SURVEY OF THE MARINE MAMMALS OF OKINAWA (SUMMO) PROJECT

Contract No. N62470-10-D-3011, CTO KB13

FINAL REPORT

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Cover Photo: Dwarf sperm whale (*Kogia sima*) observed on 25 May 2012, offshore of the southeastern portion of Okinawa. Photographed by T.A. Jefferson.

Executive Summary

The Survey of the Marine Mammals of Okinawa (SuMMO) Project was conducted by HDR in 2011-2012, on behalf of the U. S. Marine Corps (USMC), to fulfill the requirements for updating the Integrated Natural Resources / Cultural Resources Management Plan (INRCRMP) for Marine Corps Base (MCB) Camp Smedley D. Butler. There were five tasks: (1) literature and stranding review, (2) deployment and retrieval of three passive acoustic monitoring devices (PAMs), (3) 26 days of small-vessel field work, (4) analysis of PAM data, and (5) reporting. The literature and stranding review provided historical background, data gap identification, and an accurate species list for an area in which no previous systematic surveys of marine mammals have occurred. The vessel surveys, the first systematic surveys of marine mammals in Okinawa, were conducted during 8 days of field work in October 2011 and 18 days during May 2012, providing some seasonal information. A total of 913 kilometers (km) of line-transect survey effort was conducted in four survey areas in the USMC water surface areas (WSAs) around Okinawa (Ie Shima, Camp Schwab, Kin Bay, and Tsuken). Only a single on-effort sighting of common bottlenose dolphins was made, in addition to five off-effort sightings (three of humpback whales, one of dwarf sperm whales, and one of bottlenose dolphins). The PAMs were Ecological Acoustic Recorders (EARs) and were deployed between late October 2011 and late May 2012. The very low sighting rates and acoustic detection rates strongly suggest that (other than possibly for humpback whales in winter) cetaceans occur in low densities in the study area. This may be related to heavy and uncontrolled hunting of small cetaceans by local people in these waters over the last several decades.

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Acronyms and Abbreviations

BSS	Beaufort Sea State
EAR	Ecological Acoustic Recorder
FGS	Final Governing Standards
GoJ	Government of Japan
INRCRMP	Integrated Natural Resources / Cultural Resources Management Plan
JEGS	Japan Environmental Governing Standards
km	kilometer(s)
km^2	square kilometer(s)
m	meter(s)
mm	millimeter(s)
MMO	Marine Mammal Observer
NTR	Navy Technical Representative
NAVFAC PAC	Naval Facilities Engineering Command, Pacific
PAM	Passive acoustic monitoring
SOW	Scope of Work
SuMMO	Survey of the Marine Mammals of Okinawa
TPjM	Technical Project Manager
USMC	United States Marine Corps
WSA	Water Surface Area

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Section 1 Introduction

The United States military maintains Marine Corps, Navy, and Air Force installations on the Japanese island of Okinawa in the western Pacific Ocean. Naval Facilities Engineering Command Pacific (NAVFAC PAC) has executed a marine mammal monitoring project for the U.S. Marine Corps (USMC) for up to eight water surface areas (WSAs) adjacent to USMC installations in Okinawa. This monitoring will update the Integrated Natural Resources/Cultural Resources Management Plan (INRCRMP) developed for Marine Corps Base (MCB) Camp Smedley D. Butler. Chapter 13 of the Japan Environmental Governing Standards (JEGS) establishes criteria for required plans and programs needed to ensure proper protection, enhancement, and management of natural resources and any species (flora or fauna) declared endangered or threatened by either the U.S. or the appropriate Government of Japan (GoJ) authorities. JEGS Section 13.3.1 requires installations in Japan that have land and water areas shall to take reasonable steps to protect and enhance known endangered or threatened species and GoJ-protected species and their habitat. To meet this policy requirement, JEGS Section C13.3.3 requires that installations with significant land or water areas coordinate with the appropriate GoJ authorities to develop natural resources management plans. JEGS Section C13.3.4 provides that installations may conduct surveys to determine the presence of any threatened or endangered species or GoJ-protected species and to implement natural resources management plans, "if financially and otherwise practical and in such a way that there is no net loss of mission capability.

The Survey of the Marine Mammals of Okinawa (SuMMO) Project was conducted in 2011-2012 by HDR, at the request of the USMC, to fulfill the requirements described above. This report, along with the three appendices, describes the results of the project.

Project Objectives

The HDR Monitoring Team was tasked to determine the baseline occurrence of marine mammals within the WSAs of Okinawa, Japan, through proven marine mammal monitoring and research techniques, by concentrating on the following three goals:

1. To advance the knowledge of marine mammals that may be found in the USMC WSAs adjacent to Okinawa.
2. To advance the knowledge of the seasonal and diel patterns of marine mammals within the WSAs.
3. To advance the knowledge of the spatial distribution of marine mammals within the WSAs.

Project Tasks

Task 1 – Literature Search, Translation, and Stranding Data. The first task was a comprehensive literature review, compilation of stranding reports, and translation of articles (translations conducted by K. Sekiguchi) published on marine mammals in Okinawa, especially after 2005, when the Department of the Navy Marine Resource Assessment for the Japan and Okinawa Operating Complex (DoN 2005) was completed. The Technical Project Manager (TPjM), Dr. Thomas Jefferson, identified local experts to assist in identifying relevant literature.

Findings were sorted into three categories: high relevance, intermediate relevance, and low relevance. Translations were initiated based on ranking. The results of this literature review and assessment are presented in **Appendix A**.

Task 2 – Deploy and Retrieve PAM (Passive Acoustic Monitoring) Devices. Deployment and retrieval of three Ecological Acoustic Recorders (EARs) were conducted during the first and last small-vessel survey, respectively. The TPjM coordinated with the Navy Technical Representative (NTR) and a marine mammal biologist/acoustician from University of Hawaii regarding exact locations. The deployment was made without the use of a dive team. The devices used acoustic releases so that a dive team was not required for retrieval.

HDR subcontractor Dr. Whitlow Au (University of Hawaii) prepared the EARs for deployment. The EARs had the following capabilities as outlined in the Scope of Work (SOW): variable depths (10-500 meter [m]) or shallow water; ability to detect a variety of marine species; minimum sampling rate of 44.1 kHz; ability to calibrate; deployable and recoverable with a self-release mechanism; and high success rate of recovery.

Task 3 – Small-Vessel Surveys. The HDR Monitoring Team designed and conducted two small-vessel surveys (totaling 26 days) to establish baseline data on marine mammals in the WSAs in Okinawa. Jefferson served as Chief Scientist for the project. The other Marine Mammal Observers (MMOs) consisted of a NAVFAC PAC biologist (Ms. Morgan Richie), one local Japanese MMO (Dr. Keiko Sekiguchi), and an additional HDR staff MMO (Mr. Michael Richlen), who is also qualified as an acoustician. All observers had extensive experience in marine mammal observation and/or survey, and were familiar with the common species of marine mammals found around Okinawa. The survey team produced a detailed survey plan, which described how field work was maximized for characterization of marine mammal presence, distribution, population structure, and density (see **Appendix B**).

The survey was designed to include a combination of line-transect and photo-ID mark/recapture methods to obtain density/abundance information for as many species of marine mammals as possible. There is a local small-cetacean fishery (Nishiwaki and Uchida 1977), and some species were expected to be difficult to approach for photography, due to being evasive, so having sighting rate and density data from the line-transect component was considered important. On days when poor weather conditions prevented vessel-based monitoring, the survey team conducted shore-based marine mammal monitoring from high vantage points on land. Observers used Canon 18X image-stabilized binoculars to conduct a complete scan of the viewable water area every 15 minutes, and naked eye scans were conducted in between.

Task 4 – Analyze PAM data. The HDR subcontractor (Au) and his staff performed the analysis of the EAR data. Measures that could be taken were agreed upon by the NTR, HDR, and the subcontractor prior to analysis. These measures included a description of the diversity of marine mammal species (cetacean and sirenian) captured on the recording to the highest degree of confidence possible, the types of vocalizations, seasonal patterns, and diel patterns of detections. The preliminary results of the PAM monitoring are presented in **Appendix C**.

Task 5 - Reporting. Preliminary Draft Reports were generated for small-vessel surveys and PAM data analysis. This final report combines all elements of this task order and includes graphics as described in the Deliverables section of the SOW.

Section 2 Materials and Methods

Study Area

Okinawa (see **Figure 1**) is among the southern Ryukyu Islands and is governed by Okinawa Prefecture, one of the 47 self-governing units within Japan. Because of its proximity to Southeast Asia, Okinawa has been desirable as a location for Unites States military installations (DoN 2005). There are currently seven USMC camps on Okinawa: Schwab, Hansen, Courtney, McTureous, Lester, Foster and Kinser. There is one USMC air station, Futenma. There are six training areas: Jungle Warfare Training Center, Central Training Area, Kin Blue Beach Training Area, Kin Red Beach Training Area, Ie Shima Training Facility and Tsuken Training Area.

There were four primary survey areas, which collectively cover five USMC WSAs adjacent to the coastline of Okinawa and its associated islands:

1. *Camp Schwab* – a 115-square kilometer (km^2) survey area directly offshore of Camp Schwab and Henoko Ammunition Storage Point (ASP) (see **Figure 2**). The continental shelf edge is at the outer edge of the survey area, beyond which is the Ryukyu Trench. The Schwab WSA is relatively shallow on the southeastern end (approximately 100 m) and becomes deeper at the northeastern end (approximately 500 m). A fringing reef blocks the entrance to Oura Bay, except for a narrow channel that provides access to Camp Schwab beach-based boat launches and a commercial small-boat harbor. The surrounding land area is relatively undeveloped in comparison to Kin Bay and Tsuken.
2. *Kin Bay* – a 146-km^2 area covering Kin Bay and several USMC WSAs off the east coast of Okinawa. The entire area is on the continental shelf (see **Figure 3**). Nearly the entire survey area is shallower than 65 m, with the northeastern corner being the deepest at approximately 50-65 m. The surrounding land area is highly developed with industrial facilities.
3. *Tsuken Training Area* – a 61-km^2 trapezoidal area on the continental shelf off Okinawa's east coast (see **Figure 4**). The survey area is relatively shallow with nearly the entire survey area being shallower than 60 m.
4. *Ie Shima Range* – a 979-km^2 area off the northwestern side of the small island of Ie Shima on Okinawa's west coast. The shelf edge cuts across the middle of the survey area, and this area contains the deepest waters of the entire study area, over 500 m deep (see **Figure 5**).

Okinawa and the other Ryukyu islands have a subtropical climate, with a rainy season extending from May to June (average over 2,000 millimeters [mm]/year). High humidity and high winds occur throughout the year. Typhoon season extends from May to November, with a peak in August and September. Okinawa lies in what is considered the Pacific Ocean's "Typhoon Alley," and usually three or four storms pass through annually (DoN 2005).

The locations of the survey areas are all within 20 kilometers (km) of shore and therefore relatively shallow, compared to the nearby Ryukyu Trench (see **Figure 1**). This trench is a feature within 100 km of Okinawa where the Philippine Sea Plate is subducting under the

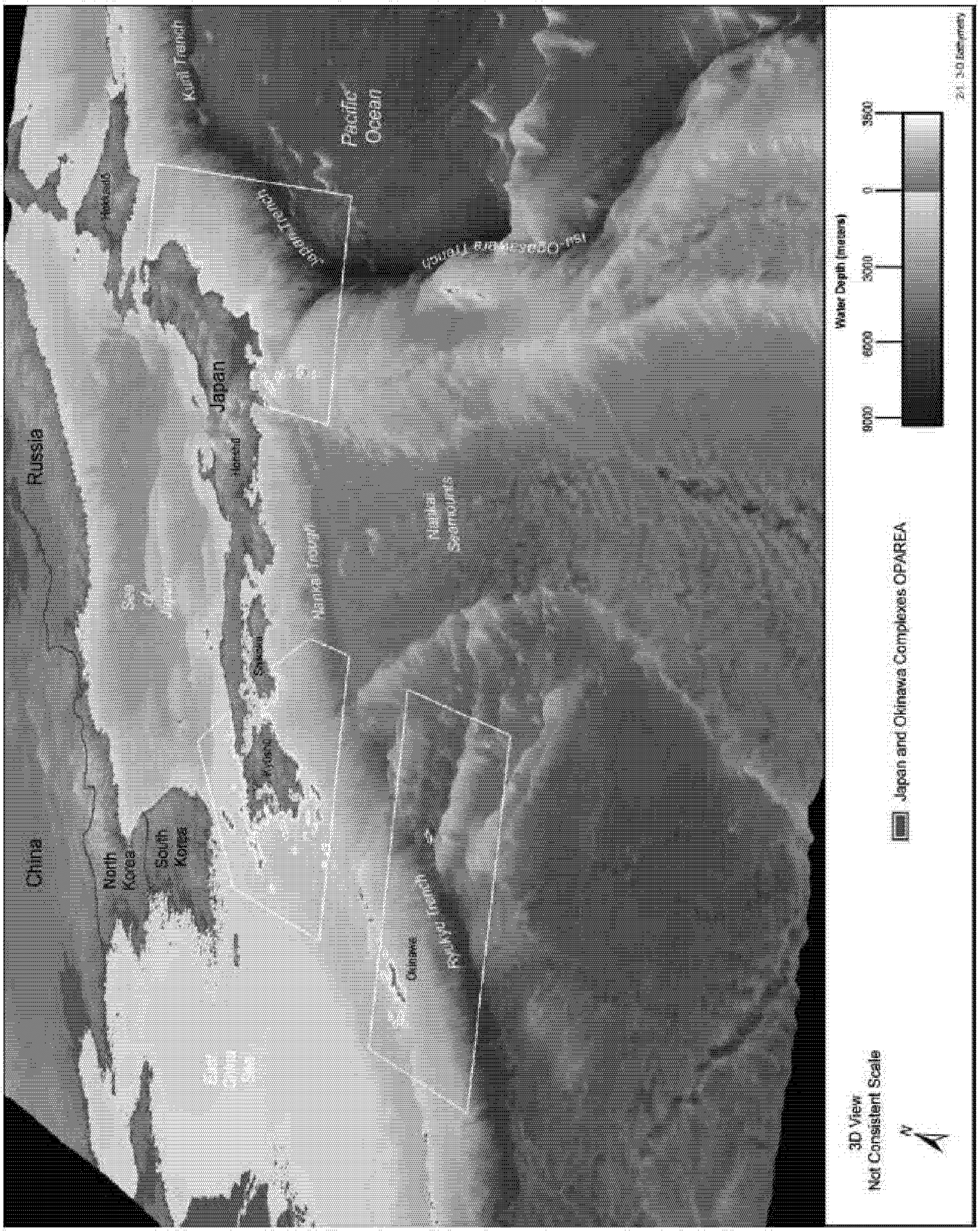

Figure 1. Map showing the location of Okinawa, and geographic context in the western North Pacific Ocean. Navy OPAREA boundaries are also shown in white.

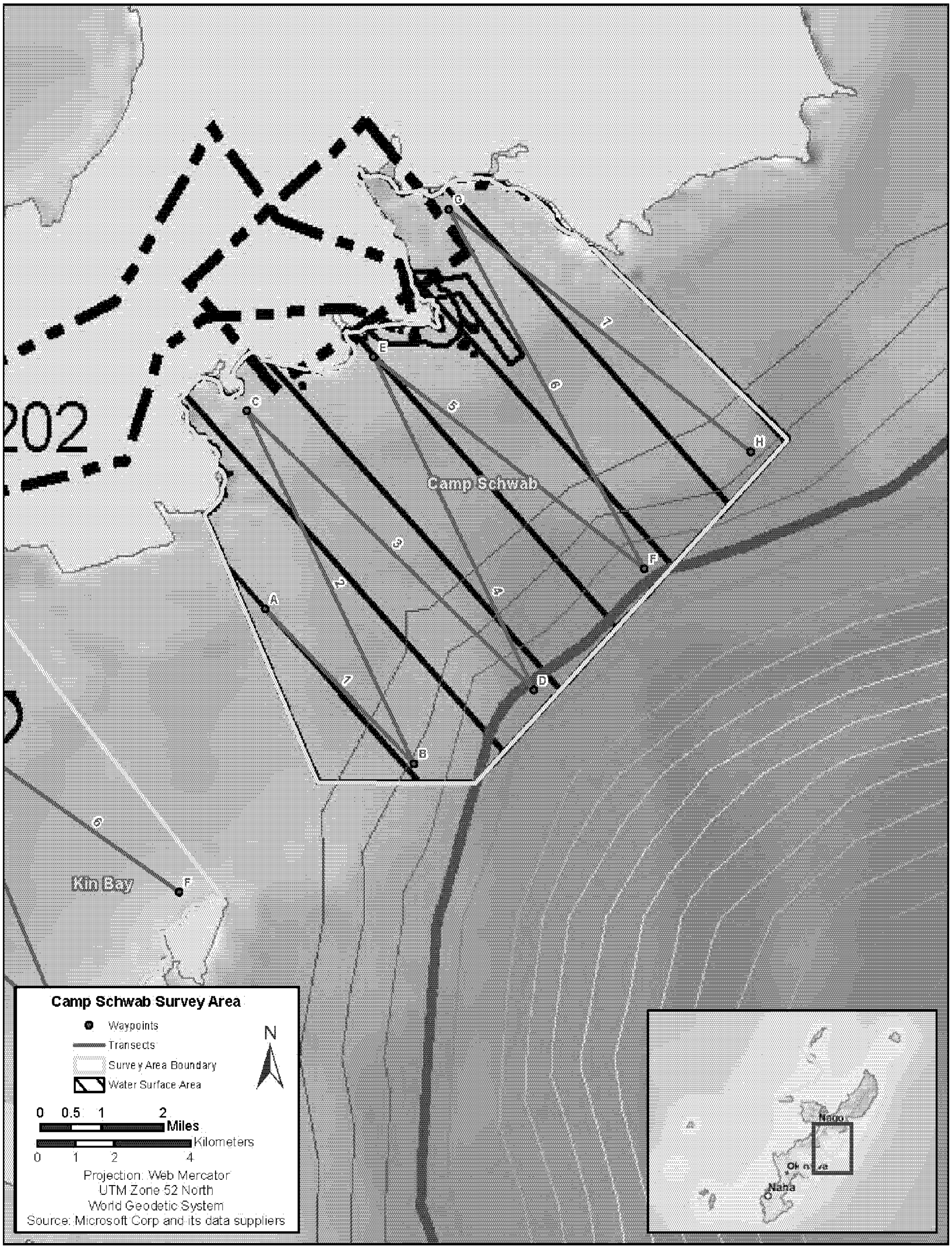

Figure 2. SuMMO study area—Camp Schwab survey area, showing boundaries and transect lines. USMC WSAs are outlined in black.

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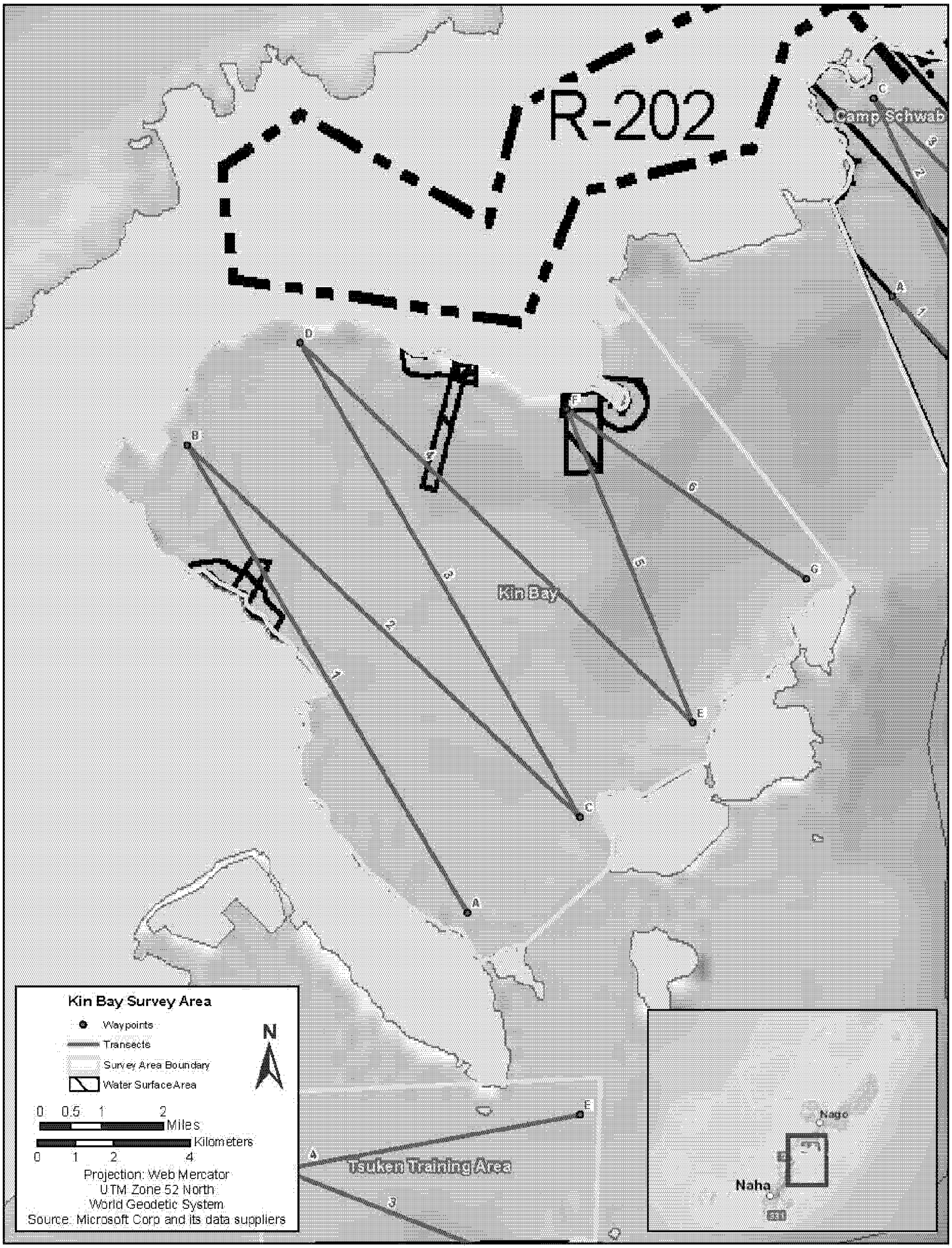

Figure 3. Kin Bay survey area, showing boundaries and transect lines. USMC WSAs are outlined in black.

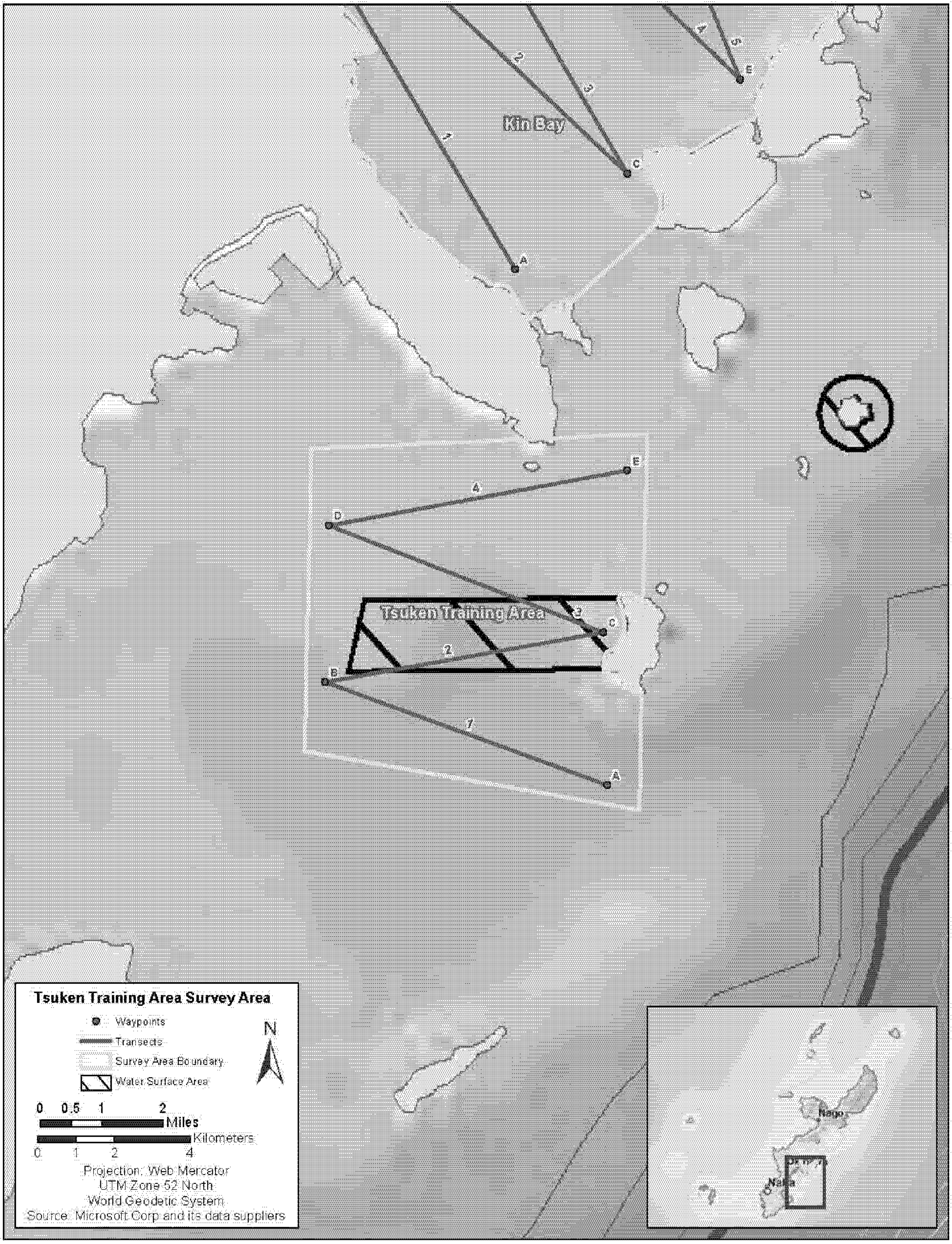

Figure 4. Tsuken survey area, showing boundaries and transect lines. USMC WSAs are outlined in black.

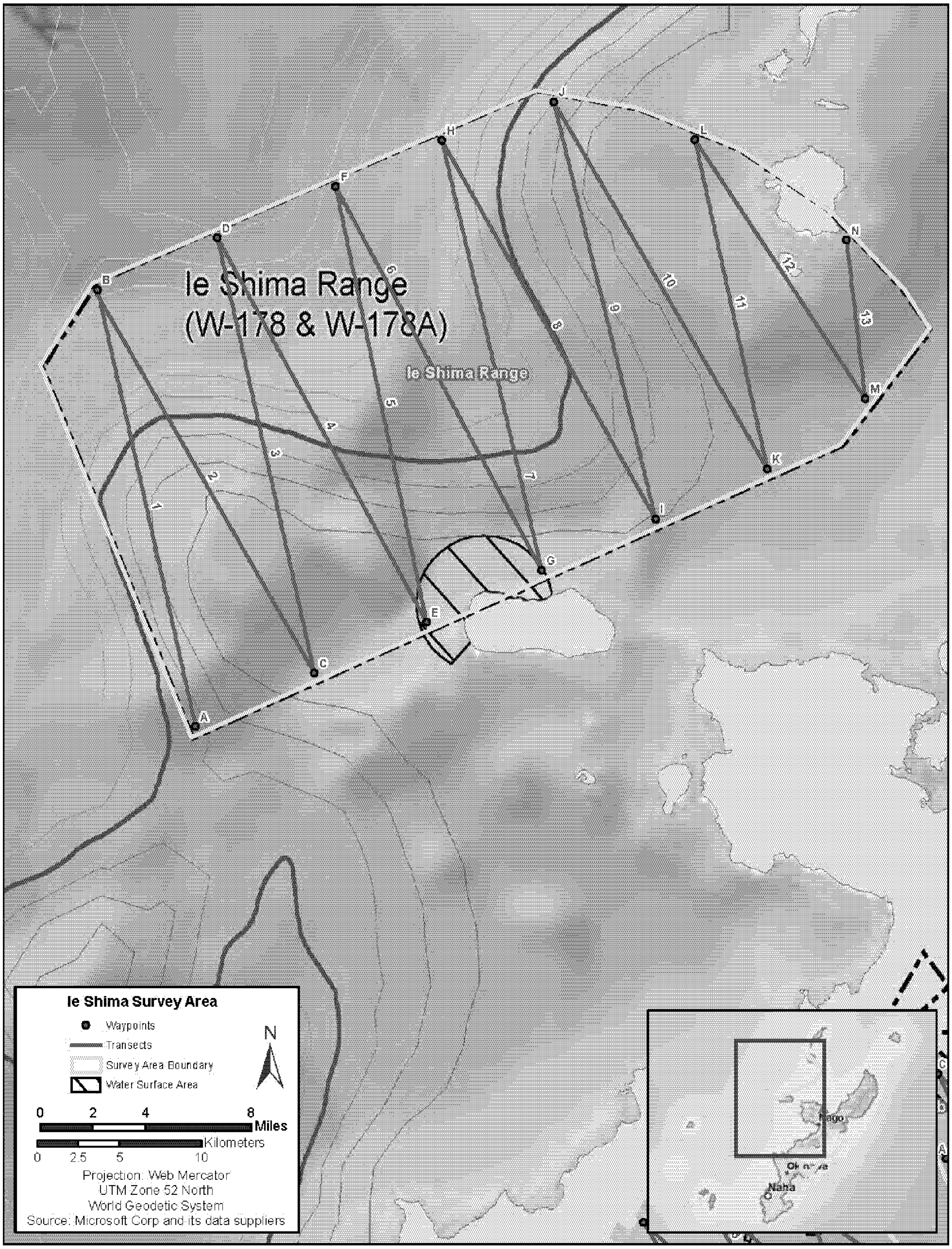

Figure 5. Ie Shima survey area, showing boundaries and transect lines. USMC WSAs are outlined in black.

Eurasia Plate. This continental margin is referred to as an "island arc" and results in a rapid transition of the bottom from shelf to slope to deep trench. The shelf edge is located between 5 and 40 km from the coastline (DoN 2005). Knowledge of bathymetry is important, as most cetacean species around the world are associated with habitats which are based on depth (Davis et al. 1998). Marine mammal species of Okinawa which are expected (but not limited) to occur in very shallow coastal habitats over the continental shelf include common bottlenose dolphins, Indo-Pacific bottlenose dolphins, spinner dolphins, humpback whales, and dugongs. Other species in the species list may occur in coastal waters, but are not traditionally thought of as closely associated with the continental shelf (see Jefferson et al. 2008).

Methods – Vessel Survey

In October 2011, the HDR Monitoring Team conducted an 8-day small-vessel survey to establish baseline data on marine mammals in the WSAs around Okinawa. A second survey was conducted in May 2012, and it consisted of 18 days of field work. Field work was maximized for characterization of marine mammal presence, distribution, population structure, and density. Sea turtles and some large fish (e.g., large sharks, mola mola, etc.) sightings were also recorded. Due to their importance as a potential threat and disturbance factor for Okinawan marine mammals, observations of vessels were also recorded on the May 2012 survey.

Standard line-transect vessel surveys were conducted from the *Blue Fin* (a 50-foot local vessel used for sportfishing and diving trips) (see **Figure 6**), weather permitting (Beaufort Sea States [BSS] 0-5, no heavy rain, and visibility greater than 1 km). The observer team conducted searches and observations from the flying bridge area, about 4-5 m eye height above the water's surface. Two observers made up the on-effort survey team. As the vessel transited the survey lines at a constant speed of 13-15 km/hour, the Primary Observer searched for marine mammals continuously through 7x35 marine binoculars. The other on-effort observer searched primarily with the naked eye, to avoid missing groups on and near the trackline. The Data Recorder recorded data on a laptop computer in the pilot house using specialized software (*VisSurvey* in 2011 and *Mysticetus* in 2012) and was not part of the searching team. Both observers searched ahead of the vessel, between 270° and 90° (in relation to the bow, which was defined as 0°). Observers rotated positions approximately every 30 minutes. Off-effort observers rotated into position to give observers who had been on-effort a rest after each 60 minutes of search effort, thereby minimizing fatigue.

Effort data collected during on-effort survey periods included time and position for the start and end of search effort, vessel speed, sea state (Beaufort scale), visibility, and other environmental conditions. When marine mammals were sighted, the Data Recorder took the team off-effort (after collecting associated sighting data) and the vessel was diverted from its course to approach the marine mammal group for group size estimation, photography, and behavioral observations. Sighting information collected included information on sighting angle and distance, position of initial sighting, BSS, group size and composition, and behavior, such as response to the survey vessel. Location data and vessel speed were obtained from a Globalsat BU-353 lollipop-type Global Positioning System. Photographs taken during sightings were sorted and examined for presence of individuals that could be identified by their natural markings. Cameras used included: Canon 7D with 100-400 mm lenses (Richie), Canon 7D with 70-200-mm zoom and 300-mm fixed lenses (Jefferson).

