable tripod-mounted platform might introduce artifacts, the qualitative result was that disabling on-lens IS yielded no improvement in image quality. Similarly, stepping down one increment from the maximum aperture yielded no improvement in image quality, although this result may be confounded with the commensurate lengthening of shutter speed.

Figure 5 and **Figure 6** illustrate the other comparisons 1–3. For the lens comparison, as expected the f/5.6 800-mm lens yielded higher quality photographs in comparison to the f/4 500mm lens, in conditions of bright sunlight. For the teleconverter comparison, a Canon 1.4x EF Extender III was utilized. The teleconverter on the 500-mm lens on both bodies appeared to yield poorer-quality images than by using the 800-mm lens alone; however note the bottom-left image of **Figure 6** (for the full-frame body) appears to exhibit confounding camera shake, and the decrease in quality may be an artifact. Also the teleconverter with the 800-mm lens on the APS-C cropped sensor also yielded a poorer quality image than omitting it. However, use of the teleconverter on the 800-mm lens on the full-frame sensor body marginally improved image quality (see top left image, **Figure 5** and **Figure 6**). **Figure 7** shows this comparison in more detail, where the lettering on the boat contains more detail using the teleconverter.

For the body comparison, although the APS-C sensor of the Canon 7D mk II has higher pixel pitch (density) at 59410 pixels/mm^2 than the full frame sensor of the Canon 5D mk III at 25600 pixels/mm^2, there was more detail in the full frame photographs (see left column of **Figure 5** and **Figure 6**), likely due to the physically larger pixels yielding less light noise, chroma (color) noise and diffraction-limited sharpness. However, a similar comparison made with a nearby terrestrial target (a truck at an approximate 100-m distance) did not yield a clear benefit for the full-frame body at higher shutter speeds despite an even closer crop of 120 pixels for the 7D mk II and 78 pixels for the 5D mk III (**Figure 8**). Two factors likely affecting results for the more distant photos to the boat were: 1) the presence of atypically high volcanic smog (i.e., “vog”) in the viewing area, and 2) the fact that the shore station site on Maui was on a gradual slope rather than presenting a view off a steep cliff, resulting in more thermal distortion from the additional intervening land below a longer portion of the sight line.

In summary, the 800-mm lens is preferable to the 500-mm lens, even if the 500-mm lens is fitted with a 1.4x teleconverter. Due to minimum aperture necessary for autofocus, the Canon 2x teleconverter would disable autofocus on both these lenses, and was not considered in favor of the 1.4x model. The 1.4x teleconverter may yield marginal benefits on the 800-mm lens on the tested full-frame body. However, newer full-frame bodies with pixel pitches comparable to the 7D mk II, such as the Canon 5DS and 5DS R at 58241 pixels/mm^2, coupled with the disabling of the anti-aliasing low pass filter in the 5DS R, may provide greater benefit, even without use of a teleconverter. Due to the wider full-frame sensor, image capture of the sighting will also become more likely, since at the extreme ranges of some of the more distant sightings, the animals are not visible to the photographer despite being located within the viewfinder; in these cases during the Guam survey, the photographer matched the horizontal angle using the camera’s GPS-compass, and estimated vertical angle by looking through the theodolite viewfinder or Big Eyes, and collected photographs without being able to see the sighting.

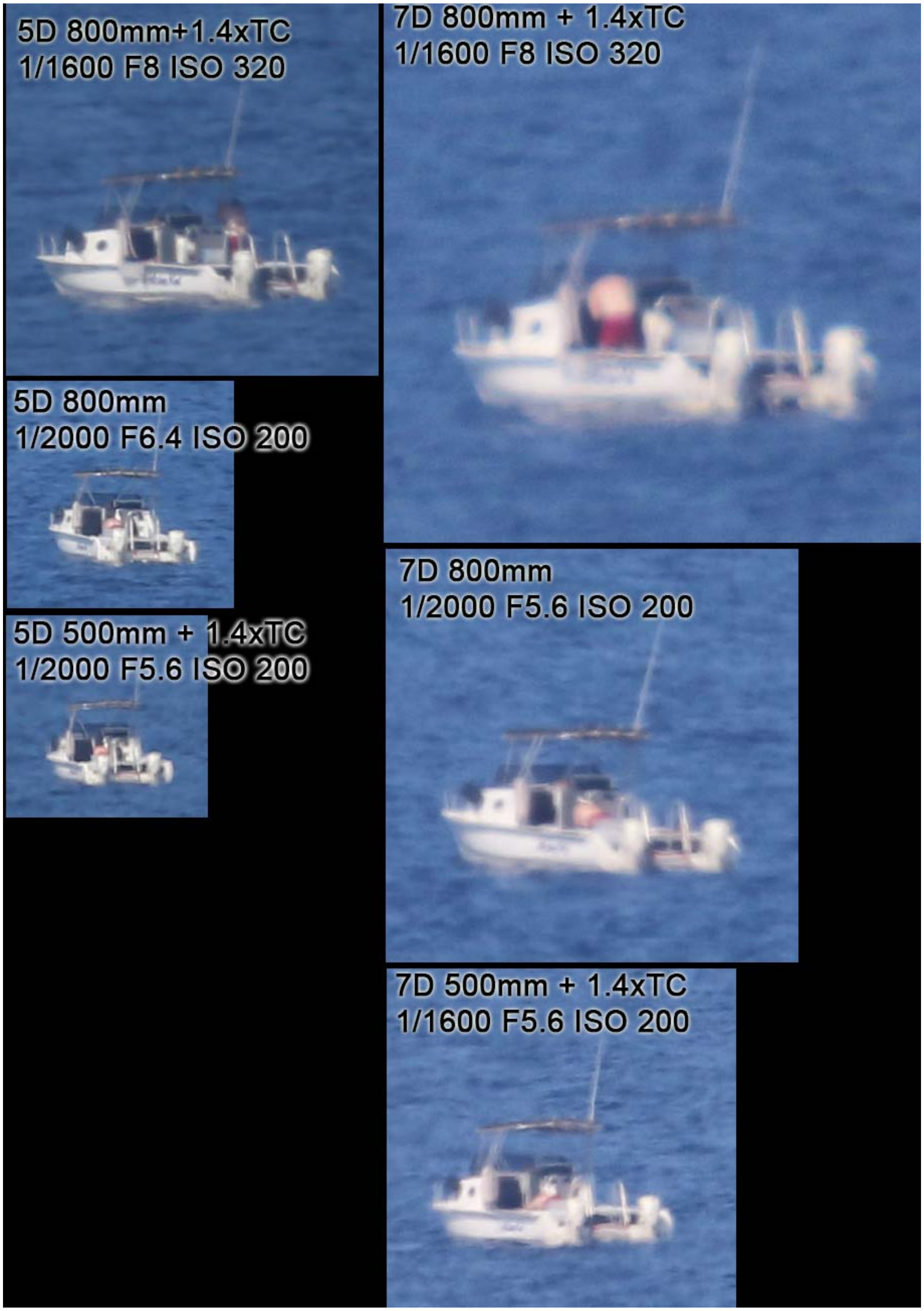


Figure 5. **Comparison of lens choice (500- or 800-mm), teleconverter use, and body Key: 7D= Canon 7D mark II APS-C cropped sensor body; 5D= Canon 5D mark III full frame sensor body. Images are cropped but not resized relative to one another. All photographs taken with autofocus and on-lens image stabilization (IS) enabled.**

Figure 6. Comparison of lens choice (500mm or 800mm), teleconverter use, and body, with resized images Key: 7D= Canon 7D mark II APS-C cropped-sensor body; 5D= Canon 5D mark III full frame sensor body. All photographs taken with autofocus and on-lens image stabilization (IS) enabled. Images from Figure 5 have been resized for comparison of detail and sharpness.

