APPENDIX D

GUAM MARINE SPECIES MONITORING SURVEY, SHORE STATION FEASIBILITY STUDY

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14. ABSTRACT
In order to train with mid-frequency active sonar (MFAS), the United States (U.S.) Navy has obtained a permit from the National Marine Fisheries Service (NMFS) under the Marine Mammal Protection Act and Biological Opinion under the Endangered Species Act. The Mariana Islands Range Complex (MIRC) Monitoring Plan was developed with NMFS to comply with the requirements under the permits. The monitoring plan and reporting requirements provide science-based answers to questions regarding whether or not marine mammals are exposed to, and react to, Navy MFAS and explosives. As such, the Navy developed the MIRC Monitoring Plan to conduct activities that meet these monitoring goals. 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 hazardous. A 10-day pilot study examined the effectiveness of conducting visual observations from shore, using Big Eye and handheld binoculars and a theodolite to identify and determine the location of marine mammals and sea turtles. Two sites, on the east- and north-facing shores of Guam were surveyed for 5.5 and 4.5 days, respectively. Calibration measurements were carried out on stationary targets as far as 8.8 kilometers (km) along the shoreline with known global positioning system (GPS) locations, to measure elevation and test the accuracy of the three optic devices. Theodolite fixes on these targets proved to be a more accurate means of estimating the height of the shore station compared with using a Wide Area Augmentation System-enabled GPS. Target fixes using all three optical devices produced a mean percent error of less than 2.2 percent, indicating good accuracy by all three devices. The horizon was visible 30 km offshore on the eastern platform (157-meter [m] elevation) and 38 km offshore on the northern platform (193-m elevation). A total of 26 marine mammal

sightings were made over the 10-day survey; the majority (65 percent) being spinner dolphins (Stenella longirostris), all within 500 m of the coastline. Seven unidentified cetaceans were sighted, with the furthest being 15.2 km from shore in a Beaufort sea state (BSS) 3. The ability to answer how far large whales could be detected from a shore station could not be answered since no large whales were observed. Although small dolphins were seen at distances of 9 km in a BSS 3 or less, and dolphins leaping out of the water cued by feeding birds as far as 15 km away in a BSS 6, it is difficult to infer a general rule about how far a dolphin can be seen from a particular elevation in a particular BSS since many variables can affect sightability. The farthest successful odontocete species identification was for pilot whales (Globicephala macrorhynchus) 5.8 km away. Based on the visual detection of a small (8-m) vessel 22 km from the theodolite, it can be inferred that the splash of a surface-active large whale, which is much more visible, could be seen at that distance. Sea turtles were sighted 19 times, all within 1 km of shore primarily using handheld binoculars and by naked eye. Species observed were consistent with other visual survey platforms. A sighting rate of 0.47 sightings per hour, or 2.6 sightings per day, suggests an overall low density of marine mammals in the surveyed areas in late winter. Spinner dolphins accounted for 65 percent (17 of 26) of all marine mammal sightings and a greater number occurred on the windward, northeastern side of Guam compared with the north side. Many more offshore odontocete sightings occurred off the north-facing site, possibly due to greater concentrations of marine mammals in this area or improved visual detection capabilities in calmer waters. This study was not able to validate the full detection range capability of Big Eyes from a shore-station platform due to a lack of large whale sightings available at a range of distances.

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GUAM MARINE SPECIES MONITORING SURVEY, SHORE STATION FEASIBILITY STUDY

Final Report
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Acronyms and Abbreviations

BSS	Beaufort sea state
ESA	Endangered Species Act
GPS	global positioning system
hr	hour(s)
km	kilometer(s)
m	meter(s)
mm	millimeter(s)
MFAS	mid-frequency active sonar
min	minute(s)
MIRC	Mariana Islands Range Complex
MMPA	Marine Mammal Protection Act
NMFS	National Marine Fisheries Service
TG	triangle geometry
U.S.	United States
WAAS	Wide Area Augmentation System

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Abstract

In order to train with mid-frequency active sonar (MFAS), the United States (U.S.) Navy has obtained a permit from the National Marine Fisheries Service (NMFS) under the Marine Mammal Protection Act and Biological Opinion under the Endangered Species Act. The Mariana Islands Range Complex (MIRC) Monitoring Plan was developed with NMFS to comply with the requirements under the permits. The monitoring plan and reporting requirements provide science-based answers to questions regarding whether or not marine mammals are exposed to, and react to, Navy MFAS and explosives. As such, the Navy developed the MIRC Monitoring Plan to conduct activities that meet these monitoring goals. 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 hazardous. A 10-day pilot study examined the effectiveness of conducting visual observations from shore, using Big Eye and handheld binoculars and a theodolite to identify and determine the location of marine mammals and sea turtles. Two sites, on the east- and north-facing shores of Guam were surveyed for 5.5 and 4.5 days, respectively. Calibration measurements were carried out on stationary targets as far as 8.8 kilometers (km) along the shoreline with known global positioning system (GPS) locations, to measure elevation and test the accuracy of the three optic devices. Theodolite fixes on these targets proved to be a more accurate means of estimating the height of the shore station compared with using a Wide Area Augmentation System-enabled GPS. Target fixes using all three optical devices produced a mean percent error of less than 2.2 percent, indicating good accuracy by all three devices. The horizon was visible 30 km offshore on the eastern platform (157-meter [m] elevation) and 38 km offshore on the northern platform (193-m elevation). A total of 26 marine mammal sightings were made over the 10-day survey; the majority (65 percent) being spinner dolphins (*Stenella longirostris*), all within 500 m of the coastline. Seven unidentified cetaceans were sighted, with the furthest being 15.2 km from shore in a Beaufort sea state (BSS) 3. The ability to answer how far large whales could be detected from a shore station could not be answered since no large whales were observed. Although small dolphins were seen at distances of 9 km in a BSS 3 or less, and dolphins leaping out of the water cued by feeding birds as far as 15 km away in a BSS 6, it is difficult to infer a general rule about how far a dolphin can be seen from a particular elevation in a particular BSS since many variables can affect sightability. The farthest successful odontocete species identification was for pilot whales (*Globicephala macrorhynchus)* 5.8 km away. Based on the visual detection of a small (8-m) vessel 22 km from the theodolite, it can be inferred that the splash of a surface-active large whale, which is much more visible, could be seen at that distance. Sea turtles were sighted 19 times, all within 1 km of shore primarily using handheld binoculars and by naked eye. Species observed were consistent with other visual survey platforms. A sighting rate of 0.47 sightings per hour, or 2.6 sightings per day, suggests an overall low density of marine mammals in the surveyed areas in late winter. Spinner dolphins accounted for 65 percent (17 of 26) of all marine mammal sightings and a greater number occurred on the windward, northeastern side of Guam compared with the north side. Many more offshore odontocete sightings occurred off the north-facing site, possibly due to greater concentrations of marine mammals in this area or improved visual detection capabilities in calmer waters. This study was not able to validate the full detection range capability of Big Eyes from a shore-station platform due to a lack of large whale sightings available at a range of distances.

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Section 1 Introduction

Background

The United States (U.S.) Navy conducts military training in the Marianas Island Range Complex (MIRC) that may impact protected marine species. As such, under the Marine Mammal Protection Act (MMPA) and a Biological Opinion under the Endangered Species Act (ESA), National Marine Fisheries Service (NMFS) issues permits limiting the number of takes during training exercises. Additionally, the MIRC Monitoring Plan was drafted with NMFS to comply with the requirements under the permits. The monitoring plan and reporting requirements provide science-based answers regarding the potential impact on animals that are exposed to Navy mid-frequency active sonar (MFAS) and explosive training activities (DoN 2012).

Since the implementation of the monitoring plan, marine mammal and sea turtle monitoring in MIRC has involved small-vessel operations (Hill et al. 2013a,b,c; HDR 2012) and passive acoustic monitoring (Munger et al. 2014). Although much has been learned about species presence, abundance, distribution, and group dynamics, monitoring in MIRC presents its challenges. One of these includes visually monitoring the windward sides of islands due to strong winds and large swell, especially during the winter months.