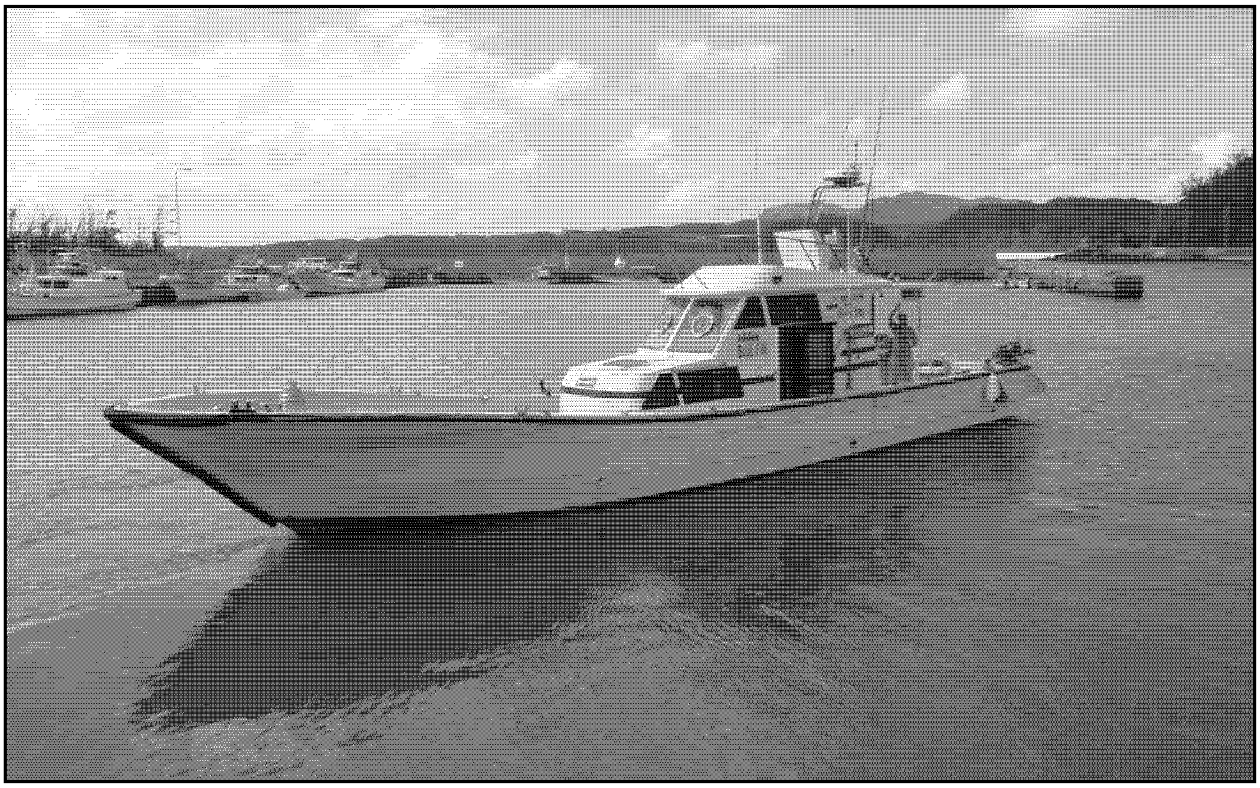

Figure 6. Our survey vessel, the *Blue Fin*. Note that after this photo was taken a canopy was attached to the upper flying bridge deck to provide some protection from sun and rain.

Methods – Shore-based Survey

On some days when we were unable to survey from the vessel (BSS 6 and above, or when the vessel transited from one side of the island to the other), the MMO team conducted shore-based surveys for marine mammals from one of several high vantage points on land. We located several vantage points that provided views of the survey areas, and ideally also provided some shelter from the effects of wind on the water's surface. We intended shore-based data to supplement vessel survey and acoustic data to elucidate the distribution and relative abundance of marine mammals around Okinawa, and in particular in the four survey areas. It was also deemed useful to help determine the feasibility of obtaining density and habitat-use information on dugongs and other marine mammals for future research and monitoring.

To locate marine mammal groups, two observers used Canon 18X image-stabilized binoculars to conduct a complete scan of the viewable water area every 15 minutes. Any marine mammal group sighted would be tracked until it left the viewable area or until it was lost by the observer team.

Methods – PAM

Deployment and retrieval of three EARs were conducted during the first and last small vessel survey, respectively. The deployments were made without the use of a dive team. The devices were deployed with acoustic releases so that a dive team was not required for retrieval. A trip by Richie and Richlen to refurbish the EARs was conducted in February 2012.

Section 3 Visual Survey Results

The first SuMMO survey was conducted from 21 to 28 October 2011 (see **Table 1, Figure** 7). This was to be the first of two 13-day small-vessel surveys to establish baseline data on marine mammals in the WSAs around Okinawa. However, due to unfavorable (bordering on unsafe) weather conditions and an adverse weather forecast, we cut the field work short by 5 days. Of the total of 8 days in the field, we conducted 5 days of vessel surveys, completing 425 km of on-effort line-transect survey in the Ie Shima survey area. No marine mammal sightings or other marine megafauna sightings were made.

Table 1. Summary of Okinawa surveys, October 2011.

Date	Area	Lines Completed	Effort (km)	Sightings	
				Mammals	Other
21-Oct-11	Ie Shima	I1,I2,I3	65	0	0
22-Oct-11	Ie Shima	I5,I7,I8	75	0	0
23-Oct-11	Ie Shima	I9-I12	99	0	0
24-Oct-11	Ie Shima	I7-I13	141	0	0
25-Oct-11	Ie Shima	I3-I4	45	0	0
26-Oct-11	In port (weather)	No survey	0	0	0
27-Oct-11	In port (weather)	No survey	0	0	0
28-Oct-11	Schwab (EAR deploy)	No survey	0	0	0
TOTALS			**425**	**0**	**0**

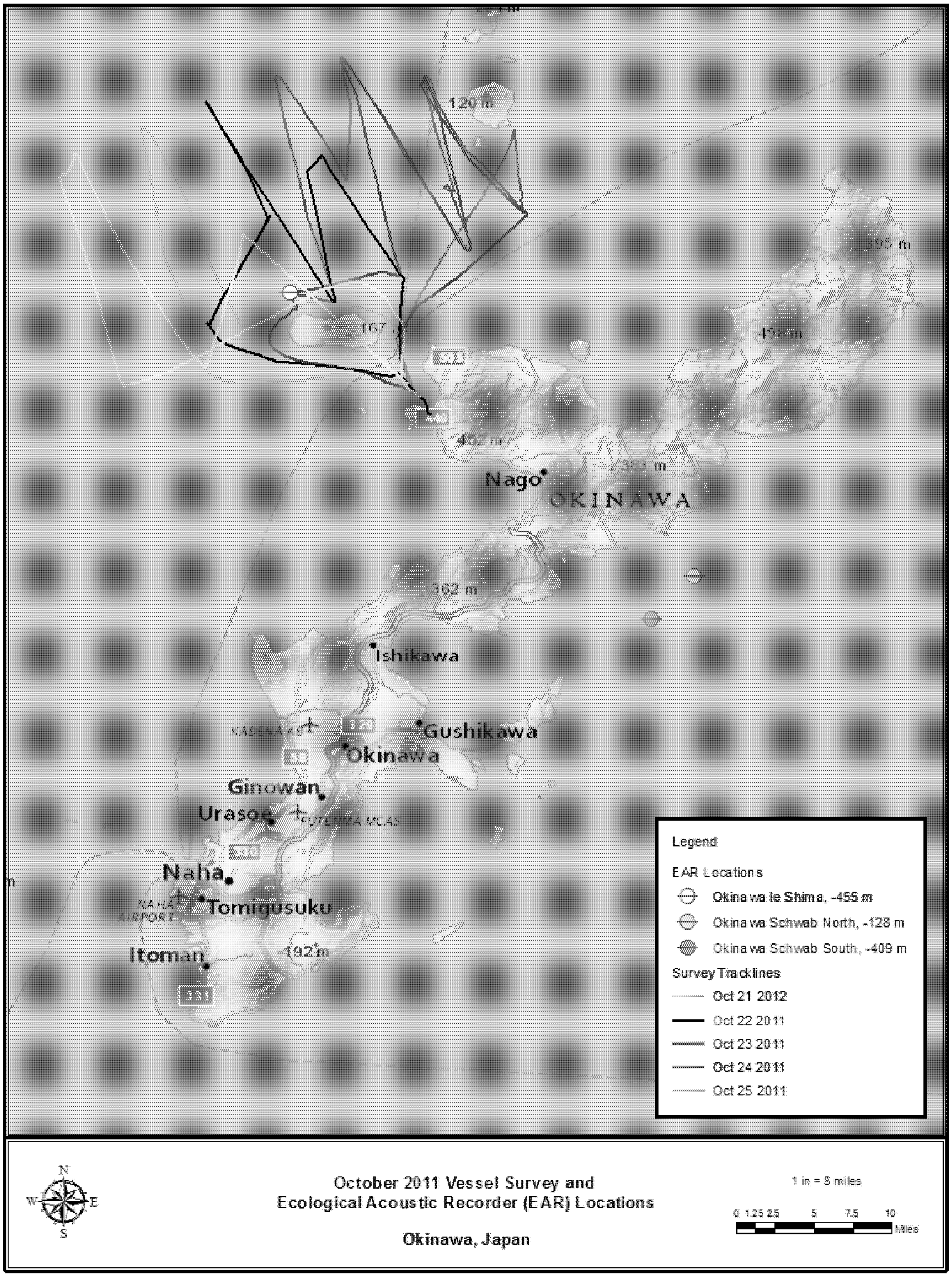

Figure 7. Tracklines completed during the October 2011 SuMMO survey.

The second SuMMO survey was conducted from 8 to 25 May 2012 (see **Table 2, Figure 8**). The 5 lost days from the October 2011 survey were added to this survey, to make the total 18 days (instead of the originally-intended 13 days). We conducted boat operations on 12 days, completing 488 km of line-transect survey effort. We also conducted 2 days of land-based surveys and searched for land-based survey stations on several days in which we were not able to survey by boat. Three marine mammal sightings were made during the boat surveys (see **Table 3**), but none were recorded during the land-based surveys. These included a small group of common bottlenose dolphins on-effort and two groups off-effort (a large group of dwarf sperm whales and a very large group of common bottlenose dolphins; see **Table 3**).

Table 2. Summary of Okinawa surveys, May 2012.

Date	Area	Lines Completed	KM Effort	MM STGS	OTH STGS
8-May-12	Tsuken	All	25	0	1 ray
9-May-12	Kin Bay	All	44	0	0
10-May-12	Schwab	Lines S3-7	36	0	0
11-May-12	TRANSIT	No survey	0	0	0
12-May-12	Ie Shima	Lines I1-2	50	0	0
13-May-12	Ie Shima	Land-based survey	0	0	0
14-May-12	N/A	Land survey search	0	0	0
15-May-12	In Port (weather)	No survey	0	0	0
16-May-12	Ie Shima	Lines I3-6	85	1	1 shark
17-May-12	Ie Shima	Lines I7-10	88	0	1 unid. animal
18-May-12	Ie Shima	Lines I11-13	45	0	0
19-May-12	TRANSIT	No survey	0	0	0
20-May-12	In Port (weather)	No survey	0	0	0
21-May-12	Kin Bay attempt	No survey	0	0	0
22-May-12	Schwab	All	43	0	1 turtle
23-May-12	Kin Bay attempt	No survey	0	0	0
24-May-12	Kin Bay/Tsuken	All (both areas)	72	0	0
25-May-12	Offshore/Kudaka Island	N/A	0	2	0
TOTALS			**488**	**3**	**4**

Overall, combining both October 2011 and May 2012 surveys, we completed 913 km of on-effort line-transect survey effort, and we surveyed the Camp Schwab, Kin Bay, and Tsuken survey areas twice each. Ie Shima was surveyed a total of three times. Most line-transect effort was conducted during moderate to poor conditions of BSS 3-5, but a smaller amount was conducted in good conditions of BSS 0-2 (see **Figure 9**). Overall, (including sightings made on an EAR refurbishment trip), we had six marine mammal sightings—three groups of humpback whales, two groups of common bottlenose dolphins, and one group of dwarf sperm whales (see **Figures 8** and **10–12; Table 3**).

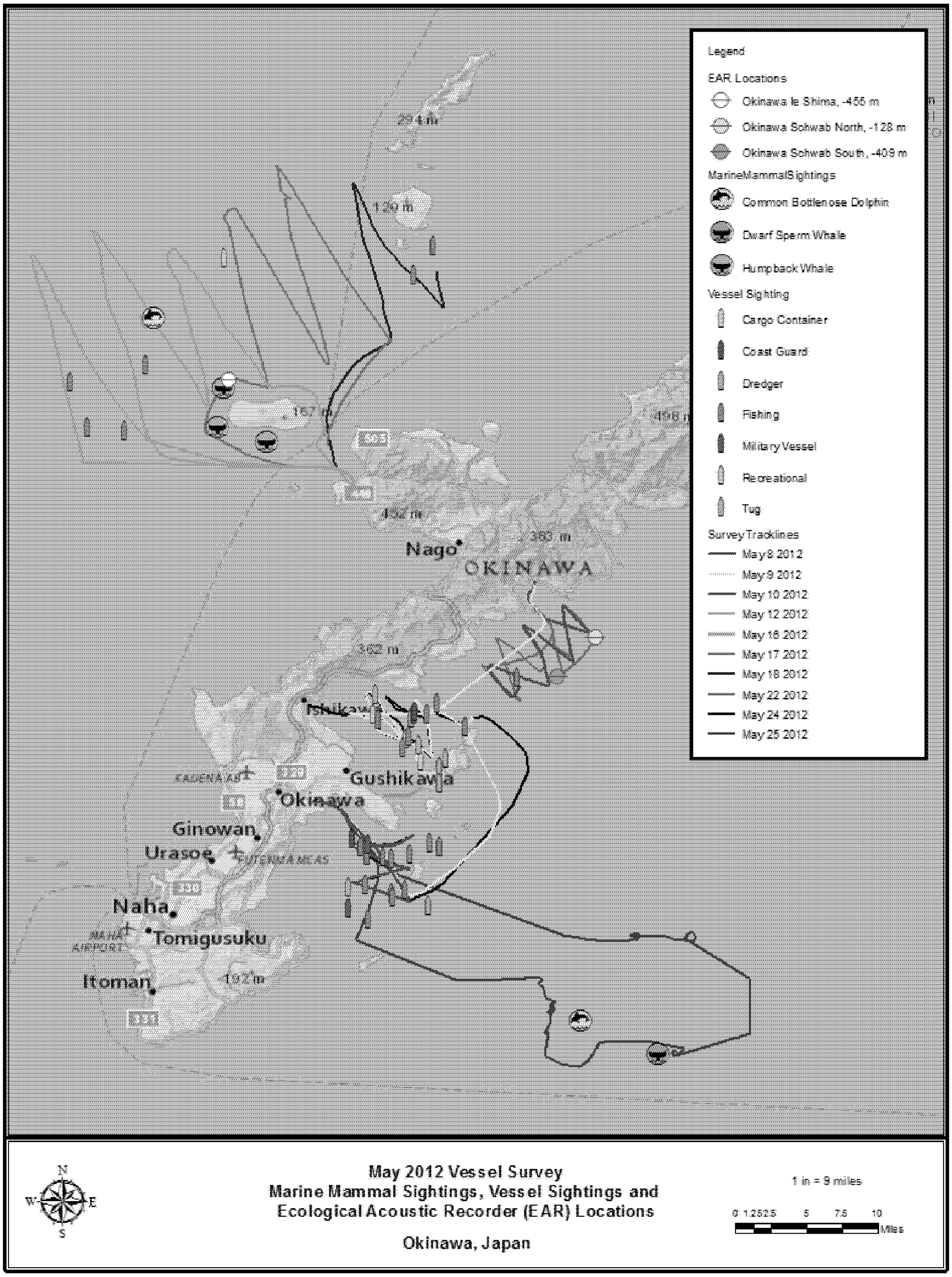

Figure 8. Tracklines completed and marine mammal sightings made during the May 2012 SuMMO survey.

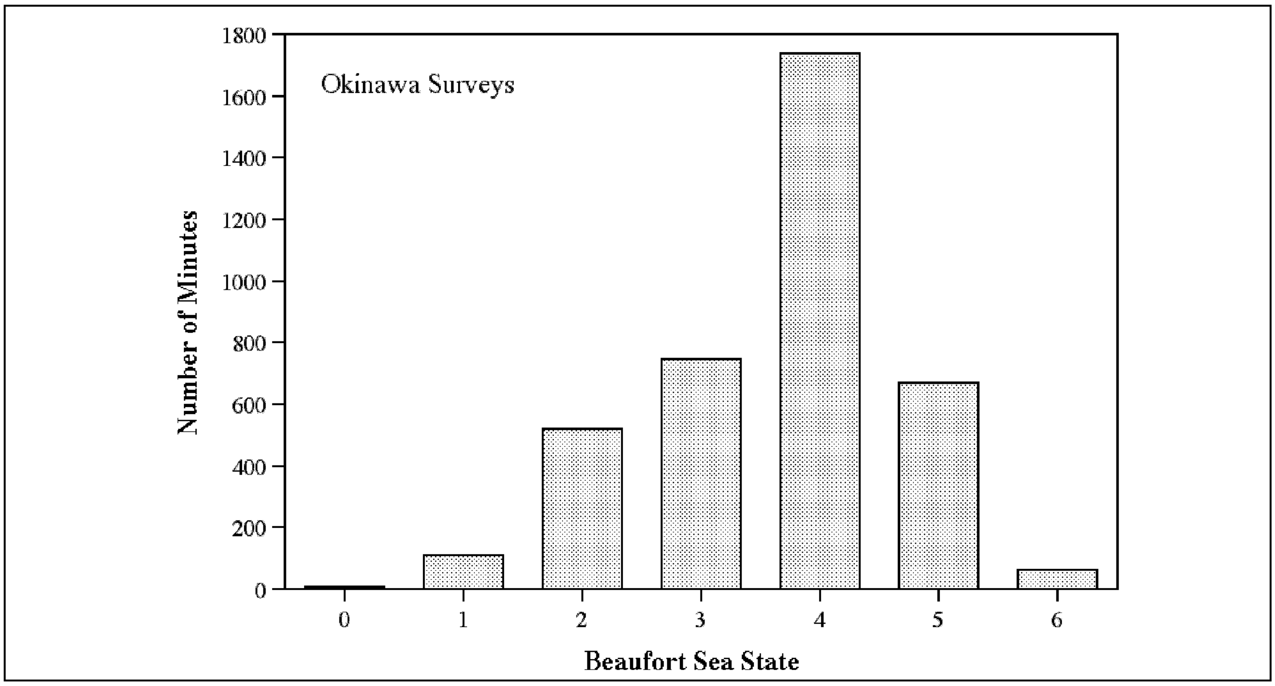

Figure 9. Distribution of sighting effort by Beaufort Sea State.

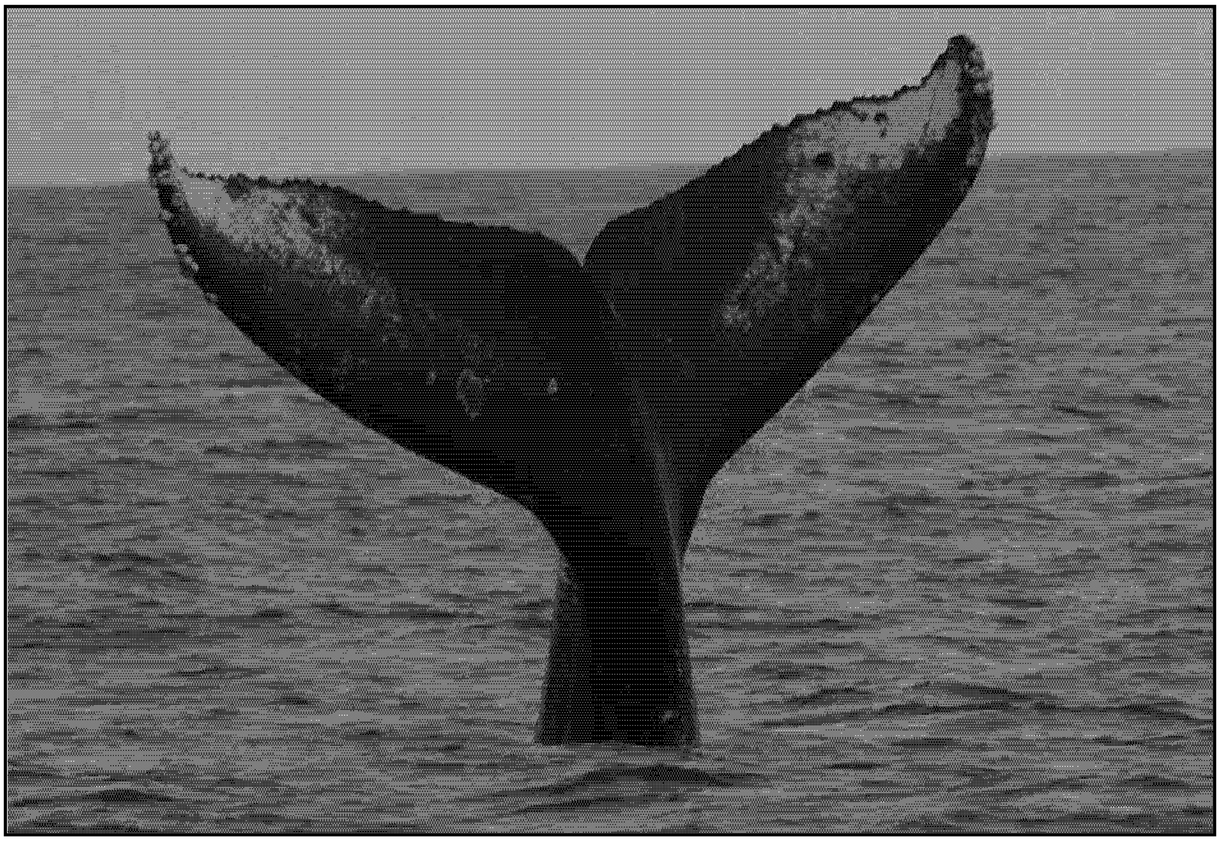

Figure 10. Flukes of humpback whale (*Megaptera novaeangliae*) group observed on 29 February 2012 near Ie Shima.

Figure 11. Dwarf sperm whale (*Kogia sima*) observed on 25 May 2012, offshore of the southeastern portion of Okinawa.

Figure 12. Common bottlenose dolphin (*Tursiops truncatus*) observed on 25 May 2012, offshore of the southeastern portion of Okinawa.

Table 3. Marine mammal sighting summary.

Date	Time	Species	Grp Sz	PSD	Position	Effort	# Photos	Notes
29-Feb-12	n/d est. 0900-1100	*Megaptera novaeangliae*	5	n/d	26°42'32"N, 127°44'17"E	Off	13 (MWR)	While refurbishing EAR
29-Feb-12	n/d est. 0900-1100	*Megaptera novaeangliae*	2	n/d	26°44'54"N, 127°44'38"E	Off	58 (MWR)	While refurbishing EAR
29-Feb-12	n/d est. 0900-1100	*Megaptera novaeangliae*	2	n/d	26°41'36"N, 127°47'17"E	Off	25 (MWR)	While refurbishing EAR, cow/calf
16-May-12	1029	*Tursiops truncatus*	2	0.13 km	26°49'12"N, 127°40'20"E	On	0	Brief sighting
25-May-12	1244	*Kogia sima*	18	0 km	26°03'58"N, 128°11'13"E	Off	56 (KS), 79 (TJ) 62 (MFR) 143 (MWR)	Very large group
25-May-12	1456	*Tursiops truncatus*	120	3.33 km	26°06'03"N, 128°06'29"E	Off	155 (KS), 190 (TJ) 96 (MFR) 215 (MWR)	Acoustic recordings obtained

Key:
PSD = Perpendicular Sighting Distance
n/d = no data
ks = *Kogia sima*
TJ = Thomas Jefferson
KS = Keiko Sekiguchi
MWR – Morgan Richie
MFR = Michael Richlen

Section 4 Passive Acoustic Monitoring

Three EARs were deployed during the vessel survey in areas of interest in Okinawa for the purposes of marine mammal monitoring and assessment. The deployments were made without the use of a dive team. The devices were deployed with acoustic releases so that a dive team was not required for retrieval. The locations of the EAR deployments are listed below:

Ie Shima	26°45.480'N, 127°45.011'E	Depth 455 m
Camp Schwab N	26°29.611'N, 128°07.464'E	Depth 128 m
Camp Schwab S	26°27.224'N, 128°05.130'E	Depth 409 m

All three EARs were deployed initially in October 2011, recovered, refurbished and redeployed in February-March 2012, and recovered (without redeployment) in May 2012. The Ie Shima EAR malfunctioned during the first deployment, and therefore only data from the second deployment were available for analysis. Acoustic data from both Camp Schwab deployments and the second Ie Shima deployment were analyzed for various species. Dolphin whistles were analyzed using the Long-Term Spectral Averages of Triton toolbox, and classified using the ROCCA classifier. Biosonar signals from deep-diving odontocetes were recognized using three different detectors (M3R, ERMA and Echo-Clusters). Sounds from baleen whales, including blue whales, fin whales, sei whales, minke whales and humpback whales, were analyzed using an automated baleen whale detector. More information on the passive acoustic monitoring component of the project can be found in **Appendix C**.

Section 5 Conclusions and Discussion

Twenty-six species of marine mammals are known to occur in and around the islands of Okinawa, making it an area with high marine mammal diversity (see **Appendix A**). While it is not possible to make numerical estimates of density and abundance from the line-transect data, we can make some preliminary observations about the marine mammals of the four WSAs around Okinawa. Considering that a substantial amount of sighting efforts were conducted with only a single sighting, this strongly suggests that densities of most cetaceans are low in the survey areas. The one exception may be for humpback whales in the winter to early spring months, when there appear to be significant numbers present in the Ie Shima survey area, and elsewhere along the southwestern part of Okinawa (see Uchida 2007). While we did not survey in this season, we did have three humpback whale sightings in February 2012 during the EAR refurbishment trip. Additionally, the initial results from the analysis of the two Schwab EARs are consistent with the visual survey results. Both demonstrate that acoustic detections are much lower in Okinawa than in Hawaii, another isolated tropical island chain with a similar assemblage of species. While acoustic detections alone cannot be used to estimate abundance, they do provide additional information that, when combined with visual survey data, support the conclusion that densities of marine mammals in the near-shore environment surveyed are extremely low.

Visual surveys (vessel and/or land-based) and passive-acoustic detection surveys are additional methods that may be used when attempting to detect marine mammals in an area. If there is a visual sighting, that observation can be recorded to provide information of marine mammals at known locations on a certain day and can usually identify species and group size estimates for that particular sighting. However, visual surveys can be hampered by poor weather, especially bad visibility from heavy rain or fog, and high winds, which create whitecaps that make marine mammals difficult to see with the naked eye. Such sighting conditions (BSS 4/5 and above) are common in Okinawa throughout the year. Additionally, visual surveys can only be conducted during daylight hours. Acoustic monitoring, on the other hand, provides challenges in obtaining exact species identifications (as many species of marine mammals sound very much like other species), and group sizes may be impossible to obtain in many cases. However, PAM has the advantage of being relatively unaffected by weather and visibility conditions and can sample 24 hours a day for long periods of time. Thus, in many ways the two techniques are complementary. The PAM analysis appears to largely agree with the results of visual survey that marine mammals are rare in the survey area, except with respect to humpback whales during certain times of the year in certain locations, as noted above.

It is not possible to say anything definitive about densities of dugongs. Dugongs can be difficult to detect from vessels in anything but flat calm waters and surveys in eastern Okinawa waters of Camp Schwab and Kin Bay were in relatively rough sighting conditions. There were several possible acoustic detections of dugong vocalizations on the EAR located in Schwab, but these detections cannot be confirmed with certainty.

,The apparent very low density of cetaceans in the survey areas may seem surprising at first. However, when one considers the extensive hunting that has occurred in Okinawan waters over the past 50+ years, it becomes somewhat easier to understand. A minimum of 6,210 small cetaceans of at least 10 species have been killed intentionally in Okinawa since 1960 using drive and crossbow fishery methods (see **Table 4**) (Nishiwaki and Uchida 1977; Uchida 1985; Kishiro and Kasuya 1993; Kasuya 2011). The vast majority of these have been short-finned pilot whales. Between the years of 1960 and 2009, at least 4,937 short-finned pilot whales were killed by Nago fishermen in the area around Okinawa, representing an average annual take of 101 whales (80 percent of the total reported take). It is possible that unreported takes also occurred. Assuming a maximum sustainable harvest of 4 percent and no mortality from other sources, this means that the affected population(s) would have to number at least 2,525 individuals for the take to be sustainable. Work in other areas of the Pacific suggests that pilot whales near islands often have a high degree of residency—for instance around the Big Island of Hawai'i (Shane and McSweeney 1990) and around Kaua'i and Ni'ihau (Baird et al. 2006). If this was the case around Okinawa as well, then it seems very likely that the population would have been depleted by the high levels of mortality caused by hunting (and local bycatch) in Okinawan waters.

Table 4. Minimum number of small cetaceans killed by direct hunting in Okinawa, 1960 to present.

Year	G mac	P cra	T tru	P ele	O orc	F att	S bre	G gri	S att	Delphinus	Unid.
1960	243		<77								
1961	281										
1962											
1963	189										
1964	318										
1965											
1966											
1967	150										
1968	150										
1969	500										
1970											
1971	165	<19	<45								
1972	170										
1973	87		<87								
1974	53										
1975	49										
1976	36						23			23	
1977	301									37	
1978		90		3						25	
1979				140	1	1				49	49
1980	91	5		4						22	
1981	50	7	2	1						25	
1982	9									82	
1983	131	17	16								
1984	88	5	63						3		
1985	70		31		2	42			3		
1986	82	2	77								2
1987	92	2	18				1	1			22
1988	116	6	9								17
1989	93	25	44				1	1			26
1990	74	3									2
1991	52	9	16								3
1992	79		1								
1993	89	2	9								
1994	81		10								

Year	G mac	P cra	T tru	P ele	O orc	F att	S bre	G gri	S att	Delphinus	Unid.
1995	90	9	10								
1996	84	10	4					14			
1997	66	3	8		1						
1998	61	8	7								
1999	79	5	8								
2000	89	8	8								
2001	92	8	8								
2002	38		3								
2003	36	4	7								
2004	72	3	10								
2005	90	1	10								
2006	56	5	12								
2007	79	4	4								
2008	62	5	1								
2009	54	1	4								
2010	?	?	?								
2011	?	?	?								
TOTAL	**4,937**	**247**	**400**	**148**	**4**	**43**	**25**	**16**	**6**	**263**	**121**

G mac = *Globicephala macrorhynchus*
P cra = *Pseudorca crassidens*
T tru = *Tursiops truncatus*
P ele – *Peponocephala electra*
O orc = *Orcinus orca*
F att = *Feresa attenuata*
S bre = *Steno bredanensis*
G gri = *Grampus griseus*
S att = *Stenella attenuata*

Data from Nishiwaki and Uchida (1977); Uchida (1985); Kishiro and Kasuya (1993); Kasuya (2011). Includes both drive and crossbow fisheries.

All of these kills have occurred with no known stock assessment research, and no known measures to ensure that they are sustainable. It appears to us very likely that cetacean densities around the island have been drastically reduced by this uncontrolled take. This most likely explains our near absence of marine mammal sightings in nearly 1,000 km of line-transect surveying, and our low acoustic detection rates for cetaceans.

Section 6 Acknowledgements

We would like to thank the USMC for funding this project and NAVFAC PAC for facilitating its conduct through existing channels. Our boat captain, Chris Pancoast, was gracious and accommodating throughout and also helped us with the benefit of his many years of experience in Okinawa. Our local contact, Sugiyama-san, and his colleagues at USMC facilities in Okinawa assisted us in many ways. The staff of the Okinawa Churaumi Aquarium, especially director Senzo Uchida, veterinarian Keiichi ("crazy vet") Ueda, and marine mammal survey coordinator Ms. Haruna Okabe, were very helpful and shared their knowledge of the marine mammals of Okinawa with us on several visits to the aquarium. Thanks also to Bob Brownell for assistance with the literature review portion of the work.

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APPENDIX A

Marine Mammals of Okinawa: A Preliminary Review and Checklist

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MARINE MAMMALS OF OKINAWA:
A PRELIMINARY REVIEW AND CHECKLIST

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MARINE MAMMALS OF OKINAWA: A PRELIMINARY REVIEW AND CHECKLIST

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Abstract

The marine mammal fauna of Okinawa is known primarily from old whaling and dugong-hunting records, as well as strandings, captures, and sightings documented by staff of the Okinawa Churami Aquarium. There are 3-4 species of baleen whale recorded from the islands, with only the humpback whale being common in the area (breeding there in winter and spring months). There are six species of large toothed whales known from Okinawa, but none of these is considered common in local waters. Thirteen species of delphinids (dolphins and small toothed whales) have been confirmed in Okinawa (with a fourteenth species still unconfirmed), and many of these are considered common in local waters. The short-finned pilot whale is regular enough to be the main target of the local small cetacean fishery, which until 1975 used drive methods, and now uses harpoons fired from crossbows. The only species of porpoise known from Okinawa is the narrow-ridged finless porpoise, which is considered extralimital in these waters. Aside from the cetaceans listed above, the dugong is the only other species of marine mammal known to occur in the area. While dugongs may have been common in the past, today they are locally depleted and very rare in Okinawa. Overall, the marine mammal fauna of Okinawa is diverse and considered tropical, with a few warm temperate species also represented.