Figure 7. **Comparison of use of 1.4x teleconverter with full-frame sensor body and 800-mm lens Key: 5D= Canon 5D mark III full frame sensor body. All photographs taken with autofocus and on-lens image stabilization (IS) enabled.**

Figure 8. **Comparison of lens choice (500- or 800-mm), teleconverter use, and body Key: 7D= Canon 7D mark II APS-C cropped-sensor body; 5D= Canon 5D mark III full frame sensor body. All photographs taken with autofocus and on-lens image stabilization (IS) enabled. Images from Figure X1 have been resized for comparison of detail and sharpness.**

3.3 Guam Marine Mammal and Sea Turtle Surveys

3.3.1 Survey Effort

A total of 54.9 hours of dedicated, systematic survey effort were conducted in 2013 (May 11–20) and a total of 63.5 hours were conducted in 2015 (March 3–12), each for 10 days and a total of 118.5 hours (**Table 2**).

Table 2. Survey Effort Distribution by Year, Shore Station and BSS.

	BSS 3	BSS 4	BSS 5	BSS 6	BSS 7	Total Time (hours)
2013 Surveys						
N Station Time on Effort (hours)	12.3	6.2	4.6	2.2	-	25.3
NE Station Time on Effort (hours)	-	4.1	12.1	13.4	-	29.6
2013 Total	12.3	10.3	16.7	15.6	-	54.9
2015 Surveys						
N Station Time on Effort (hours)	-	4.4	7.2	9.7	0.8	22.0
NE Station Time on Effort (hours)	-	0.9	15.8	24.9	-	41.6
2015 Total	-	5.3	23.0	34.6	0.8	63.6
Grand Total	12.3	15.6	39.7	50.2	0.8	118.5
Percentage	10%	13%	33%	42%	1%	

BSS ranged from 3 to 7 during all 2013 and 2015 surveys in Guam (**Table 2, Figure 9**). Big Eyes observers provided a BSS estimate at the start of each rotation, approximately every 30 minutes. During the 2015 survey, when two Big Eyes observers were scanning simultaneously, an average of the left and right Big Eyes observer BSS value was taken for that rotation period. These BSS values represent the sea conditions of the majority of the offshore visual arena. The BSS very near to the shoreline was often more calm than conditions offshore but represented a small proportion of the visual arena.

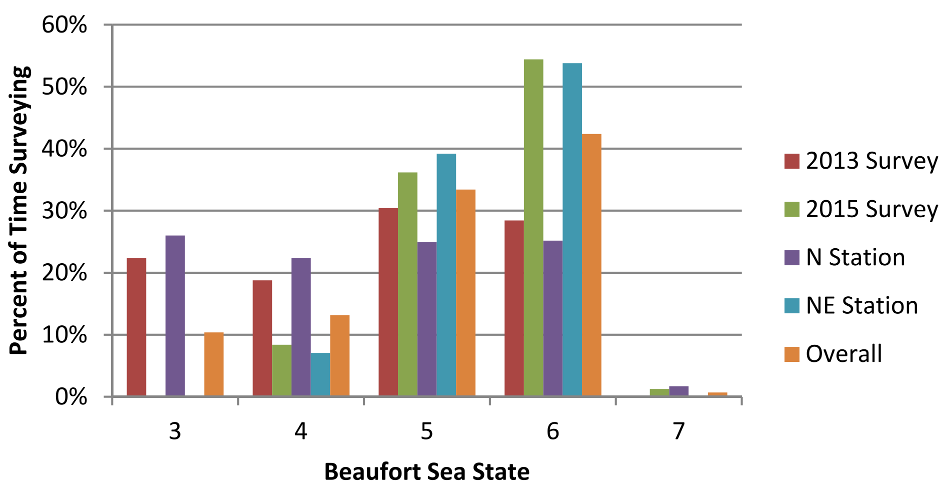


Figure 9. Chart showing the percentage of time surveyed by BSS for each survey year and for each shore station location.

The majority of observation time was spent surveying in a BSS of 6 (76 percent of the time) for all surveys with the exception of the N Station in 2013, where a BSS of 3 represented 49 percent of the observation time (**Table 2**). Of the 54.9 survey hours in 2013, 59 percent were spent observing in BSS of 5 or greater. Of the 63.6 hours of time spent on effort in 2015, over half of the time (54 percent) was spent surveying in BSS 6 and 92 percent of the time observing in BSS 5 or greater.

3.3.2 Survey Sightings

A total of 32 marine mammal groups were sighted during the 2013 and 2015 surveys on Guam (**Table 3, Figure 10**); 10 (31 percent) from the N Station and 22 (69 percent) from the NE Station.

Two thirds (66 percent) of all sightings were spinner dolphins (*Stenella longirostris*) and the majority of these sightings (81 percent, n=17) occurred in 2013 with only four sightings in 2015 (**Table 3**). Unidentified small dolphins were the next most common sighting (16 percent, n=5) with all of them occurring in 2013. Bottlenose dolphins (*Tursiops truncatus*) were seen twice (6 percent, n=2) all of them occurring in 2015. Only a single sighting was made for the remaining four groups: unidentified medium cetacean, unidentified small whale, short-finned pilot whales (*Globicephala macrorhyncus*) and melon-headed whales (*Peponocephala electra*) (**Figure 10**).

The majority of sightings occurred at the NE Station (69 percent, n=22), 19 of which were spinner dolphins (86 percent). The mean BSS when observations were made was 5 for the NE station in both years, while the mean N station BSS was 3 in 2013 and 5 in 2015 (**Table 3**). The maximum distance for a sighting, from either of the two Guam shore sites, was an unidentified medium cetacean at a distance of 15.2 km from the N Station (5.8 km from the nearest point of land). The furthest sighting of a confirmed species was of melon-headed whales seen at a distance of 13.9 km from the NE Station (10.0 km from the nearest point of land).

Half of the marine mammal sightings were unaided eye sightings (50 percent), while 28 percent were initially found through the Big Eyes, and 22 percent were discovered using handhelds. Remarkably, during the 2015 surveys when the Big Eyes effort was doubled, only 14 percent of the sightings were made with Big Eyes compared to 32 percent in 2013 with only a single Big Eyes observer.

Among the 38 turtle sightings across all surveys, seven (18 percent) were confirmed to species either in the field or by reviewing photographs (**Table 4, Figure 11**). Those confirmed to species were all green sea turtles (*Chelonia mydas*). As reported for the 2013 survey (HDR 2014), one unidentified sea turtle was considered to be a possible loggerhead (*Caretta caretta*), based on photography. The furthest turtle sighted was 1.6 km away from the shore station, which was also the turtle furthest (660 m) from the closest point on shore and in the deepest water (estimated to be 105 m). All sightings except for two (5 percent) were within 200 m of the shoreline and in less than 35 m depth.

Table 3. Guam shore station marine mammal sightings for year 2013 and 2015.