A theodolite is a surveying instrument that can be used to calculate x/y coordinates on a map for a particular target by obtaining horizontal and vertical angles to the target (Lerczak and Hobbs 1998). This has become a useful tool for surveying large whales (e.g., Helweg and Herman 1994) and dolphins (e.g., Würsig and Würsig 1979) for: 1) measuring movement patterns and habitat preferences of near-shore groups of marine mammals (Cipriano 1992; Frankel et al. 1995; Helweg and Herman 1994; Würsig and Würsig 1979; Würsig et al. 1991; Yin 1999); 2) foraging studies (e.g., Bailey and Thompson 2006); and 3) anthropogenic impact studies (e.g., Bejder et al. 2006; Clark et al. 1983; Cox et al. 2004; Frankel and Clark 2002; Gailey et al. 2007; Lundquist et al. 2012; Malme et al. 1984; Smultea 1994; Timmel et al. 2008). In addition to documenting the behavior of marine mammals unobtrusively (Bailey and Thompson 2006), shore-based theodolite 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 cetacean occurrence of many species at once (Shelden and Rugh 2010).

The goal of this pilot study was to determine the effectiveness of a shore-based observation platform as a low-cost substitute for visually surveying marine mammals and sea turtles in areas that are difficult to survey by small vessels due to strong winds and large swell. Large ship visual surveys capable of operating in rougher waters tend to be cost prohibitive. In the MIRC, most areas are inaccessible by smaller vessels throughout the year, especially in the winter months, due to poor sea conditions. Apart from the Mariana Islands Sea Turtle and Cetacean Survey cruise, baleen whale sightings have been very infrequent in MIRC waters and are most likely to occur during the winter months (Fulling et al. 2011; Munger et al. 2014; Oleson 2014). 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 monitoring as ESA-listed species.

The survey design was developed with the goal of answering the following questions: 1) what species of cetaceans occur around Guam; 2) are there locations of greater relative cetacean abundance around Guam; and 3) are shore-based visual surveys an effective method to address the previous two questions. Additionally, an assessment of the methodology itself was carried out to better understand the calculation of shore-station elevations, and the accuracy of high power Big Eye binoculars, handheld binoculars, and theodolite. Lastly the functionality of the software program "Mysticetus" (www.mysticetus.com) for shore-station work was beta-tested in the field for the first time with the objective of refining, debugging, and validating the software's configurations, layout, and computations.

Section 2 Methods

A preliminary shore station was setup at Napili Bay in Maui, Hawaii, for the purpose of field testing the data collection software and theodolite. Theodolite fixes were taken at the waterline on a person holding a global positioning system (GPS). The GPS coordinates were used to measure the elevation of the theodolite and the accuracy of its fixes.

On Guam, suitable shore-station locations were assessed by driving the perimeter of the island and investigating elevated shoreline vantage points that were easily accessible with a wide unobstructed visual field, high enough to provide good range with minimal setback inland from the shoreline, and overlooking waters that were difficult to survey by small vessel. The two locations most suitable were both on the Andersen Air Force Base. The first was situated 300 meters (m) inland on the northeastern corner of the island facing the windward side of Guam (**Figure 1**) which will be referred to as "Shore Station 1[1]." The second shore station was also located on the northeastern corner of Guam, 500 m inland, facing north towards the island of Rota (**Figure 2**), and will be referred to as "Shore Station 2[2]."

An integral component to obtaining accurate positions (fixes) is having a precise measure of the elevation of the theodolite above sea level. Although several methods exist (Bailey and Lusseau 2004; Frankel et al. 2009; Würsig et al. 1991), some require a person to stand at the waterline or to have a clear view of stationary targets of known location at the water line or on the water. Unfortunately, clear visibility of the waterline is not always feasible, nor is having someone with a GPS in hand visible on the water; therefore, an automated approach is sometimes necessary.

A Wide Area Augmentation System (WAAS)-enabled GPS can be used to obtain elevation readings. For this study, altitude (elevation) data were read directly from a GPS device that was communicating and downloading data to the "Mysticetus" software.

Equipment

The equipment used for shore-station surveys included one pair of high-powered Fujinon 25 × 150-millimeter (mm) MTM Big Eye binoculars with mounting stanchion (**Figure 3**), two pairs of Fujinon 7 × 50-mm FMTRC-SX Polaris handheld reticle binoculars with a magnetic compass bearing and monopod mount, a Sokkia DT5 theodolite interfacing with a Lenovo laptop computer with Mysticetus software, and a Garmin 76 WAAS-enabled GPS. Additionally, a tripod mounted Canon 7D APS-C Digital Single Lens Reflex (DSLR) camera equipped with a fixed 500-mm lens (Canon f/4L IS III USM) and a Canon 1.4x teleconverter (Extender EF 1.4x III) was used to document sightings as well as confirm species identification, group size, and animal behavioral state (if possible).

[1] This site, at 13.57550′N 144.94552′E, is also known as Installation Restoration Program (IRP) site 9.
[2] This site, at 13.59542′N 144.94615′E, is adjacent to what is also known as IRP site 12.

Figure 1. Map of Shore Station 1 location looking northeast.

Figure 2. Map of Shore Station 2 location looking west.

Figure 3. Big Eye binoculars with mounting stanchion stabilized with cinder blocks (photograph by J. Aschettino).

Surveys

A GPS position of the theodolite at each shore station was recorded in addition to a horizontal reference point (a visible antennae or communication tower at least one mile away). The true bearing between the theodolite position and the reference target was used to calibrate the theodolite and the Big Eyes to true north. A team of four observers scanned the waters continuously roughly between 0800 and 1600 each day. Each observer rotated amongst four stations every 30 minutes (min): 1) Big Eye scans; 2) data recorder; 3) handheld scans; and 4) theodolite operator. Surveying ceased for one hour for lunch. Each observer scanned the entire visual arena in front of the shore station. For each binocular sighting, a true north bearing (Big Eye) or magnetic bearing (handheld) was provided to the recorder and entered into Mysticetus, which then calculated the location of the sighting and plotted an estimated location on a map. Big Eye reticles were converted using a 0.0779 arc angle per reticle, and handheld reticles were converted using a 0.2943 arc angle per reticle as per the manufacturer's specifications. The Big Eye observer focused primarily on the offshore areas since they had the greatest magnification and obtaining a proper reticle reading requires viewing the horizon at the first reticle marker in the viewfinder, which is not possible when viewing too close to shore. The handheld observer focused more on the inshore waters. Although not "primary" observers, the computer and theodolite operators also scanned for sightings with handheld binoculars or by naked eye when not occupied with other tasks. The theodolite operator attempted to get a fix on all marine mammal sightings, even if a fix was obtained using Big Eyes. During sightings, observers would opportunistically take photos using the telephoto lens as long as they were not already engaged in tracking or fixing the animals with any other method during the sighting.

At the start and end of each day and following each observer rotation, the computer operator entered the environmental conditions, which included Beaufort sea state (BSS), percentage of the visual field with severe glare, and percentage of the visual area covered by clouds.

For details on theodolite setup and observer protocols, see **Appendix A.**

Elevation

When a known position at sea level is visible from the shore station, the angle measured by the theodolite to that position can be used to estimate the elevation of the Theodolite using triangle geometry (TG) (see **Appendix B** for calculations). When a known position at sea level is not visible from the shore station, a WAAS-enabled GPS can be used to estimate the elevation of the shore station.

A WAAS GPS was used to calculate the elevation of Shore Station 1 where known sea level positions were not obtainable. Elevation readings were taken every 10 seconds for a minimum of 5 minutes and a mean of all elevations were calculated. WAAS GPS systems are reported to have accuracy within 3 m 95 percent of the time (http://www8.garmin.com/aboutGPS/waas.html).

At Shore Station 2, TG was used on six known sea-level positions to calculate elevation. The mean elevation estimated here was used as the eye level of the theodolite for this shore station. A strong enough WAAS GPS signal could not be received at Shore Station 2 in order to obtain an elevation.

Accuracy

Distinct landmarks with known geographic coordinates at the shoreline (taken with one handheld GPS), visible from Shore Station 2, were used to get fixes with the theodolite, Big Eyes, and handheld binoculars. The difference between the actual position and the estimated position was calculated using a percent error to compare the accuracy of each optic device.

Additionally, during survey scans, boats were routinely fixed with each of the optical devices at the same time for comparison. Although the actual position is not known, the accuracies of Big Eye and handheld binoculars fixes were compared to the position fixed by the theodolite.