Introduction

Until research on marine mammals in Okinawa began in the mid-1970s, very little was known about animals in the area. Even such basics as what species of marine mammals occurred there was not documented. Today, due mostly to directed research conducted by staff from the Okinawa Churami Aquarium (and its predecessor, the Okinawa Expo Aquarium), the situation is much improved. Thousands of recent records of marine mammals in the area have been compiled and published, and we can now produce a reasonably-accurate species list for Okinawa. However, most of the work has been opportunistic, associated with whale-watching activities, dolphin and small whale fisheries, or live-capture operations associated with the aquarium. There have been virtually no systematic sighting surveys, and estimates of density and abundance for marine mammals in the region are still largely lacking. As part of the preparations for an upcoming survey of marine mammals in Okinawan waters, we conducted a preliminary review of marine mammal records for the archipelago. Our field survey, to be conducted in 2011 and 2012, will be the first to attempt a systematic survey of marine mammals in Okinawa and produce indices of abundance.

Direct Hunting of Marine Mammals in Okinawa

Hunting of cetaceans has a long history in Okinawa, with the people of Nago (a town in the northwestern part of Okinawa's main island) hunting pilot whales for over 170 years (Miyasato 1988). After the end of WWII, under the supervision of the US Government, Okinawa also began hunting great whales. Between 1950 and 1957, Nago-based whalers began to target humpback whales, killing 52 of them in these years (Nishiwaki 1959). Beginning in 1958 and lasting through 1965, several whaling companies from the main islands of Japan took an interest and began to cooperate with the Nago whalers. During this latter period, at least 788 humpbacks, 31 sperm whales, and 1 Bryde's whale were killed around Okinawa in commercial whaling operations (Kasuya 2009).

Fishermen based in Nago also hunt small cetaceans, with the primary target species being the short-finned pilot whale. Between 1960 and 1982, 2,753 pilot whales were recorded as being taken in this fishery, and they take smaller numbers of other species of delphinids on occasion as well (e.g., killer whale, false killer whale, pygmy killer whale, melon-headed whale, rough-toothed dolphin, pantropical spotted dolphin, Risso's dolphin, and bottlenose dolphin). In the early years, the hunting was done by driving schools into shore, but beginning in 1975, harpoon hunting with crossbows began, and soon after replaced the drive fishery (Kishiro and Kasuya 1993). The last two drives occurred in 1982 and 1989, and the drive fishery is today illegal and considered 'extinct' in Okinawa (Kishiro and Kasuya 1993). The harpoon fishery, in which the steel projectiles are fired from crossbows at the bow of the ship, is apparently still active. It operates mainly in May and June between the latitudes of 26° and 27°N (Kishiro and Kasuya 1993). The allowable take quota for this latter fishery in 2007/2008 was 121 dolphins (9 bottlenose dolphins, 92 pilot whales, and 20 false killer whales – Kasuya 2009). More than 4,100 small cetaceans of at least nine species have been taken by the combined drive and harpoon fisheries of Okinawa since 1960 (Uchida 1982, 1985; Kishiro and Kasuya 1993; Kasuya 2009), and the impacts of these catches on local populations are not known, but are suspected to be significant in at least some cases.

Dugong hunting has been conducted in Okinawa and some surrounding island groups (Miyako and Yaeyama islands) for millennia, based on finds of dugong parts and other artifacts in archaeological sites (Welch et al. 2010). Dugongs were desirable targets due to their tasty flesh, as well as the value of their bones and teeth in trading and commerce. Due to the importance of dugong hunting, the species is considered a cultural resource in Okinawa. Hunting in the last few centuries involved mostly netting, but harpooning may also have been involved (Uni 2003). Between 1894 and 1916, at least 327 dugongs were killed in Okinawa, but due to apparent overhunting, dugongs became harder to catch, and the fishery largely closed-down by about 1916 (Uni 2003). In the impoverished post-WWII years, however, hunting resumed, this time mostly using dynamite (according to anecdotal information from Kasuya and

Brownell 2001; Uchida 2005; Shirakihara et al. 2007). Today, dugong hunting is illegal in Okinawa, but it is likely that some illicit hunting may still occur on a small scale.

Work by the Okinawa Churami Aquarium

The International Marine Exposition was held in Okinawa from July 1975 to January 1976. As part of the exposition, an aquarium was established in 1975 at the expo site on the Motobu Peninsula (Uchida 1976). This facility was originally called the Okinawa Expo Aquarium, but was later renamed the Okinawa Churami Aquarium, and it still operates today as a commercial oceanarium, catering to tourists. Beginning in 1975, studies and captures of marine mammals were initiated through the aquarium, and were supervised by its director, Dr. Senzo Uchida. Over the past 36 years, aquarium staff has collected a significant amount of information on marine mammals of Okinawa, using interview surveys, ship and aerial surveys, stranding recovery, lethal sampling, and live-capture operations. Although these surveys did not quantify effort and therefore do not provide density information, they have substantially increased our knowledge of the marine mammals of the Okinawa area (see Uchida 1982, 1985, 1994, 2005, 2006; Uchida et al. 1993).

Species Accounts

Sei whale *Balaenoptera borealis*

The sei whale is a medium-sized rorqual whale. It is less commonly sighted than the other rorquals, and spends more of its time in temperate waters than other species in the family. There are no specific records of the sei whale available from Okinawa, but Uchida (1994) mentioned that they were taken around 1960 in small numbers in Ryukyan whaling operations. It is possible that there has been some confusion with the Bryde's whale here, and thus the sei whale should not yet be considered confirmed from Okinawa.

Bryde's whale *Balaenoptera edeni/brydeii*

This is a mid-sized species in the rorqual family of baleen whales. Bryde's whale is common in many tropical zones, and does not migrate to high-latitude regions like other mysticete whales. There are apparently two stocks in the western North Pacific and East China Sea (Kato 2000). There is a single record of a Bryde's whale, which was taken in whaling operations around Okinawa in 1960 (specific date unknown – Nishiwaki 1960). Besides this record, Uchida (1994) mentioned that they were seen in the East China Sea, but did not give any specifics.

Common minke whale *Balaenoptera acutorostrata*

Common minke whales are the smallest of the rorquals, and these animals are common in many coastal zones in temperate to polar latitudes. Minke whales are represented in Okinawa only by a single specific record, a stranding of an individual on Aguni Island (Uchida 2005). Uchida (1994) also mentioned that there has been photo-identification work on this species since 1990, but he did not give any details and we are unaware of any such work in Okinawa. We suspect that this is an error, and he meant to refer to the humpback whale.

Humpback whale *Megaptera novaeangliae*

The humpback whale is a mid-sized rorqual. It is undoubtedly the most well-known and most frequently-sighted of the species in the rorqual family in many coastal areas. Humpback whales are, without a doubt, the most common species of great whale to occur in Okinawa, although they are seasonal, only occurring there during their winter/spring breeding season (from about November to April). They supported extensive whaling operations in the Ryukyu Islands from 1914 to at least 1961 (Nishiwaki 1959, 1960, 1962; Miyasato 1988), in which a total of at least 946 humpbacks were killed (see **Appendix A, Table 2**).

Starting in the late 1970s, many sightings of this species were reported around the islands, and there is now a small whale watching industry based around observing this spectacular species during winter and early spring months (Uchida 1985, 2005; Uchida et al. 1993; Darling and Mori 1993; Maeda et al. 2000a,b). The industry focuses most of its effort around the Zamami Islands, just southwest of the main island of Okinawa, apparently due to a higher density of humpbacks there. Additional recent records include several humpback whale strandings and captures in fishing gear (Uchida 2005). Japanese and Canadian researchers have compiled individual identification photos of the humpback whales that use the waters around Okinawa, and these photo-ID catalogs are now providing important information on the migratory destinations and ecology of Okinawan humpbacks (Darling and Mori 1993; Uchida et al. 1993; Uchida 2005). Okinawan humpbacks are part of the western North Pacific subpopulation, which has several more-or-less distinct breeding grounds (Fleming and Jackson 2011). In other words, there is little interchange between whales that breed in Okinawa and those that breed in other western North Pacific locations (e.g., Ogasawara, Taiwan, the Philippines – Calambokidis et al. 2008). These whales migrate to feed in scattered summering locations, mostly off the coast of the Kamchatka Peninsula, but some also move to Alaskan waters to feed (Calambokidis et al. 2008; Fleming and Jackson 2011).

Sperm whale *Physeter macrocephalus*

The sperm whale is the largest of the toothed whales, and is common in many regions of the world, from the tropics to the high latitudes of both hemispheres. Sperm whales have been recorded around Okinawa on a number of occasions, from sightings, strandings and captures (Nishiwaki 1960, 1962; Uchida 1982, 1985, 2005). This was a secondary target species of the Ryukyan whaling operations that operated in the mid-twentieth century in the area. From 1959 to 1961, a total of at least 30 sperm whales were killed in the Nago-based operations (Nishiwaki 1960, 1962). This deepwater species presumably occurs relatively far offshore, and may not be sighted often in Okinawa for this reason.

Pygmy sperm whale *Kogia breviceps*

Pygmy sperm whales are mid-sized odontocetes, and although they may not necessarily be uncommon, they are very rarely sighted in most areas, largely due to their cryptic behavior and low surface profile. There are several records of this species from Okinawa, including a sighting in 1984 and 10 stranding records (Uchida 1985, 2005). In addition, there are several records of *Kogia* sp. that were not identified to species and may be of this species (Uchida 1985).

Dwarf sperm whale *Kogia sima*

Dwarf sperm whales are mid-sized odontocetes, and although they may not necessarily be uncommon, they are very rarely sighted in most areas, largely due to their cryptic behavior and low surface profile. The dwarf sperm whale is represented in Okinawa by a single capture record and 10 records of strandings (5 of these occurred between 1980 and 1991 – Uchida 1982, 1994, 2005). In addition, there are several records of *Kogia* sp. that were not identified to species and may be of this species (Hirasaki 1937; Uchida 1985).

Cuvier's beaked whale *Ziphius cavirostris*

One of the largest of the beaked whales, Cuvier's beaked whales are ubiquitous, but not commonly observed, due to their inconspicuousness, offshore distribution, and deep diving habits. Cuvier's beaked whale is known from Okinawa through four stranding records, and two sightings, one of which is of questionable identification (Uchida 1982, 1985, 2005).

Blainville's beaked whale *Mesoplodon densirostris*

Blainville's beaked whales, like other species in the genus *Mesoplodon*, are poorly-known, medium-sized toothed cetaceans. Blainville's beaked whale is among the most common species of beaked whale in many tropical and subtropical areas of the world and Okinawa appears to be no exception. There have been 4 strandings and several captures of this species in the region (Uchida 1994, 2005). A 3.7 m male specimen that was captured alive was held briefly at the Okinawa Churami Aquarium (Uchida 1994).

Gingko-toothed beaked whale *Mesoplodon ginkgodens*

The only other species of mesoplodont known from Okinawa is the ginkgo-toothed beaked whale. Gingko-toothed beaked whales, like other species in the genus *Mesoplodon*, are poorly-known, medium-sized toothed cetaceans. This species is distributed only in the Indo-Pacific region, and does not appear to be common. The only record of this species is a capture which apparently occurred after the animal 'wandered in' (the term 'wandering in' is used in Japan as something akin to 'assisted stranding', meaning that the animals are found in nearshore waters and captured before actually coming ashore) at Urasoe City in July 1982 (Uchida 1982, 1994).

Killer whale *Orcinus orca*

Probably the most instantly-recognizable cetacean, due to its unique color pattern, prevalence in captivity, and exposure in film and print media, is the killer whale. It is the largest species in the dolphin family (Delphinidae). The killer whale is a wide-ranging species that presumably occurs in virtually every marine region in the world. It does not appear to be common in Okinawa, however. There are two records of its capture in the Nago drive fishery (from 1979 and 1985), as well as some anecdotal sighting records with details unavailable (Uchida 1994).

Short-finned pilot whale *Globicephala macrorhynchus*

Short-finned pilot whales are one of the largest species of the dolphin family. They are found in the tropical and warm temperate waters around the world. Pilot whales appear to be quite common in waters of Okinawa. There are a large number of sighting and stranding records (Uchida 1982, 1985, 2005; Higashi et al. 1992), and this species was the main target of a drive fishery for small cetaceans that operated at Nago (Nishiwaki and Uchida 1977), and is still targeted by the harpoon fishery. The specific reasons that this species became the main target are not known, but probably relate to the common occurrence and relatively large size of pilot whales (vs. other small cetaceans). Between 1960 and 1982, at least 2,753 pilot whales were recorded as being taken in this fishery (see **Appendix A, Table 2**).

False killer whale *Pseudorca crassidens*

The false killer whale is a large delphinid. It is common in many tropical and warm temperate seas. False killer whales have been recorded as captured in the Nago small cetacean drive fishery (in 1971 – Nishiwaki and Uchida 1977; Uchida 1985), and there have been several stranding records as well from Okinawa (Uchida 1994, 2005).

Pygmy killer whale *Feresa attenuata*

This may be one of the rarest of the delphinid family. Pygmy killer whales occur in all the tropical seas and in some warm temperate waters. Pygmy killer whales, although not known to be particularly common anywhere, have nonetheless been recorded from Okinawan waters through a number of sightings, stranding, and captures (Uchida 1985, 1994, 2005). Among these records, a notable one was the driving ashore and capturing of 42 dolphins of this species in 1985 (Uchida 1994, 2005).

Melon-headed whale *Peponcephala electra*

Melon-headed whales are not uncommon in most tropical and warm temperate seas. This is a medium-sized delphinid species. A small number of sighting, stranding, and capture records of melon-headed whales have been made in Okinawa (Uchida 1982, 1985, 1994, 2005). Most notable among these was a school of 140 individuals that was driven to shore and captured in the Nago small cetacean fishery on 9 July 1979 (Uchida 1982, 1985, 1994).

Risso's dolphin *Grampus griseus*

Risso's dolphin is the largest of the species of cetaceans that have the common name 'dolphin'. They are common in temperate zones around the world, and also occur in virtually all tropical waters, although at lower average densities. Although there are only a small number of specific records for the species, the Risso's dolphin is reported to be a common species off Okinawa. There are several sighting and stranding records (Uchida 1982, 1994, 2005)), and Uchida (1994) mentioned that this species has been observed on 'many' surveys by the staff of the Okinawa Churami Aquarium.

Rough-toothed dolphin *Steno bredanensis*

The rough-toothed dolphin is a smallish delphinid species. It is reasonably common in some tropical zones, and also occurs in certain regions of the warm temperate zones. Although the number of specific sighting, stranding, and capture records of this species off Okinawa is not very large (Nishiwaki and Uchida 1977; Uchida 1985, 1994, 2005; AMSL 2006), the rough-toothed dolphin nonetheless appears to be quite common off the islands. Uchida (1994) and Akajima Marine Science Laboratory (2006) both mentioned that they are 'often' sighted in Okinawan waters. An individual of this species was held captive at the Okinawa Churami Aquarium when the senior author visited in March 2010, and it was still alive as of 2011 (Sekiguchi, pers. observ.).

Common bottlenose dolphin *Tursiops truncatus*

The common bottlenose dolphin is one of the largest dolphin species with a beak. It is a very common species, and is generally one of the most frequently encountered cetaceans in many warmer parts of the world, especially in coastal and inshore waters. Bottlenose dolphins are recorded from a moderate number of stranding, sighting, and capture records from Okinawa, and these dolphins are occasionally taken in the Nago drive fishery for small cetaceans (Nishiwaki and Uchida 1977; Uchida 1982, 1985, 2005). Because the two species of bottlenose dolphins are difficult to distinguish at sea, the author suggests that at least some of these records might have actually been of *T. aduncus*, and may have been misidentified.

Indo-Pacific bottlenose dolphin *Tursiops aduncus*

Relatively newly recognized by marine mammal biologists, the Indo-Pacific bottlenose dolphin is still poorly-known. It is a smallish beaked dolphin, and is found only the in the coastal waters of the Indo-Pacific. Only one specific record of the Indo-Pacific bottlenose dolphin is known from the Okinawa region, a 'wandering in' stranding in 1985 (Uchida 1994, 2005). However, based on what is known of this species' habitat preferences, it would be expected to be common around Okinawa. The author predicts that it may in fact be regularly seen there, and simply not recognized (and misidentified as *Tursiops truncatus*). There was also a capture of 7 of these dolphins at the nearby Amami Islands, for the Okinawa Churami Aquarium in 1974 (Miyazaki 1989; Uchida 2005).

Common dolphin *Delphinus* sp.

The two species of common dolphins (short-beaked *Delphinus delphis* and long-beaked *D. capensis*) are both small, long-beaked cetaceans. Both are common in warmer parts of the world, although the long-beaked species generally only occurs in continental shelf and slope waters. Uchida (1994) mentioned a sighting by M. Nishiwaki of common dolphins from the waters around Okinawa, but gave no details of how the animals were identified. Although Nishiwaki was a highly-experienced marine mammal biologist, at the time of sighting (presumably in the 1960s), the taxonomy and diagnostic characters of long-beaked dolphins of the genera *Delphinus* and *Stenella* were poorly-known, and misidentification of various *Stenella* spp. as common dolphins were frequent, even among experienced marine mammal biologists (see Fertl et al. 2003). Therefore, we consider this record to be unverifiable, and this leaves common dolphins (*Delphinus*) as a genus not confirmed from Okinawa.

Fraser's dolphin *Lagenodelphis hosei*

Only described about six decades ago, Fraser's dolphin is still among the most poorly known of all the delphinid species. This species is relatively small and is found in all tropical and subtropical parts of the world. There is only a single record of Fraser's dolphin from Okinawa, an individual that was captured alive in a gillnet on 1 September 1984, and was held and treated at the Okinawa Churami Aquarium for 20 days before it died (Uchida 1985, 1994).

Pantropical spotted dolphin *Stenella attenuata*

One of the most common and abundant of all cetaceans worldwide, the pantropical spotted dolphin is a small, tropical delphinid. The pantropical spotted dolphin is 'regularly' sighted by Okinawa Churami Aquarium staff on their surveys, and this may be one of the most common cetacean species off Okinawa (Uchida 1994). There are dozens of sightings, strandings, and captures of this species (Uchida 1982, 1985, 2005), and most older sighting records of *Stenella* sp. dolphins are presumably of this species as well (Uchida 1982).

Striped dolphin *Stenella coeruleoalba*

Striped dolphins are small dolphins found in regions ranging from the tropics to some cold temperate waters around the world. They are very abundant, especially in certain warm temperate regions. Only a single record of the striped dolphin exists for Okinawa, a stranding from an unknown date (Uchida 2005).

Spinner dolphin *Stenella longirostris*

Spinner dolphins are small, slender dolphins. They are common in tropical waters worldwide, but appear to be most common around continental and island margins. Until 1992, the spinner dolphin was not known from Okinawan waters. However, in that year, an individual of this species was captured in an unspecified fishery at Nago (Uchida 1994).

Narrow-ridged finless porpoise *Neophocaena asiaeorientalis*

The only phocoenid species to occur in the Indo-Pacific, the finless porpoise is common in coastal waters. It is a small, elusive type of small cetacean. The finless porpoise has very recently been split into two species: *Neophocaena phocaenoides and Neophocaena asiaeorientalis* (Jefferson and Wang 2011). Although finless porpoises have sometimes been reported from Okinawa, based on the finding of two finless porpoise carcasses in the stomach of a great white shark captured off Ie shima (Uchida 1994; Kasuya 1999), the shark could have eaten the porpoises some distance away before swimming to Okinawa. Thus, we consider the stranding of a narrow-ridged finless porpoise on the Motubu Peninsula in 2004 (Yoshida et al. 2010) to be the first confirmed record of this genus in Okinawa. However, this is generally a coastal species that does not occur around oceanic archipelagoes, and thus this record is considered extralimital.

Dugong *Dugong dugon*

The dugong is one of four living species of herbivorous marine mammals in the order Sirenia. It is a medium-sized marine mammal and is considered rare today in most parts of its range, largely due to unrestricted hunting in the past. The dugong reaches the northern limits of its distribution in waters around Okinawa. Although apparently rare today in Okinawa, the dugong has a long history of recorded presence in the region, being documented in Okinawa archaeological sites dating back several millennia (Welch et al. 2010). There are many recent records of sightings, strandings, and captures (both direct and indirect), although by all accounts the species is now badly depleted and considered endangered in Okinawa (see Welch et al. 2010 for a recent review). There are no statistically-defensible estimates of abundance for the species around Okinawa, but six individuals were observed in a single group in 1999 (Marsh et al. 2002). Several reports, including a review by the Mammalogical Society of Japan, have suggested that the local population probably does not number more than about 50 individuals (Kasuya and Miyazaki 1997). As part of an environmental impact assessment, there have several aerial surveys in recent years, and dugongs have been sighted on a number of these surveys, so it is apparent that the species has not been extirpated in Okinawa.

Conclusions

The above review has made it clear that the marine mammal fauna of Okinawa is tropical in nature. All of the species recorded there are well known to be inhabitants of tropical waters, and there is no evidence that any species restricted to cold temperate waters occurs in Okinawa (at least on anything other than an extralimital basis). The marine mammal fauna of the island is apparently of high diversity, but low density. Based on what is known from other Pacific archipelagos (e.g., Hawaii) it is possible that there may be some residency for some of the species around Okinawa. This makes understanding their population status all the more important, as this would be a very critical piece of information for proper management.

Among the species of marine mammals of Okinawa are a single species of baleen whale and 6-7 species of toothed whales and dolphins that can be considered reasonably common, based on the record of past sightings, strandings, and captures. The humpback whale is clearly the only baleen whale that is regularly seen in the area, and then only during the breeding season which lasts from about November to April.

For the odontocetes, the short-finned pilot whale is clearly common and regular, and it became the target species for the local small cetacean drive (and later harpoon) fishery, based in Nago. Three other species of 'blackfish' also appear to be reasonably common, based on the presence of a number of sightings, strandings, and captures (pygmy killer whale, melon-headed whale, and Risso's dolphin [the latter are only sometimes included among the 'blackfish' species]). Two long-beaked dolphins also appear to be common in Okinawa: the rough-toothed dolphin (represented by a number of sightings, strandings, and captures) and the pantropical spotted dolphin (which is believed to the most common cetacean species around the islands). Finally, although there are few specific records, we predict that the Indo-Pacific bottlenose dolphin will prove to be present in considerable numbers in local coastal waters, and we think that many of the past records of common bottlenose dolphins have been misidentified examples of this species.

Any of the above eight species can reasonably be expected to be observed on marine mammal surveys in the Okinawa area. The other species of cetaceans that have been recorded there (see above) would appear to be rather rare in Okinawan waters (or very cryptic and difficult to detect in visual surveys), and we would not necessarily expect them to be observed during a marine mammal survey there. In addition to those that have been recorded there, several additional species of baleen whales (e.g., North Pacific right whale, blue whale, fin whale, Omura's whale) and beaked whales (e.g., Longman's beaked whale, Stejneger's beaked whale) may also occur in Okinawan waters, although likely only sporadically or in very low densities in the shallower waters near the islands.

The final species of marine mammal present, the dugong (a sirenian, and the only non-cetacean marine mammal known from the area), is apparently a resident species and there are numerous records of its occurrence along the central and northern portions of the east coast of the main island of Okinawa. Despite this, it is an elusive species and is quite rare, so we would be very fortunate indeed to observe dugongs during our work in Okinawa. An effective dugong monitoring program would likely involve more focused, dedicated surveys involving one or more of the following: aerial surveys, diving surveys for detection of dugong feeding trails, and passive acoustic monitoring with sensors specific to the low frequency sounds made by dugongs.

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Appendix A - Tables

Table 1. Marine Mammal Species Recorded in Okinawa

Species	Sightings	Strandings	Captures
Sei whale - *Balaenoptera borealis*			X?
Bryde's whale - *Balaenoptera brydei/edeni*	X		X
Common minke whale - *Balaenoptera acutorostrata*		X	
Humpback whale - *Megaptera novaeangliae*	X	X	X
Sperm whale - *Physeter macrocephalus*	X	X	X
Pygmy sperm whale - *Kogia breviceps*	X	X	
Dwarf sperm whale - *Kogia sima*		X	X
Cuvier's beaked whale - *Ziphius cavirostris*	X	X	
Blainville's beaked whale - *Mesoplodon densirostris*		X	X
Ginkgo-toothed beaked whale - *Mesoplodon ginkgodens*			X
Killer whale - *Orcinus orca*	X		X
Short-finned pilot whale - *Globicephala macrorhynchus*	X	X	X
False killer whale - *Pseudorca crassidens*		X	X
Pygmy killer whale - *Feresa attenuata*	X	X	X
Melon-headed whale - *Peponocephala electra*	X	X	X
Rough-toothed dolphin - *Steno bredanensis*	X	X	X
Risso's dolphin - *Grampus griseus*	X	X	
Common bottlenose dolphin - *Tursiops truncatus*	X	X	X
Indo-Pacific bottlenose dolphin - *Tursiops aduncus*		X	
Pantropical spotted dolphin - *Stenella attenuata*	X	X	X
Striped dolphin - *Stenella coeruleoalba*		X	
Spinner dolphin - *Stenella longirostris*			X
Common dolphin - *Delphinus* sp.	X?		
Fraser's dolphin - *Lagenodelphis hosei*			X
Narrow-ridged finless porpoise - *Neophocaena asiaeorientalis*		X	
Dugong - *Dugong dugon*	X	X	X

Table 2. Marine Mammal Occurrence Records from Okinawa

Species	Date	Location	Type *	Notes	Reference(s)
B. acutorostrata	??	Aguni Isl., Okinawa	STR	3.3 m long	Uchida 2005
B. borealis	1960	Okinawa	CAP	Small numbers taken in Ryukyu whaling	Miyasato 1988; Uchida 1994
B. edeni	1960	Okinawa	CAP	1 whaling record (possibly sei whale)	Nishiwaki 1960
B. edeni	??	East China Sea	STG	Near Okinawa?	Uchida 1994
Delphinus sp.	??	Off Okinawa?	STG	Sighting by M. Nishiwaki (extralimital?)	Uchida 1994
F. attenuata	1985	Kouri Island	CAP	42 dolphins driven	Uchida 2005
F. attenuata	27-Jun-79	Kushi Beach, Nago	STR	Decomposed; about 220 cm	Uchida 1985, 1994
F. attenuata	9-Jul-79	north of Okinawa	CAP	Harpooned; about 210 cm male	Uchida 1985, 1994
F. attenuata	9-May-84	26°41'N,127°10'E	STG	Group of about 15	Uchida 1985, 1994
F. attenuata	22-Mar-85	Ishikaki-shima	?	ca. 170 cm	Uchida 1994
F. attenuata	6-May-85	Kouri-shima	CAP	42 animals driven to shore	Uchida 1994
F. attenuata	13-Mar-91	Zamami-shima	STG	ca. 50 animals	Uchida 1994
F. attenuata	13-Mar-91	Zamami-shima	STG	ca. 10 animals	Uchida 1994
F. attenuata	13-Mar-91	Zamami-shima	STG	3 animals	Uchida 1994
F. attenuata	??	Okinawa	CAP	Caught by harpoon; SUM 020	Uchida 1982
G. griseus	16-Apr-82	26°58'N,128°14'E	STG		Uchida 1982
G. griseus	14-Jul-82	27°09'N,128°28'E	STG		Uchida 1982
G. griseus	??		STG	"Many" sightings on aquarium surveys	Uchida 1994
G. griseus	??	Okinawa	STR	7 stranding records	Uchida 2005
G. griseus	??	Ishigaki Harbor	STR		Uchida 1994
G. griseus	??	Yonabaru Harbor	STR		Uchida 1994
G. griseus	??	Machinato Bay	STR		Uchida 1994
G. griseus	??	Yonashiro-mura	STR		Uchida 1994

Species	Date	Location	Type *	Notes	Reference(s)
G. macrorhynchus	5-Mar-60	26°36'N,127°59'E (Nago)	CAP	70 captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
G. macrorhynchus	22-Mar-60	26°36'N,127°59'E (Nago)	CAP	96 captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
G. macrorhynchus	28-Mar-60	26°36'N,127°59'E (Nago)	CAP	77 captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
G. macrorhynchus	16-Mar-61	26°36'N,127°59'E (Nago)	CAP	140 captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
G. macrorhynchus	3-Apr-61	26°36'N,127°59'E (Nago)	CAP	141 captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
G. macrorhynchus	15-Mar-63	26°36'N,127°59'E (Nago)	CAP	189 captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
G. macrorhynchus	8-Apr-64	26°36'N,127°59'E (Nago)	CAP	150 captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
G. macrorhynchus	25-Apr-64	26°36'N,127°59'E (Nago)	CAP	168 captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
G. macrorhynchus	3-Apr-67	26°36'N,127°59'E (Nago)	CAP	150 captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
G. macrorhynchus	29-Jun-68	26°36'N,127°59'E (Nago)	CAP	150 captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
G. macrorhynchus	1-May-69	26°36'N,127°59'E (Nago)	CAP	270 captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
G. macrorhynchus	2-May-69	26°36'N,127°59'E (Nago)	CAP	70 captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
G. macrorhynchus	4-May-69	26°36'N,127°59'E (Nago)	CAP	60 captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
G. macrorhynchus	6-May-69	26°36'N,127°59'E (Nago)	CAP	100 captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
G. macrorhynchus	22-Mar-71	26°36'N,127°59'E (Nago)	CAP	90 captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985

Species	Date	Location	Type *	Notes	Reference(s)
G. macrorhynchus	27-Mar-71	26°36'N,127°59'E (Nago)	CAP	19 captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
G. macrorhynchus	22-Apr-71	26°36'N,127°59'E (Nago)	CAP	11 captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
G. macrorhynchus	22-Jul-71	26°36'N,127°59'E (Nago)	CAP	45 captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
G. macrorhynchus	10-Mar-72	26°36'N,127°59'E (Nago)	CAP	56 captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
G. macrorhynchus	13-Mar-72	26°36'N,127°59'E (Nago)	CAP	2 captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
G. macrorhynchus	25-Apr-72	26°36'N,127°59'E (Nago)	CAP	112 captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
G. macrorhynchus	9-Aug-73	26°36'N,127°59'E (Nago)	CAP	87 captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
G. macrorhynchus	6-Mar-74	26°36'N,127°59'E (Nago)	CAP	53 captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
G. macrorhynchus	8-Mar-75	26°36'N,127°59'E (Nago)	CAP	27 captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
G. macrorhynchus	7-May-75	26°36'N,127°59'E (Nago)	CAP	22 captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
G. macrorhynchus	6-Mar-77	26°36'N,127°59'E (Nago)	CAP	110 captured in Nago drive fishery	Uchida 1985
G. macrorhynchus	8-Mar-77	26°36'N,127°59'E (Nago)	CAP	19 captured in Nago drive fishery	Uchida 1985
G. macrorhynchus	14-Mar-77	26°36'N,127°59'E (Nago)	CAP	43 captured in Nago drive fishery	Uchida 1985
G. macrorhynchus	2-Apr-77	26°36'N,127°59'E (Nago)	CAP	126 captured in Nago drive fishery	Uchida 1985
G. macrorhynchus	19-Apr-80	26°36'N,127°59'E (Nago)	CAP	38 captured in Nago drive fishery	Uchida 1985
G. macrorhynchus	4-Jun-80	26°36'N,127°59'E (Nago)	CAP	23 captured in Nago drive fishery	Uchida 1985
G. macrorhynchus	1-Jul-80	26°36'N,127°59'E (Nago)	CAP	30 captured in Nago drive fishery	Uchida 1985
G. macrorhynchus	16-Apr-82	27°07'N,128°10'E	STG		Uchida 1982
G. macrorhynchus	20-Apr-82	26°53'N,127°33'E	STG		Uchida 1982
G. macrorhynchus	14-May-82	26°36'N,127°59'E (Nago)	CAP	9 captured in Nago drive fishery	Uchida 1985