Date	Time	Species	Initial Sighting Method	Estimated Group Size	Latitude (North)	Longitude (East)	Distance from Theodolite (m)	Distance from Shore (m)	Depth (m)	BSS
N Station										
05/17/13	16:10	Sl	Big Eyes	3	13.6255	144.9021	5820	520	26	5
05/18/13	14:24	Gm	Handheld	30	13.6442	144.9651	5800	5020	720	3
05/18/13	15:04	USD	Big Eyes	1	13.6368	144.9718	5370	4480	617	3
05/18/13	16:06	USD	Handheld	22	13.6622	144.9821	8380	7520	783	3
05/19/13	9:33	UMC	Big Eyes	1	13.7100	144.8698	15180	5880	458	3
05/19/13	11:33	USW	Big Eyes	4	13.6396	144.9382	4990	4270	557	3
05/19/13	13:45	USD	Big Eyes	50	13.6820	144.9369	9670	6650	718	3
05/19/13	14:58	USD	Unaided Eye	8	13.6036	144.9504	1020	310	70	4
05/20/13	10:24	Sl	Big Eyes	16	13.6028	144.9486	860	280	49	4
2013 Count		**9**				***Maximum***	**15180**	**7520**	**783**	**3 (mean)**
03/06/15	08:11	Tt	Handheld	20	13.60173	144.95301	1035	125	12	5
2015 Count		**1**				***Maximum***	**1035**	**125**	**12**	**5 (mean)**
Total Count		**10**				***Overall Maximum***	**15180**	**7520**	**783**	**4 (mean)**
NE Station										
05/11/13	15:48	Sl	Unaided Eye	7	13.5650	144.9494	1240	800	49	5
05/11/13	16:04	Sl	Unaided Eye	30	13.5771	144.9550	1040	530	53	5
05/12/13	10:17	Sl	Unaided Eye	112	13.5744	144.9502	510	200	19	4
05/12/13	11:53	Sl	Unaided Eye	130	13.5675	144.9482	930	220	38	5
05/12/13	13:34	Sl	Unaided Eye	80	13.5531	144.9443	2500	470	52	5
05/13/13	9:10	Sl	Unaided Eye	100	13.5722	144.9498	590	290	26	5
05/13/13	10:34	Sl	Unaided Eye	60	13.5756	144.9524	740	340	29	6
05/13/13	11:00	USD	Big Eyes	5	13.5570	145.0161	7910	7230	1203	6
05/13/13	13:51	Sl	Unaided Eye	90	13.5758	144.9504	530	150	17	5
05/13/13	13:57	Sl	Handheld	50	13.5725	144.9509	670	380	31	5
05/13/13	14:19	Sl	Unaided Eye	98	13.5744	144.9502	520	200	20	5

Date	Time	Species	Initial Sighting Method	Estimated Group Size	Latitude (North)	Longitude (East)	Distance from Theodolite (m)	Distance from Shore (m)	Depth (m)	BSS
NE Station (continued)										
05/14/13	9:07	Sl	Unaided Eye	38	13.5697	144.9482	710	370	31	5
05/14/13	13:39	Sl	Unaided Eye	110	13.5700	144.9477	650	300	24	6
05/14/13	14:24	Sl	Big Eyes	90	13.5591	144.9530	1990	1470	110	6
05/15/13	11:15	Sl	Handheld	45	13.5759	144.9527	780	350	30	6
05/16/13	10:53	Sl	Handheld	80	13.5717	144.9511	730	430	35	6
2013 Count		**16**				***Maximum***	**7910**	**7230**	**1203**	**5 (mean)**
03/09/15	10:56	Sl	Unaided Eye	30	13.56960	144.94491	666	89	17	5
03/09/15	15:29	Sl	Handheld	35	13.57669	144.95105	607	155	21	5
03/10/15	10:20	Sl	Unaided Eye	40	13.57312	144.94985	538	229	24	5
03/10/15	15:01	Tt	Unaided Eye	11	13.57255	144.94806	430	98	18	6
03/12/15	10:21	Sl	Unaided Eye	30	13.57280	144.94883	371	27	20	5
03/12/15	13:36	Pe	Big Eyes	160	13.45986	144.99362	13874	10019	1165	5
2015 Count		**6**				***Maximum***	**13874**	**10019**	**1165**	**5 (mean)**
Total Count		**22**				***Overall Maximum***	**13874**	10019	**1203**	**5 (mean)**
Grand Total		**32**				***Overall Maximum***	**15180**	10019	**1203**	**5 (mean)**

Sl = *Stenella longirostris*, USD = unidentified small dolphin, Gm = *Globicephala macrorhyncus*, UMC = unidentified medium cetacean, USW = unidentified small whale, Pe = *Peponocephala electra*, Tt = *Tursiops truncatus*

Note: Date and time are local Guam time.