Range

At each of the Guam shore stations, a series of fixes were obtained on the horizon to get a sense of the size of the arena from each particular elevation. In addition, boats of various sizes were fixed to get a sense of the distance from which a target of a particular size could be observed with respect to BSS.

Section 3 Results

Elevation

Napili Bay Shore Station Elevation

The only location in which both WAAS GPS elevation readings and fixes on known locations at sea level were obtained was at the Napili Bay station. WAAS GPS elevation readings were obtained every second for 7 minutes and ranged from 10.52 m to 18.01 m, with a mean elevation of 12.92 m (SD=1.54, N=423). For a direct comparison, the elevation was also calculated using TG on 12 different known sea-level GPS coordinates relative to the theodolite site. Using this method, estimated elevations ranged from 8.33 m to 12.10 m with a mean elevation of 9.40 m (SD=1.05, N=12).

Both of these mean elevation estimates were used to plot estimated positions to compare with the known GPS positions. Using the WAAS GPS mean elevation of 12.92 m, there was a mean error of 95.02 m (SD=58.44, N=12), while the TG elevation of 9.40 yielded a mean error of 13.31 m (SD=5.93, N=12).

Shore Station 1 Elevation

WAAS GPS elevation readings were taken on four different days at Shore Station 1 to examine daily variations in these readings (**Table 1**). The mean elevation for all GPS measurements taken over a total of 27 minutes was 156.70 m (SD=3.66, N=1197), with a minimum of 147.40 m and a maximum of 170.80 m. Since no known positions at sea level were possible to fix on due to steep cliffs and a lack of access to the shoreline, the elevation of this station was only estimated using the GPS method.

Table 1. WAAS GPS Altitude Readings over 4 Days at Shore Station 1 on Guam.

Date	Elevation Min (m)	Elevation Max (m)	Elevation Mean (m)	STD	Total GPS Readings
5/11/2013	154.70	170.80	161.37	4.48	173
5/12/2013	154.40	158.00	156.01	0.80	569
5/13/2013	147.40	154.60	151.18	1.34	188
5/14/2013	156.90	164.20	159.03	1.54	267
Total	**147.40**	**170.80**	**156.70**	**3.66**	**1197**

Shore Station 2 Elevation

A clear WAAS GPS signal was not obtainable at Shore Station 2 so this method was not used to obtain elevation. Instead, six known GPS locations at sea level, visible from the shore station, were used to calculate the elevation using TG. The mean elevation at Shore Station 2 using this method was 192.92 m (SD=0.46, N=6), with a minimum of 192.44 m and a maximum of 193.50 m.

Accuracy

Six sea-level GPS coordinates between 6.0 km and 8.5 km away from the precise theodolite location at Shore Station 2 were obtained (**Table 2**). With known sea-level coordinates visible from the shore station, one can measure the accuracy of the shore-station fixes using various optical devices. At Shore Station 2, fixes were taken with the theodolite, Big Eyes, and handheld binoculars on the six targets at sea level of known location. The difference between the estimated fixed position and the actual position for each optical method was quantified using percent error (**Table 2**). A comparison of how closely the estimated position using each of the optical devices is shown in **Table 2**. The mean error was smallest for theodolite fixes (0.20 percent), followed by handheld binoculars (1.51 percent) and Big Eyes (2.11 percent). In addition, several boats on the water were fixed by multiple optical devices to compare how closely each optical device would estimate each vessel's position. The distance from the theodolite of each fix and the percent error in comparison with the theodolite fix are shown in **Table 3**. The mean percent error for Big Eyes when fixing on the same boat as the theodolite was 4.25 percent compared with 7.99 percent when fixing with the handheld binoculars.

Table 2. 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 Shore Station 2.

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**

Table 3. Fixes on boats comparing the percent error of Big Eye and handheld binocular fixes from its corresponding theodolite fix.

Boat #	Type	Theodolite Distance (km)	Big Eye		Handheld Binoculars	
			Distance (km)	% Error	Distance (km)	% Error
5	n/a	12.39	12.09	2	n/a	n/a
7	20–25'	21.85	20.79	5	n/a	n/a
10	n/a	24.62	n/a	n/a	22.47	9
11	n/a	22.96	21.98	4	19.61	15
13	n/a	13.11	12.92	1	11.98	9
14	20–25'	21.63	22.51	4	21.38	1
17	n/a	22.79	21.17	7	20.92	8
Mean				**4.02**		**8.26**

n/a = data not collected

Range

The mean distance to the horizon from Shore Station 1 (158 m elevation estimated by WAAS GPS) was 30.18 km, and from Shore Station 2, (193-m elevation estimated by TG) was 38.56 km, (shaded areas seen in **Figure 4**). The horizontal angle of view was 126 degrees and 149 degrees for Shore Stations 1 and 2 respectively. The longest distance for a fix on a small 6–8-m vessel was 21.85 km.

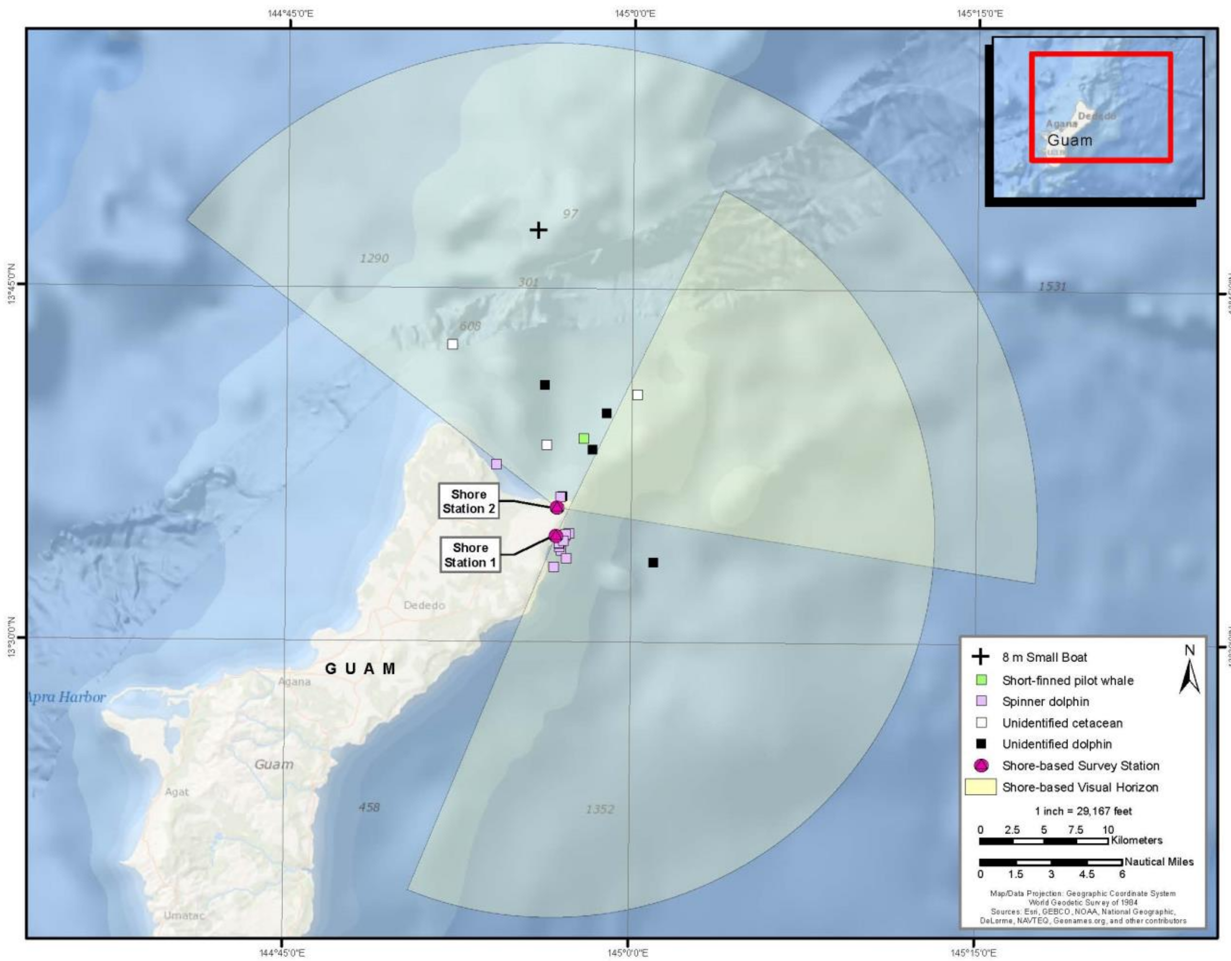

Figure 4. Map showing Shore Stations 1 and 2, all marine mammal sightings from 10 days of visual surveys, and the furthest small-boat fix. The estimated sighting range to the horizon is shaded for each of the two respective sites.