Species	Date	Location	Type *	Notes	Reference(s)
G. macrorhynchus	29-May-84	26°52'N,127°32'E	STG		Uchida 1985
G. macrorhynchus	1-Mar-85	26°55'N,127°33'E	STG		Uchida 1985
G. macrorhynchus	5-Dec-91	24°40'N,123°38'E	STG		Higashi et al. 1992
G. macrorhynchus	??	Okinawa	STR	2 stranding records	Uchida 2005
G. macrorhynchus	?? Jul 78	Hentona	STG		Uchida 1982
K. breviceps	29-May-84	26°26'N,127°29'E	STG		Uchida 1985
K. breviceps	??	Okinawa	STR	10 stranding records	Uchida 2005
K. sima	??	north of Okinawa (Oogimi Village)	CAP	SUM 026; 2.1 m females; reported as K. breviceps	Uchida 1982, 1994
K. sima	??	Okinawa	STR	10 stranding records (5 from 1980-1991)	Uchida 1994, 2005
Kogia sp.	19-May-84	Naha Military Base	STR	Male; probably K. sima	Uchida 1985
Kogia sp.	early 1935	Ohama Village	CAP	Probable K. sima	Hirasaka 1937
L. hosei	1-Sep-84	North Nakajo Village	CAP	Gillnet capture; SUM 038; 208 cm female	Uchida 1985, 1994
M. densirostris	6-Oct-85	Naha Harbor	CAP	Caught after wandering in; 4.3 m male	Uchida 1994
M. densirostris	15-May-96	Nago	CAP	Live-capture; 3.6 m male; kept at OK Aquarium	Uchida 1994
M. densirostris	??	Ishigaki-shima	STR	4.6 m male	Uchida 1994
M. densirostris	??	Kiro-shima	STR	Skull	Uchida 1994
M. densirostris	??	Okinawa	STR	3 stranding records	Uchida 2005
M. ginkgodens	20-Jul-82	Urazoe City	CAP	Caught after wandering in	Uchida 1982, 1994
M. novaeangliae	1914	Okinawa area	CAP	90 whaling records	Nishiwaki 1959
M. novaeangliae	1919	Okinawa area	CAP	26 whaling records	Nishiwaki 1959
M. novaeangliae	1921	Okinawa area	CAP	8 whaling records	Nishiwaki 1959
M. novaeangliae	1922	Okinawa area	CAP	3 whaling records	Nishiwaki 1959
M. novaeangliae	1934	Okinawa area	CAP	4 whaling records	Nishiwaki 1959
M. novaeangliae	1954	Okinawa area	CAP	4 whaling records	Nishiwaki 1959
M. novaeangliae	1955	Okinawa area	CAP	11 whaling records	Nishiwaki 1959

Species	Date	Location	Type *	Notes	Reference(s)
M. novaeangliae	1956	Okinawa area	CAP	13 whaling records	Nishiwaki 1959
M. novaeangliae	1957	Okinawa area	CAP	23 whaling records	Nishiwaki 1959
M. novaeangliae	1958	Okinawa area	CAP	290 whaling records	Nishiwaki 1959; Miyasato 1988
M. novaeangliae	1959	Okinawa area	CAP	217 whaling records	Nishiwaki 1959; Miyasato 1988
M. novaeangliae	1960	Okinawa area	CAP	167 whaling records	Nishiwaki 1960; Miyasato 1988
M. novaeangliae	1961	Okinawa area	CAP	90 whaling records	Nishiwaki 1962; Miyasato 1988
M. novaeangliae	1962	Okinawa area	CAP	24 whaling records	Miyasato 1988
M. novaeangliae	6-May-78	NW of Okinawa	STG		Uchida 1985
M. novaeangliae	26-Apr-79	5.5 km N of Kouri Isl.	STG		Uchida 1985
M. novaeangliae	8-Apr-81	Motubu Peninsula	STG		Uchida 1982, 1985
M. novaeangliae	30-Apr-82	26°50'N,127°29'E	STG		Uchida 1982
M. novaeangliae	30-Apr-82	26°50'N,127°29'E	STG		Uchida 1982
M. novaeangliae	30-Apr-82	NW of Ie Island	STG		Uchida 1985
M. novaeangliae	30-Apr-82	NW of Ie Island	STG		Uchida 1985
M. novaeangliae	3-Jun-84	Naha Harbor	STG		Uchida 1985
M. novaeangliae	19-Jul-84	Motubu, Park Aquarium	STG		Uchida 1985
M. novaeangliae	15-Feb-85	NW of Ie Island	STG		Uchida 1985
M. novaeangliae	16-Mar-85	Kerama Archipelago	STG		Uchida 1985
M. novaeangliae	21-Mar-93	Tokashiki Isl., Kerama	STR		Uchida 2005
M. novaeangliae	9-Feb-96	Yomitan, OK	CAP	Caught in fishing net	Uchida 2005
M. novaeangliae	12-Feb-96	Yomitan, OK	CAP	Caught in fishing net	Uchida 2005
M. novaeangliae	? Jan 79	Iheya	STG		Uchida 1985
M. novaeangliae	1954-1959	Okinawa area	CAP	446 whaling records	Nishiwaki 1959
M. novaeangliae	1989/1990	Okinawa	STG	Multiple sightings	Darling and Mori 1993
M. novaeangliae	1989-2000	Okinawa	STG	Multiple sightings	Uchida 2005
M. novaeangliae	1991 to 1997	Zamami Island (26°N,127°E)	STG	Multiple sightings	Maeda et al. 2000a,b

Species	Date	Location	Type *	Notes	Reference(s)
M. novaeangliae	Feb-Mar 1991	26°15'N,127°15'E	STG	86 sighting records	Uchida et al. 1993
N. asiaeorientalis	17-Feb-04	NW Motobu Peninsula	STR	Live-stranded (extralimital?)	Yoshida et al. 2010
Neophocaena sp.	? Jun 82	Ie shima	CAP	Recovered from stomach of great white shark	Uchida 1994; Kasuya 1999
O. orca	1979		CAP	1 caught in Nago fishery	Uchida 1994
O. orca	1985		CAP	2 caught in Nago fishery	Uchida 1994
O. orca	??		STG	Non-specific sighting records	Uchida 1994
P. crassidens	27-Mar-71	26°36'N,127°59'E (Nago)	CAP	Captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
P. crassidens	??	Zamami-shima	STR		Uchida 1994
P. crassidens	??	Motubu-cho coast	STR		Uchida 1994
P. crassidens	??	Okinawa	STR	3 stranding records	Uchida 2005
P. electra	18-Mar-78	Okinawa	CAP	3 animals harpooned	Uchida 1994
P. electra	9-Jul-79	26°36'N,127°59'E (Nago)	CAP	140 captured in Nago drive fishery (SUM 022)	Uchida 1982, 1985
P. electra	? May 80	"Off main island"	CAP	1 animal harpooned	Uchida 1994
P. electra	? Aug 80	"Off Miyako-shima"	CAP	3 animals harpooned	Uchida 1994
P. electra	19-Feb-81	"Off main island"	CAP	1 animal harpooned	Uchida 1994
P. electra	19-Sep-81	Nago Bay	STG	3 animals signted	Uchida 1994
P. electra	5 or 7 Jul 82	26°15'N,127°11'E	STG	50 animals sighted by aquarium staff	Uchida 1982, 1994
P. electra	8-Sep-90	Camp Schwab (Nago)	STR	1 animal stranded; 230 cm	Uchida 1994
P. electra	? Apr 84	Nago Bay	STG	50 animals sighted (poss. F. attenuata)	Uchida 1994
P. electra	??	Okinawa	STR	3 stranding records	Uchida 2005
P. macrocephalus	1959	Okinawa area	CAP	7 whaling records	Nishiwaki 1962; Miyasato 1988
P. macrocephalus	1960	Okinawa area	CAP	14 whaling records	Nishiwaki 1960, 1962; Miyasato 1988

Species	Date	Location	Type *	Notes	Reference(s)
P. macrocephalus	1961	Okinawa area	CAP	9 whaling records	Nishiwaki 1962; Miyasato 1988
P. macrocephalus	1963	Okinawa area	CAP	1 whaling record	Miyasato 1988
P. macrocephalus	6-Jul-82	26°27'N,126°59'E	STG		Uchida 1982
P. macrocephalus	1-Jul-84	26°33'N,127°40'E	STG		Uchida 1985
P. macrocephalus	??	Okinawa	STR	5 stranding records	Udhia 2005
S. attenuata	9-Jul-82	26°22'N,126°54'E	CAP	180 cm F; SUM 030	Uchida 1982
S. attenuata	29-May-84	26°37'N,127°31'E	STG		Uchida 1985
S. attenuata	31-May-84	26°44'N,127°31'E	STG		Uchida 1985
S. attenuata	5-Jun-84	26°50'N,127°40'E	STG		Uchida 1985
S. attenuata	5-Sep-84	26°47'N,127°42'E	STG	One captured	Uchida 1985
S. attenuata	5-Sep-84	26°47'N,127°42'E	CAP	SUM 041; 164 cm M	Uchida 1985
S. attenuata	1-Mar-85	26°55'N,127°33'E	STG		Uchida 1985
S. attenuata	??	Okinawa	STR	12 stranding records	Uchida 2005
S. bredanensis	15-Jan-76	26°36'N,127°59'E (Nago)	CAP	23 captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
S. bredanensis	22-Jan-85	26°56'N,127°52'E	STG		Uchida 1985
S. bredanensis	15-Jun-05	Kushibaru, NW of Akajima	STR	196-cm mature female	AMSL 2006
S. bredanensis	??		CAP	2 captured in harpoon fishery	Uchida 1994
S. bredanensis	??		STG	4 sightings on aquarium surveys	Uchida 1994
S. bredanensis	??	Okinawa	STR	6 stranding records	Uchida 2005
S. bredanensis	??		CAP?	1 held at OK Aquarium in 2011	Jefferson, Sekiguchi,, pers. observ.
S. coeruleoalba	??	Okinawa	STR		Uchida 2005
S. longirostris	1992	Nago	CAP	First capture record in Okinawa	Uchida 1994
Stenella sp.	12-Apr-82	26°36'N,127°45'E	STG	Prob. S. attenuata	Uchida 1982
Stenella sp.	12-Apr-82	26°50'N,127°40'E	STG	Prob. S. attenuata	Uchida 1982
Stenella sp.	2-Jun-82	26°41'N,127°38'E	STG	Prob. S. attenuata	Uchida 1982
Stenella sp.	9-Jul-82	26°22'N,126°54'E	STG	Prob. S. attenuata	Uchida 1982
Stenella sp.	9-Jul-82	26°22'N,126°54'E	STG	Prob. S. attenuata	Uchida 1982

Species	Date	Location	Type *	Notes	Reference(s)
Stenella sp.	9-Jul-82	26°24'N,126°51'E	STG	Prob. S. attenuata	Uchida 1982
Stenella sp.	8-Nov-82	26°45'N,128°28'E	STG	Prob. S. attenuata	Uchida 1982
Stenella sp.	11-Dec-82	27°27'N,128°48'E	STG	Prob. S. attenuata	Uchida 1982
T. aduncus	1985	Chatan	STR	"Wandering in"	Uchida 1994; 2005
T. truncatus	28-Mar-60	26°36'N,127°59'E (Nago)	CAP	Captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
T. truncatus	22-Jul-71	26°36'N,127°59'E (Nago)	CAP	Captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
T. truncatus	9-Aug-73	26°36'N,127°59'E (Nago)	CAP	Captured in Nago drive fishery	Nishiwaki & Uchida 1977; Uchida 1985
T. truncatus	29-Apr-82	26°44'N,127°29'E	STG		Uchida 1982
T. truncatus	11-May-82	26°52'N,127°42'E	STG		Uchida 1982
T. truncatus	11-May-82	26°52'N,127°42'E	STG		Uchida 1982
T. truncatus	9-May-84	26°50'N,127°28'E	STG		Uchida 1985
T. truncatus	20-Jul-84	Off Ie Island	CAP	Female, harpoon capture	Uchida 1985
T. truncatus	1-Mar-85	26°55'N,127°33'E	STG	One captured	Uchida 1985
T. truncatus	1-Mar-85	26°55'N,127°33'E	CAP	SUM 040; 224 cm M	Uchida 1985
T. truncatus	??	Okinawa	STR	1 stranding record	Uchida 2005
T. truncatus	??	Okinawa	CAP?	232 cm F; SUM 028	Uchida 1982
Unidentified	10-Jul-82	26°20'N,127°16'E	STG		Uchida 1982
Unidentified	10-May-84	26°26'N,127°04'E	STG		Uchida 1985
Unidentified	29-Jun-84	26°49'N,127°30'E	STG		Uchida 1985
Z. cavirostris	6-Dec-73	Hitachi, Ibaraki Pref.	STR		Uchida 1982
Z. cavirostris	29-Jun-84	26°49'N,127°30'E	STG		Uchida 1985
Z. cavirostris	??	Okinawa	STR	3 stranding records	Uchida 2005
Z. cavirostris?	7-Jul-82	26°15'N,127°05'E	STG		Uchida 1982

Key: STG = sighting, STR = stranding, CAP = capture

APPENDIX B

Survey Protocol for Okinawa Marine Species Surveys, 2011 – 2012

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SURVEY PROTOCOL FOR OKINAWA MARINE SPECIES SURVEYS, 2011-2012

No. N62470-10-D-3011, NEW (CTO 25) KB13

Prepared by:

HDR
9449 Balboa Avenue Suite 210
San Diego, CA 92123

OCTOBER 2011

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Acronyms

PAM	Passive Acoustic Monitoring
WSA	water surface area
USMC	United States Marine Corps

SURVEY PROTOCOL FOR OKINAWA MARINE SPECIES SURVEYS, 2011-2012

No. N62470-10-D-3011, NEW (CTO 25) KB13

Thomas A. Jefferson
Clymene Enterprises, under contract to HDR

Objectives

The HDR Monitoring Team is tasked to determine the baseline occurrence of marine mammals within the water surface areas (WSAs) of Okinawa, Japan, by concentrating on the following three goals:

1) To advance the knowledge of marine mammals that may be found in the United States Marine Corps (USMC) WSAs adjacent to Okinawa.
2) To advance the knowledge of the seasonal and diel patterns of marine mammals within the WSAs.
3) To advance the knowledge of the spatial distribution of marine mammals within the WSAs.

Survey Dates

The first survey (13 days) is currently scheduled for 21 October to 2 November 2011. The second survey (13 days) is tentatively planned for some time between late April and early June 2012.

Study Area

There will be four primary survey areas, which collectively cover several USMC WSAs adjacent to the coastline of Okinawa and its associated islands:

1) *Camp Schwab* – a moderate-size region directly offshore of Camp Schwab and Henoko Ammunition Storage Point (ASP), off Okinawa's east coast. The continental shelf edge is at the outer edge of the survey area.
2) *Kin Bay* – a moderate-size area covering Kin Bay and several USMC WSAs off the east coast of Okinawa. The entire area is on the shelf.
3) *Tsuken Training Area* – a small trapezoidal area on the continental shelf off Okinawa's east coast.
4) *Ie Shima Range* – a large area off the northern side of the small island of Ie Shima on Okinawa's west coast. The shelf edge cuts across the middle of the survey area, and this area contains the deepest waters for this study.

Additional survey work may occur in other WSAs, and/or in waters outside of the WSAs (pending any needed permits/permissions from the USMC, and the Japanese and Okinawan governments). There will need to be flexibility in the survey schedule, as we will need to account for possible inclement weather, possible delays due to equipment issues, and unexpected restrictions due to safety and water depth considerations.

Equipment Needed

List of Equipment Required for Okinawa Survey

ITEM	NO.	STATUS
Laptop computer with VisSurvey installed	1	HDR-SD
GPS with cable to connect to laptop data port	1	HDR-SD
External HD for backup of data/photos	1	HDR?
7X50 marine binoculars with reticle and compass	2	NavFac
Monopod binocular support	2	TAJ, KS
Smaller 7X binoculars	1	HDR-SD
SLR digital camera with long lens	2 or 3	TAJ, MR, MTR, KS
Satellite phone	1	HDR-SD
Clipboard and paper data sheets	1	TAJ
Angle boards	1	TAJ will make
Pelican cases for shipping	2 or 3	HDR-SD

Survey Team

Dr. Thomas A. Jefferson - *Chief Scientist/Technical Project Manager* Contact: 1 858 945-4240; sclymene@aol.com

Ms. Morgan Richie - *NAVFAC-Pac biologist* Contact: 1 949 291-2729; morgan.richie@navy.mil

Dr. Keiko Sekiguchi - *Japanese MMO* Contact: 011 090-9835-8040; ksekiguc@hawaii.edu

Mr. Michael Richlen - *HDR staff MMO* Contact: 1 808 247-5063; richlen@hawaii.edu

Methods

In 2011/2012, the HDR Monitoring Team will conduct two 13-day small vessel surveys to establish baseline data on marine mammals in the WSAs around Okinawa. Fieldwork will be maximized for characterization of marine mammal presence, distribution, population structure, and density. Sea turtle sightings will also be recorded.

Standard line-transect vessel surveys will be conducted from the *Blue Fin* (a 50' local vessel used for sportfishing and diving trips), weather permitting (Beaufort 0-4, no rain, and visibility

> 1,200 m). The observer team will conduct searches and observations from the flying bridge area, about 4-5 m eye height above the water's surface. Two observers will make up the on-effort survey team. As the vessel transits the survey lines at a constant speed of 13-15 km/hr, the Primary Observer will search for marine mammals continuously through 7 X 35 marine binoculars. The other on-effort observer, the Data Recorder, will search with unaided eye and record data in software VisSurvey on the computer. Both observers will search ahead of the vessel, between 270° and 90° (in relation to the bow, which was defined as 0°). Observers will rotate positions approximately every 30 minutes. Off-effort observers will rotate into position to give observers who have been on effort a rest after each 60 minutes of search effort, thereby minimizing fatigue.

Effort data collected during on-effort survey periods will include time and position for the start and end of search effort, vessel speed, sea state (Beaufort scale), visibility, and other environmental conditions. When marine mammals are sighted, the Data Recorder will take the team off-effort (after collecting associated sighting data) and the vessel will be diverted from its course to approach the marine mammal group for group size estimation, photography, and behavioral observations. Sighting information collected will include information on sighting angle and distance, position of initial sighting, sea state, group size and composition, and behavior, such as response to the survey vessel. Location data and vessel speed will be obtained from a hand-held Global Positioning System.

Photographs taken during sightings will be sorted and examined for presence of individuals that can be identified by their natural markings. If adequate photographic material is collected, we will initiate preliminary photo-ID catalogs for appropriate species. If this effort is continued over the long term, important biological data may be obtained from photo-identification studies (e.g., information on movement patterns, association patterns, population size, reproductive parameters, social structure, and health indices).

Deployment and retrieval of three Passive Acoustic Monitors (PAMs) will also be conducted during the first and last small vessel survey, respectively. The TPM will coordinate with the NTR regarding exact locations. The deployment will be made without the use of a dive team. The devices will be deployed with acoustic releases so that a dive team is not required for retrieval. HDR will inform the NTR of the location of depth of the devices within 24 hours of deployment.

Data Processing

Each evening after completion of the day’s survey work, all data and photos will be downloaded and backed up on a dedicated external hard-drive, which will be left on shore.

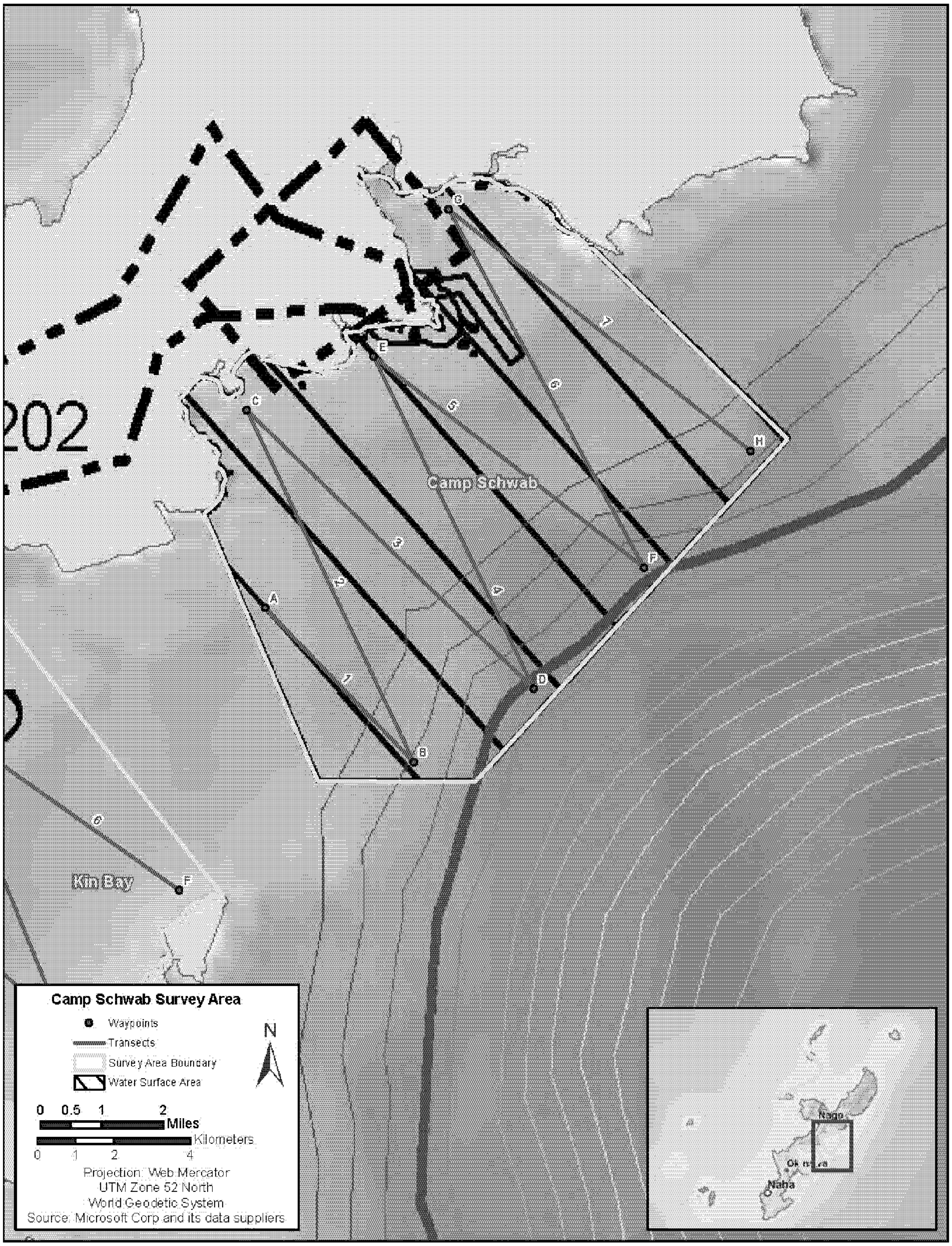
Reporting

Preliminary Draft Reports will be generated for small each 13 –day vessel survey and the PAM data analysis. The final report will combine all elements of this task order and will include graphics, as described in the Deliverables section of the RFP.

Health and Safety Plan

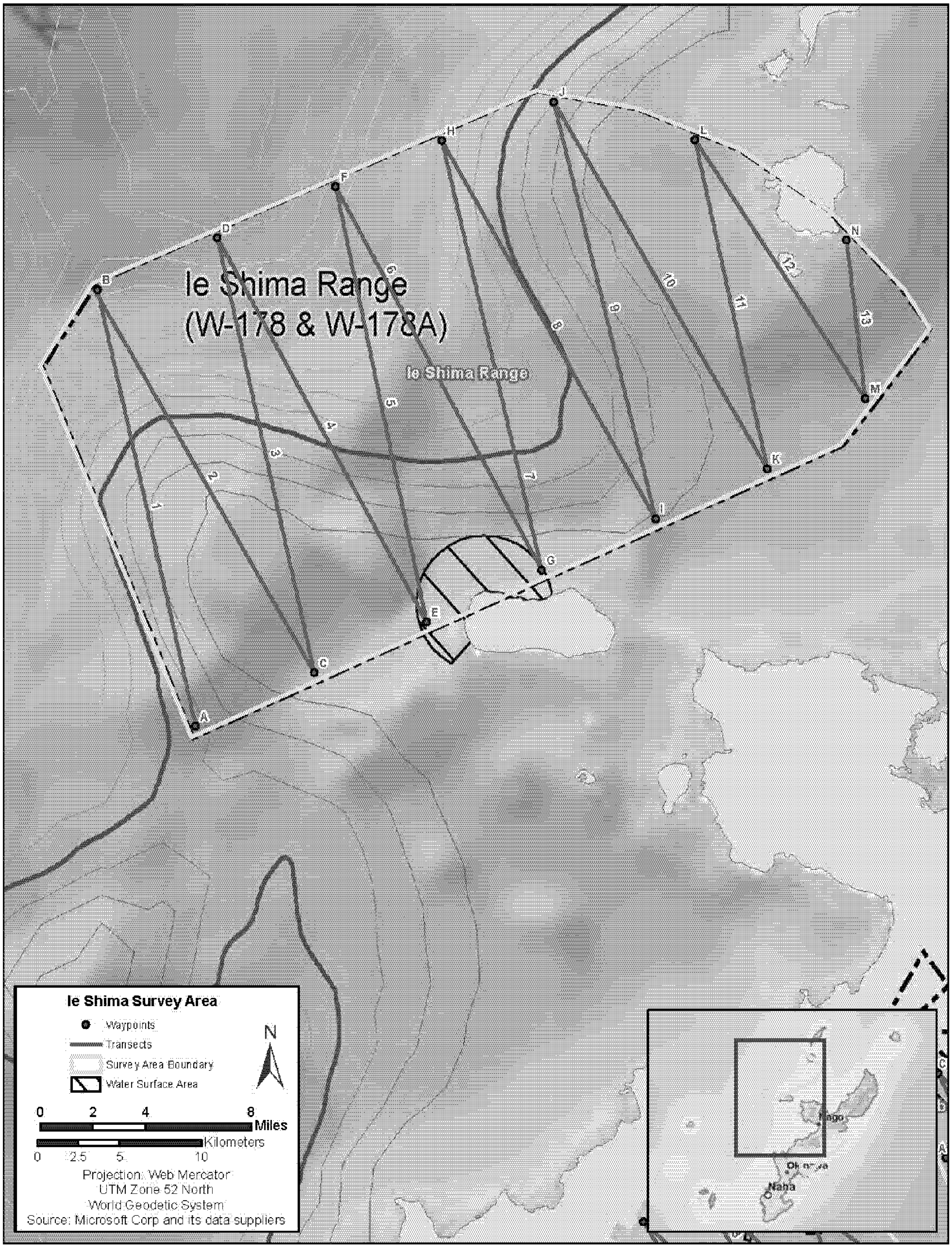
See separate document.