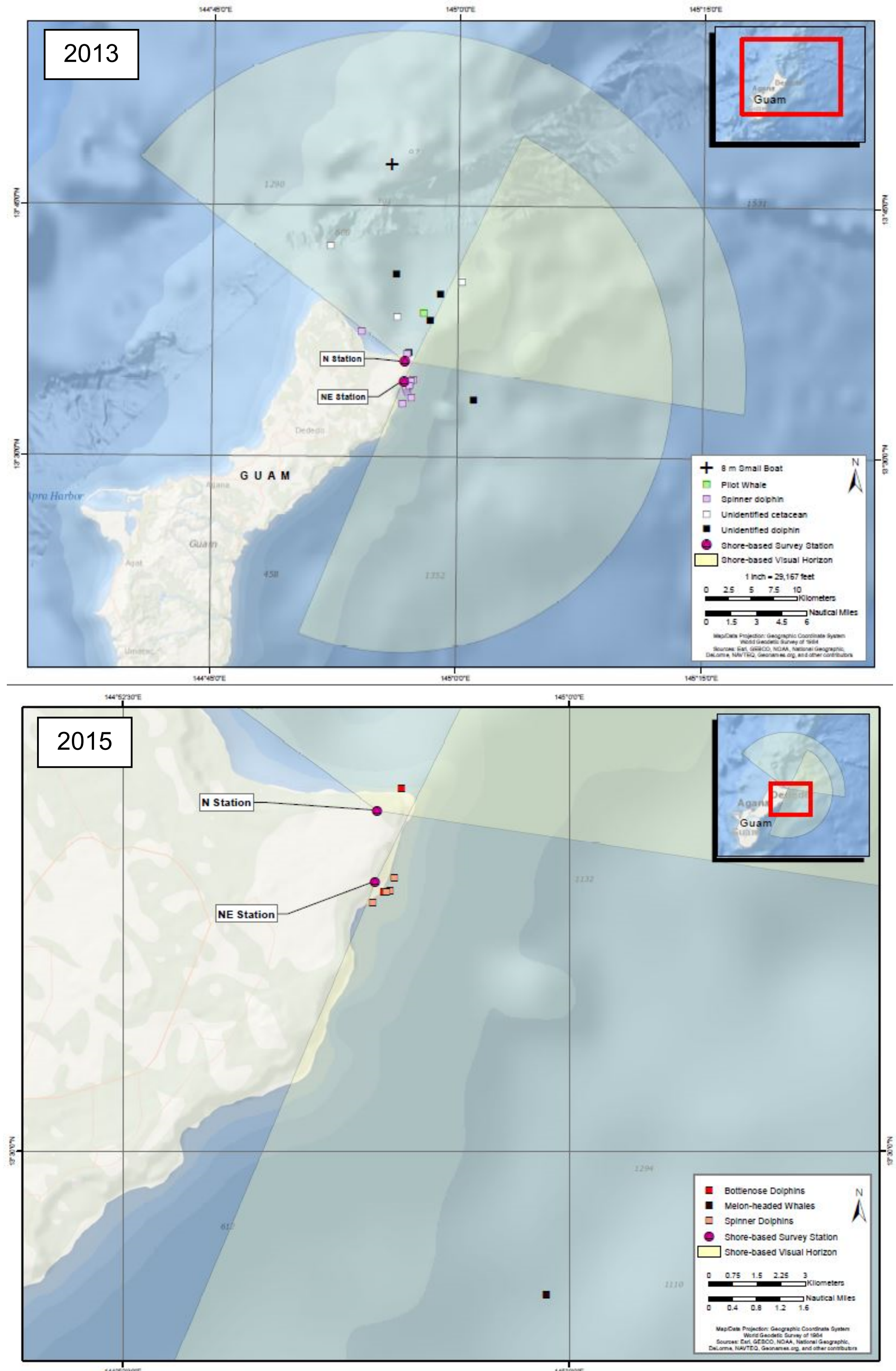


Figure 10. Maps showing Shore Stations 1 and 2, all marine mammal sightings from 10 days of visual surveys and the calculated distance to the horizon for each of the two respective sites is shown as the shaded area. Top: 2013 surveys; Bottom: 2015 surveys.

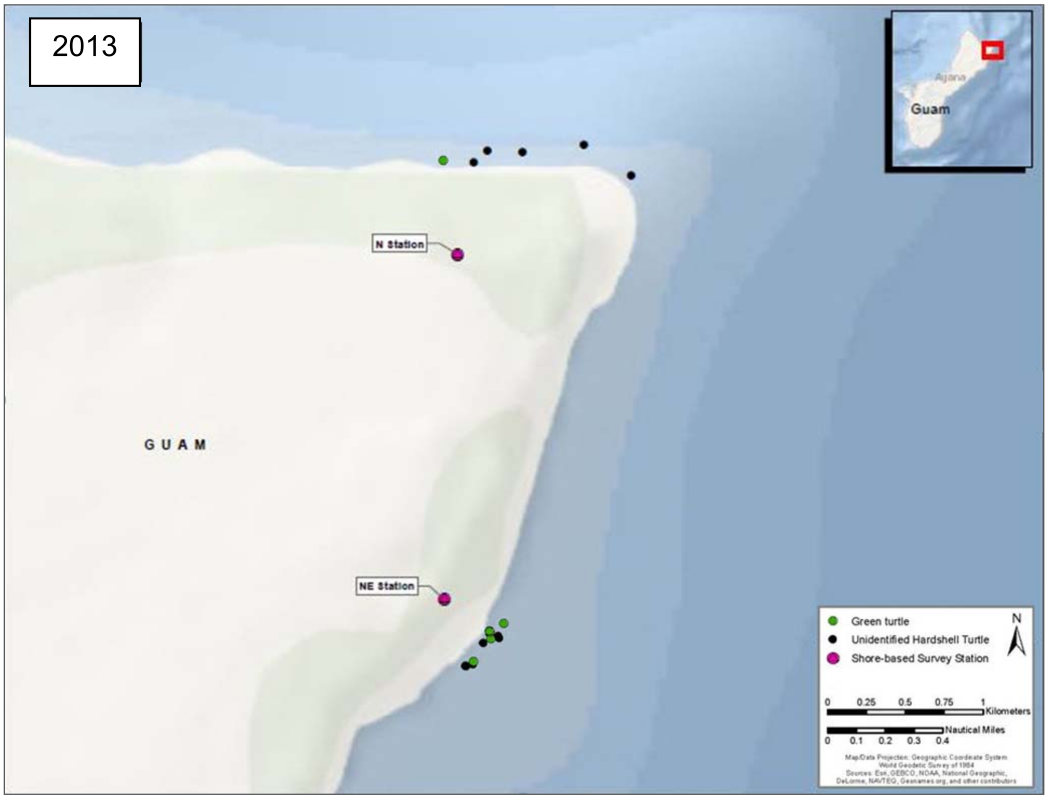
Table 4. Guam shore station turtle sightings for year 2013 and 2015.

Date	Time	Species	Initial Sighting Method	Latitude (North)	Longitude (East)	Distance from Theodolite (m)	Distance from Shore (m)	Depth (m)	Beaufort Sea State
N Station									
05/17/13	10:02	Cm	Unaided Eye	13.6009	144.9453	620	80	18	5
05/17/13	14:32	UH	Handheld	13.6002	144.9564	1220	100	8	5
05/20/13	10:11	UH	Handheld	13.6008	144.9471	610	70	13	4
05/20/13	14:26	UH	Handheld	13.6014	144.9499	780	100	17	3
05/20/13	14:26	UH	Handheld	13.6019	144.9535	1070	150	10	3
05/20/13	15:39	UH	Handheld	13.6015	144.9479	700	150	16	3
2013 Count		**6**			***Maximum***	**1220**	**150**	**18**	**4 (mean)**
03/03/15	11:34	UH	Unaided Eye	13.60055	144.94627	587	44	10	5
03/03/15	13:52	UH	Handheld	13.60060	144.94412	629	49	13	5
03/04/15	10:32	Cm	Big Eyes	13.60591	144.95596	1591	660	105	7
03/04/15	14:29	UH	Unaided Eye	13.60183	144.95257	1009	121	23	6
03/04/15	14:58	UH	Unaided Eye	13.60187	144.95253	1009	123	23	6
03/05/15	11:44	UH	Handheld	13.60200	144.95232	1004	132	35	5
03/05/15	13:19	UH	Handheld	13.60159	144.94389	742	162	28	4
03/06/15	09:21	UH	Handheld	13.60094	144.94247	742	93	13	5
03/06/15	10:06	UH	Unaided Eye	13.60067	144.94999	731	1	4	6
03/06/15	13:18	UH	Handheld	13.60176	144.95132	914	100	28	6
03/06/15	13:47	UH	Unaided Eye	13.60023	144.94512	561	20	4	6
03/06/15	14:23	UH	Handheld	13.60125	144.94980	775	69	14	6
03/06/15	14:55	UH	Handheld	13.60080	144.95588	1221	139	12	6
03/06/15	15:04	Cm	Handheld	13.60081	144.94600	615	69	16	6
2015 Count		**14**			***Maximum***	**1591**	**660**	**105**	**6 (mean)**
Total Count		**20**			***Overall Maximum***	**1591**	**660**	**105**	**5 (mean)**