Sightings

A total of 26 marine mammal sightings were made during the 10 survey days. The majority of these sightings (N=17, 65 percent) were spinner dolphins (*Stenella longirostris*), which were sighted within 2 km from shore. The next greatest number were unidentified small dolphins (N=5, 19 percent), followed by one pilot whale (*Globicephala macrorhynchus*) sighting, one unidentified small whale sighting, and one unidentified medium cetacean sighting (**Table 4** and **Figure 4**). Water depths estimated by the charted depth for each fix ranged from 17 m (150 m away from shore) for spinner dolphins to 1,203 m (7.23 km away from shore) for an unidentified

Table 4. Guam shore station marine mammal sightings between 11 and 20 May 2013.

Date	Time	Species	Initial Sighting Method	Latitude (North)	Longitude (East)	Distance from Theodolite (km)	Distance from Shore (km)	Depth (m)	Beaufort Sea State
Shore Station 1, Elevation 156.70 m									
05/11/13	15:48	Sl	Naked Eye	13.5650	144.9494	1.24	0.80	49	5
05/11/13	16:04	Sl	Naked Eye	13.5771	144.9550	1.04	0.53	53	5
05/12/13	10:17	Sl	Naked Eye	13.5744	144.9502	0.51	0.20	19	4
05/12/13	11:53	Sl	Naked Eye	13.5675	144.9482	0.93	0.22	38	5
05/12/13	13:34	Sl	Naked Eye	13.5531	144.9443	2.50	0.47	52	5
05/13/13	9:10	Sl	Naked Eye	13.5722	144.9498	0.59	0.29	26	5
05/13/13	10:34	Sl	Naked Eye	13.5756	144.9524	0.74	0.34	29	6
05/13/13	11:00	USD	Big Eye	13.5570	145.0161	7.91	7.23	1203	6
05/13/13	13:51	Sl	Naked Eye	13.5758	144.9504	0.53	0.15	17	5
05/13/13	13:57	Sl	Handheld	13.5725	144.9509	0.67	0.38	31	5
05/13/13	14:19	Sl	Naked Eye	13.5744	144.9502	0.52	0.20	20	5
05/14/13	9:07	Sl	Naked Eye	13.5697	144.9482	0.71	0.37	31	5
05/14/13	13:39	Sl	Naked Eye	13.5700	144.9477	0.65	0.30	24	6
05/14/13	14:24	Sl	Big Eye	13.5591	144.9530	1.99	1.47	110	6
05/15/13	11:15	Sl	Handheld	13.5759	144.9527	0.78	0.35	30	6
05/16/13	10:53	Sl	Handheld	13.5717	144.9511	0.73	0.43	35	6
Mean						**1.38**	**0.86**	**110**	**5.31**
Shore Station 2, Elevation 192.44 m									
05/17/13	16:10	Sl	Big Eye	13.6255	144.9021	5.82	0.38	26	5
05/18/13	14:24	Gm	Handheld	13.6442	144.9651	5.80	5.02	720	3
05/18/13	15:04	USD	Big Eye	13.6368	144.9718	5.37	4.48	617	3
05/18/13	16:06	USD	Handheld	13.6622	144.9821	8.38	7.52	783	3
05/19/13	9:33	UMC	Big Eye	13.7100	144.8698	15.18	5.88	458	3
05/19/13	11:33	USW	Big Eye	13.6396	144.9382	4.99	4.27	557	3
05/19/13	13:45	USD	Big Eye	13.6820	144.9369	9.67	6.65	718	3
05/19/13	14:58	USD	Naked Eye	13.6036	144.9504	1.02	0.31	70	4
05/20/13	10:24	Sl	Big Eye	13.6028	144.9486	0.86	0.28	49	4
Mean						**6.34**	**3.87**	**444**	**3.44**

MM = marine mammal, Sl = *Stenella longirostris*, USD = unidentified small dolphin, Gm = *Globicephala macrorhyncus*, UMC = unidentified medium cetacean, , USW = unidentified small whale

Note: Date and time are local Guam time.

small delphinid. The furthest sighting was an unidentified medium cetacean at an estimated chart depth of 458 m (15.18 km from the theodolite) but only 5.88 km from the shoreline. The furthest sighting able to be identified to species was the pilot whale sighting at 5.8 km from the theodolite (5.02 km from the shoreline).

A total of 19 sea turtles were sighted over the 10-day survey, all within 1 km from the shore and in water less than 101 m deep (**Table 5**, **Figure 5**). All turtles were initially classified as unidentified hardshell but upon further examination of photos by a subject matter expert (Meredith Fagan, NAVFAC Pacific, pers. comm.), six were confirmed as green sea turtles (*Chelonia mydas*; **Figure 6**). Photographs of the turtle sighting of 13:44 on May 12 featured a larger triangular head and brown carapace coloration possibly indicative of a loggerhead sea turtle (*Caretta caretta*), but positive species identification was not possible because the carapace appeared circular in the photograph, and scute numbers were not able to be counted (**Figure 7**). The furthest turtle sighted from the theodolite station was 1.22 km away but no more than 170 m from the shoreline. Sightings were made with handheld binoculars for 58 percent of the turtle sightings and by naked eye for the remaining 42 percent. The near shore portions of water directly in front of the shore station were scanned primarily using handheld binoculars and unaided naked eye methods while the Big Eyes were used to focus primarily offshore.

Table 5. Guam shore station turtle sightings between 11 and 20 May 2013.

Date	Time	Species	Initial Sighting Method	Latitude (North)	Longitude (East)	Distance from Theodolite (km)	Distance from Shore (km)	Depth (m)	Beaufort Sea State
Shore Station 1, Elevation 156.70 m									
05/12/13	9:58	UH	Handheld	13.5730	144.9465	0.29	0.17	26	4
05/12/13	13:19	Cm	Naked Eye	13.5718	144.9472	0.44	0.11	17	5
05/12/13	13:44	UH	Handheld	13.5716	144.9468	0.46	0.11	17	5
05/12/13	14:36	UH	Handheld	13.5717	144.9472	0.46	0.13	18	5
05/13/13	11:30	UH	Naked Eye	13.5729	144.9478	0.38	0.08	11	6
05/13/13	13:28	Cm	Handheld	13.5740	144.9490	0.41	0.13	16	5
05/13/13	14:01	UH	Handheld	13.5732	144.9488	0.43	0.14	16	5
05/13/13	14:03	Cm	Handheld	13.5736	144.9482	0.36	0.07	10	5
05/14/13	11:30	UH	Naked Eye	13.5731	144.9431	0.37	0.00	101	6
05/14/13	13:44	UH	Naked Eye	13.5735	144.9482	0.37	0.07	10	6
05/14/13	15:12	Cm	Naked Eye	13.5736	144.9482	0.35	0.07	9	6
05/15/13	14:14	Cm	Naked Eye	13.5731	144.9483	0.39	0.09	15	6
05/16/13	11:48	UH	Naked Eye	13.5733	144.9487	0.42	0.13	16	6
Mean						**0.40**	**0.10**	**21.85**	**5.38**
Shore Station 2, Elevation 192.44 m									
05/17/13	10:02	Cm	Naked Eye	13.6009	144.9453	0.62	0.08	18	5
05/17/13	14:32	UH	Handheld	13.6002	144.9564	1.22	0.10	8	5
05/20/13	10:11	UH	Handheld	13.6008	144.9471	0.61	0.07	13	4
05/20/13	14:26	UH	Handheld	13.6014	144.9499	0.78	0.10	17	3
05/20/13	14:26	UH	Handheld	13.6019	144.9535	1.07	0.15	10	3
05/20/13	15:39	UH	Handheld	13.6015	144.9479	0.70	0.15	16	3
Mean						**0.83**	**0.11**	**13.67**	**3.83**

UH = unidentified hardshell, Cm = *Chelonia mydas*

Note: Date and time are local Guam time.