Appendix A - Figures

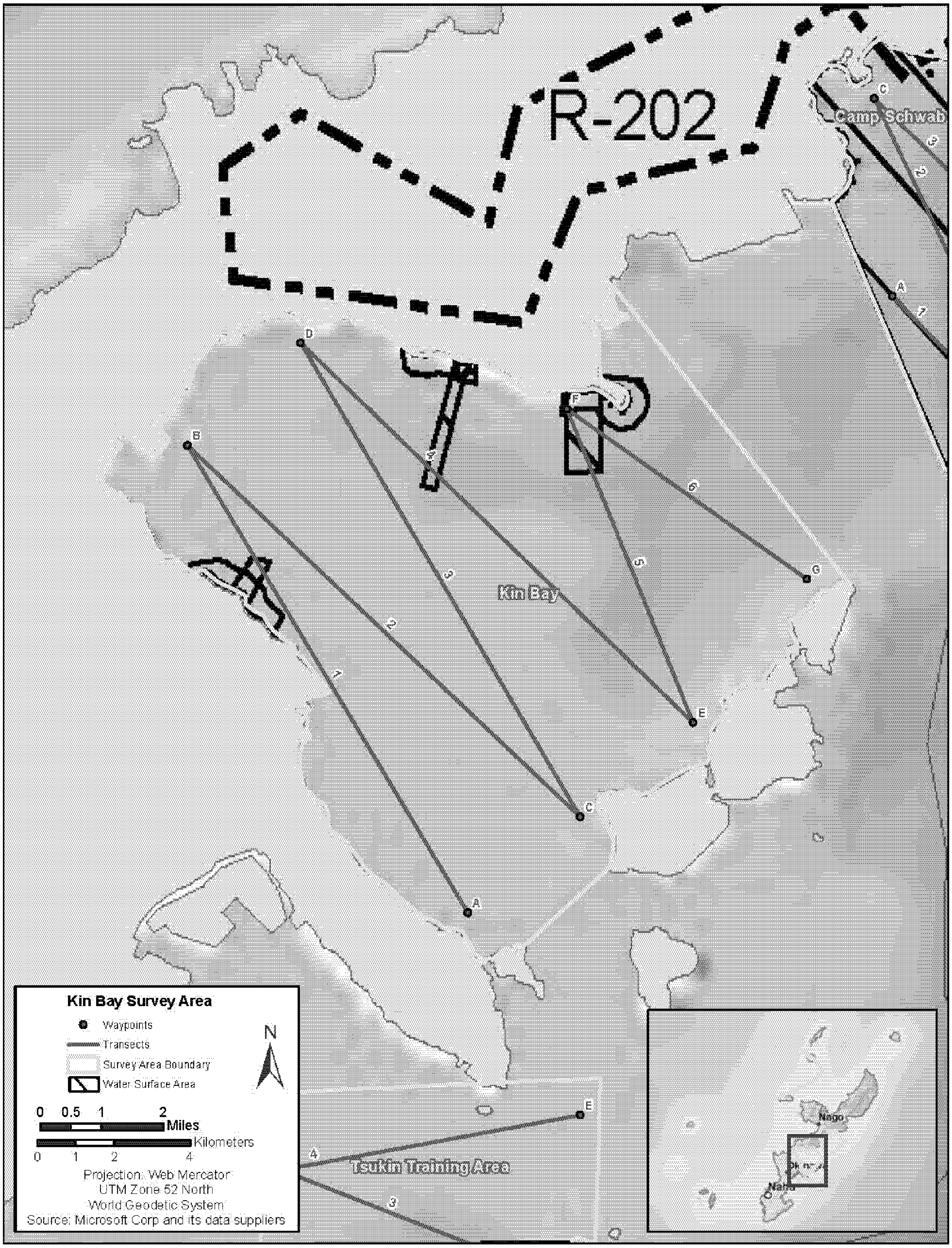


Camp Schwab Survey Area

US00009309

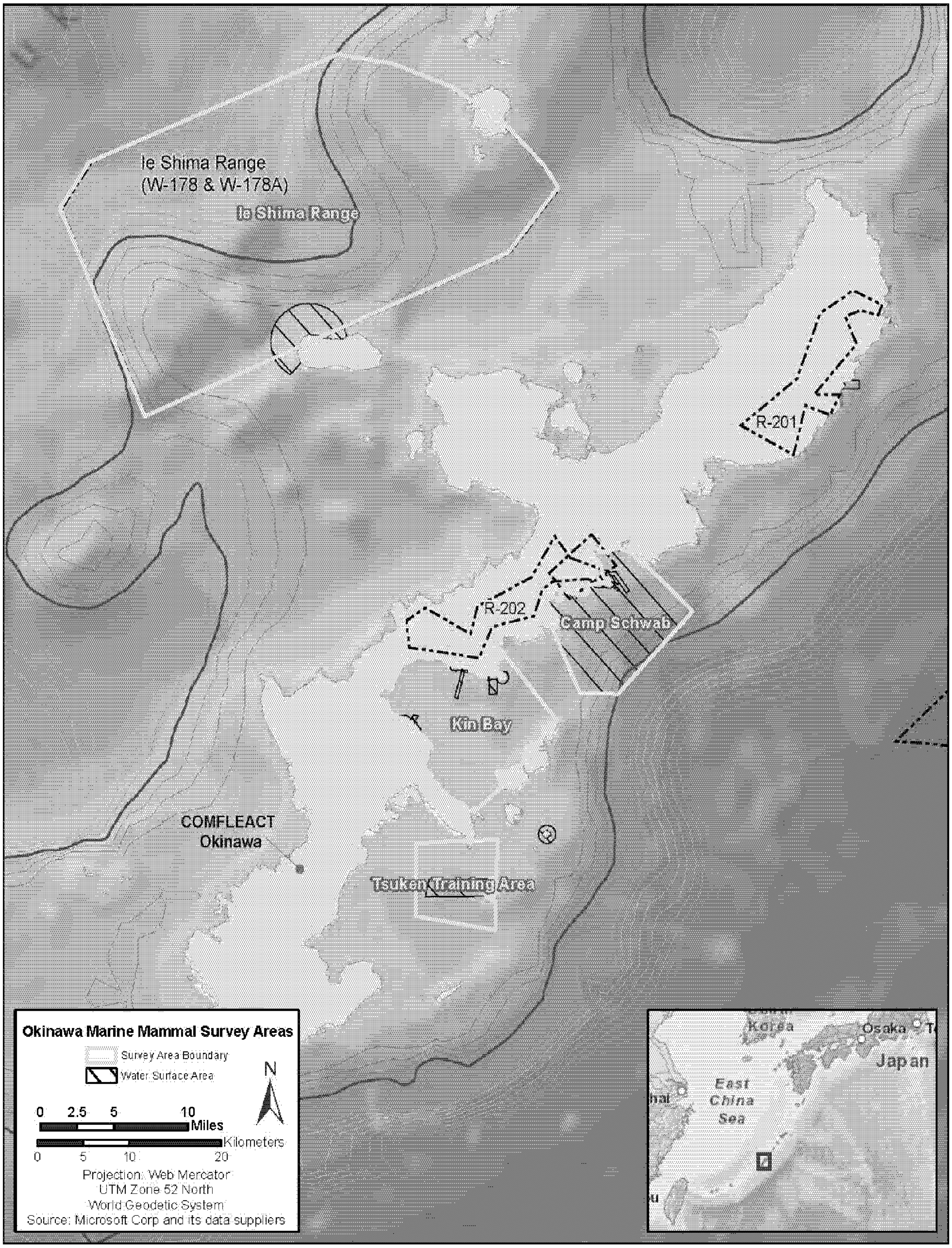


Ie Shima Survey Area



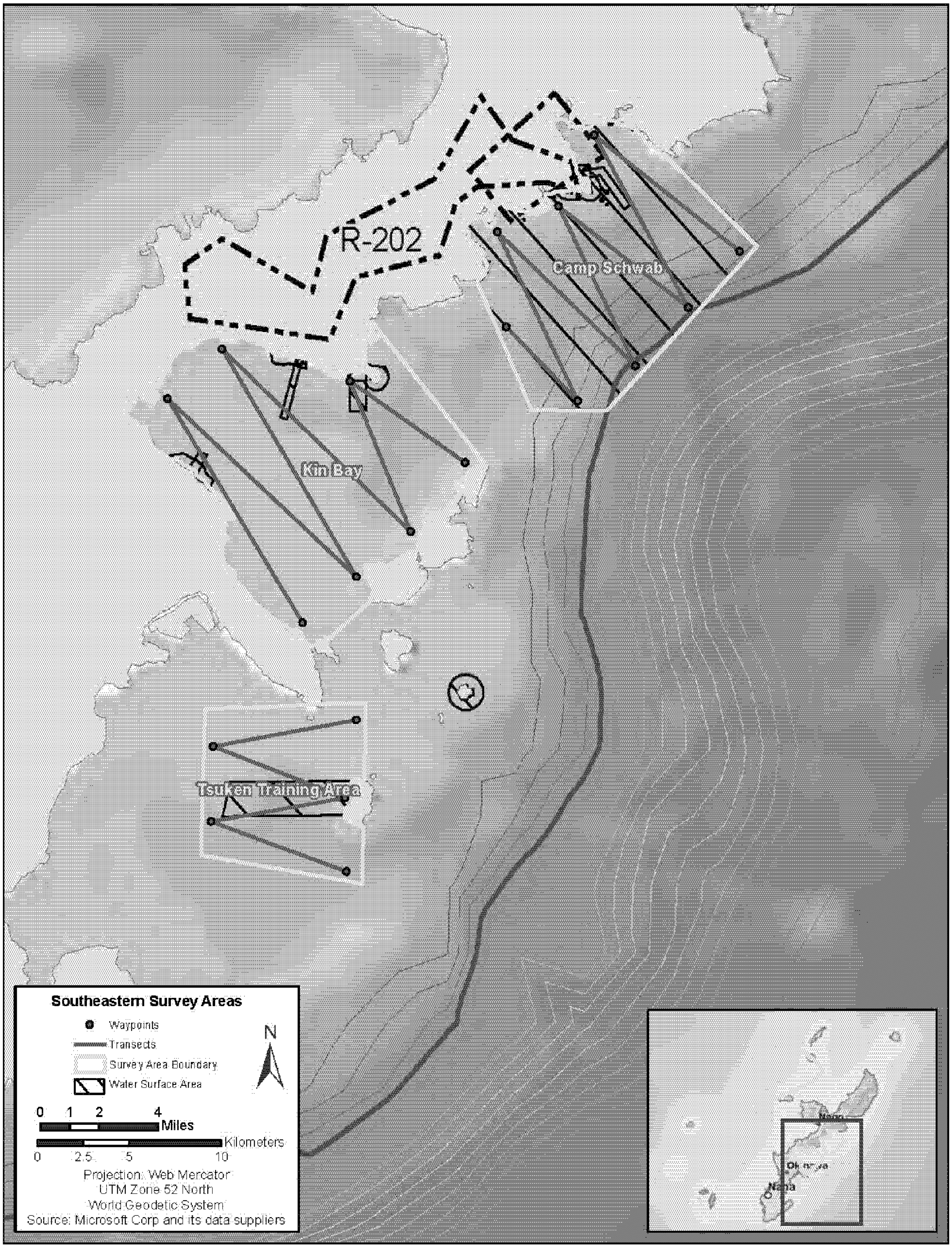
Kin Bay Survey Area

US00009311

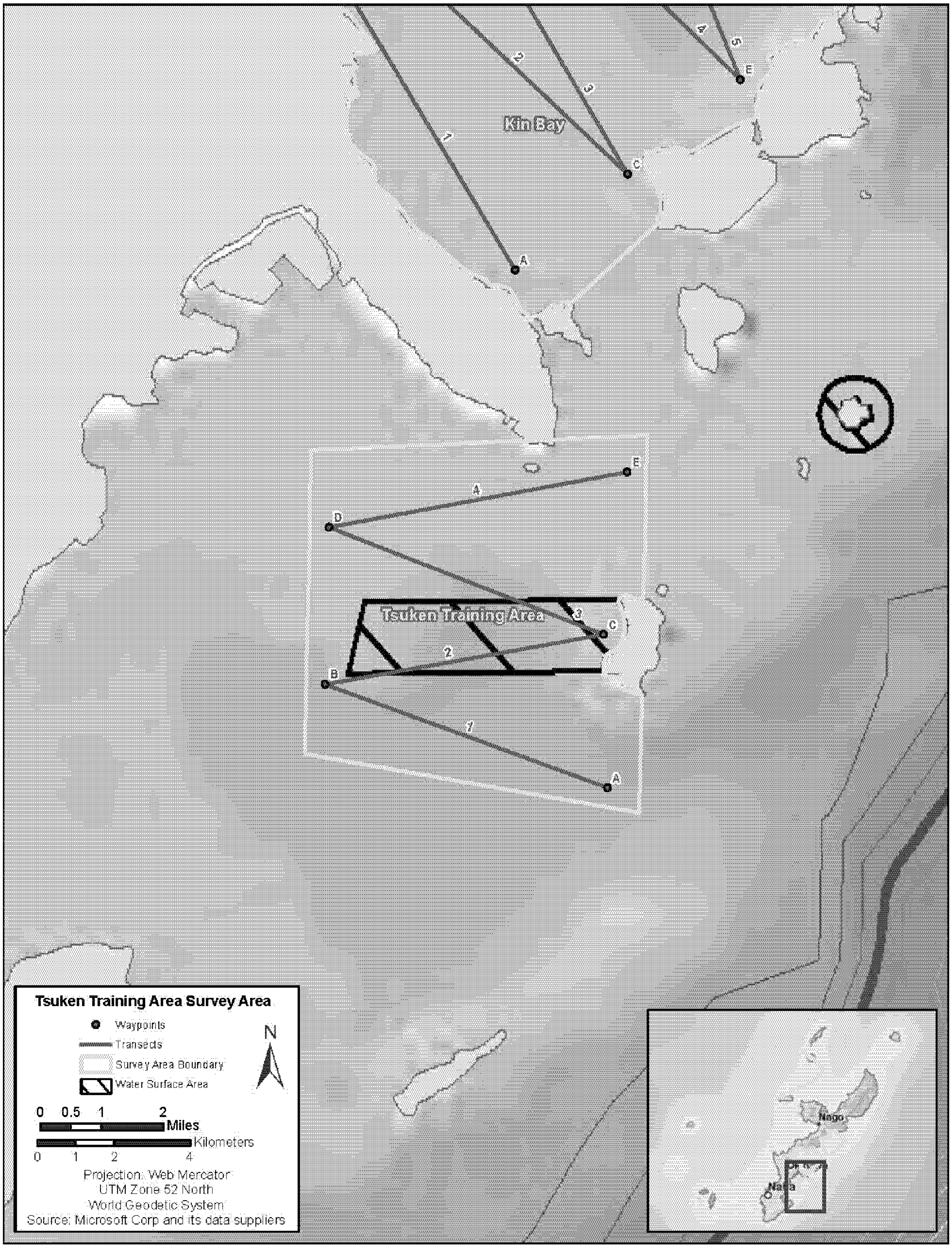


Okinawa Marine Mammal Survey Area

US00009312



Southeastern Survey Area



Tsuken Training Area Survey Area

APPENDIX C
Passive Acoustic Monitoring of Marine Mammals in Okinawa

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PASSIVE ACOUSTIC MONITORING OF MARINE MAMMALS IN OKINAWA

FINAL REPORT

August 2013

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SUBJECT:	Final 2012 Technical Report to HDR (1st and 2nd Deployments)
PROJECT:	Marine Mammal Monitoring: Okinawa
PRINCIPAL INVESTIGATOR:	Whitlow W. L. Au Marine Mammal Research Program Hawaii Institute of Marine Biology University of Hawaii P.O. Box 1106 Kaneohe, HI 96734
COLLABORATORS:	Helen Ou – HIMB Michael Richlen – HIMB Giacomo Giorli – HIMB Marc Lammers – HIMB & OSI Jade Delevaux – OSI Julie Oswald – Bio-Waves, Inc.
DATE:	August 2013

Executive Summary

Ecological Acoustic Recorders (EARs) were deployed in waters offshore of U.S. Marine Corps Camp Schwab, Okinawa, and off the small island of Ie Shima, for marine mammal monitoring and assessment. Acoustic data from two EARs deployed at northern and southern Schwab, and one EAR deployed off Ie Shima, were analyzed for various species. Dolphin whistles were analyzed using the Long-Term Spectral Averages of Triton toolbox, and identified to species using the Real-Time Odontocete Call Classification Algorithm. Biosonar signals from deep-diving odontocetes were recognized using three different software detectors: Marine Mammal Monitoring on Navy Ranges, Energy Ratio Matching Algorithm, and a custom Echo-Clusters program. Sounds from baleen whales, including blue whale, fin whale, sei whale, and humpback whale, were analyzed using an automated baleen whale detector. A few possible dugong vocalizations were also found in this recording. The rest of this report introduces the methods used for detection and demonstrates the results for each species.

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Appendices

Figures

US00009321

Tables

Acronyms and Abbreviations

AUTEC	Atlantic Undersea Test and Evaluation Center
CART	classification and regression tree analysis
dB	decibel(s)
dB re 1 μPa	decibels referenced to 1 microPascal
DFA	discriminant function analysis
EAR	Ecological Acoustic Recorder
ERMA	Energy Ratio Matching Algorithm
HAA	Hourly Acoustic Abundance
HIMB	Hawaii Institute of Marine Biology
HF	High Frequency—greater than 10 kHz
Hz	Hertz
km	kilometer(s)
kHz	kilohertz
LF	Low Frequency—less than 10 kHz
LTSA	Long-term spectral average
m	meter(s)
M3R	Marine Mammal Monitoring on Navy Ranges
MISTCS	Mariana Islands Sea Turtle and Cetacean Survey
nmi	nautical mile(s)
NOAA	National Oceanographic and Atmospheric Administration
OBSPER	Observation Period
OSI	Oceanwide Science Institute
PAM	passive acoustic monitoring
PMRF	Pacific Missile Range Facility
ROCCA	Real-time Odontocete Call Classification Algorithm
SCORE	Southern California Offshore Range
sec	second(s)
SVM	support vector machine
WSA	water surface area

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PART I DETECTION OF MARINE MAMMALS

Section 1 Acoustic Data Collection

Three passive acoustic monitoring (PAM) instruments were deployed to acoustically detect the presence of phonating marine mammals in areas of interest off Okinawa. The areas were part of the restricted areas under U.S. Marine Corps jurisdiction, which are designated as Water Surface Areas (WSAs). The instruments used were Ecological Acoustic Recorders (EARs) (see **Figure 1**) (Lammers et al. 2008). A map of the locations of the three EARs that were deployed for this study is shown in **Figure 2**.

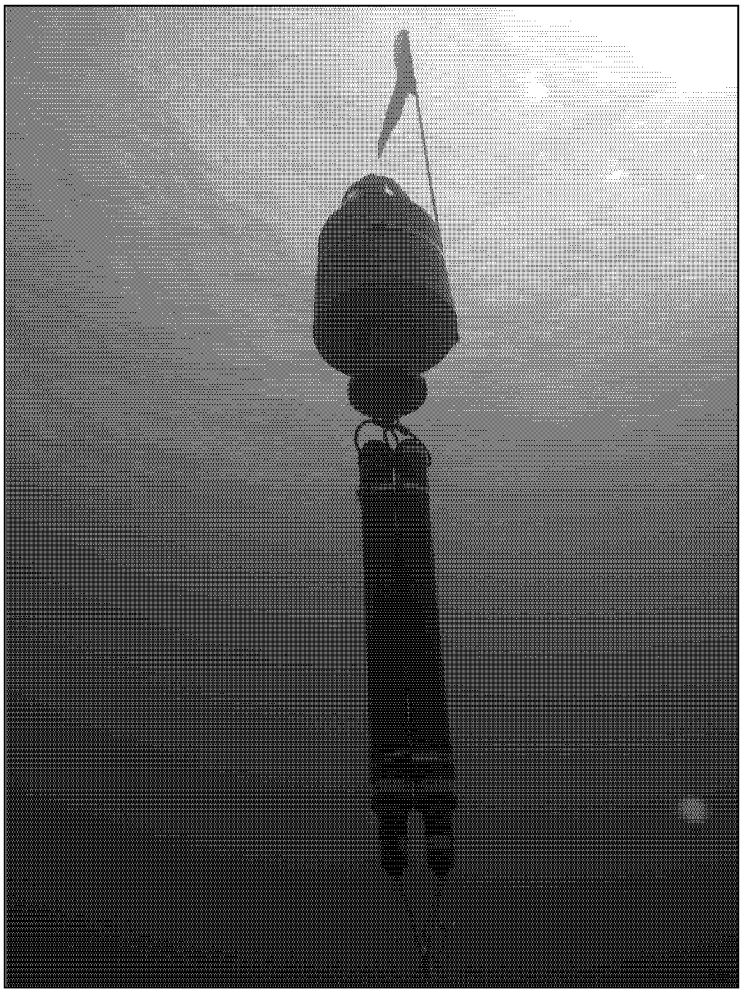

Figure 1. An Ecological Acoustic Recorder (EAR) deployed

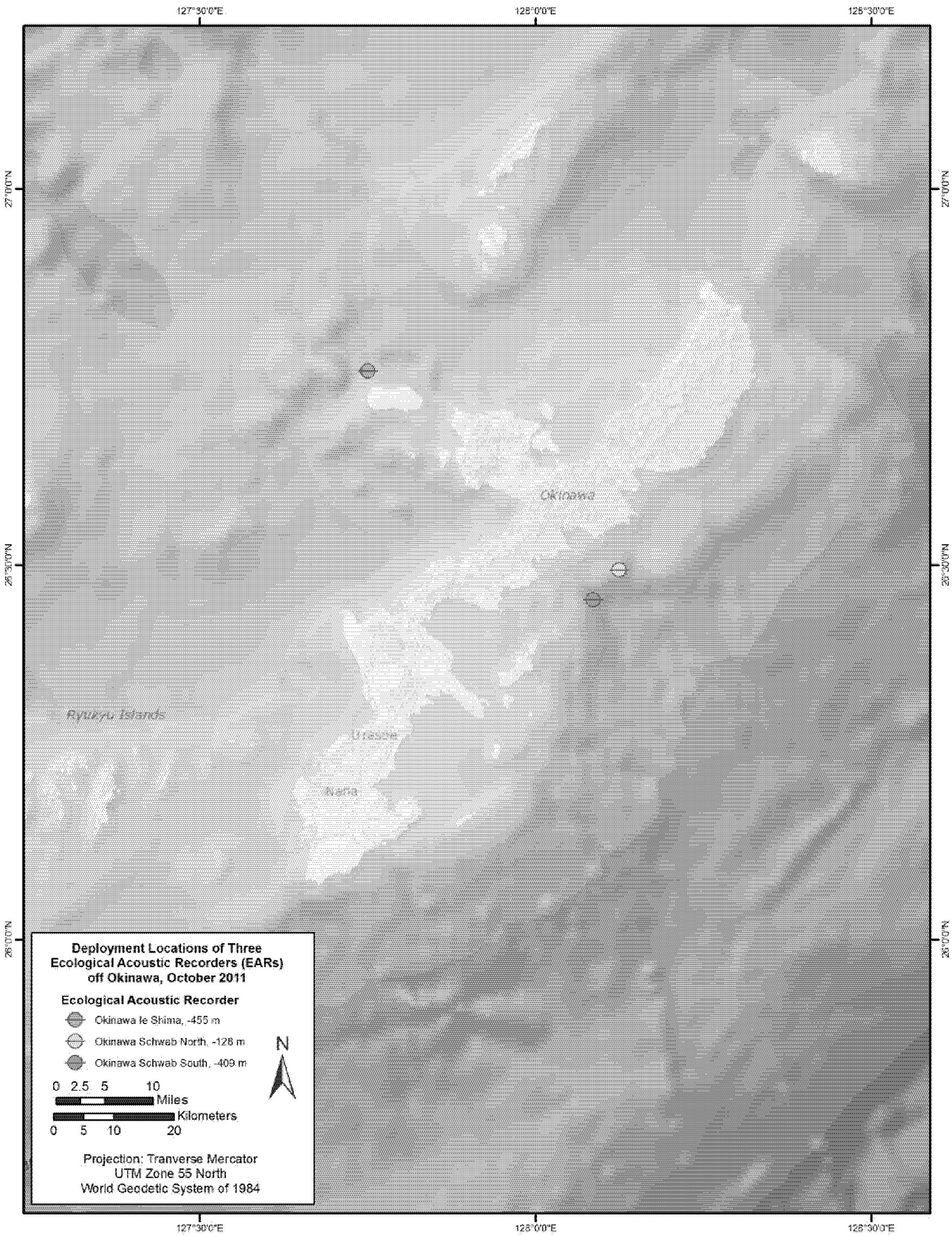

Figure 2. Map indicating the positions of the EAR deployments at three sites around Okinawa.

The EARs used for this project were programmed to operate on a 10 percent duty cycle (i.e., to record for 30 seconds [sec] every 5 minutes) to maximize both the hard drive space and battery life (see **Table 1** for programming specifics). One EAR was deployed in the deepest portion of the Ie Shima WSA (455-meter [m] depth) and two were deployed in the Schwab WSA. The Schwab northern deployment was at a depth of 128 m, and the southern deployment was at a depth of 409 m (see **Table 2**). Since the majority of the Schwab WSA is on the continental shelf, the deployment locations were selected to optimize a range in depth rather than spatial coverage—to maximize the detection of species that may occur in deep water exclusively. All of the EARs were deployed with acoustic releases (ORE Edge Tech PORT LF). The first deployment of the three EARs was on 23 October 2011. They were recovered on 1 March 2012 and were redeployed with new disks and batteries after the data disk had been retrieved. The second deployments were made at the same locations with the same settings for recording. These were recovered on 17 May (Ie Shima) and 22 May (Schwab North and South) 2013.

Table 1. EAR parameters used for each of the deployments.

Sampling Rate	80 kHz
Recording Time (duration)	30 sec
Recording Period (how often)	300 sec or 5 min
Anti-Aliasing Filter	90%
Hydrophone Sensitivity	Approx. -193 dB re 1µPa
Clock	Local Time
Disk Space	320 GB maximum
Energy Detection	Disabled

Table 2. Deployment Sites for EARs.

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

All instruments operated as expected except for a defective hard drive, which prevented the data from the first Ie Shima deployment from being downloaded. All equipment, including the hard drives, was tested extensively prior to the deployment and the malfunction could not have been foreseen. The sampling frequency was set to 80 kilohertz (kHz), which covered the frequency range of baleen whale vocalizations, odontocete whistles and echolocation signals (biosonar signals), and dugong sounds.

Section 2 Marine Mammal Monitoring Methods and Results

2.1 Detection of Dolphin Whistles and Echolocation

a. LTSA Data analysis

Dolphin whistles were analyzed using the Matlab™ script Triton developed at Scripps Institution of Oceanography (Wiggins 2003) and adapted for use with EAR data. Triton was used to create Long-Term Spectral Averages (LTSAs) of the recordings. LTSA is a composite spectrogram made up of Fourier transforms averaged over a user-defined period. It provides visual representation of the acoustic energy distribution in frequency and time for a user-selected period of the deployment. Dolphin whistles were detected by visually examining the LTSA for the presence of "hot spots" of acoustic energy in the frequency bands around 10 kHz, such as the example shown in **Figure 3**. The compressed nature of the LTSAs allows an analyst to rapidly scan hours of data and to identify periods of possible dolphin presence in the whole data set. Whistles identified using LTSA were then verified by examining a spectrogram of the original recording (1024-point Fast Fourier Transform [FFT], Hann window, no overlap). A spectrogram displays the frequency content of a signal (vertical axis) as a function of time (horizontal axis) with a gray or color scale to designate the intensity of the time-varying features of frequency.

Whistles were categorized into three classes: low-frequency whistles (LF) for whistled sounds below 10 kHz, high-frequency whistles (HF) for whistled sounds above 10 kHz, and the designation of "LF&HF" indicates the presence of LF and HF whistles within a single 30-sec recording. Broadband pulses produced by odontocetes were classified as echolocation clicks. **Figure 3** shows two spectrograms with different time scales within an LTSA window containing both whistles and echolocation clicks.

Dolphin calls were logged on an hourly-based protocol, which means that the amount of daily dolphin acoustic activity was measured using a metric termed the Hourly Acoustic Abundance (HAA). This measurement quantifies the call activity for each hour that dolphin sounds were detected and recognized (defined as a 'detection'). HAA was calculated by assigning a scalar value based on the sound type and the signal repetition rate (see **Table 3**) to the three 30-sec recordings samples with the highest number of signals within 1 hour. For hours with less than three recording samples containing dolphin signals, zeros were scored instead. The abundance values were then averaged to produce a measure of the amount of signaling for each hour, and the result is the HAA of that hour. To show the amount of daily dolphin acoustic activity, the sum of the day's HAA values was calculated and plotted. A count of the number of 'detection days' (days with one or more detections in the 24-hour period) was also made. Finally, to link signals that may have originated from the same group of animals, detections that were separated by less than 1 hour were grouped into a single 'encounter.

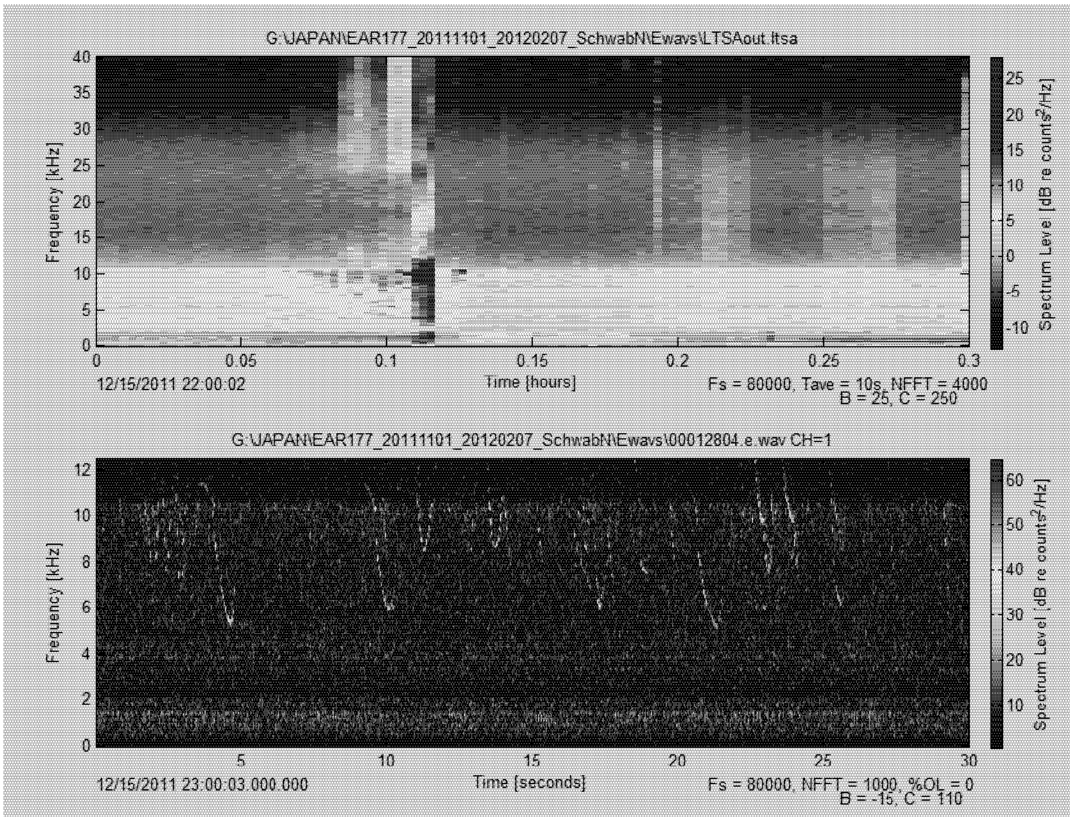

Figure 3. Example of a user-selected LTSA period showing the presence of dolphin signals. The top panel consists of thirty-six averaged 30-sec spectrograms displayed side-by-side. The energy around 10 kHz represents dolphin whistles. The broadband energy to 40 kHz represents echolocation pulses. An expanded spectrogram representing the user-selected (reddish-yellow) area in the top panel is shown in the bottom panel where the dolphin whistles can be seen, confirming the presence and identity of calls.

Table 3. The hourly abundance scale assigned based on the types of signals and the repetition rate of each encounter observed in recordings used to calculate HAA.

Signal Type & Rate of Occurrence	Abundance Scale
1-5 calls/whistles	1
<5 buzzes/click trains	1
1-5 calls/whistles, <5 buzzes/click trains	1
1-5 calls/whistles, >5 buzzes/click trains	2
6-10 calls/whistles	2
>5 buzzes/click trains	2
6-10 calls/whistles, <5 buzzes/click trains	2
6-10 calls/whistles, >5 buzzes/click trains	3
10 calls/whistles	3
10 calls/whistles, <5 buzzes/click trains	3
10 calls/whistles, >5 buzzes/click trains	4

b. Summary of data obtained

Data were obtained at the Schwab North and South locations between 1 November 2011 and 7 February 2012 and again between 3 March 2012 and 22 May 2012. No data were recovered from the first deployment at the Ie Shima site due to a disk drive malfunction on the EAR. However, data were recovered from a second successful deployment at Ie Shima between 2 March 2012 and 17 May 2012. **Table 4** summarizes the data obtained.

Table 4. EAR recording summary for all deployments.

Site	Start Recording	End Recording	# of 30-sec Files	Total Recording Hours
Ie Shima – 1st	23 October 2011	NA*	NA*	0
Schwab North – 1st	1 November 2011	7 February 2012	28,325	236
Schwab South – 1st	1 November 2011	7 February 2012	28,329	236
Ie Shima – 2nd	2 March 2012	17 May 2012	21,985	183
Schwab North – 2nd	3 March 2012	22 May 2012	23,099	192
Schwab – 2nd	3 March 2012	22 May 2012	23,102	192

Note: *Denotes an instrument with a manufacturer defect in the hard drive.

c. Schwab North Results for Dolphin Detections

A total of 30 acoustic detections comprising 15 encounters (as defined above) were recorded during the first deployment and 135 detections comprising 72 encounters during the second deployment. **Table 5** gives the classification results for all deployments. The number of encounters recorded during the second deployment was significantly greater than during the first deployment ($\chi^2 = 34.177$, DF = 1, $p < 0.0001$). Also greater was the percentage of 'detection days' (as defined above) during the second deployment (53 percent) than the first deployment (16 percent). This indicates a seasonal trend, with greater odontocete acoustic activity/presence during spring months (March-May) than in winter (November-February).

Table 5. Detection summary for the all EAR deployments. HF = high frequency (>10 kHz) whistles, LF = low frequency (<10 kHz) whistles.

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

Figure 4 shows the HAA for each type of signal. Signals of all categories (LF, HF, LF&HF, and echolocation) were found during the second deployment, but no HF whistles where encountered during the first deployment. LF whistles were the most common whistle type detected. Echolocation clicks also commonly occurred, both in conjunction with whistles and alone. The absence of whistles in multiple detections is likely an indication of animals producing sonar signals for the purpose of foraging. It is unlikely that these acoustic encounters were from species that only produce echolocation signals but no whistles. Sperm whales (*Physeter macrocephalus*) and beaked whales are two species found off Okinawa that only produce echolocation clicks, but these are almost always found in deeper waters (greater than 400 m) than the habitat where the Schwab North EAR was deployed. Finless porpoises (*Neophocaena phocaenoides*) belonging to the family Phocoenidae also only produce ultrasonic clicks. However, the distribution of this species is confined to coastal areas of the Japanese mainland as well as China and is rarely found in Okinawan waters (Yoshida et al. 2010).

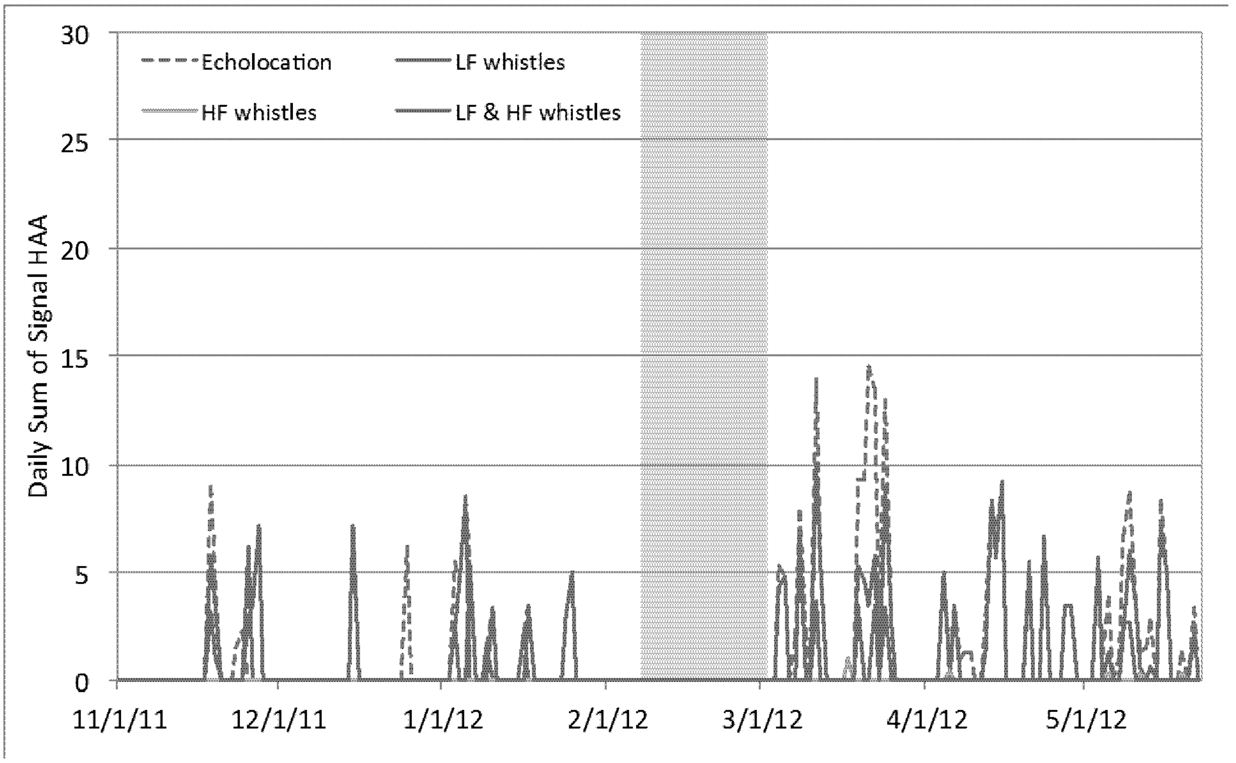

Figure 4. Compiled plot of acoustic detections on the EAR deployed at Schwab North between 1 November 2011 and 22 May 2012. Lines of different color represent sound category. The gray area represents the time when an EAR was not deployed and recording.

Approximately 77 percent of detections (of all types) occurred between 18:00 and 06:00 local time, indicating a strong diel trend in acoustic activity. This trend is likely representative of nocturnal foraging behavior on vertically migrating mesopelagic communities of organisms (Benoit-Bird and Au 2003). This trend was consistent across both deployments, suggesting that the springtime increase in odontocete activity/presence may be associated with greater prey availability.

d. Schwab South Results for Dolphin Detections

The EAR deployed at the Schwab South site was placed in the deepest water possible within the WSA. There is a ledge that extends beyond the continental shelf and the EAR was deployed on this ledge in 409 m of water. A total of 76 detections comprising 43 encounters were recorded during the first deployment and 179 detections comprising 73 encounters during the second deployment. The number of encounters recorded during the second deployment was significantly greater than the first deployment (χ^2 = 9.087, DF = 1, p = 0.003) and the percentage of 'detection days' was greater during the second deployment (62 percent vs. 34 percent). Also, there were significantly more detections at the Schwab South site than at Schwab North during the first (wintertime) deployments (χ^2 = 13.306, DF = 1, $p < 0.0001$), but no significant difference during the second (springtime) deployments (χ^2 = 2.116, DF = 1, p = 0.146). This suggests that during winter months, odontocetes are not only less acoustically active/abundant in the area, but they may also limit their occurrence to deeper waters further offshore.