Date	Time	Species	Initial Sighting Method	Latitude (North)	Longitude (East)	Distance from Theodolite (m)	Distance from Shore (m)	Depth (m)	Beaufort Sea State
NE Station									
05/12/13	9:58	UH	Handheld	13.5730	144.9465	290	170	26	4
05/12/13	13:19	Cm	Unaided Eye	13.5718	144.9472	440	110	17	5
05/12/13	13:44	UH	Handheld	13.5716	144.9468	460	110	17	5
05/12/13	14:36	UH	Handheld	13.5717	144.9472	460	130	18	5
05/13/13	11:30	UH	Unaided Eye	13.5729	144.9478	380	80	11	6
05/13/13	13:28	Cm	Handheld	13.5740	144.9490	410	130	16	5
05/13/13	14:01	UH	Handheld	13.5732	144.9488	430	140	16	5
05/13/13	14:03	Cm	Handheld	13.5736	144.9482	360	70	10	5
05/14/13	11:30	UH	Unaided Eye	13.5731	144.9431	370	0	101	6
05/14/13	13:44	UH	Unaided Eye	13.5735	144.9482	370	70	10	6
05/14/13	15:12	Cm	Unaided Eye	13.5736	144.9482	350	70	9	6
05/15/13	14:14	Cm	Unaided Eye	13.5731	144.9483	390	90	15	6
05/16/13	11:48	UH	Unaided Eye	13.5733	144.9487	420	130	16	6
2013 Count		**13**			***Maximum***	**460**	**170**	**101**	**5 (mean)**
03/07/15	13:13	UH	Handheld	13.57104	144.94813	574	203	26	6
03/09/15	10:24	UH	Big Eyes	13.56491	144.94022	1316	66	8	5
03/09/15	11:25	UH	Handheld	13.57425	144.94813	314	6	8	6
03/09/15	13:50	UH	Big Eyes	13.57066	144.94507	547	16	10	6
03/12/15	10:03	UH	Handheld	13.57277	144.94744	371	27	12	5
2015 Count		**5**			***Maximum***	**1316**	**203**	**26**	**6 (mean)**
Total Count		**18**			***Overall Maximum***	**1316**	**203**	**101**	**5 (mean)**
Grand Total		**38**			***All Stations Overall Maximum***	**1591**	**660**	**105**	**5 (mean)**

UH = unidentified hardshell, Cm = *Chelonia mydas*

Note: Date and time are local Guam time. All sightings are single turtles.



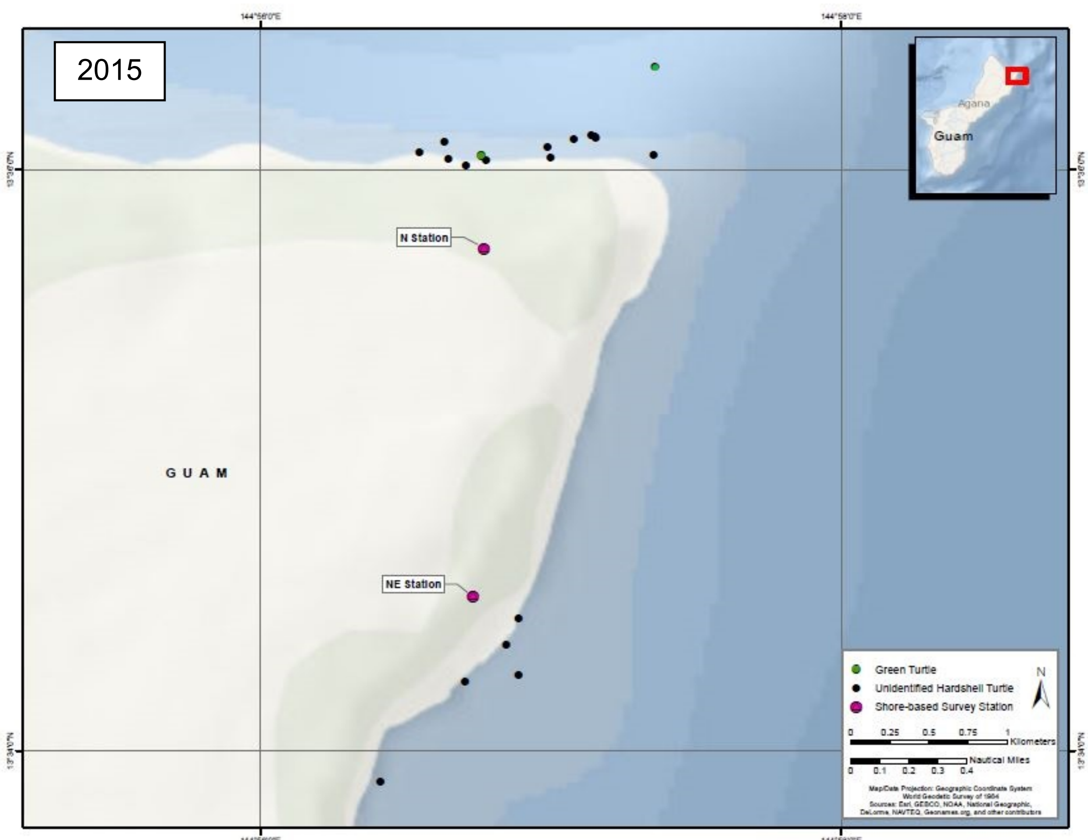


Figure 11. Map displaying all turtle sightings from the N and NE Stations over each of the 10-day surveys. Top: 2013 surveys; Bottom: 2015 surveys.

Among cetaceans, a rate of 0.486 sightings per hour (2.5 sightings per day) in 2013 was more than four times the rate of 0.11 sightings per hour (0.70 per day) in 2015 (**Table 5**). Among sea turtles, two more were sighted in 2015 than in 2013 and two more were sighted at the N station than the NE station. In May 2013, 72 percent of the turtle sightings were from the NE Station (0.44 sightings per hour) whereas in March 2015, 75 percent of the sightings were from the N Station (0.68 sightings per hour) (**Table 5**).

Table 5. Guam shore station marine mammal and sea turtle sighting rates for year 2013 and 2015.

Shore Station by Year	Observation Time (hours)	Marine Mammal Sightings	MM Sighting Rate (sightings per hour)	Turtle Sightings	Turtle Sighting Rate (sightings per hour)
N Station	25.3	9	0.36	5	0.20
NE Station	29.6	16	0.54	13	0.44
2013 Total	54.9	25	0.46	18	0.33
N Station	22.0	1	0.05	15	0.68
NE Station	41.5	6	0.14	5	0.12
2015 Total	63.5	7	0.11	20	0.31
Overall	118.4	32	0.27	38	0.32

3.3.3 Initial Sighting Method

Big Eyes were responsible for 28 percent of marine mammal sightings compared with 22 percent using handheld and 50 percent with the unaided eye (**Table 6**). The average sighting distance for Big Eyes was 7.3 km with a maximum of 15.2 km. This compares to 2.6 km for handheld with a maximum of 8.4 km. There was an average sighting distance of 0.8 km for unaided eyes with a maximum of 2.5 km. The initial cue for all sightings was the animal's body except for the melon-headed whale sighting, which was a splash.

Table 6. Proportion of sightings made by each visual method and average and maximum distances from the shore station.

Visual Method	Total Sightings	Minimum Distance from Station (km)	Maximum Distance from Station (km)	Average of Distance from Station (km)
Marine Mammals				
Big Eyes	9 (28%)	0.9	15.2	7.3
Handheld	7 (22%)	0.6	8.4	2.6
Unaided Eye	16 (50%)	0.4	2.5	0.8
Overall	32	0.4	15.2	3.0
Turtles				
Big Eyes	3 (8%)	0.6	1.6	1.2
Handheld	22 (58%)	0.3	1.2	0.7
Unaided Eye	13 (34%)	0.4	1.0	0.6
Overall	38	0.3	1.6	0.7

The majority of turtle sightings were initially made with handheld binoculars (58 percent), followed by unaided eye (34 percent) and Big Eyes (8 percent). The majority of turtle sightings were also made in BSS 6 (45 percent) and 86 percent of all sightings were made in a BSS greater than 5. Among turtle sightings, 92 percent were with handheld or unaided eye and an overall maximum of 1.6 km from shore and an average of only 0.7 km from shore.