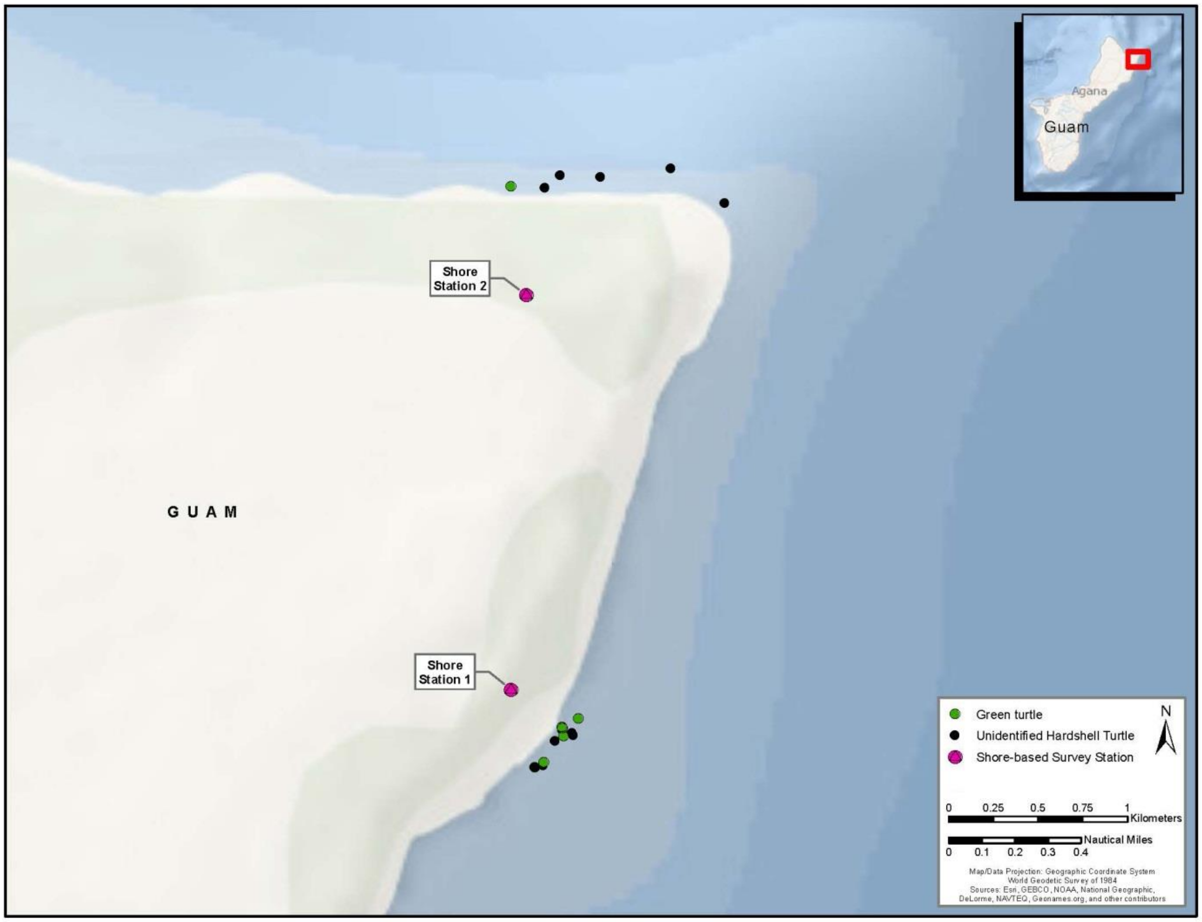

Figure 5. Map displaying all turtle sightings from the 10-day survey at Shore Stations 1 and 2.

Figure 6. Photos of a green sea turtle taken close to shore for species identification (photograph by J. Aschettino).

Figure 7. Unidentified sea turtle on 12 May 2014 at 13:44.
(photograph by J. Aschettino).
Visible features include large triangular head, brown coloration but circular carapace.

Beaufort Sea State

BSS conditions ranged from 3 to 6; however, it should be noted that these were average conditions for the entire visual arena. BSS along the coastline was sometimes more calm than conditions offshore. Sighting conditions closer to shore were generally much better than offshore conditions and the mean BSS was a reflection of offshore conditions or the majority of the visual arena. The mean BSS for the 29 hours of survey effort at Shore Station 1 was 5.31 and 4.00 for the 27 hours of survey effort at Shore Station 2. The mean BSS in which a marine mammal was observed at Shore Station 1 was 5.31 compared with 3.44 at Shore Station 2. However, if we only include sightings that were greater than 500 m offshore, which are more representative of the BSS, the mean sighting BSS for Shore Station 1 was 5.50 (n=4) and the mean BSS for Shore Station 2 was 3.00 (n=6).

Section 4 Discussion

The goal of this study was to examine the feasibility of a shore-station platform as a method to visually survey marine mammals and sea turtles on the windward sides of the islands in MIRC, where access by small vessels is usually unsafe and not feasible due to strong winds and large swell, and large-vessel surveys are cost prohibitive.

Elevation

The first component of accuracy needed for estimating the location of fixed targets at sea is a known elevation. This can be difficult when working in remote areas where the elevation of the shore station is unknown.

For estimating the elevation of a shore station, the WAAS GPS elevations showed much more variability (10 m across 4 days), compared with the TG method using known locations along the shoreline, at sea level, which are visible from the shore station. The TG method should be used as the primary elevation method with the WAAS GPS method as an alternative when known GPS coordinates at sea level are not possible, such as with the Shore Station 1. When both methods were used at the same shore-station site (Napili Bay on Maui), almost one third more variability occurred with the WAAS GPS elevation estimates compared with measurements using known sea level coordinates.

An overestimate of the elevation will plot fixes further away, and an underestimate will plot fixes much closer than they actually are. When theodolite fixes are taken of targets at known positions and consistently plot the estimated position too far or too close, this is likely an indication that the estimated elevation of the shore station is inaccurate. Based on the results from the Napili Bay shore station and Shore Station 2, where fixes were taken on known GPS locations at sea level, the elevation is presumed to be relatively accurate since calculated positions were not consistently closer or further than the actual position, indicating the elevation calculated using the TG method was relatively precise. It should be noted that the elevation of the two Guam shore stations (157m and 192 m) was substantially higher than other reported shore station platforms that are typically below 100 m in elevation (e.g., Bailey and Thompson 2006; Bejder et al. 2006; Cipriano 1992; Cox et al. 2004; Gailey et al. 2007; Frankel and Clark 2002; Würsig and Würsig 1979).

Accuracy

All three optics proved to be very accurate methods at estimating the position of targets relative to one another when a bearing and reticle could be obtained. The theodolite was 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. The accuracy of handheld binoculars was very good considering the difficulty in maintaining the top reticle mark, in the viewfinder, level with the horizon when taking a reticle reading, or estimating the reticles if the sighting was too close to shore and the horizon could not be maintained in the viewfinder. The accuracy of handheld binocular reticles in providing range was also reported by Yin et al. (2005), and, for this study, binoculars were mounted on monopods to help aid in stability.

Range

One of the shortcomings of traditional shore-based visual surveys is the limited range capability of detecting marine mammals far offshore. Adding Big Eyes as a surveying tool greatly expanded the range. Big Eye sightings accounted for six of the eight sightings that were 5 km and further away from the theodolite. Although the horizon itself could be viewed as far as 38 km away at Shore Station 2, this is not indicative of the range capability for detecting marine mammals. Many variables will influence the detectability of a sighting including the size of the animal, the number of animals in the group, whether or not it produces a blow, arches its back or lifts a tail out of the water when diving, and whether or not it is surface active. Sea conditions (BSS and swell height), weather (rain and haze), and sun glare are also significant factors in the detectability of a marine mammal. Since all these variables can change independently at any time, quantifying a sightability range is difficult. For example, an unidentified small dolphin was detected with the Big Eyes at 7.91 km away from the theodolite in BSS 6. This particular sighting was cued by a flock of birds that were diving at the surface (likely feeding on a school of fish), creating large splashes that were visible beyond the visual noise of the poor sea state. Careful focus on the flock of birds enabled the observer to catch a glimpse of two dolphins leaping out of the water. So although a sighting was made of a small dolphin at almost 8 km in BSS 6, it would not be fair to say that, in general, the detectability range of a small dolphin in BSS 6 would be 8 km.