Signals of all categories (HF, LF, HF&LF, and echolocation) were found during both deployments. **Figure 5** shows the daily sum of HAA for the deployment period, and provides a relative measure of delphinid acoustic activity at the location. As was the case at Schwab North, LF whistles were the most common whistle type detected. Echolocation clicks were also common, both in conjunction with whistles and alone. HF whistles were more common (especially during the wintertime deployments) in the deeper, offshore Schwab South site than the shallower Schwab North site, suggesting a difference in the species diversity between the two sites. Finally, as was the case at Schwab North, the majority (79 percent) of detections (of all types) occurred between 18:00 and 06:00, local time, revealing a strong nocturnal bias in acoustic activity, presumably tied to foraging.

e. Ie Shima Results for Dolphin Detections

The EAR deployed at Ie Shima was the deepest of the three locations at 455 m. No data were obtained from the first deployment due to a malfunction in the EAR's hard disk drive. However, the second deployment was successful, resulting in 123 detections comprising 79 encounters. **Figure 6** shows the HAA for each type of signal. There was no significant difference in the number of detections between Ie Shima, Schwab North and Schwab South during the second deployment (χ^2 = 3.308, DF = 2, p = 0.191). However, Ie Shima did have the greatest percentage of detection days (65 percent).

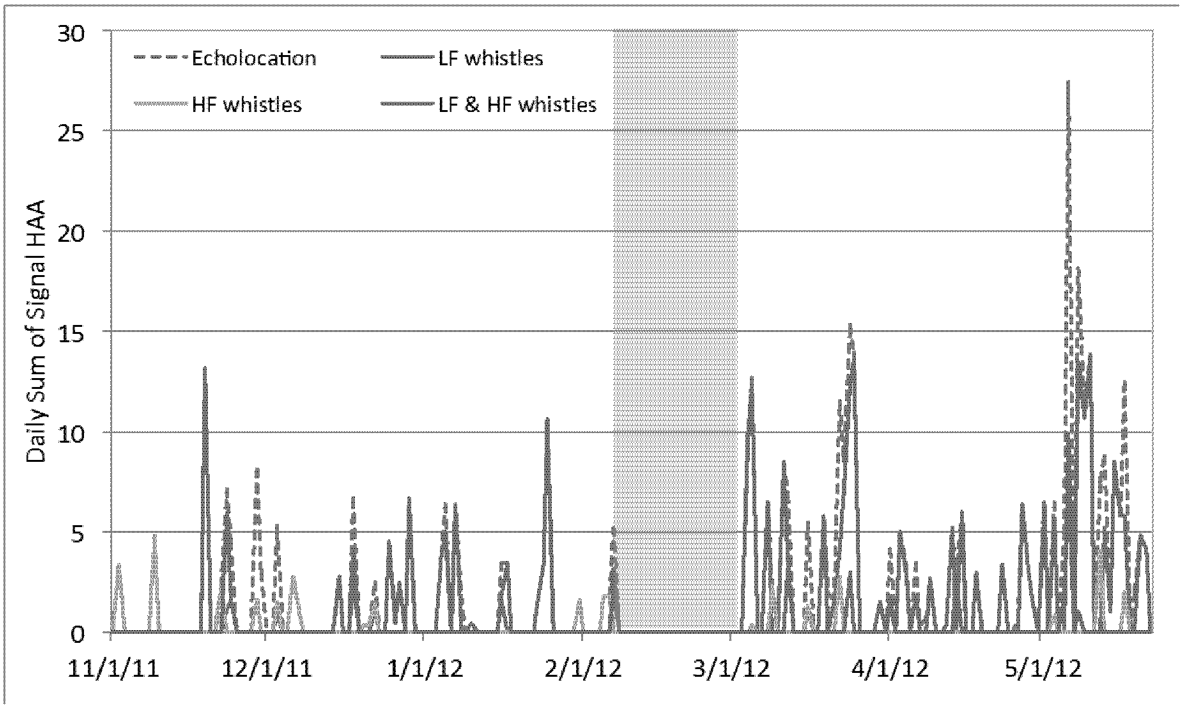

Figure 5. Compiled plot of acoustic detections on the EAR deployed at Schwab South between 1 November 2011 and 22 May 2012. Lines of different color represent signal detection type. The gray area represents the time that the EAR was not recording.

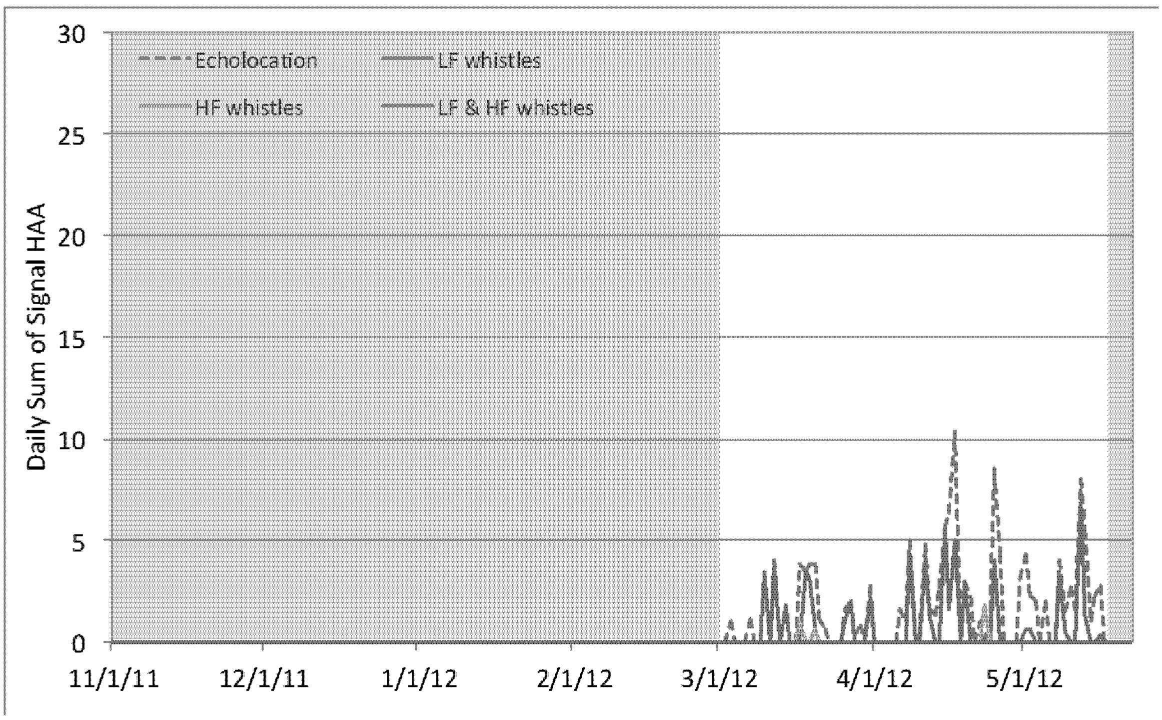

Figure 6. Compiled plot of acoustic detections on the EAR deployed at Ie Shima between 23 October 2011 and 17 May 2012. Lines of different color represent signal detection type. The grey area represents the period without an operational EAR.

All signal types except HF&LF whistles occurred at Ie Shima. However, LF whistles were recorded significantly less often at Ie Shima, both in terms of number of detections (χ^2 = 17.38, DF = 2, p < 0.0001) and median daily HAA (Kruskal-Wallis test: H = 8.66, DF = 2, p = 0.013) than at the other two locations. 'Echolocation only' detections, on the other hand, were significantly more common at Ie Shima (χ^2 = 6.91, DF = 2, p = 0.032). Therefore, it appears that Ie Shima may either have different species that whistle less, or not at all, or that it is an area used primarily for foraging. As was observed at both Schwab locations, the majority of detections (81 percent) occurred at night (18:00 and 06:00), consistent with foraging behavior.

f. Discussion of Dolphin Whistles and Echolocation Detection

The designation of whistle types (HF, LF, and HF&LF) can be used as a very broad categorization for groups of delphinid species. In general, low-frequency whistlers are larger delphinids, such as the "blackfish"—pilot whales (*Globicephala macrorhynchus*), false killer whales (*Pseudorca crassidens*), pygmy killer whales (*Feresa attenuata*), killer whales (*Orcinus orca*) and melon-headed whales (*Peponocephala electra*). Higher-frequency whistles are more common among the smaller dolphin species in the genus *Stenella*; pantropical spotted dolphins (*Stenella attenuata*), striped dolphins (*Stenella coeruleoalba*), and spinner dolphins (*Stenella longirostris*), as well as Fraser's dolphins (*Lagenodelphis hosei*). For the waters off Okinawa, the two bottlenose dolphin species (*Tursiops aduncus* and *T. truncatus*) and rough-toothed dolphins (*Steno bredanensis*) are likely to be more variable and produce LF whistles and HF whistles, thus potentially falling into all three whistle categories.

LF species were more commonly recorded than either HF or HF&LF species at all three sites. This suggests a higher occurrence of LF species at these locations, but could also be explained by the fact that lower frequency sounds propagate further than higher frequency sounds in open ocean environments (Urick 1983), and therefore can be detected at a greater distance. In contrast to the results presented here, research conducted by Lammers and Au (2012 unpublished data) using EARs recording with the same duty cycle off Oahu in the Main Hawaiian Islands showed that LF dolphin whistles were detected on 26 percent of recording days, HF whistles on 76 percent of recording days, and echolocation activity on 93 percent of recording days. Therefore, despite differences in sound propagation, HF species were recorded more frequently than LF species and the daily rate of acoustic occurrence of dolphin whistles at the three Okinawa sites were lower than those off Oahu.

Based on the results obtained, there appear to be differences in either the species occurrence or the acoustic behavior of animals at the three locations monitored. Schwab South had the greatest variability of signal types across both deployment periods, suggesting the presence of a variety of species. Schwab North had greater acoustic activity and signal diversity in springtime than in wintertime. Finally, Ie Shima had substantially more 'echolocation only' activity, which may indicate a greater presence of non-whistling species (e.g., beaked whales) or simply reflect a behavioral difference (more emphasis on foraging).

Although no data are available to determine whether a seasonal trend is present at Ie Shima, there is clear evidence of a pattern at the two Schwab sites. The data do not provide a means to distinguish between greater animal abundance and signaling rate, so it is not possible to say with certainty which factor contributed to the observed seasonality (more animals or more signaling). However, it is evident that odontocete activity differs at both Schwab North and South between wintertime and springtime.

2.2 Detection of Deep-Diving Odontocetes

a. Deployment 1: 23 October 2011 to 7 February 2012

Deep diving echolocation detections were made for both Schwab South deployments and the second deployment at Ie Shima. Due to the shallow depth of the Schwab North EAR, no deep diving odontocete clicks were expected to be observed.

The acoustic data were analyzed with the support vector machine (SVM) portion of the M3R (Marine Mammal Monitoring on Navy Ranges) software (Jarvis et al. 2008, Jarvis 2012), an energy ratio mapping algorithm (ERMA) for detecting beaked whales (Klinck and Mellinger 2010), and a custom MATLAB echo cluster program. M3R is the primary U.S. Navy software used to detect and discriminate deep-foraging odontocetes at the following U.S. Navy ranges: Atlantic Undersea Test and Evaluation Center (AUTEC), Southern California Offshore Range (SCORE), and Pacific Missile Range Facility (PMRF). The SVM portion of M3R uses nine dimensional feature vectors formed by computing the time between six zero crossings about the peak and three normalized envelope amplitude peaks. M3R contains templates of biosonar signals from the short-finned pilot whale, Risso's dolphin, sperm whale, Cuvier's and Blainville's beaked whales, and spinner dolphins. A preliminary performance check can be found in Jarvis et al. (2008), with a more detailed performance evaluation in Jarvis (2012). The classification precisions of M3R on test data sets for all the species included are high, 85 percent or higher (Jarvis 2012). We combined Cuvier's and Blainville's beaked whales into a "beaked whale" category. False killer whale (*Pseudorca crassidens*) biosonar signals are not one of the signal templates in M3R. However, the characteristics of biosonar signals of short-finned pilot whales when compared to "blackfish" and false killer whales are very similar (Bauman-Pickering et al. 2011). Therefore, we renamed the short-finned pilot whale designation to "blackfish" to include false killer whales. In Hawaii, short-finned pilot whales are sighted almost 10 times as often as false killer whales (Robin Baird, Cascadia Research Collective, personal communication), but such information is not available for Okinawa. Therefore, creating a blackfish category seemed to be a reasonable solution. We also renamed the spinner dolphin category to "unknown dolphins," because many small dolphin species produce biosonar signals (i.e., clicks) that are highly variable and virtually indistinguishable from each other.

The percentages of observation periods (OBSPER) (i.e., 30-sec samples) or percentages of files that contained biosonar signals (i.e., clicks) from each group that can be detected by the M3R algorithm are shown in **Figure 7** for the Schwab South site. Blackfish were detected most often followed by beaked whales. The daily results were highly variable, with some days in which very few (2 to 4 percent) detections were made and other days in which many detections (greater than 10 percent) were made. At least one odontocete species was detected every day, although there were days in which one or several of the particular species were never detected.

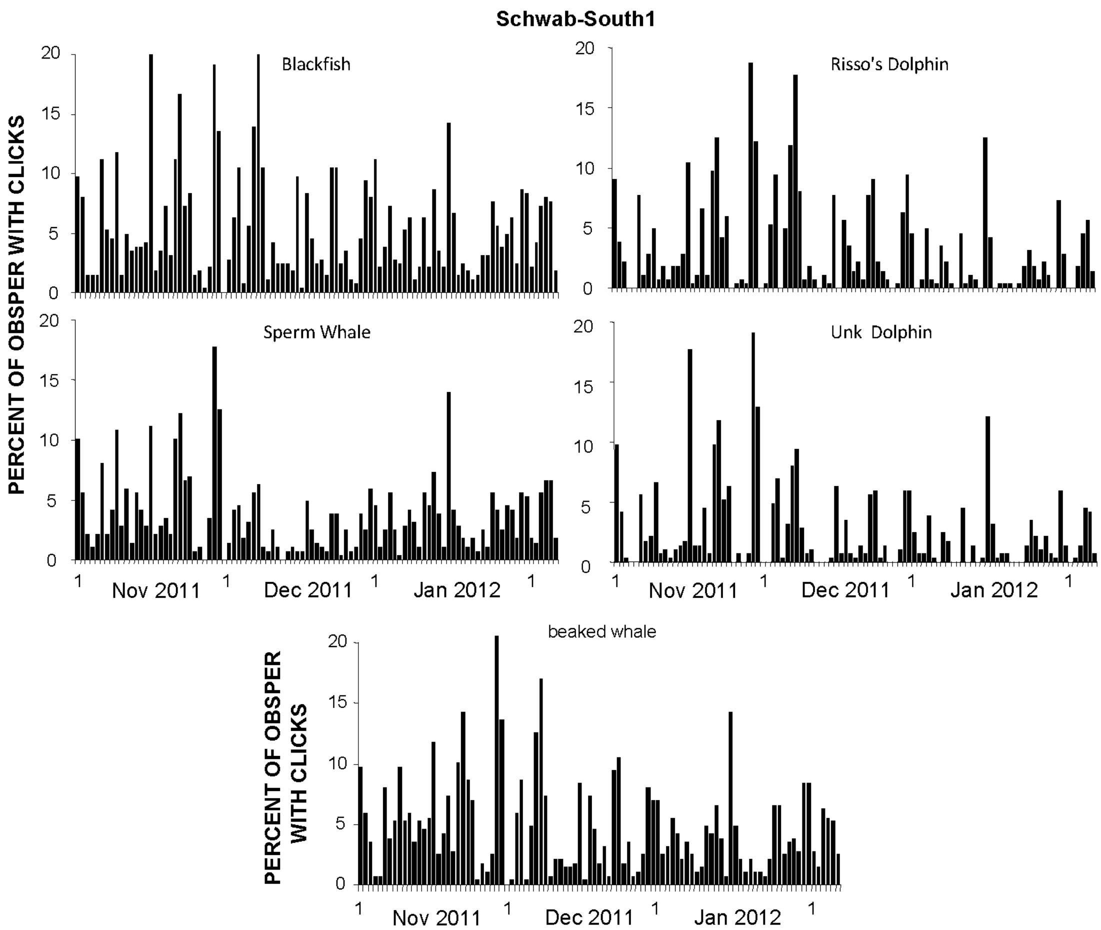

Figure 7. Percentage of observation periods (OBSPER) containing biosonar signals (i.e., clicks) for each of the five groups of deep-diving odontocetes during 1 November 2011 to 7 February 2012 at Schwab South site.

The total of OBSPER in which biosonar signals (i.e., clicks) were detected for all the deep-diving odontocetes used to generate **Figure 7** was calculated and used to determine the percentage of OBSPER with clicks associated with each of the different groups. The results in **Figure 8** show that 30 percent of the OBSPER containing biosonar signals (i.e., clicks) of deep-diving odontocetes were attributed to "blackfish," 26 percent to beaked whales, 18 percent to Risso's dolphins and 14 percent for sperm whales. It is important to note that **Figure 7** pertains to the number of OBSPER in which biosonar signals (i.e., clicks) were detected, and should not be used to draw any conclusions as to the relative abundance of foraging deep-diving odontocetes.

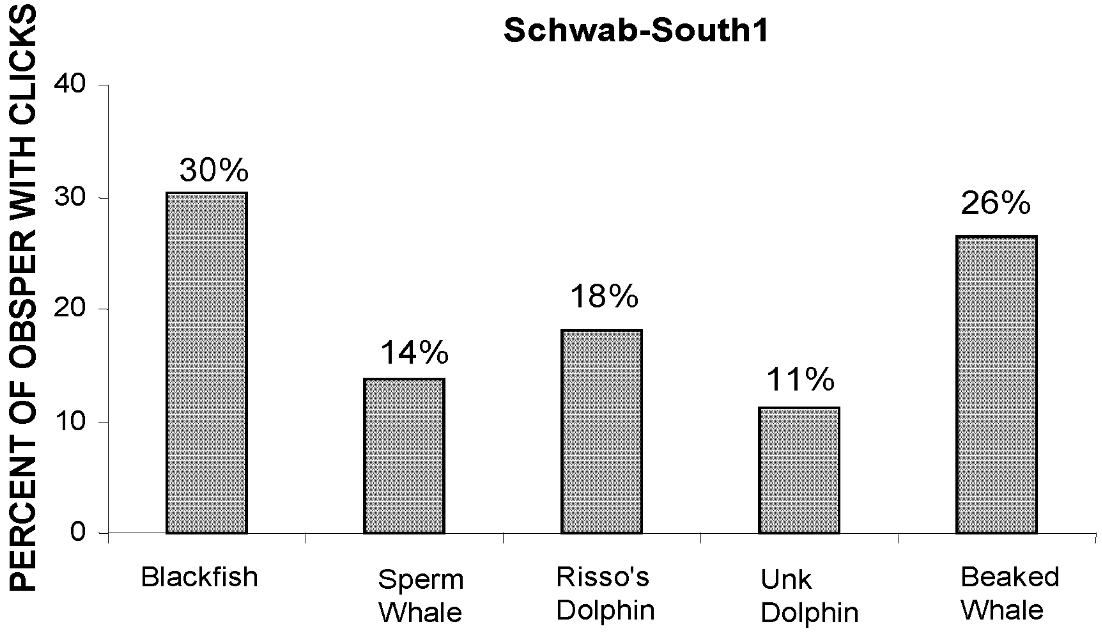

Figure 8. The percentage of observation periods (OBSPER) with biosonar signals (i.e., clicks) from each of the five different groups of deep-diving odontocetes during 1 November 2011 to 7 February 2012 at Schwab South site.

Diel foraging behavior by deep-diving odontocetes was examined by dividing the 24 hours in a day into two 12-hour periods: dusk-night-dawn and day. Sunrise on 15 December 2011 in Okinawa occurred at approximately 07:00, so the dusk-night-dawn period was defined as 19:00 until 07:00 and the day period as 07:00 to 19:00. The average numbers of OBSPER per hour in which signals from the various species were detected as a function of the time of day is shown in **Figure 9**. The shaded areas on each histogram plot represent the dusk-night-dawn time period. The dusk twilight and dawn twilight periods are referred to crepuscular periods, when many animals display increased activity. The shaded block with a percentage value attached to each histogram is the percentage of time that OBSPER with biosonar signals (i.e., clicks) were detected during the twilight-night period. The percentage of OBSPER with biosonar signals (i.e., clicks) detected during the dusk-night-dawn period was considerably higher than the day-time period for each of the five groups of deep-diving odontocetes indicating a higher preference for foraging at night. Foraging also occurred during the day, but not as much as during the night.

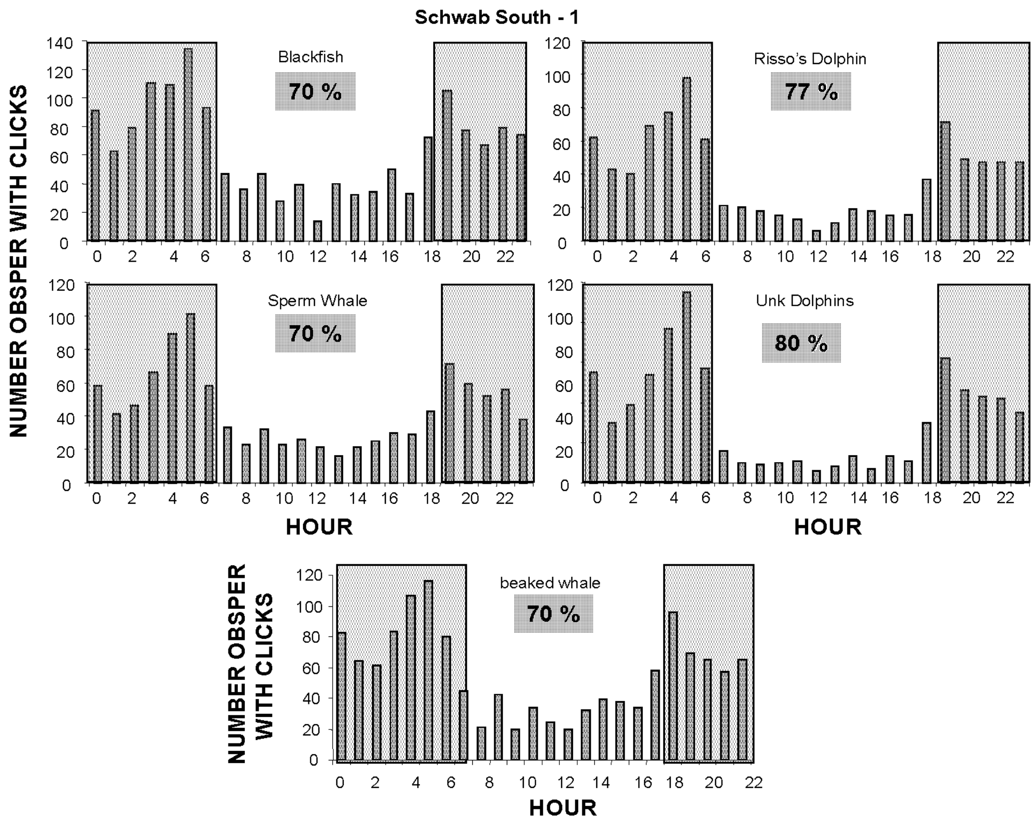

Figure 9. The average number of observation periods (OBSPER) in which biosonar signals (i.e., clicks) from the different species of deep-diving odontocetes were detected on an hourly basis during 1 November 2011 to 7 February 2012 at Schwab South site. The percentage of dusk-night-dawn detections is shown in the shaded block of each histogram.

b. Deployment 2: 2 March– 22 May 2012

The percentages of OBSPER in which biosonar signals (i.e., clicks) associated with each species were detected by the M3R algorithm at the Ie Shima location are shown in **Figure 10.** The most detections were of biosonar signals (i.e., clicks) associated with blackfish; these findings are similar to the Schwab South site during Deployment 1 (1 November to 7 February). Biosonar clicks associated with beaked whales were the next most common click type detected. Daily results were highly variable; there were some days with very few detections, while other days had many. At least one species was detected every day, although there were days in which certain species were never detected. An interesting result, shown in **Figure 10** is the high percentage of detections of all species during 15 to 17 May 2012. The highest detection rates for all species occurred during this time period, with biosonar signals (i.e., clicks) associated with blackfish and beaked whales were detected in about 30 percent of the OBSPER on 17 May 2012. Although the reason for these results is not known, oceanographic and prey sampling of the area conducted in conjunction with acoustic sampling (which was beyond the scope of this project) could provide some insight into this phenomenon.

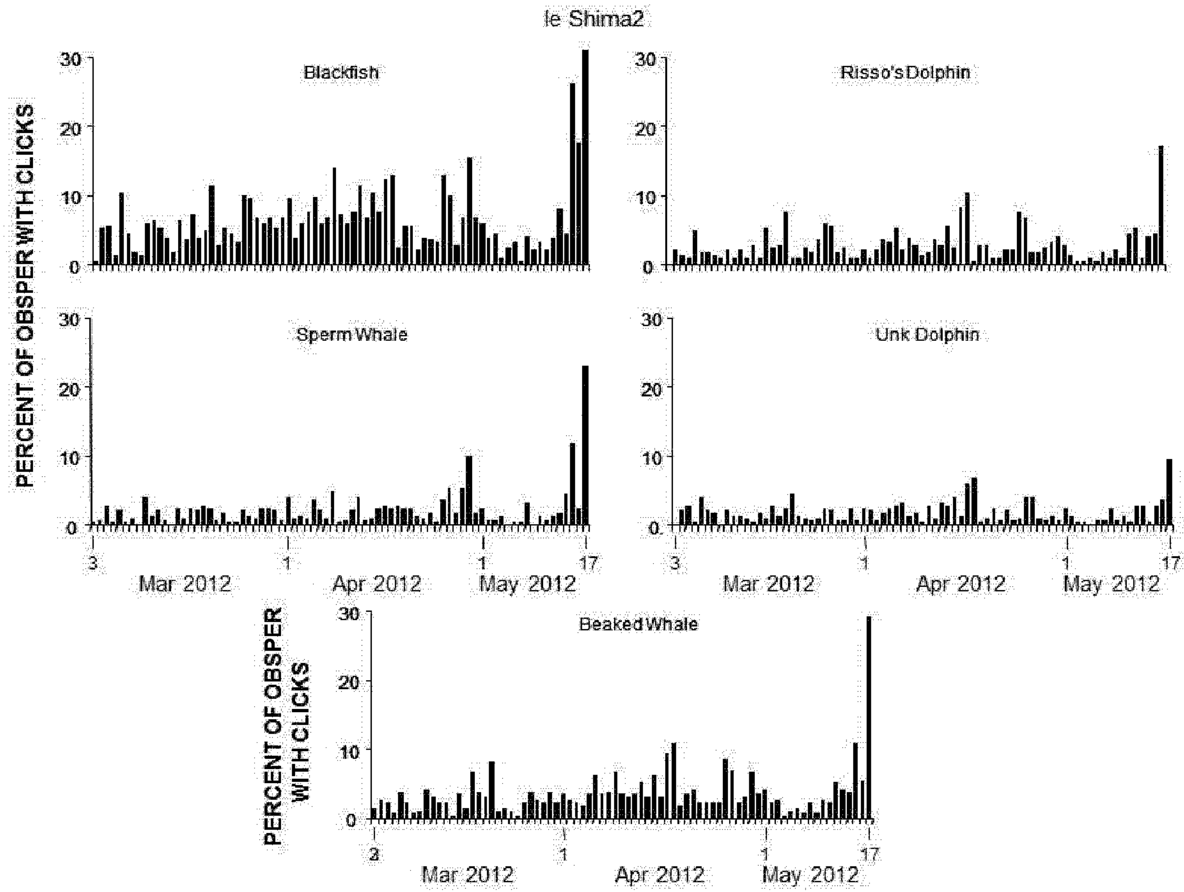

Figure 10. Percentage of observation periods (OBSPER) containing biosonar signals (i.e., clicks) for each deep-diving odontocete group during 2 March to 17 May 2012 at Ie Shima site.

The total of all the biosonar signals (i.e., clicks) by all the species used to generate **Figure 10** was calculated and used to determine the percentage of OBSPER with clicks produced by the different species. The results in **Figure 11** show that 38 percent of the OBSPER contained biosonar signals (i.e., clicks) attributed to blackfish, followed by 21 percent attributed to beaked whales, 16 percent to Risso's dolphins, and 13 percent to sperm whales. It is important to note that **Figure 11** pertains to the number of OBSPER in which biosonar signals (i.e., clicks) were detected, and should not be used to draw any conclusions as to the relative abundance of the foraging animals without making some major assumptions.

Diel foraging behavior by deep-diving odontocetes was examined by dividing the 24 hours in a day into two 12-hour periods. Sunrise on 3 March 2012 in Okinawa occurred at approximately 07:00, so the dusk-night-dawn period was defined as the period from 19:00 until 07:00 and the day period as 07:00–19:00. The average number of OBSPER per hour in which signals from various species were detected, shown as a function of time of day, is seen in **Figure 12**. The percentage of dusk-night-dawn

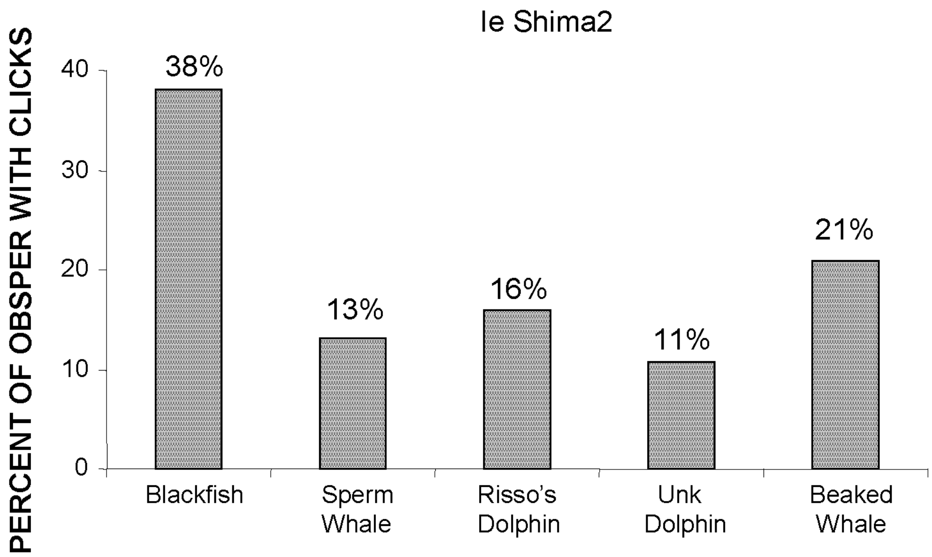

Figure 11. The percentage of 30-sec sample periods with biosonar signals (i.e., clicks) from deep-diving odontocetes during 2 March to 17 May 2012 at Ie Shima site.

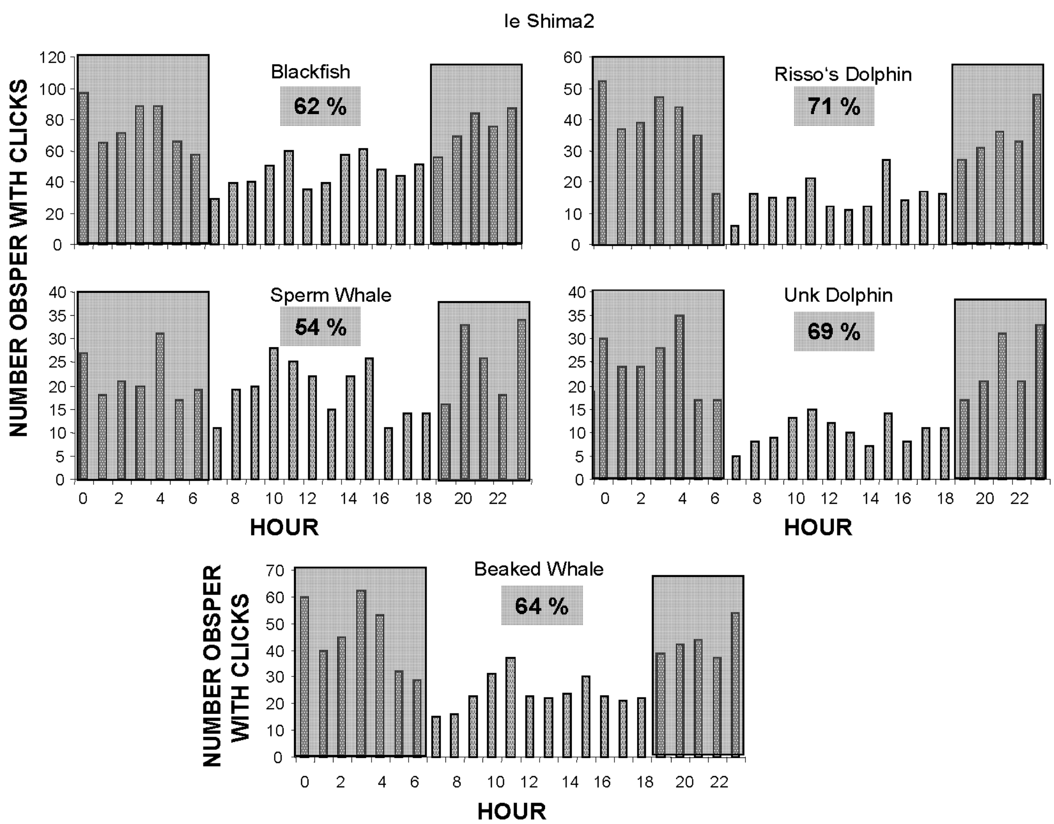

Figure 12. The average number of observation periods (OBSPER) in which foraging clicks from deep-diving odontocetes detected on an hourly basis during 2 March to 17 May 2012 at Ie Shima site.