3.3.4 Photographic Data

Various methods of photography and videography were used for the 2013 and 2015 surveys to determine which equipment was most effective at helping to determine species identification. In 2013, a Canon 7D Mark II equipped with a Canon fixed 500-mm lens was used to confirm species of spinner dolphins following the coastline at 1.9 km away (**Figure 12**) and pilot whales at distances up to 5 km away (**Figure 13**). In 2015, a Canon 7D camera with a fixed 800-mm lens was used to confirm melon-headed whales initially sighted using photos taken at distances between 3.4 and 9.0 km (Error! Reference source not found.). The initial melon-headed whale sighting was 13.9 km away, sighted with Big Eyes.

(Photo by J. Aschettino)

Figure 12. Photo taken of spinner dolphins 1.9 km away, providing species confirmation. The camera used was a Canon 7D equipped with a fixed 500-mm lens and a 1.4x teleconverter on a tripod mount.

(Photos by M. Richlen and J. Aschettino)

Figure 13. Several photos of pilot whales taken from 5 km away. The camera used was a Canon 7D equipped with a fixed 500-mm lens on a tripod mount.

(Photos by M. Richlen and J. Aschettino)

Figure 14. Photos of melon-headed whales were taken at various distances from the shore station to assist with species identification. The camera used was a Canon 7D equipped with a fixed 800-mm lens on a tripod mount.

3.3.5 Focal Follow

For the single melon-headed whale sighting, a total of 14 sighting positions were obtained by conducting a focal follow (**Figure 15)** for the purpose of confirming species and improving group size estimates.

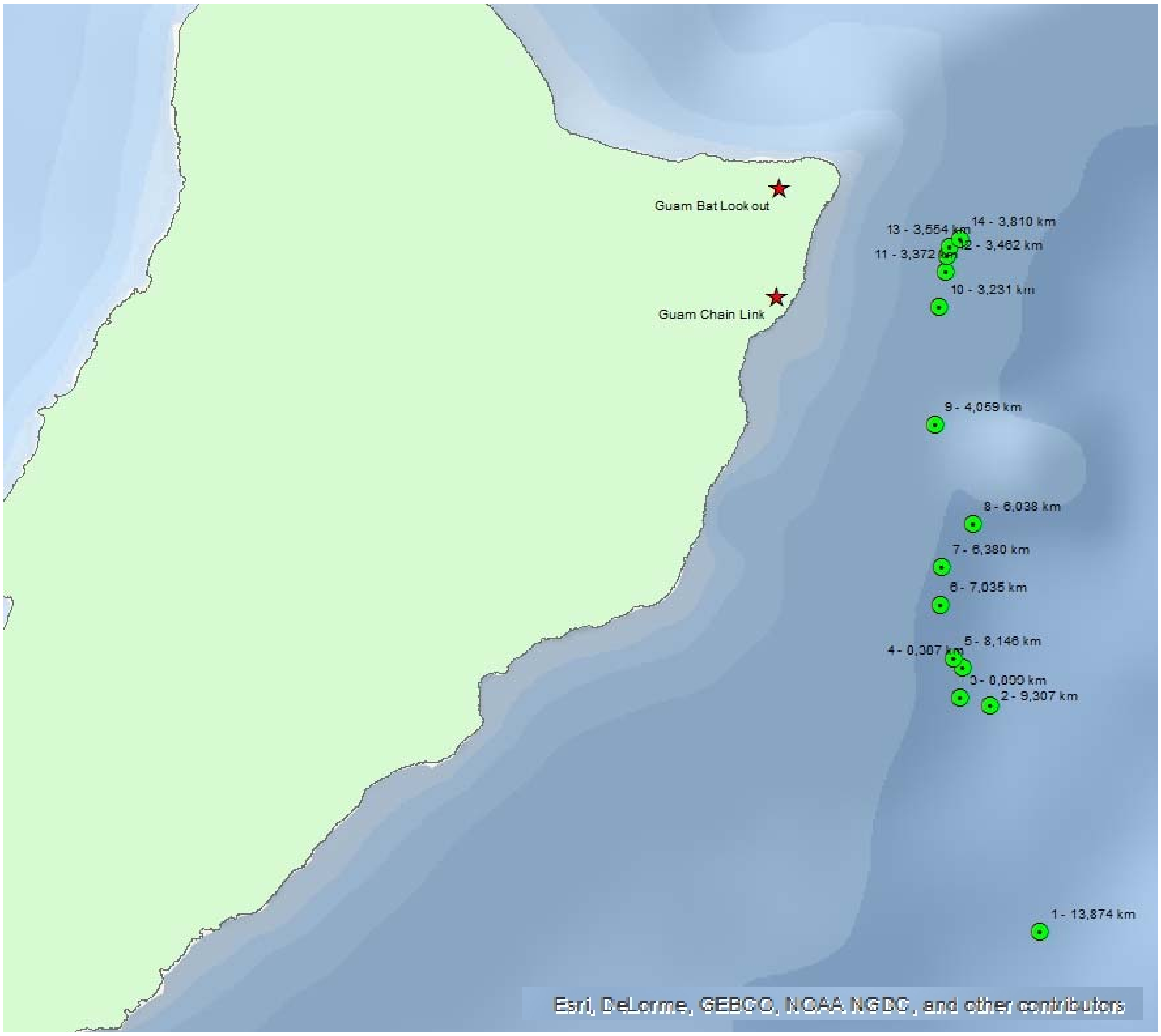


Figure 15. Map of repeat sighting positions for a group of about 160 melon-headed whales first observed with Bigeyes at a distance of 13,874 m traveling north and first photographed at a distance of 9,307 m. Due to the high BSS 5 and the group being largely spread out over multiple Big Eyes fields of view, positions do not necessarily represent the center of the group.

4. Discussion

This study surveyed for marine mammals and sea turtles on the windward side of the island of Guam, where access by small vessels is limited due to strong winds and large swells. Since the visual detection range of marine mammals offshore can limit traditional shore-based surveys, the addition of high-powered Big Eyes binoculars was incorporated into the survey method to extend the visual arena where marine mammals and sea turtles could be detected.

4.1 Hawaii Survey Big Eyes Range Estimation

To help quantify the visual detection range of the Big Eyes, 2 days of surveying were conducted on the island of Maui and one on the island of Oahu. Maui was chosen because of its high density of humpback whales during the winter breeding season and the surrounding islands of Molokai, Lanai, and Kahoolawe provide shallow waters where whales have a preference (Herman and Antinoja 1977). With prevailing trade winds coming from the northeast, the Auau channel between the islands of Maui County, has a variety of windy and calm areas providing a range of sea state conditions (BSS 0 to 6) for identifying the maximum range at which large whales can be detected. In order to extrapolate detection range results from Hawaii to the Guam shore station surveys, it was important to have a consistent BSS of 5 (the mean BSS for the 2013 Guam shore surveys) (HDR 2014) or greater.