An unidentified medium cetacean was also observed 15 km away from the shore station in BSS 3. Again, one cannot make a general rule about a detection range for medium cetaceans in BSS 3. However, these sightings do provide some insight on how far some marine mammals may be seen from a shore station of a certain elevation. Maps provided by Hill et al. (2013b) of the area covered in their small-vessel survey report show their effort ranged to about 20 km offshore with relatively uniform coverage of the water, suggesting a conservative average of 10 km offshore. This comparison, although not systematically computed, provides context of the shore-station visual range with that of small-vessel surveys.

Since the main benefit of having a shore-station visual 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 no large whales were detected in this study but some idea of baleen whale detectability can be inferred from sightings of less visible species and small vessels. Large whale blows can be quite visible at very long distances and splashes from surface activity such as breaches can be seen even further. A small 6–8-m boat was fixed at just under 22 km from the shore station. Since the splash produced from a surface-active large whale could be more visible than an 8 m boat, it may be safe to say that large surface-active whales could be seen as far out as 22 km. Once again, many variables come into play with detectability such as the length of time the signal is available to the observer (a boat is constantly visible at the surface whereas the whale signal is dependent on the number of surface-active behaviors performed), and therefore an interpretation of detectability must be treated with caution as the context of the signal can have many forms.

These data do show promise that shore-based visual surveys can be an effective platform for locating and plotting marine mammals and sea turtles within a large arena greater than 10 km offshore, that may otherwise be problematic for small-vessel visual surveys. Shore-based surveys can assist visual marine species monitoring during the winter months, when baleen whales are more likely to be seen, or could complement small-vessel visual surveys by monitoring the windward sides of the islands. The methods could also be used simultaneously to further assess the level of accuracy for marine mammal species identification and estimation of group size.

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

The 10-day shore station survey successfully detected 26 marine mammal and 20 sea turtle sightings demonstrating this research method is capable of helping to answer the question of what protected species occur around Guam and Saipan where suitable shoreline vantage points exist. A sighting rate of 0.47 sightings per hour, or 2.6 sightings per day, suggests that low densities of marine mammals occur in the surveyed areas. Of these sightings, 65 percent were spinner dolphins and this may also be indicative of low species diversity close to shore around islands in the MIRC. These low density observations are consistent with small-vessel surveys conducted in the entire MIRC region resulting in 0.22 species per hour or 1.7 species per day with 48 percent being spinner dolphins (interpreted from Hill et al. 2013a). However, unlike small-vessel surveys, the ability to approach the animals for photo-identification is not possible from a shore station, though photographs taken with the 500-mm fixed lens binoculars on a tripod with a teleconverter could be used to identify very distinct dolphin individuals traveling close to shore (**Figure 8**) and could be used to help identify species over 5 km away (pilot whales in **Figure 9**). As a result 7 out of 26 (27 percent) sightings were listed as unconfirmed species identifications compared with all 43 sightings identified to species by the small-vessel surveys in 2013 (Hill et al. 2013a). Therefore, although detecting marine mammals is possible from relatively long horizontal distances using Big Eyes, confirming species is much more difficult. Only two species were confirmed; spinner dolphins and pilot whales. Other than one unidentified medium cetacean, no baleen whales or beaked whales were observed, and there are no new species to report for this area. A large-vessel visual survey conducted in the winter of 2007 (Fulling et al. 2011) did not observe any baleen whales in the areas surveyed from shore in this study.

Sea turtles were commonly sighted within 200 m of the shoreline primarily on the northeast side of Guam and occasionally along the northern coastline. Of the 19 unidentified turtle sightings, photos analysis confirmed six as green, one as a possible loggerhead, and the rest unknown. Although hawksbill turtles (*Eretmochelys imbricata*) are known to occur in Guam waters (Jones and Van Houtan 2013), none were confirmed in this study.

Figure 8. Photo taken from Shore Station 1 of spinner dolphins, providing species confirmation (photograph by J. Aschettino).

Figure 9. Several photos of pilot whales taken from 5 km away with a Canon camera mounted on a tripod equipped with a 500-mm lens and a 1.4 teleconverter (photographs by M. Richlen and J. Aschettino).

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

A greater number of spinner dolphin sightings occurred on the northeastern coast of Guam (15) compared with the northern coast (2). Spinner dolphins were also observed transiting through the area several times per day, but only after the dolphins moved out of visual range and returned, was the next sighting considered a new sighting since it was not possible to determine if a group that moved out of visual range was the same group as one seen later in the day. Sea turtles were also regularly seen along this northeastern coastline in waters shallower than 100 m and within 1 km from the shoreline. 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.

Of the seven sightings of unidentified species of dolphin or small whale, six were on the north side of Guam in waters around 1,200 m deep. This could be an indicator of greater densities of more “deep water” marine mammals concentrating on northern habitats, or may simply be an artifact of better sighting conditions on the north side.

Estimated water depths, from a bathymetric chart, at each sighting position ranged from 17 m for a spinner dolphin (observed 530 m horizontally from the shoreline) to 1,203 m for an unidentified small dolphin sighted 7.91 km offshore. The furthest sighting from the island was an unidentified medium cetacean at 15.18 km offshore where the water was estimated to be 468 m deep.

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

The 10-day shore-based visual survey proved to be a cost effective and viable alternative for conducting marine mammal visual surveys in areas where strong winds and large swell make small-vessel surveys challenging, and large ship surveys are often cost-prohibitive. The sighting rate of 0.47 per hour, or 2.6 sightings per day (65 percent being spinner dolphins) was greater than a sighting rate of 0.22 species per hour or 1.7 species per day (48 percent being spinner dolphins) obtained from small boat surveys (extracted from Hill et al. 2013b). However, more coastal, shallow water species are more likely to be identified to species unless the cues offshore are very obvious and conspicuous. The Pacific Islands Fisheries Science Center effort maps (Hill et al. 2013b) indicate the majority of effort was between a few hundred meters offshore to about 10 km offshore on the western side of Guam. Shore station sightings of marine mammals 4–8 km offshore suggests offshore coverage is somewhat comparable with that of small-vessel work, and focused on waters to the north and east of Guam where small-vessel surveys had little coverage. It should be noted that when it comes to confirming offshore, deeper-water cetaceans, the small vessel platform is much more successful.

Lessons Learned

Mysticetus, the data collection software used in this study, presented some challenges, as the new theodolite functionality had not yet been beta tested from a field study platform. Since the study has been completed, and as a direct result of these efforts, the software has been greatly improved. The implementation of this newly developed software made evident the importance of validating all algorithms used to estimate position information based on azimuth and declination inputs. Validation can be done by fixing on targets at sea level with known positions such as shoreline features at sea level on land or a boat equipped with a GPS that can provide a time synced location.

The low density of marine mammals characteristic of this region makes it difficult to assess the full capability of this visual survey platform. The absence of baleen whale observations after 10 days of surveys could be an accurate assessment of low density baleen whale presence considering similar results from other visual surveys in the same area also yielded no sightings. However, without evidence of baleen whale sightings at various distances from the theodolite, quantifying how much of the visual arena can be properly surveyed for baleen whales is difficult to say. Further investigation of range capability is warranted, especially for the detection of large whales, a priority species under the MIRC monitoring plan.

The further distances of sightings obtained with the Big Eyes posed a challenge for the theodolite operator when trying to locate the sighting with the theodolite. The same was found to be true for the camera operator trying to locate the sighting in the field of view of the fixed camera lens on a tripod. Having a table to convert Big Eye reticles to a theodolite vertical angle proved useful in improving the theodolite operator's ability to fix on the sighting. Additionally, providing a reference to a visual cue such as a cloud, boat, or birds in close proximity of the sighting was useful to assist both the theodolite and camera operators to more quickly locate the sighting in the viewfinder.

Section 5 Literature Cited

Bailey, H., and Lusseau, D. (2004). Increasing the precision of theodolite tracking: modified technique to calculate the altitude of land-based observation sites. *Marine Mammal Science, 20*(4), 880-885.

Bailey, H., and Thompson, P. (2006). Quantitative analysis of bottlenose dolphin movement patterns and their relationship with foraging. *Journal of Animal Ecology*, *75*(2), 456-465.

Bejder, L., Samuels, A., Whitehead, H., and Gales, N. (2006). Interpreting short-term behavioural responses to disturbance within a longitudinal perspective. *Animal Behaviour*, *72*(5), 1149-1158.