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detections is shown in the shaded block of each histogram. The percentage of OBSPER with biosonar signals (i.e., clicks) detected during the dusk-night-dawn period was higher than the day period for each of the five groups. The percentage of OBSPER was not nearly as high as for Schwab South during the first deployment but still indicate a slight preference for biosonar activities at night. Some biosonar activities also occurred during the day. For example, sperm whales spent more time clicking at night than during the day 54 percent of the time, compared to 70 percent for Schwab South during Deployment 1. Again, oceanographic and prey sampling of the area conducted in conjunction with acoustic sampling (beyond the scope of this project) could provide some insight into this phenomenon.

Figure 13 shows the percentage of OBSPER that contained biosonar clicks from each species during Deployment 2 at the Schwab South site. As with Deployment 1 at the Schwab South site, blackfish had the most detections, followed by beaked whales during Deployment 2. The daily results were highly variable, with some days having had very few detections, while other days had many. At least one species was detected every day, although there were days in which certain species were never detected.

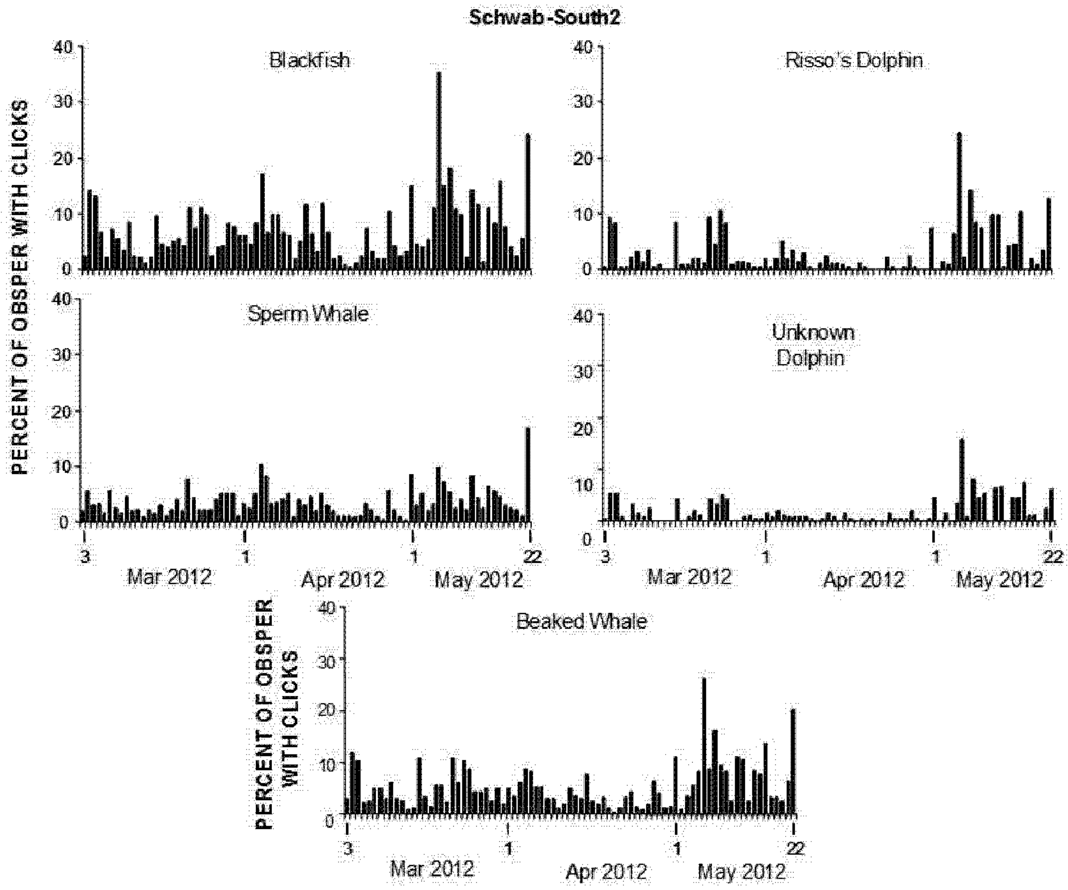

Figure 13. Percentage of 30-sec samples (OBSPER) containing biosonar clicks for each species during the 3 March to 22 May 2012 period at Schwab South site.

The total of all the biosonar signals (i.e., clicks) by all the deep-diving odontocetes used to generate **Figure 13** was calculated and used to determine the percentage of OBSPER with biosonar signals (i.e., clicks) associated with the different species. The results in **Figure 14** show that 34 percent of the OBSPER contained clicks attributed to blackfish, 26 percent to beaked whales, 17 percent to sperm whales, and 14 percent to Risso's dolphins. As with **Figure 11, Figure 14** pertains to the number of OBSPER in which biosonar signals (i.e., clicks) were detected. These results should not be used to draw any conclusions as to the relative abundance of foraging animals, without making some major assumptions that are discussed later.

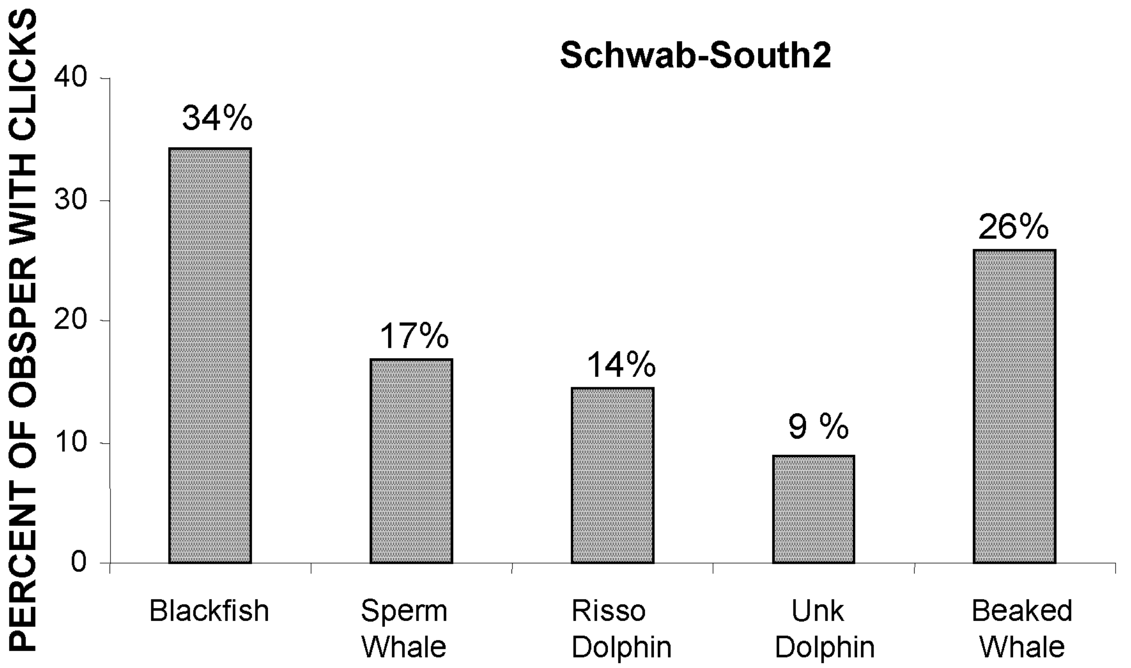

Figure 14. The percentage of observation periods (OBSPER) with biosonar signals (i.e., clicks) from deep-diving odontocetes from 3 March to 22 May 2012 at Schwab South site.

Results from examination of diel foraging behavior by deep-diving odontocetes at Schwab South site are shown in **Figure 15**. The percentage of dusk-night-dawn detections is shown in the shaded block of each histogram. The percentage of OBSPER with biosonar signals (i.e., clicks) detected during the night period was very similar to the results for the Schwab South site during the first deployment, indicating a preference for foraging at night. Foraging also occurred during the day, but occurred mostly at night.

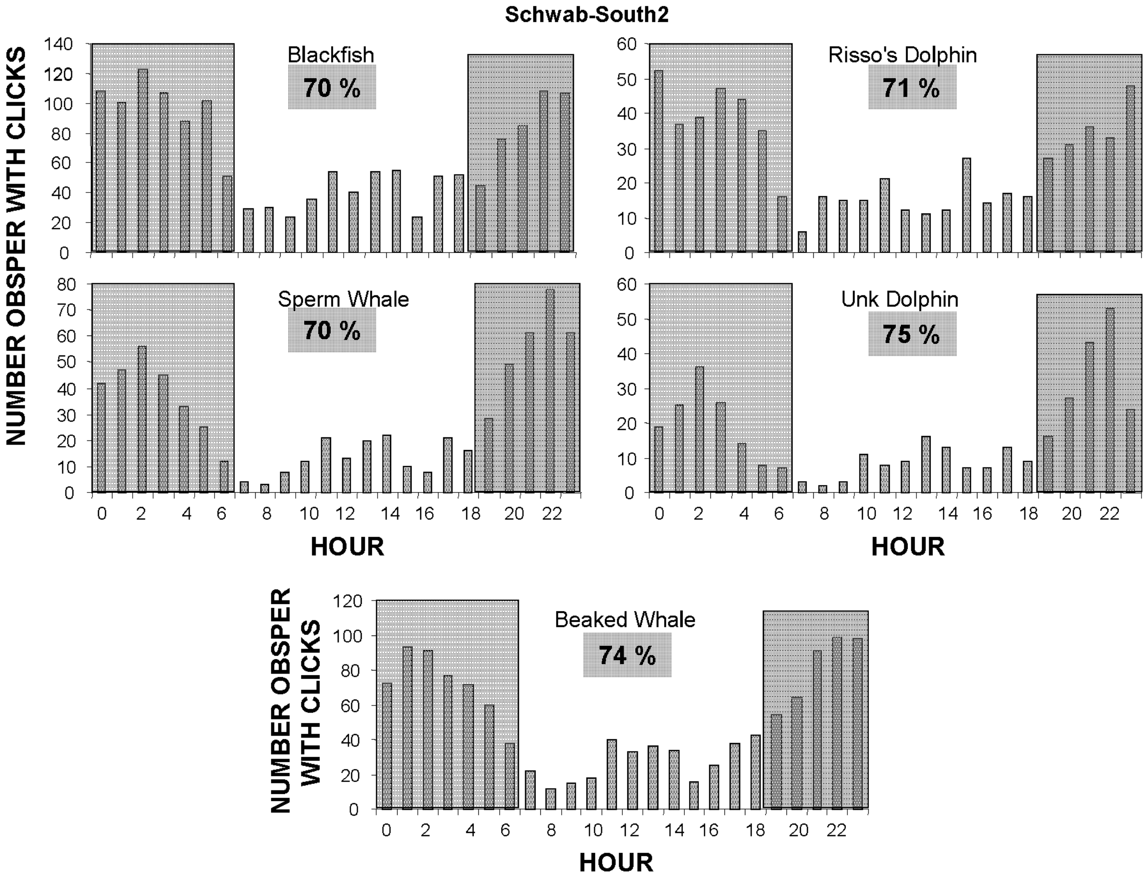

Figure 15. The average number of observation periods (OBSPER) in which biosonar signals (i.e., clicks) from deep-diving odontocetes were detected on an hourly basis for the time period between 3 March and 22 May 2012 at Schwab South site.

2.3 Baleen Whales

An automated baleen whale detector was developed to identify the calls of five species: blue whale (*Balaenoptera musculus*), fin whale (*Balaenoptera physalus*), sei whale (*Balaenoptera borealis*), minke whale (*Balaenoptera acutorostrata*), and humpback whale (*Megaptera novaeangliae*). Since the sample rate of the EAR was high-frequency at 80 kHz, resulting in poor frequency resolution in the low-frequency band in which baleen whales produce most of their calls and song, the data were filter-decimated to obtain a lower effective sample rate. For the detectors for blue, fin, and sei whales, the original 80-kHz sampled data were filter-decimated by a factor of 80, resulting in 30-sec samples with sample rates of 1 kHz. For the humpback whale detector, the original data were filter-decimated by a factor of 40 providing an effective sample rate of 2 kHz. For the minke whale detector, the original data were filter-decimated by a factor of 20, providing an effective sample rate of 4 kHz. Results are reported based on the number of sample files with positive detections for each day of the deployment. The number of point used in each window was chosen so that the frequency resolution was 1.95 Hertz (Hz) for detecting each group of whales.

a. Automated baleen whale detector results

Sounds from baleen whales were detected based on the characteristics of spectrographic images (e.g., frequency-time patterns). **Figure 16** shows some example spectrograms of sounds from blue, fin, humpback, and sei whales during this study. Minke whale sounds were not detected off Okinawa. The acoustic data were first analyzed using a frequency bandpass filter to obtain signals in the appropriate frequency range. Potential baleen whale signals in the desired frequency range were extracted using an envelope detector and applying an adaptive threshold level based on ambient sound level for every 30-sec sample. The final step validated the time and frequency characteristics of the sounds and classified them as various baleen whale species. The algorithms were previously tested on known baleen whale sounds, which were verified by visual inspection of spectrograms.

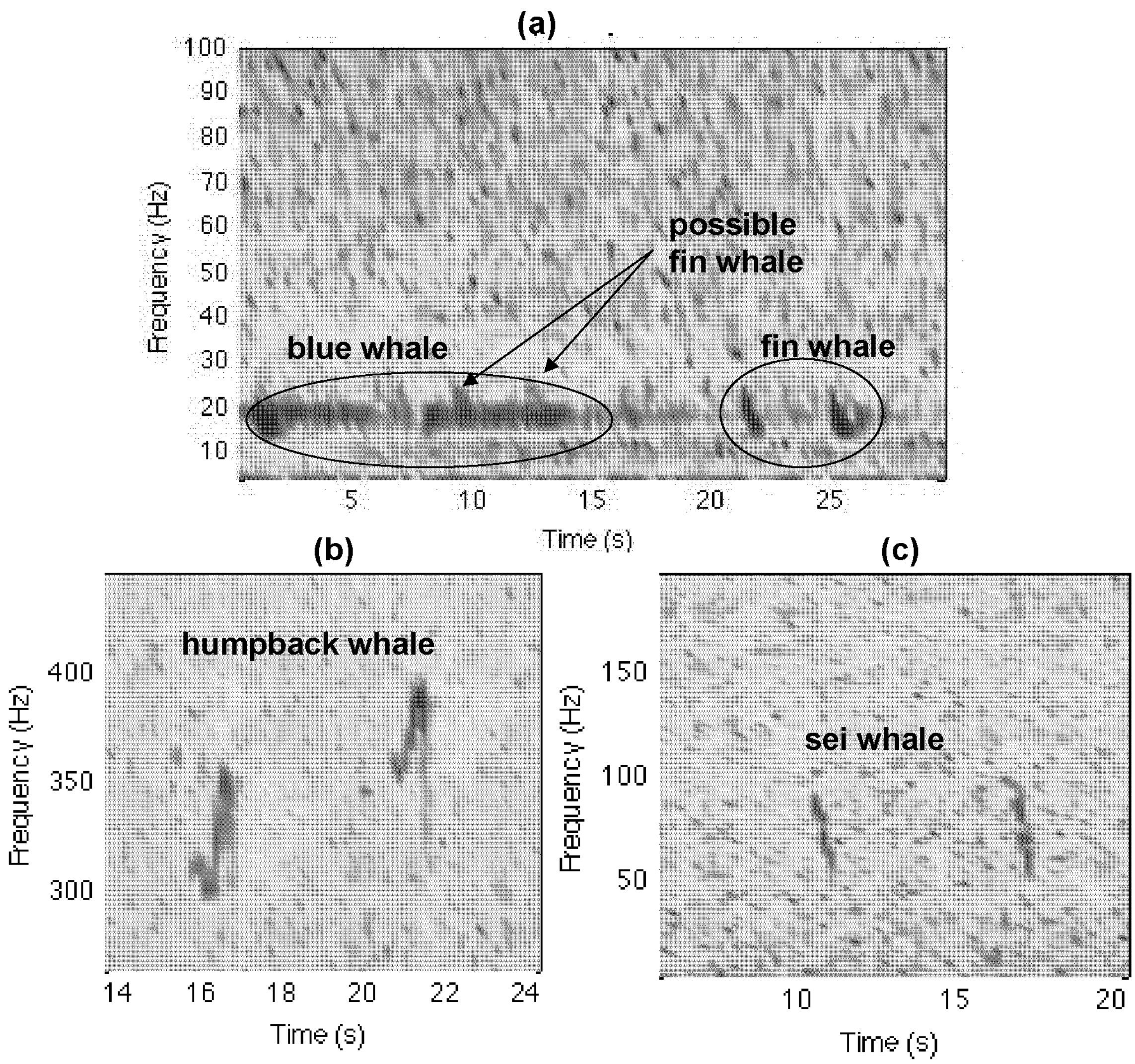

Figure 16. Spectrograms of baleen whale sounds:
(a) blue whale and fin whale (b) humpback whale (c) sei whale.

b. Results of baleen whale detections in Schwab North and Schwab South – Deployment 1 (23 October Nov 2011 to 1 March 2012)

The baleen whale detector was applied on the data recorded at the Schwab North and Schwab South recording sites. **Figure 17** shows the number of 30-sec samples detected per day for each species recorded at the Schwab North site. **Figure 18** shows results for the Schwab South site. The vertical scale of each graph is the same for each site so that a quick comparison can be made as to the relative acoustic occurrences of each baleen whale species at each site. Note that the number of samples with humpback sounds was considerably higher than for the other baleen whale species. As a result, the maximum value of the vertical scale for all species was determined by the number of humpback whale sounds detected.

c. Results of baleen whale detections – Deployment 1 (23 October 2011–7 February 2012)

Results for baleen whale detections were similar for both the Schwab North and Schwab South sites. Baleen whales were detected on a few days in December, January, and February, with an increasing trend for the number of samples containing humpback sounds per day (**Figures 17** and **18**) during late December through early February. Blue whale sounds were detected in late November at the Schwab North and Schwab South sites, with a few detections also around early February at the Schwab South site. Several fin and sei whale sounds were detected in each month, with an increase in detections from November to February. The detector found no minke whale sounds at either location.

d. Results of baleen whale detections – Deployment 2 (2 March 2012–22 May 2012)

Figures 19, 20 and **21** show the detections of baleen whales at the Ie Shima, Schwab North, and Schwab South sites, respectively. Considerably more baleen whales were detected at Ie Shima then at the Schwab North and Schwab South sites. At Ie Shima from 1 March until 18 April, an average of 102 30-sec samples per day (a total of 4,467 30-sec samples) contained humpback sounds; an average of 25 30-sec samples per day contained fin whale sounds; and an average of 13 30-sec samples per day contained sei whale sounds. Therefore, over this time period at the Ie Shima site, there were approximately 4 times more humpback whale detections than fin whale detections, and 8 times more humpback whale detections then sei whale detections. In comparison, the Schwab North site had a total of 451 30-sec samples with humpback whale sounds, versus 130 30-sec samples at the Schwab South site. Therefore, approximately 10 times more humpback whales calls (probably parts of songs) were detected at the Ie Shima site than at the Schwab North site, and 34 times more than at the Schwab South site. Blue whale calls were not detected during Deployment 2.

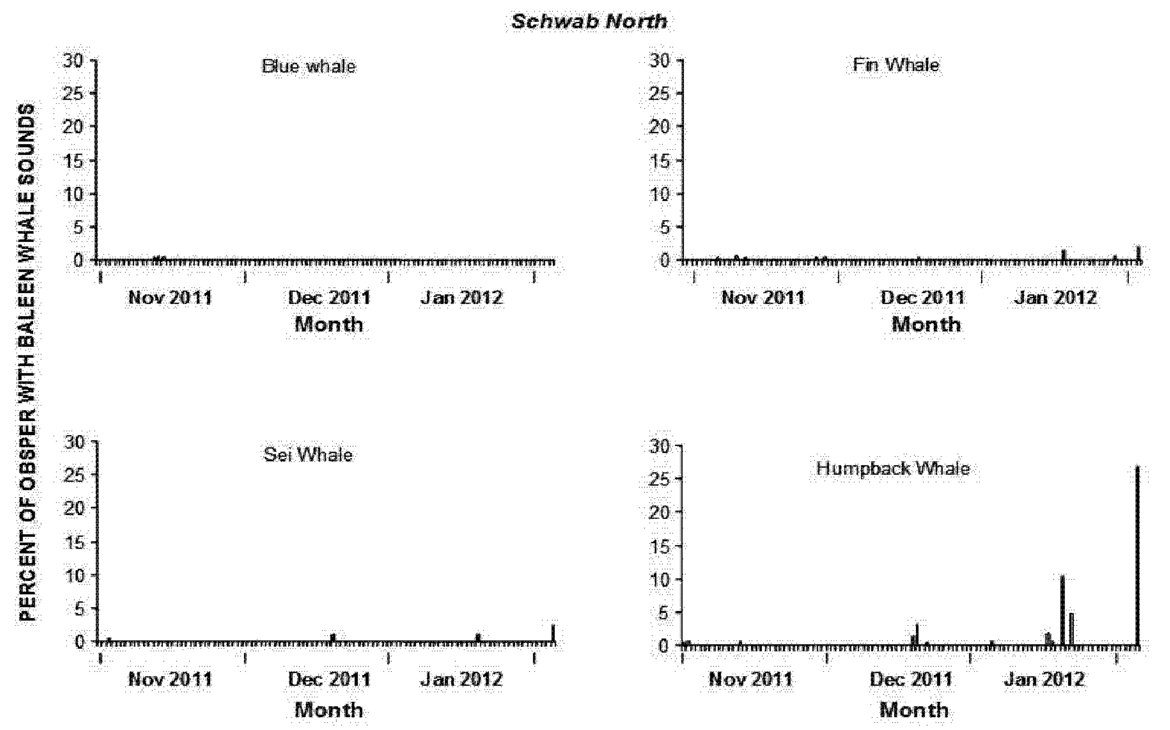

Figure 17. Baleen whale detections at Schwab North site. The graphs indicate the percentage of OBSPER with baleen whale signals detected during 1 November 2011 to 7 February 2012.

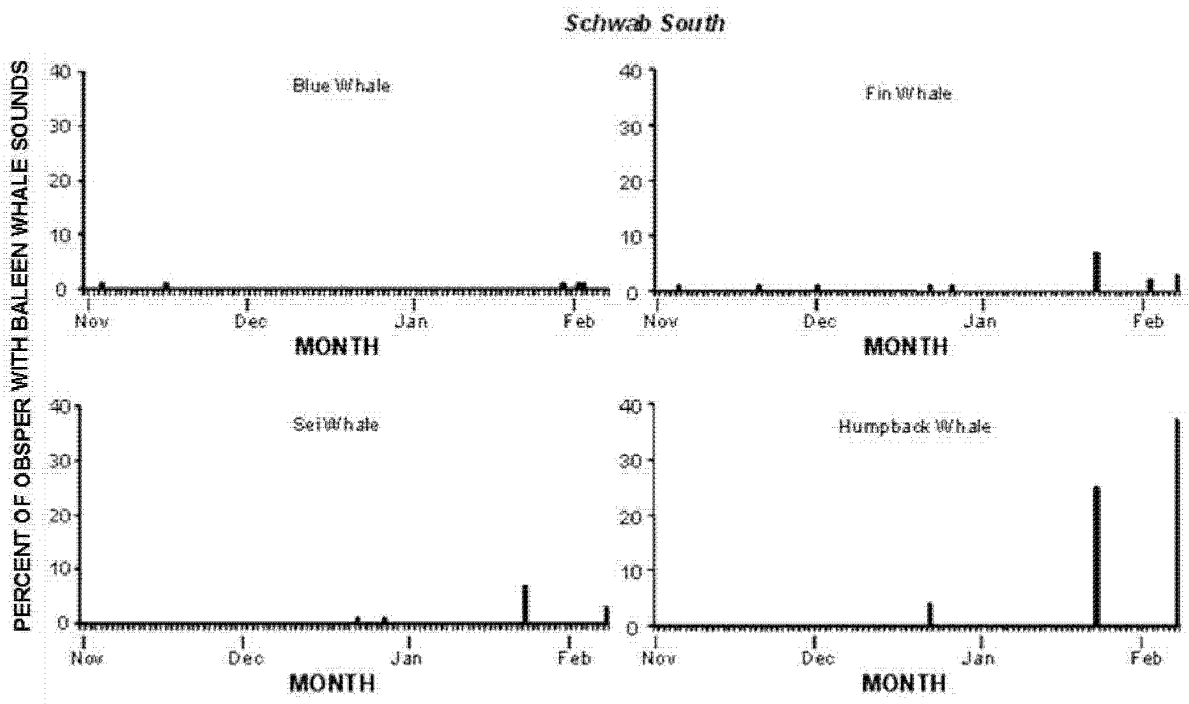

Figure 18. Baleen whale detections at Schwab South site. The graphs indicate the percentage of OBSPER with baleen whale signals detected during 1 November 2011 to 7 February 2012.

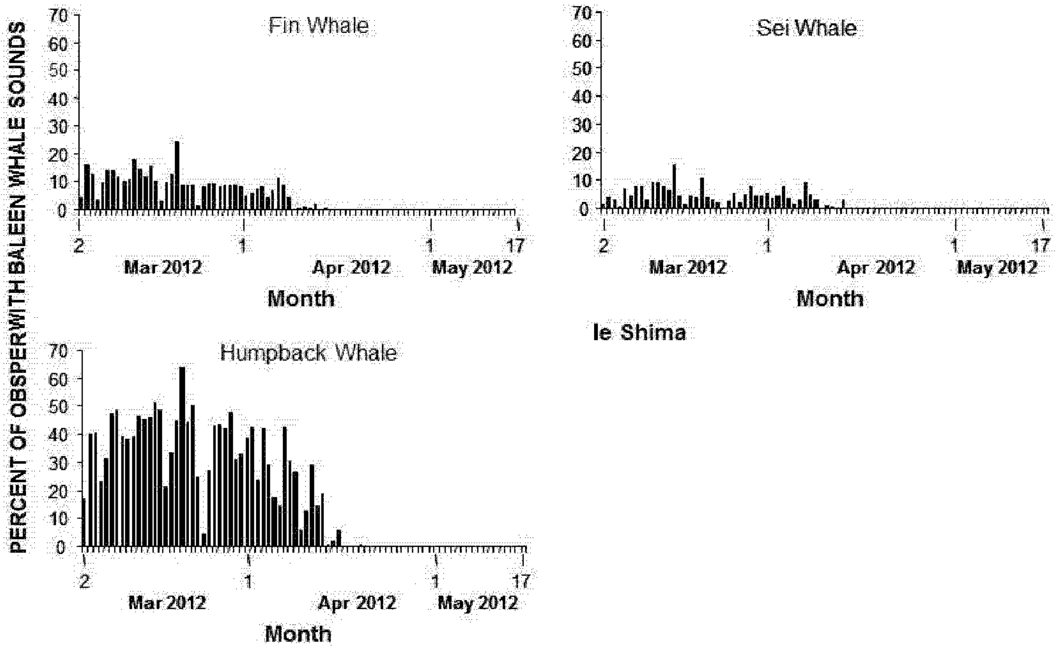

Figure 19. Baleen whale detections at Ie Shima site. The graphs indicate the percentage of OBSPER with baleen whale signals during Deployment 2 (23 March to 22 May 2012). "1" on the x-axis denotes the first day of each month.

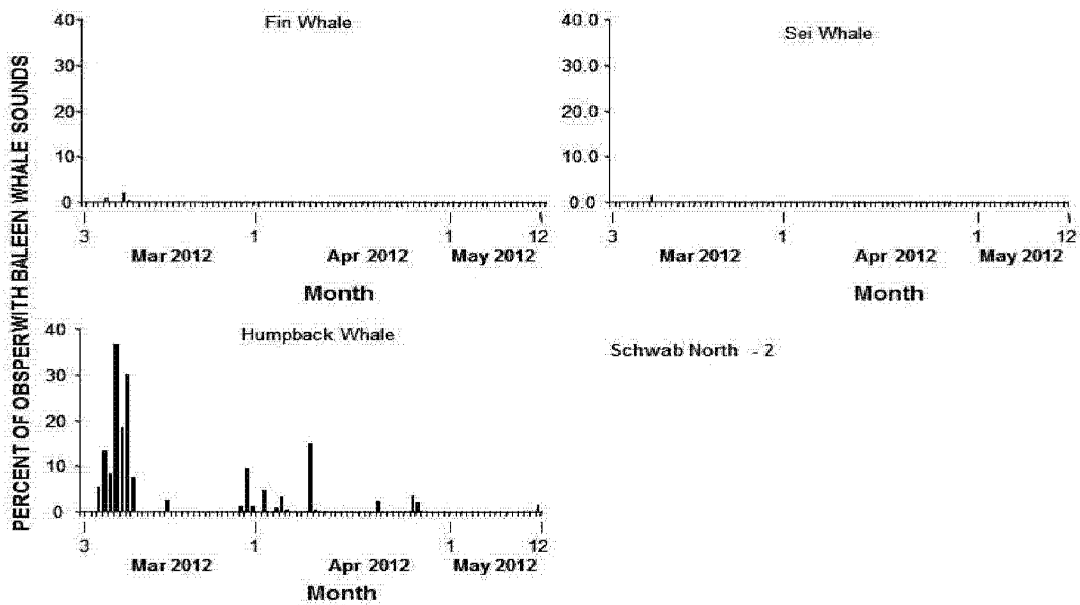

Figure 20. Results of baleen whales detected at Schwab North. Baleen whale detections at Schwab North. The graphs indicate the percentage of OBSPER with baleen whale signals during Deployment 2 (3 March to 22 May 2012). "1" on the x-axis denotes the first day of each month.

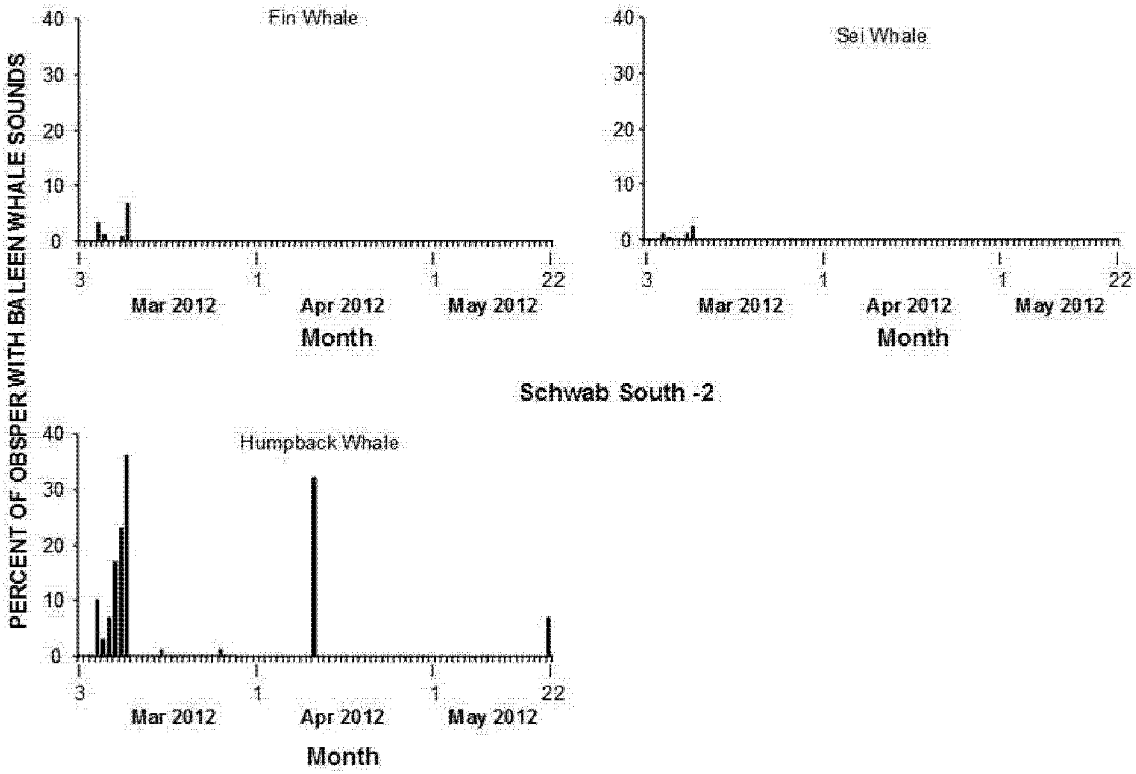

Figure 21. Baleen whale detections at the Schwab South site. The graphs indicate the percentage of OBSPER with baleen whale signals during Deployment 2 (3 March to 22 May 2012). "1" on the x-axis denotes the first day of each month.

Baleen whale sounds ceased to be detected at Ie Shima after 22 May. Sounds from fin and sei whales were detected on only a few days (2 days for the fin whale and 1 day for sei whale) at the Schwab North site, and only slightly more often at Schwab South site. Overall, the detections of baleen whales other than humpback whales during both deployment periods at both Schwab sites were very low. However, as earlier noted, baleen whale detections (other than humpback whales) were considerably higher at the Ie Shima site than at either of the Schwab sites.