The Hawaii effort quantified the detection range capability for large whales and demonstrated that they can be detected as far as 38 km from a shore platform that is 278 m in elevation and 22.6 km from a platform that is 65 m in elevation. Given that the Guam shore platforms are 193 and 143 m in elevation, somewhere in between the Hawaii stations, the furthest a large whale should be visible would be expected to be somewhere between 22 and 38 km.

Unusually calm winds occurred during the Maui effort when the BSS was a 2 or less, failing to replicate the average BSS of 5 on Guam. Therefore, care must be taken when interpreting the furthest estimated distance that a whale can be detected in BSS greater than 2. It should also be noted that due to the light winds from the south carrying volcanic gases from the island of Hawaii (vog), the additional haze made sighting distant large whale blows more challenging.

Although high BSS can significantly reduce an observer’s ability to see the body of a marine mammal, the impairment may be less significant for adult large whale exhalations (blows) that can reach 3 to 7 m in height. Barlow (2015) reported that the probability of detecting large whales on the trackline during line transect surveys was least affected by BSS unlike small whales and delphinoids. Relative trackline detection probabilities (RTDP) for large whales would drop by half at a BSS of approximately 5. The strong winds associated with a high BSS would likely have more of an impact by dissipating the blow quickly rather than the waves themselves keeping the blow out of view. Additionally, sightability in high BSS is often reduced due to accompanying conditions on survey vessels. The stability of a shore-based shore station reduces many effects that impair visibility during high BSS, such as increased rocking, bouncing, or other vessel movement. Thus, when considering the absence of large whale blows observed during the two 10-day surveys in 2013 and 2015, large whale blows would likely have been seen within 25 km of either shore station. The absence of large whale sightings suggests that they are either absent or very rarely occurring in the areas surveyed during the months of March and May.

For small-vessel marine mammal surveys, typically once sea conditions reach a BSS greater than 4, surveys are either terminated or the boat will transit to areas with smoother water. Given that more than 90 hours (76 percent) of Guam shore-based observation effort were conducted in a BSS of 5 or greater, the majority of this effort could not have been conducted from a small vessel as has been the only visual method in recent years (Hill et al. 2014).

4.2 Guam Marine Mammal and Sea Turtle Surveys

4.2.1 Survey Sightings

The 20 days of shore observations successfully detected 32 marine mammal and 38 sea turtle groups. The sighting rate for cetaceans in 2015 was 0.11 per hour, or 0.7 per day, a rate less than one quarter of that from the 2013 survey of 0.47 per hour, or 2.6 per day despite having an additional Big Eyes observer in 2015. This could be attributed to a seasonal difference in cetacean use of those areas in March compared to May. It may also simply be an artifact of better viewing conditions from the N Station in 2013 when seven cetacean sightings were made, mostly greater than 5 km away. However, the doubling of turtle sightings in 2015 compared with 2013 suggests that the BSS had little impact on inshore sightings.

At the N Station across years, marine mammal sightings dropped from 16 in 2013 to only 1 sighting in 2015. The same applies to the NE Station where sightings were almost three times higher in 2013 compared with 2015; however, 90 percent of those sightings were spinner dolphins. This may suggest a different use of these inshore waters during different times of the year. It is unlikely that the mean BSS of 5 in 2013 compared to a BSS 6 in 2015 would have a significant impact on the decreased sightings.

This substantial decrease in marine mammal sightings from 25 in 2013 to only 7 in 2015, despite having an additional observer and second pair of Big Eyes, not only supports the notion of very low densities of marine mammals in this area but also a possible temporal shift in use of these areas, primarily by the most dominant species sighted: spinner dolphins. However, the poorer sighting conditions in 2015 cannot be ruled out as a contributing factor to the fewer sightings. Barlow (2015) concluded that increasing BSS can have a significant impact on reducing sighting rates during line transect surveys for 17 of 20 cetacean species examined, 17 of these known to occur in Guam waters (Fulling et al. 2011). Small whale sightings including beaked whales and minke whales were most impacted by high BSS primarily due to their low profile in the water, lack of a blow or a splash during surfacings and small group sizes. The RTDP of Cuvier's beaked whales was reduced by half at a BSS 3, whereas Mesoplodon species and minke whales was reduced by half at a BSS 1.5 and Kogia species at a BSS 1. Given their habitat preference for deeper waters, it is likely that minke and beaked whales would have gone undetected if they were present due to the high BSS conditions of this study. Among the delphinoids, the RTDP among killer and pilot whales, and Risso's dolphins was reduced by half at BSS 4.5, while Dall's porpoise and stripped, spotted and bottlenose dolphins at a BSS 3, and rough-toothed dolphins a BSS 1. Given these results and the mean BSS for this study, many of the smaller delphinoids and rough-toothed dolphins may have gone undetected if present in the visual arena of this study.

Between 2010 and 2014, spinner dolphins were also the most frequently encountered species during small-vessel surveys conducted by the Pacific Islands Fisheries Science Center around Guam (Hill et al. 2014). Most of their spinner dolphin encounters were within 1 km of shore and in water depths less than 300 m. Of the 21 shore station sightings of spinner dolphins, 20 (95 percent) were sighted in water estimated to be less than 53 m deep and less than 800 m from shore.

The 38 sea turtle observations were almost evenly split between the two shore stations on Guam; however, in 2013, the majority (72 percent) of sightings were off the N Station, and in 2015 the majority (75 percent) were off the NE Station. Turtles were sighted with a mean distance offshore of 107 m in a mean estimated depth of 20 m. With the exception of three turtle sightings (8 percent), all occurred within 200 m of the shoreline. The turtle sighting rate was slightly higher for the N Station (0.42 turtles per hour) compared with the NE Station (0.32 turtles per hour). Once turtles submerged, there was no way to determine if a new turtle sighting was a new animal or if it was one previously sighted; therefore, any interpretation of the abundance of sea turtles in these areas should be treated with caution since the total number of turtle sightings likely includes many resights of the same individuals.

4.2.2 Initial Sighting Method

As would be expected, Big Eyes were useful at detecting marine mammals further offshore at an average distance of 7.3 km away. Handhelds were best for surveying the mid-range at an average distance of 2.6 km away. Lastly, unaided eye observations were best used for monitoring inshore sightings at an average distance of 0.8 km away.

Since many factors can affect the sightability of an animal during a survey (e.g., BSS, glare, the amount of body exposed during a surfacing, surface activity, or the presence of birds), caution must be exercised when interpreting the distance at which a particular species can be observed. During these surveys, an unidentified medium cetacean was seen more than 15 km out in BSS 3, an unidentified small dolphin was seen almost 8 km out in BSS 6, and a group of melon-headed whales were seen almost 14 km out in BSS 5, but each had its own unique set of cues. The first sighting had much calmer conditions, whereas the second sighting had a flock of birds as the initial cue and porpoising dolphins visible amongst them. The third sighting was composed of a large group of 160 animals with many individuals porpoising. If some of these additional cues were not present, these sightings may likely have not occurred, so care must be taken when using the distance of an offshore sighting as a detectable range for that particular species, but these sightings do provide a general idea of detectability.

Since the main benefit of having a visual shore-station survey during the winter months would be to detect baleen whales assumed to be migrating or utilizing the MIRC region seasonally, getting some sense of range for baleen whale detections (be it a blow, body, or surface active splash) would be beneficial. Unfortunately, this was not the case.