Cipriano F.W. (1992). Behavior and Occurrence Patterns, Feeding Ecology, and Life History of Dusky Dolphins *(Lagenorhynchus obscurus)* off Kaikoura, New Zealand, Department of Ecology and Evolutionary Biology, University of Arizona, Tucson, Arizona. pp. 219.

Clark C., Tyack P., Bird J., and Rowtree V. (1983). Effects of underwater noise on migrating gray whales off the coast of California. *Journal of the Acoustical Society of America* 74:S54.

Cox, T. M., Read, A. J., Swanner, D., Urian, K., and Waples, D. (2004). Behavioral responses of bottlenose dolphins, *Tursiops truncatus*, to gillnets and acoustic alarms. *Biological Conservation*, *115*(2), 203-212.

DoN (Department of the Navy) (2012). Mariana Islands Range Complex Marine Species Monitoring Plan, FY13-2015. Prepared for the National Marine Fisheries Service, Office of Protected Resources by U.S. Pacific Fleet Environmental Readiness Office, Pearl Harbor, HI.

Frankel A.S., and Clark C.W. (2002) ATOC and other factors affecting the distribution and abundance of humpback whales (Megaptera novaeangliae) off the north shore of Kauai. *Marine Mammal Science* 18:644-662. DOI: 10.1111/j.1748-7692.2002.tb01064.x.

Frankel A.S., Clark C.W., Herman L.M., Gabriele C.M. (1995). Spatial distribution, habitat utilization, and social interactions of humpback whales, *Megaptera novaeangliae*, off Hawai'i, determined using acoustic and visual techniques. *Canadian Journal of Zoology*. 73:1134-1146. DOI: 10.1139/z95-135.

Frankel, A. S., Yin, S., and Hoffhines, M. A. (2009). Alternative methods for determining the altitude of theodolite observation stations. *Marine Mammal Science, 25*(1), 214-220.

Fulling, G.L., Thorson, P.H. and Rivers, J. (2011). Distribution and abundance estimates for cetaceans in the waters off Guam and the Commonwealth of the Northern Mariana Islands. *Pacific Science* 65, 321-343.

Gailey, G., Würsig, B., and McDonald, T. L. (2007). Abundance, behavior, and movement patterns of western gray whales in relation to a 3-D seismic survey, Northeast Sakhalin Island, Russia. *Environmental Monitoring and Assessment*, *134*(1-3), 75-91.

HDR. (2012). *Guam and Saipan Marine Species Monitoring: Winter-Spring Survey 15-29 March*. Prepared for U.S. Pacific Fleet and submitted to Naval Facilities Engineering Command (NAVFAC) Pacific, Pearl Harbor, Hawaii, under Contract No. N62470-10-D-3011 Task Order 17, issued to HDR, Inc. 15 November 2012.

Helweg D.A., and Herman L.M. (1994). Diurnal patterns of behavior and group membership of humpback whales (*Megaptera novaeangliae*) wintering in Hawaiian waters. *Ethology* 98:298-311.

Hill M.C., A.D. Ligon, M.H. Deakos, A.C. Ü, A.J. Milette-Winfree, and E.M. Oleson. (2013c). Cetacean Surveys of Guam and CNMI Waters: May – July, 2012: Including Individual Photo-Identification of Pilot Whales, Spinner Dolphins and Bottlenose Dolphins (2010-2012). Prepared for the U.S. Pacific Fleet Environmental Readiness Office, Pearl Harbor, HI. PIFSC Data Report DR-13-001. Pacific Islands Fisheries Science Center, Honolulu, HI. 40 pp.

Hill M.C., A.D. Ligon, M.H. Deakos, A.C. Ü, and E.M. Oleson. (2013b). Cetacean Surveys of Guam and CNMI Waters: June–July 2013. Prepared for the U.S. Pacific Fleet Environmental Readiness Office. PIFSC Data Report DR-13-019. Pacific Islands Fisheries Science Center, Honolulu, HI. 21 pp.

Hill, M., A. Ligon, A. Ü, M. Deakos, and E. Oleson. (2013a). Marianas Cetacean Surveys 2013: Guam, Rota, Saipan, Tinian and Aguijan (19 June–31 July). PIFSC Data Report DR-13-017. Pacific Islands Fisheries Science Center, Honolulu, HI. 40 pp.

Jones, T.J., and K.S. Van Houtan. 2013. Sea Turtle Tagging in the Mariana Islands Range Complex (MIRC). Interim Report. Prepared for the U.S. Navy by the Marine Turtle Assessment Group, Protected Species Division, Pacific Islands Fisheries Science Center, National Marine Fisheries Service, Honolulu, HI.

Lerczak J.A., and Hobbs R.C. (1998). Calculating sighting distances from angular readings during shipboard, aerial, and shore-based marine mammal surveys. *Marine Mammal Science* 14:590-598. DOI: 10.1111/j.1748-7692.1998.tb00745.x.

Lundquist, D., Gemmell, N. J., and Würsig, B. (2012). Behavioural responses of dusky dolphin groups (*Lagenorhynchus obscurus*) to tour vessels off Kaikoura, New Zealand. *PloS one*, *7*(7), e41969.

Malme C.I., Miles P.R., Clark C.W., P. T., and Bird J.E. (1984). Investigations of the Potential Effects of Underwater Noise from Petroleum Industry Activities on Migrating Gray Whale Behavior. Phase 2: January 1984 Migration, Technical Report PB-86-218377/XAB; BBN-5586, Bolt, Beranek and Newman, Inc., Cambridge, Massachusetts.

Munger, L.M., M.O. Lammers, and W.W.L. Au. (2014). Passive Acoustic Monitoring for Cetaceans within the Mariana Islands Range Complex (MIRC). Preliminary Report. Submitted to Naval Facilities Engineering Command Pacific, Honolulu, HI under Contract No. N62470-10-D-3011, Task Orders KB14 and KB 17, issued to HDR Inc., Honolulu, HI. Prepared by Oceanwide Science Institute, Honolulu, Hawaii and Hawaii Institute of Marine Biology, Kaneohe, HI. February 2014.

Oleson, E. (2014). Interim Progress Report: Analysis of Long-term Acoustic Datasets from MIRC. Report prepared under Agreement No. NOAA-NMFS-PIFSC-13-008 between National Marine Fisheries Service and the U.S. Navy.

Shelden, K. E., and Rugh, D. J. (2010). Forty years of winter: Cetaceans observed during the southbound migration of gray whales, *Eschrichtius robustus*, near Granite Canyon, central California. *Marine Fisheries Review*, *72*(4), 1-19.

Smultea M.A. (1994). Segregation by humpback whale (*Megaptera novaeangliae*) cows with a calf in coastal habitat near the island of Hawaii. *Canadian Journal of Zoology* 72:805-811.

Timmel, G., Courbis, S., Sargeant-Green, H., and Markowitz, H. (2008). Effects of human traffic on the movement patterns of Hawaiian spinner dolphins (*Stenella longirostris*) in Kealakekua Bay, Hawaii. *Aquatic Mammals*, *34*(4), 402-411.

Würsig B., Würsig M. (1979). Behavior and ecology of the bottlenose dolphin, *Tursiops truncatus*, in the south Atlantic. *Fisheries Bulletin* 77:399-412.

Würsig, B., Cipriano, F., and Wiirsig, M. (1991). Dolphin movement patterns: information from radio and theodolite tracking studies. *Dolphin societies: discoveries and puzzles*, 79-111.

Yin S., Frankel A.S., Gabriele C.M., and Rickards S.H. (2005). Using compass and reticle binoculars to measure animal position: an evaluation and comparison to theodolite data, Poster presented at the Sixteenth Biennial Conference, Society for Marine Mammalogy, San Diego, CA. December 2005.

Yin S.E. (1999). Movement Patterns, Behaviors, and Whistle Sounds of Dolphin Groups off Kaikoura, New Zealand, Texas A&M University, Galveston, Texas. pp. 117 pp.

Appendix A: Guam Shore Station Protocol

Calibrating Horizontal Angle

Calibrating the horizontal bearing of the theodolite requires knowing the location of the theodolite and the location of a target that can be fixed by the theodolite. Obtain a WAAS GPS position at the shore station and a second GPS reading of a target that can be seen from the shore station but over 2 miles away. The further away the target is from the theodolite, the better. The bearing calculated from the theodolite position to the target is used to calibrate the theodolite azimuth. Once the theodolite is level, turn it on its horizontal axis until it reads the true bearing to the target. Lock the bearing so that when the theodolite turns the number remains. Fix the theodolite onto the reference target and unlock the horizontal. The theodolite is now calibrated to true north.