Results from these surveys support visual shore-based surveys as an effective alternative platform for detecting marine mammals and sea turtles within a large visual area that may otherwise be difficult to survey by small vessel. In particular, the efforts in Hawaii demonstrated that large whales can be seen at distances as far as 30 km offshore depending on the elevation of the shore station. Shore stations can be used to monitor bodies of water that are not conducive to small-vessel surveys because of the high winds and large waves with the understanding that some cetacean species have a very low probability of detection as BSS increases.

4.3 Monitoring Questions

4.3.1 Q1. What species of cetaceans and sea turtles occur around Guam?

Four species of cetaceans (spinner dolphins, bottlenose dolphins, short-finned pilot whales and melon-headed whales) and one species of sea turtle (green sea turtle) were confirmed around the island of Guam. Two thirds (66 percent, n=21) of all sightings were spinner dolphins. Unidentified small dolphins were the next most common (16 percent, n=5) followed by bottlenose dolphins (6 percent, n=2). Only a single sighting was made of an unidentified medium cetacean, an unidentified small whale, short-finned pilot whales and melon-headed whales. No large whales were detected following 118.5 hours of visual effort.

During the 2013 surveys from the N Station, the mean BSS conditions were a 3. Under these conditions, three unidentified small dolphins, one unidentified medium cetacean and one unidentified small whale were noted suggesting that a higher density of odontocetes may occur in these areas than what is detectable in typical sea states (mean BSS of 5 or greater) for this area.

Of the 38 sea turtle sightings, only 18 percent were confirmed as green sea turtles. One unidentified sea turtle was considered to be a possible loggerhead, based on photography (HDR 2014). Confirmation of species occurred both in the field using the Big Eyes and by reviewing photographs. The majority of these turtles (95 percent) were sighted within 200 m of shore in less than 35 m of water. Hawksbill turtles (*Eretmochelys imbricata*), known to occur in Guamian waters (Jones and Van Houtan 2013), were not detected in this study.

4.3.2 Q2. Are there locations of greater relative cetacean abundance around Guam?

Shore station visual observations focused on the north- and northeast-facing shores of Guam because of the lack of visual survey coverage in these areas due to strong winds and large swells. If observers include spinner dolphins, a species that typically stays close to the shoreline during daytime hours (Norris et al. 1994; Lammers 2004), the mean distance away from the closest point of land for all sightings was 1.96 km and at a mean estimated depth of 220 m. The majority of cetacean sightings were observed from the N Station (78 percent), and even if spinner dolphins were omitted, 73 percent of the remaining cetacean sightings were from the N Station. This could be interpreted as a greater density of cetaceans using the north side of the island or may simply be an artifact of better sighting conditions in 2013.

Spinner dolphins were often seen transiting through the area several times per day, primarily in 2013 in front of the NE Station. A new sighting was considered only when the previous sighting had moved out of view for more than an hour, but it is very likely that repeat sightings within a day were the same group of spinner dolphins. If spinner dolphins, representing 66 percent of all sightings were discounted, the mean distance away from the closest point of land for the remaining 11 sightings is 4.69 km at a mean estimated depth of 575 m.

The mean distance offshore for sightings in a BSS of 4 or less (3.85 km, 443 m estimated depth) was three times greater than for sightings observed in a BSS 5 and greater (1.22 km, 133 m estimated depth). This suggests caution must be taken when interpreting Guam shore station observations in the context of inshore and offshore odontocete habitat use.

4.3.3 Q3. Is a shore-based methodology effective at addressing the two previous questions?

The 20-day shore-based visual survey is a viable alternative for conducting marine mammal visual surveys in areas where strong winds and large swell make small-vessel surveys unsafe and large ship surveys are cost-prohibitive. The sighting rate of 0.47 per hour, or 2.6 sightings per day obtained in 2013, was greater than a sighting rate of 0.22 species per hour or 1.7 species per day from small-vessel surveys (extracted from Hill et al. 2013). The Pacific Islands Fisheries Science Center effort maps (Hill et al. 2013; Hill et al. 2014) indicate the majority of effort was between a few hundred meters to about 10 km offshore on the western side of Guam. Distant shore station sightings included an unidentified medium cetacean at 15 km away, melon-headed whales 10 km away, and two separate unidentified small dolphins greater than 8 km away. This offshore coverage is somewhat comparable with that of small-vessel work focused on waters to the north and east of Guam (see DoN 2014, Figure 4) where small-vessel surveys had little coverage previously. However, when interpreting the shore station sighting rate, resighting cetaceans that show site fidelity to an area such as spinner dolphins could inflate the sighting rate if they pass through the area multiple times per day, whereas small-vessel surveys are unlikely to resight groups of animals within the same day because survey tracks are spaced to minimize this type of pseudo-replication. Observers also identified a substantial drop in the sighting rate during 2015 by more than one quarter of the rate in 2013. This could be due to a real change in habitat use by cetaceans during March compared with May or be an artifact of poorer BSS in 2015. Although the magnification provided by Big Eyes and the photos taken with a super-telephoto lens (up to 800 mm) can greatly improve species identification; when it comes to confirming offshore, deeper water cetaceans, the small-vessel platform is a more successful option, providing that sea conditions allow surveying in these areas.

4.4 Lessons Learned

The data logging software has gone through several iterations since the surveys began in 2013. Combining theodolite fixes with Big Eyes and handheld fixes presented some challenges, but the end result was a customized Filemaker Pro relational database with a modifiable front-end interface to meet the user’s needs. Several custom calculators were incorporated into the database to allow for rapid conversion of horizontal and vertical information that could be relayed to Big Eyes, handheld or theodolite operators so they could quickly lock in on the sighting.

In 2015 several custom calculators were incorporated into the data collection software to allow for vertical information to be translated for either Big Eyes, handheld, theodolite, and/or camera operators so they could quickly locate the sighting in their viewfinder. This method was more efficient than the method used in 2013 that required reference to a printed table listing a range of matching vertical angle information between Big Eyes, handheld, and theodolite. A GPS compass on the camera body allowed the photographer to quickly home in on the horizontal bearing of the sighting.

During the Hawaii efforts to determine the maximum range of the Big Eyes for detecting large whales, the Maui shore platforms did not have sufficient elevation to fully measure the limits of the Big Eyes. Therefore, an additional survey day was conducted from a much higher elevation at Kaena Point on Oahu. Knowing the elevation and the estimated distance to the horizon prior to any survey is useful to approximate the arena that can be effectively surveyed visually and determine if that range is acceptable for survey objectives.

Big Eyes tripods were more flexible than the cement-weighted ship stanchions, since finding level ground at the sites for the stanchions was difficult. The light weight and telescopic legs of the tripods also made them much more manageable for shipping and for use in remote areas.

5. Acknowledgments

We'd like to thank the U.S. Air Force Pacific Air Forces 36th Civil Engineering Squadron, without whom this study would not have been possible: Joe Vinch, Gregg Ikehara, Jeremy Adams, Ruben Guieb and Leanne Obra of 36th Civil Engineer Squadron Environmental flight, and SSgt Austin Winegardner of 36th Civil Engineer Squadron. Additional thanks to Maj Sanderlin, U. S. Air Force, Commander, Detachment 3, 21st Space Operations Squadron Kaena Point Satellite Tracking Station, Hawaii. Thank you also to Dr. Adam S. Frankel for his valuable feedback in reviewing this report.

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