Presence/Absence Scans

A team of four observers will rotate 30 min on the Big Eyes, 30 min recording, 30 min with the handheld binoculars, and 30 min on break. Rotations will occur every half hour with a one-hour break for lunch. Survey effort will begin at 08:00 and cease at 16:00, weather permitting. In the event of a sighting, the person on Big Eyes, handheld binoculars, and theodolite will attempt to obtain fixes on the sighting. The person on break will take over the theodolite position. At the end of the day (16:00) all effort will be ceased and equipment will be dismantled and stored. If a sighting is in progress, then an attempt to confirm species, group size, orientation, and speed of travel will continue.

Timeline

07:30 – setup (tent, tables, chairs, Big Eyes, tripod, theodolite, computer)
08:00 – On Effort (Big Eyes, Naked Eye, Recorder, Off)
08:30 – Rotate Observers
09:00 – Rotate Observers
09:30 – Rotate Observers
10:00 – Rotate Observers
10:30 – Rotate Observers
11:00 – Rotate Observers
12:00 – lunch break
13:00 – Resume Effort
13:30 – Rotate Observers
14:00 – Rotate Observers
14:30 – Rotate Observers
15:00 – Rotate Observers
15:30 – Rotate Observers
16:00 – Off Effort – breakdown

Position #1: Big Eye Observer

a) Scan all visible waters just below the horizon. Report sightings by calling out the angle and reticle to the recorder, the initial cue, initial guess on species ID, orientation, speed, and initial group size.

b) Provide resight information when possible. The final species ID and group size will be used for that sighting.

c) Provide angle and reticle information for sightings by others and attempt to confirm species, orientation, speed, and group size.

d) Provide angle and reticle information for any objects of interest (e.g., ships).

Position #2: Handheld binocular Observer

a) Scan all visible waters just below the horizon. Report sightings by calling out the angle and reticle to the recorder, the initial cue, initial guess on species ID, orientation, speed, and initial group size.

b) Provide resight information when possible (no closer than 2 minutes apart). The final species ID and group size will be used for that sighting.

c) Provide angle and reticle information for sightings by others and attempt to confirm species, orientation, speed, and group size.

d) Provide angle and reticle information for any objects of interest (e.g., ships).

e) Take photos using the Canon camera on a tripod equipped with a 500-mm lens (with 1.4 teleconverter) to obtain species ID photographs of a sighting, whenever possible, and provide recorder with frame numbers.

Position #3: Data Recorder

a) Create a new Mysticetus file with the current date at the start of the day.

b) Add all environmental information (wind, cloud cover, sea state, glare, swell, visibility, quality).

c) Update observer information and add an "on effort" entry if observers are not already on effort.

d) Record sightings (sighting #, observer, primary cue, ocular method, initial species ID and group size, orientation, speed of travel).

e) Record resights of sightings along with any updated variables (species ID, group size, orientation).

f) Record objects of interest (sighting#, observer, object description, orientation, speed of travel).

g) Be sure to prompt the observer for any missing information.

h) Coordinate the efforts of the entire team during sightings.

Position #4: Theodolite Operator (also the 30 min off position)

a) Balance tripod at the start of the day.

b) Balance theodolite at the start of AM and PM sessions.

c) Attempt to fix on all sightings and resightings by cueing the recorder to push the proper key on the computer "ready…fix."

d) Fix on all targets of interest.

Behavioral Focal Follow Protocol

The goal for focal following groups or individuals will be to attempt a one-hour focal session each day, if possible, to assess the feasibility of using Mysticetus to conduct focal behavioral observations. Preference will be given to dolphin species due to more frequent surfacings, behavior state changes, and behavioral events. Determination of which groups are suitable for focal follows will be at the discretion of the survey leader.

Position #1: Big Eye Observer

a) Maintain visual contact with sighting as long as possible.

b) Call out the angle and reticle to the recorder if theodolite fixes are not obtainable.

c) Report species ID, orientation (relative to true north), speed, and group size.

d) Call out all behaviors including first surfacings, behavior state changes, behavioral events, and report any other interesting occurrences (e.g., other boats in close proximity).

Position #2: Handheld binocular Observer

a) Assist Big Eye operator in tracking the sighting.

b) Call out the angle and reticle of the sighting if theodolite or Big Eye operators are unable to fix the sighting.

c) Continue scanning the entire area for opportunistic sightings and report relevant information to the recorder (angle, reticle, species ID, orientation, speed, group size).

d) Take photos using the Canon camera on a tripod equipped with a 500 mm lens (and 1.4 teleconverter) to obtain species ID photographs of each sighting whenever possible and provide recorder with frame numbers.

Position #3: Data Recorder

a) Create a new “focal follow” Mysticetus file.

b) Record all sighting and behavioral information as reported from the observers during regular intervals or opportunistically.

c) If the sighting is lost, provide direction to the observers on where the animals are likely to be based on the map trackline.

d) If angles and reticles are given by an observer, be sure to record the appropriate visual method for proper reticle conversion.

e) Be sure to prompt the observer for any missing information.

Position #4: Theodolite Operator (also the 30 min off position)

a) Fix on all sightings and resightings possible by cueing the recorder to push the proper key on the computer “ready…fix.”

b) Fix on all targets of interest.

c) Provide resight information when possible (every minute).

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Appendix B. Shore Station Calculations

Calculating the distance between two geographic coordinates:

Latitude 1 (decimal degrees) = LAT1

Latitude 2 (decimal degrees) = LAT2

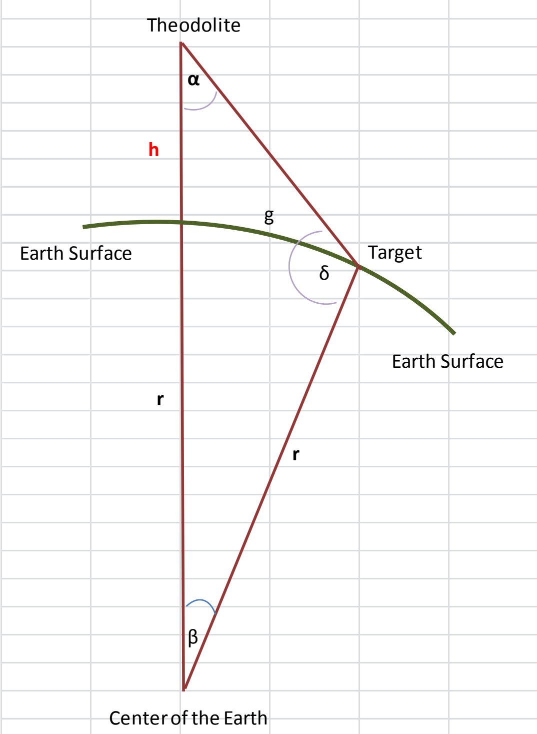
Longitude 1 (decimal degrees) = LON1

Longitude 2 (decimal degrees) = LON2

Radius of the Earth = 6370.97 km or 3958.73 nm = RE

Distance between two geographic coordinates in kilometers = RE * ((2 * ASIN(SQRT((SIN((RADIANS(LAT1 * 24)-RADIANS(LAT2 * 24))/2)^2)+COS(RADIANS(LAT1 * 24)) * COS(RADIANS(LAT2 *2 4)) * (SIN((RADIANS(LON1 * 24)-RADIANS(LON2 * 24))/2)^2)))))

Calculating Elevation using Triangle Geometry



r = radius of the Earth (6,371,000 m)
Earth Circumference = 2*pi*r = 40,075 km
α = angle from the theodolite to the target at sea level
g = arc length at se-level between theodolite and target
β = angle from center of the Earth to theo and the target at sea level
δ = angle from the target to theodolite and the center of the Earth
h = height of the theodolite above sea level

r = known
α = measured with theodolite
g = ACOS(SIN(lat1)*SIN(lat2)+COS(lat1)*COS(lat2)*COS(lon2-lon1))*r
β = (180*g)/(pi*r)
δ = 180 - β - α
h = r/sin(α)*sin(δ) - r

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