2.4 Dugongs

The data sets from Schwab North and South for Deployment 1 (1 November–7 February) were also analyzed for dugong (*Dugong dugon*) sounds using an automated detection algorithm. Dugongs produce "chirp" (i.e., short, frequency-modulated signals) and "trill" (i.e., longer duration, consisting of a sequence of notes usually rising in frequency) sounds (Ichikawa et al. 2006). The method used for dugong detection is similar to the baleen whale detector. The signals were decimated by a factor of five and filtered to a 3,000–8,000 Hz band. The detector was built based on the time-frequency features of the dugong signals reported in Ichikawa et al. (2006). The data was analyzed using 15 band-pass filters from 4.5 kHz to 19.5 kHz with 1-kHz bandwidth. The output signal from each band-pass filter was analyzed using the envelope energy detector described in Ou et al. (2012), to detect segments of signals that had higher energy than the ambient with a 3-decibel (dB) threshold. The high-energy segments extracted from all the frequency bands were stacked together to generate a representation of the time-frequency contour. The algorithm then searches for the convex-shaped frequency modulation, such as the chirp sound shown in **Figure 22**. Possible dugong signals were identified based on the matching of the contour. The algorithm was tested on dugong recordings reported in Ichikawa et al. (2006) and it was able to pick up all the dugong sounds. However, the high performance could be biased because of the small sample size.

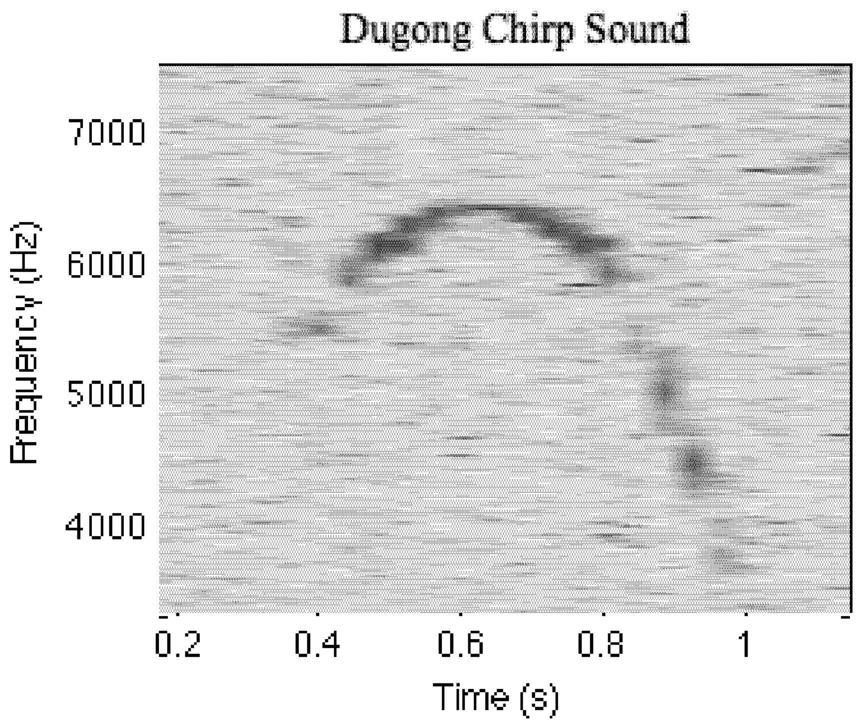

Figure 22. Spectrogram of a possible dugong "chirp" sound recorded at the Schwab North site on 5 January 2012.

Two 30-sec samples with possible dugong sounds were found in the data from Deployment 1 (23 October 2011 to 7 February 2012) at Schwab North. The sounds were recorded on 5 January 2012. One of the 30-sec samples contained a sequence of chirp sounds, while the other 30-sec samples contained a trill and a few chirps. Dolphin whistles also were present in both 30-sec samples, but at higher frequencies. There is a possibility that these sounds may have been produced by dolphins, even though they were identified as dugong sounds by the detection algorithm.

During Deployment 2 (2 March to 22 May 2012), several more possible dugong sounds were detected, although the number of detections was low (**Table 6**). Three possible dugong calls were detected at Ie Shima, six at Schwab North, and three at Schwab South.

Table 6. Summary of possible dugong sounds recorded during Deployment 2 (2 March to 22 May 2012).

Ie Shima		Schwab North		Schwab South	
3 Mar 12	1	12 Apr 12	1	8 Mar 12	1
8 Apr 12	1	15 Apr 12	2	15 Apr 12	2
15 Apr 12	1	3 May 12	1	10 May 12	1
		10 May 12	2		
		15 May 12	1		
		16 May 12	1		

e. Discussion on Deep-Diving Odontocetes, Baleen Whales and Dugongs

Deep-Diving Odontocetes: Biosonar activities of the five categories of deep-diving odontocetes—pilot whales, sperm whales, Risso's dolphins, small dolphins and beaked whales—were detected every day at Schwab South. Biosonar signals from pilot whales were detected most often (35 percent of all 30-sec samples with biosonar signals) followed by beaked whales. There may be a temptation to use the results in **Figure 7** as a measure of the relative abundance of the different species in the waters around the Schwab South site. However, this would not be a proper interpretation. Although the size of a pod will be an important factor in producing the data summarized in **Figure 7**, what is more important is how long the animals remain in the area and in range of the EAR. For example, if a pod of 10 foraging animals remains in the area for an hour, then their biosonar signals will be contained in 12 30-sec samples at most. Contrast this situation to one in which a much smaller pod of two animals remains within range of an EAR for 2 hours. In this case, up to 24 30-sec samples may contain biosonar signals. The smaller pod remaining longer within range of the EAR will have more 30-sec samples attributed to it, and an erroneous conclusion can be reached that more animals were present in the second case than in the first.

Likewise, the number of biosonar clicks detected in each 30-sec sample is not necessarily related to animal abundance. For example, **Figure 22** depicts the beam pattern of an Atlantic bottlenose dolphin (*Tursiops truncatus*) (Au et al. 2012). The beam pattern indicates that the intensity of the biosonar signals can be 40 to 60 dB lower when received from an animal that is off-axis compared to an animal that is on-axis (i.e., facing) the recording instrument. Consider two cases, one in which there are 2 animals close enough to an EAR, so that all of their biosonar signals are detected, independent of their orientation relative to the EAR, versus a situation in which 10 animals are much further away (e.g., 500 m) so that only some of their signals are detected depending on their orientation with respect to the EAR. In such a situation, there will likely be more clicks detected from the 2 close animals than from the 10 animals much further away. Unfortunately, a single EAR cannot be used to determine the relative distances of echolocating animals. Although the beam pattern in **Figure 23** is for a bottlenose dolphin, there is no reason to believe that the beam patterns of the five deep-diving odontocetes would be substantially different. Therefore, the only definitive statement that one can make in regards to **Figure 7** is that biosonar clicks of short-finned pilot whales were detected most often, followed in order by sperm whales, Risso's dolphins, small (unknown species) dolphins, and beaked whales.

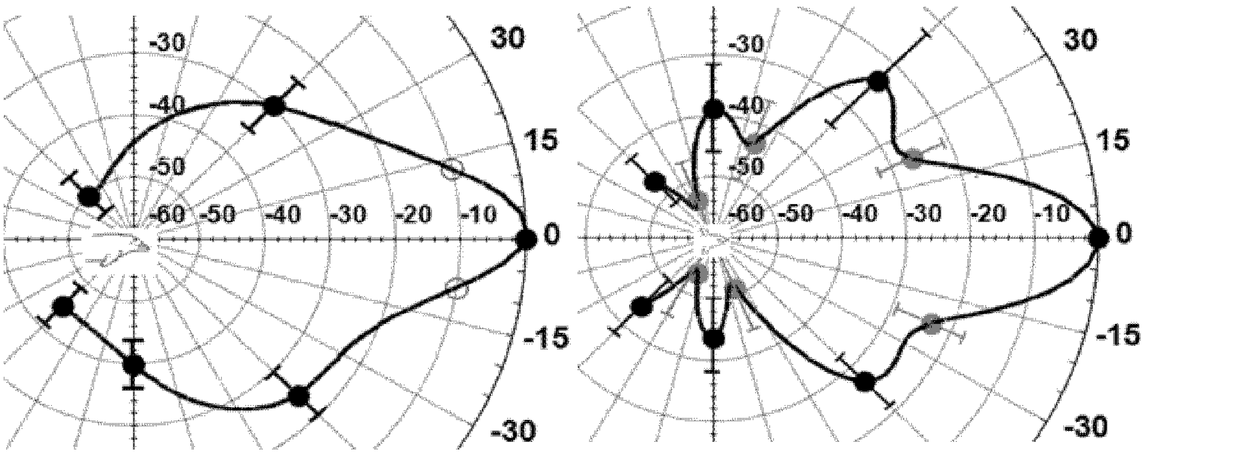

Figure 23. The biosonar beam pattern of an Atlantic bottlenose dolphin in the vertical (left) and horizontal (right) planes (from Au et al. 2012). Angles in degrees are shown along the outer circle and the number dB below the maximum value is shown on the radial axis.

An interesting behavior of the deep-diving odontocetes is their inclination towards foraging mainly during crepuscular periods (i.e., dawn and dusk), with very low foraging activity during the day. This behavior seems to follow the crepuscular movements of the primary prey of deep-diving odontocetes—primarily squid and some fish. Seagars and Henderson (1985) reported that short-finned pilot whales on the Pacific Coast of North America feed primarily on neritic squid (*Loligo* sp.). Mintzer et al. (2008) found that oceanic squid, *Brachioteuthis riisei*, was the main prey of short-finned pilot whales in the Atlantic; however, *Taonius pavo* and *Histioteuthis reversa* were also included in their diet. Sperm whales feed mainly in mesopelagic and benthic habitats on squids of different species, and occasionally on fish. The squid species consumed by sperm whales include the giant squid (*Architeuthis* sp.), jumbo squid (*Dosidicus* sp.), and Antarctic colossal squid (*Mesonychoteuthis hamiltoni*) (Clark et al. 1993, Whitehead 2003). Risso's dolphins feed mainly on squid and other cephalopods (Clarke and Pascoe 1993). Off the California coast, the jumbo squid (*Dosidicus gigas*) and the California market squid (*Loligo opalescens*) are common prey (Orr 1966, Kruse 1989). Beaked whales tend to prefer deep-water squid but sufficient data exist to suggest that the prey specimens include a variety of demersal and mesopelagic fishes (Mead 2002, Pitman 2002, Ohizumi and Kishiro 2003).

The maximum detection range of the EAR for biosonar signals of deep-diving odontocetes can be very roughly estimated by considering the noise floor of the EAR electronics, assuming different source levels of the signal and the acoustic transmission loss. The broadband peak-to-peak noise floor of the EAR is approximately 117 decibels (dB) referenced to 1 microPascal (dB re 1 μPa). If a threshold is set at 125 dB (8 dB above the noise floor) and if an animal was pointed directly at the EAR, the maximum detection slant range for a biosonar signal with source levels between 210 and 220 dB peak-to-peak will be approximately 4.5 to 6.8 kilometers (km) (assuming spherical propagation). It should be emphasized that these estimates are for an ideal situation where there are no diffractions or refractions of the acoustic signal traveling from the animal to the EAR and that the animals are at deep depths. Beaked whales and sperm whales have been shown to start echolocating after they dive beyond depths of 200 to 400 m (Madsen et al. 2005). These estimates are in general agreement with values for beaked whales from Holger Klinck (Oregon State University, personal communication) using data from acoustic gliders in the AUTEC range. To estimate maximum detection ranges for whistle signals would be extremely difficult, since whistling dolphins tend to be near the surface of the water and acoustic propagation can be highly variable depending on the sea state and area-specific bottom topography. From previous work done in the field with listening devices, acoustic detection ranges of 1.5 km are fairly typical. Maximum detection range of baleen whales is another difficult area to consider, since there is very little information on source levels and the depth at which calls are made. Acoustic propagation characteristics of the specific location are also an important factor.

Baleen whales: The 30-sec samples containing baleen whale signals were very sparse during the first deployment (23 October 2011–7 February 2012). Blue whales were detected on only 3 days at the Schwab North site and only 5 days at the Schwab South site. Sei whales were detected on only 4 days at each location. Fin whales were detected on 9 days at Schwab North and 8 days at Schwab South. Although humpback whales were detected on only 8 days at Schwab North and 3 days at Schwab South, the number of 30-sec samples containing humpback whale sounds on some of these days were much higher (30 and 70 30-sec samples – Schwab North; 25 and 37 30-sec samples – Schwab South) compared with the other baleen whale species.

Results from the second deployments (2 March–22 May) had considerably more baleen whale detections in the Ie Shima location than at both Schwab locations. Most of the baleen whales were humpback whales. There were approximately 4 times more humpback whale detections than fin whale detections, and eight times more humpback whale detections than sei whale detections at the Ie Shima site. For comparison, the Schwab North site had 451 30-sec samples with humpback whale sounds versus 130

30-sec samples for the Schwab South site. Therefore, approximately 10 times more humpback whales calls were detected at the Ie Shima site than at the Schwab North site, and 34 times the number detected at the Schwab South site. The waters of the Ryukyu Islands (Okinawa and Amami Islands) are a major breeding and calving area for the humpback whale in Japan, during December through May, with a peak during February (DoN 2005).

Dugong: Two 30-sec samples from the first EAR deployment (23 October 2011–7 February, 2012) contained sounds that may have been produced by dugongs. However, these specific 30-sec samples also contained dolphin whistles, so there is a possibility that the convex spectrogram was produced by a dolphin. To the human ear, the two 30-sec samples sounded like dugong chirps and trills. Additional possible dugong sounds were detected in the second deployment (2 March 2012–22 May 2012), but again, the actual numbers were very small. Six possible dugong sounds were detected at the Schwab North site, and three each at the Ie Shima and Schwab South sites. Dugongs typically occupy coastal waters, so it is not surprising that only small numbers of possible dugong sounds were detected by the EARs, since they were located several miles offshore.

Comments on Acoustic Recording Devices: A variety of important information can be obtained using PAM systems, including the presence of different species over different time scales (i.e., days, weeks, months and seasons) (e.g., Mellinger and Barlow 2003; Morano et al. 2012a, 2012b). Long-term baseline information covering several years is also possible using PAM (e.g., Charif and Clark 2009; Clark and Gagnon 2002; George et al. 2004). And finally, the use of an array of PAMs can provide rough localization and tracking and abundance estimates. Autonomous acoustic recorders also collect data in adverse weather conditions (e.g., high sea states) and at night. However, the use of PAM also has some built-in limitations, such as being localized in a single spot and not having the capability to accurately estimate the relative abundance of the different species being detected. Another valuable acoustic system that is slowly being adopted for marine biological research is sea gliders equipped with acoustic instruments. However, these systems tend to have limited deployment lengths and are unable to obtain long-term information in a single location. In summary, acoustic marine research techniques are quite valuable, but in order to obtain a detailed understanding of the natural history of marine mammals, a variety of acoustics instruments are necessary, including stationary moorings (e.g., EARs and High-frequency Acoustic Recording Packages [HARPs]), acoustic gliders, acoustic tags (e.g., D-Tags and Acousonde™), sonobuoys, and acoustic sensors cabled back to shore (see Sousa-Lima et al. 2013).

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PART II SPECIES IDENTIFICATION OF DELPHINID WHISTLES

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Section 4 Introduction to ROCCA (Real-time Odontocete Call Classification Algorithm)

Delphinid whistles are continuous, narrowband, frequency-modulated signals that often contain harmonic components. They range in duration from several tenths of a second to several seconds (Tyack and Clark 2000). The fundamental frequency of delphinid whistles generally ranges between 2 kHz and 20 kHz, although whistles with fundamental frequencies extending to almost 30 kHz have been reported for several species (Lammers et al. 2003, Oswald et al. 2004). The frequency, duration, and spectral characteristics of whistles often overlap among species, making these signals difficult to classify reliably. The identification of delphinid species based on whistle characteristics is a topic that is receiving more attention as passive-acoustic methods come into widespread use and is accepted for monitoring marine mammals (e.g., Matthews et al. 1999, Rendell et al. 1999, Oswald et al. 2007, Roch et al. 2007, Gannier et al. 2010).

In this study, we modified a whistle classifier (ROCCA, Oswald et al. 2007) that was developed to identify dolphin whistles recorded in the tropical Pacific Ocean. The original classification algorithm used in ROCCA included 'visually–validated' acoustic recordings from eight species and was based on linear discriminant function analysis (DFA) and classification and regression tree analysis (CART). This algorithm correctly classified 46 percent of schools to species (Oswald et al. 2007). Recent modifications to ROCCA include replacing the DFA and CART methods with random-forest analysis (Oswald et al. 2011). A random forest is a collection of decision trees. A decision tree is a predictive model that uses a series of binary tests to divide datasets into smaller groups. Each test point is termed a node, and each node has two branches that come out of it. At each node, the value of a single variable is compared to a specific test value. Those data that fall below the test value are assigned to one branch, and the remaining data are assigned to the other branch. At each node, data are split into the most homogeneous groups possible. The data continue to be split at subsequent nodes, until the branches end at terminal nodes. These terminal nodes represent the final classification. In a random forest analysis, randomness is injected into the tree-growing process by basing the decision of which variable to use as a splitter at each node on a random subsample of all variables (**Appendix C1**). The feature that produces the most homogeneous split is chosen at each node (Breiman 2001). When a whistle is run through a random forest analysis, each of the trees produces a species prediction (i.e., the final classification result). Whistles are classified as the species that the largest number of trees 'votes' for. There is no weighting, and all votes are counted equally.

In this study, we modified ROCCA's existing random-forest classifier to include only species that were expected to be found around Okinawa (based on Jefferson and Sekiguchi 2011). We then applied the modified classifier to whistles recorded around Okinawa to classify them to the lowest taxonomic group possible. Classification of delphinid whistles recorded using EARs deployed around Okinawa provides information for an area for which little is known about the seasonal or spatial occurrence of delphinids.

4.1 Classification Methodology

Whistles were detected and measured by the Hawaii Institute of Marine Biology (HIMB)/Oceanwide Science Institute (OSI) using Long-term Spectral Averages (LTSAs) as described in **Section 2.1** and were provided to Bio-Waves, Inc., for classification analysis. Random-forest classification algorithms that were previously created from a database of 1,657 whistles were used as the basis for this analysis. The whistles included in the random forest analysis were recorded in the tropical Pacific Ocean and in the waters surrounding the Hawaiian Islands and south to Palmyra Atoll during five visual and acoustic cetacean surveys that took place between the years 2000 and 2006. These surveys were run by the National Oceanic and Atmospheric Administration's (NOAA's) Southwest Fisheries Science Center (see Oswald et al. 2007 for details of the study sites and recording methods) (**Table 7**). Whistles (n = 545) from a previous visual and acoustic survey that took place in the Mariana Islands Range Complex (DoN 2007, Fulling et al. 2011) also were included in the dataset (**Table 7**). The combined dataset contained whistles recorded from single-species schools that had visual confirmation of species identity and were at least 3 nautical miles (nmi) away from schools of any other delphinid species. Whistle contours were extracted and measured using the same methods as those employed by HIMB on the Okinawa whistles (see Oswald et al. 2007 for details).

Table 7. Species and number of whistles included in the classifier training dataset. The whistles were recorded in the tropical Pacific Ocean and around the Mariana Islands.

Species	# whistles	
	Tropical Pacific	Marianas
Bottlenose dolphin	155	28
Spotted dolphin	297	101
False killer whale	309	200
Pilot whale	109	34
Rough-toothed dolphin	145	2
Striped dolphin	452	130
Spinner dolphin	170	25
Melon-headed whale	20	25

Several different random-forest classifier models were created using the tropical Pacific and Mariana Islands datasets. The first model classified all whistles to species. Subsequent models combined certain individual species into groups (e.g., 'blackfish', '*Stenella* species', etc.). Species were grouped based on the confusion matrix produced by the first random-forest model. A confusion matrix is a tabular display of the results of a classification analysis. The correct species are listed in the rows and the species predicted by the classifier are presented in the columns. The percentage of schools that were classified to the correct species is displayed along the diagonal (usually boldfaced). Classification errors are provided in the remaining cells of the matrix.

To create the random-forest models, the data first were sub-sampled so that there were equal sample sizes for each species or group of species. This avoided one class 'swamping' the data and skewing the results. To test the accuracy of the models, the data were divided randomly into two equal subsets. One subset was used to train the model and the other was used to test it. The datasets then were switched so that each dataset was used as both a test and a training dataset, and therefore every whistle in the full dataset was classified. Data were divided such that all whistles from a single school only occurred in one subset. This avoided whistles produced by one group or an individual being in both the test and train datasets and artificially inflating correct classification scores.

In this study, a whistle was considered to be "strongly classified" or "strong" if the percentage of trees voting for the predicted species exceeded a user-determined "strong whistle threshold" (Oswald et al. 2011). The strong-whistle threshold is the minimum percentage of trees that must vote for the predicted species in order for the whistle to be considered strongly classified. For example, if the strong-whistle threshold is 35 percent, at least 35 percent of trees must vote for the predicted species in order for that whistle to be strongly classified. Any whistle that was not strongly classified was omitted from the analysis. The choice of the strong whistle threshold was based on maximizing the percentage of whistles correctly classified while minimizing the number of detections that could not be classified due to the omission of weakly classified whistles. The choice of strong-whistle threshold was based on the number of classes (species or taxonomic groups) in the classifier, and therefore the correct classification score that would be expected by chance alone. For example, for seven species, if whistles contained no useful information, one would expect 14 percent of trees to vote for the correct species simply by chance. A strong-whistle threshold of 35 percent is more than two times higher than a random classification, suggesting that the whistle is being classified based on real differences rather than on chance alone. The strong whistle threshold was determined individually for each random-forest model that was tested and ranged from 35 to 50 percent.

Classification success for each random-forest model was evaluated by examining the percentage of schools that were correctly classified for each species. Schools were classified by adding the number of trees voting for each species over all of the strongly classified whistles in that school and then dividing by the total number of trees (number of whistles x number of trees in each forest) to get a percentage. The school was classified as the species that received the highest total percentage of tree votes. When a strong-whistle threshold was applied, a school was classified as 'ambiguous' if there were no strong whistles produced by that school. Classification success was also evaluated based on the 'error reduction' provided by each classification model. Error reduction provides an unbiased measure of the performance of the classifier. It is calculated as follows:

$$\{[(100 - \text{chance rate}) - (100 - \text{observed rate})]*100\}/(100 - \text{chance rate})$$

Error reduction is a measure of how a classifier performs compared to the correct classification rates expected by chance alone (Bachorowski and Owren 1999). For example, for a five-class classifier, one would expect 20 percent of cases to be classified correctly simply by chance alone. If the classifier classifies 70 percent of cases correctly, then the classifier has reduced classification error from 80 percent to 30 percent. In order to evaluate the actual magnitude of this reduction relative to chance, the error reduction is calculated. In this example, the error reduction is equal to 62.5 percent, meaning that the classifier has reduced error by 62.5 percent relative to what was expected by chance alone.

The whistles measured by HIMB/OSI (see **Section I** of this report) were run through the two best-performing classifiers (four- and six-group classifications) in order to determine which species or taxonomic groups were detected by the EARs. Because there were no visual observations associated with EAR recordings, it was not possible to determine when one school left the area (or stopped whistling) and another school entered (or started whistling). As a proxy, a school, or acoustic detection, was defined based on elapsed time between whistles. A new school, or acoustic detection, was delineated when 30 or more minutes had elapsed between whistles. Each school classification was rated on a scale of 0-4, with 0 being the least confident and 4 being the most confident in the classification. Confidence ratings were based on the following criteria:

1. At least 30 percent of trees voted for the predicted species for the six-class classifier and at least 45 percent voted for the predicted species for the four-class classifier. These values were chosen relative to the percent of trees that would be expected to vote for the predicted species by chance alone (17 percent for the six-class classifier and 25 percent for the four-class classifier). If the percentage of trees voting for the predicted species is substantially higher (double or almost double) what would be expected by chance, it is likely that the school is being classified based on real differences in the whistles.
2. No other species had a similar percentage of tree votes (within 5 percent).

3. Classifications produced by the four-class classifier and the six-class classifier matched.
4. There were at least three whistles in the detection. Basing identifications on a larger sample of whistles increases confidence in that classification, similar to larger sample size increasing power in a statistical test.

Classifications were assigned the following confidence values:

0: None of the above conditions were met.
1: One of the above conditions was met.
2: Two out of conditions 1-3 were met.
3: Conditions 1-3 were all met.
4: All four conditions were met.

A final classification decision was made for each school based both on the results of each individual classifier and on the confidence ratings and the distribution of tree votes for each classifier (**Appendix C2**). For example, for detection five at Schwab North, both the six-class and four-class classifiers weakly classified the detection as blackfish. Examination of the distribution of tree votes for detection five in **Appendix C2** shows that rough-toothed dolphins had the second highest percentage of tree votes in both classifiers. Therefore, the detection was classified as either blackfish or rough-toothed dolphins. When classifier results were not in agreement, the species with the second highest percentage of tree votes was determined. If that species matched the species that had the highest percentage of tree votes in the other classifier, then the detection was classified as either of those species. For example, for detection five at Schwab South, the six-class classifier identified the detection as bottlenose and the four-class classifier identified the detection as *Stenella*. **Appendix C2** shows that striped dolphins received the second highest percentage of tree votes in the six-class classifier and bottlenose dolphins received the second highest percentage of tree votes in the four-class classifier. Based on those results, the detection was classified as 'bottlenose or *Stenella*.'

4.2 Results

Several species of dolphin and blackfish were identified by the ROCCA classifier. The confusion matrix and error reduction values for the seven-class, random forest model are presented in **Table 8**. Melon-headed whales were not included in this model due to low sample sizes for this species, but they were included in subsequent models in which several species (false killer, pilot, and melon-headed whales) were grouped together into a blackfish species group. Several random forest models that contained classes of combined species were created based on this confusion matrix. Species that were commonly misclassified as each other were grouped together. The two classifiers that produced the best results were:

Table 8. Confusion matrix (percentages of classification) and error reduction for seven-class classifier.

Actual species	% classified as							Error reduction	n
	Bottle-nose dolphin	Spotted dolphin	False killer whale	Rough-toothed dolphin	Pilot whale	Striped dolphin	Spinner dolphin		
Bottlenose dolphin	**30**	30	30	0	0	10	0	19	10
Spotted dolphin	0	**58**	8	0	0	17	17	51	24
False killer whale	0	0	**82**	12	6	0	0	97	17
Rough-toothed dolphin	0	14	15	**71**	0	0	0	81	14
Pilot whale	0	0	17	0	**67**	8	8	76	12
Striped dolphin	11	26	3	3	9	**37**	11	33	35
Spinner dolphin	0	7	0	0	7	29	**57**	61	14

Notes:

Percentages of schools correctly classified are in bold and underlined.

The random-forest model was trained and tested using tropical Pacific and Mariana Islands acoustic data, and consisted of 500 trees and 56 variables (**Appendix C1**). Results are based on a strong-whistle threshold of 35 percent.

1. A six-class classifier, composed of individual species (bottlenose, spotted, rough-toothed, striped, and spinner dolphins) and a blackfish class (as detailed above). Best results were obtained when a strong-whistle threshold was not used (i.e., classification decisions were based on all whistles).
2. A four-class classifier, made up of two classes composed of individual species (bottlenose dolphins and rough-toothed dolphins), a blackfish class (as detailed above), and a *Stenella* genus class (spotted, spinner, and striped dolphins). A strong-whistle threshold of 45 percent gave the best results for this four-class classifier. The numbers of whistles that were strongly classified, and therefore included in the classification decision for each detection, are given in **Appendices C2 and C3**.

Overall, 60 percent and 71 percent of schools in the test dataset were correctly classified by the six-class classifier and the four-class classifier, respectively (**Tables 9** and **10**). A strong-whistle threshold of 0 percent (i.e., there was no strong-whistle threshold and every whistle was considered when making classification decisions) produced the best results for the six-class classifier and a strong-whistle threshold of 45 percent (i.e., only whistles for which 45 percent of trees voted for the predicted species were included in the analysis) gave the best results for the four-class classifier.

Table 9. Confusion matrix (percentages of classification) and error reduction for six-class classifier.

Actual species	% classified as						Error reduction	n
	Bottle-nose dolphin	Spotted dolphin	Blackfish	Rough-toothed dolphin	Striped dolphin	Spinner dolphin		
Bottlenose dolphin	**60**	10	30	0	0	0	52	10
Spotted dolphin	15	**42**	0	8	8	27	30	26
Blackfish	0	3	**91**	3	3	0	89	32
Rough-toothed dolphin	0	0	23	**62**	8	7	54	13
Striped dolphin	5	10	3	13	**56**	13	47	39
Spinner dolphin	6	19	0	12	13	**50**	40	16

Notes:
Percentage of schools correctly classified are in bold and underlined.
The random forest model was trained and tested using tropical Pacific and Mariana Islands data, and consisted of 500 trees and 56 variables (**Appendix C1**).
Results are based on a strong-whistle threshold of 0 percent.
Blackfish class includes false killer whales, pilot whales and melon-headed whales

Table 10. Confusion matrix (percentages of classification) and error reduction for four-class classifier.

Actual species	% classified as				Error reduction	n
	Bottlenose dolphin	*Stenella* species	Blackfish	Rough-toothed dolphin		
Bottlenose dolphin	**50**	20	20	10	33	10
Stenella species	18	**66**	12	4	55	56
Blackfish	4	3	**93**	0	91	29
Rough-toothed dolphin	8	0	17	**75**	67	12

Notes:
Percentage of schools correctly classified are in bold and underlined.
The random forest model was trained and tested using tropical Pacific and Mariana Islands data, and consisted of 500 trees and 56 variables (**Appendix C1**).
Results are based on a strong-whistle threshold of 45 percent.
Blackfish class includes false killer whales, pilot whales and melon-headed whales.
Stenella class includes spinner, spotted and striped dolphins.

a. Deployment 1

School classifications for Okinawa whistles recorded during deployment 1 are given in **Tables 11** (Schwab North) and **12** (Schwab South) and the percentages of trees voting for each species are given in **Appendix C2**. There appears to be more acoustic activity and more species diversity at the Schwab South location. The Schwab South location had 50 detections, including all seven species or species-groups (rough-toothed dolphins, blackfish, *Stenella* species, bottlenose dolphins, spotted dolphins, striped dolphins, and spinner dolphins) included in the classifiers. In contrast, there were

Table 11. Classification results from six-class classifier and four-class classifier for whistles recorded at Schwab North during Deployment 1.

Id #	Date	Time	4-class classifier		6-class classifier		Final classification
			Classified as	Confidence	Classified as	Confidence	
1	11/18/2011	21:50	*Stenella*	3	Striped	1	*Stenella*
2	11/18/2011	23:45	Ambig	n/a	Bottlenose	1	Unknown
3	11/19/2011	0:30	Rough-toothed	4	Rough-toothed	4	Rough-toothed
4	12/15/2011	22:45	Bottlenose	1	Striped	2	Bottlenose or *Stenella*
5	12/25/2011	4:45	Blackfish	4	Blackfish	4	Blackfish
6	1/3/2012	20:45	Blackfish	1	Blackfish	2	Blackfish or Rough-toothed
7	1/3/2012	21:50	Bottlenose	4	Bottlenose	4	Bottlenose
8	1/4/2012	5:15	*Stenella*	4	Spinner	2	*Stenella*
9	1/4/2012	15:05	Blackfish	4	Blackfish	4	Blackfish
10	1/5/2012	2:10	Blackfish	4	Blackfish	4	Blackfish
11	1/5/2012	4:05	Rough-toothed	3	Rough-toothed	3	Rough-toothed
12	1/6/2012	20:30	Bottlenose	4	Bottlenose	1	Bottlenose
13	1/9/2012	23:35	Bottlenose	4	Bottlenose	2	Bottlenose
14	1/10/2012	2:40	Rough-toothed	4	Rough-toothed	3	Rough-toothed
15	1/16/2012	23:50	Bottlenose	2	Bottlenose	1	Bottlenose
16	1/24/2012	5:20	*Stenella*	1	Rough-toothed	2	*Stenella* or Rough-toothed
17	1/24/2012	6:05	Ambig	n/a	Spotted	0	Unknown
18	1/25/2012	21:05	Blackfish	4	Blackfish	4	Blackfish
19	1/25/2012	22:00	Rough-toothed	4	Rough-toothed	3	Rough-toothed

Notes:
'Id #' refers to the detection number.
Six-class classifier had a strong whistle threshold of 0% and four-class classifier had a strong-whistle threshold of 45%.
'Ambiguous' (Ambig) means that strong whistles were not present in the encounter.
Confidence in the classification was on a 0-4 scale, with 0 being the least confident and 4 being the most confident. The 'n/a' distinction means that there were no strong whistles in the detection so the detection could not be classified. Final classification was based on certainty scores and the distribution of tree votes in the six-class and four-class classifiers.
Unknown' means that confidence values were not high enough for a final classification to be made.

Table 12. Classification results from six-class classifier and four-class classifier for whistles recorded at Schwab South during Deployment 1.

Id #	Date	Time	4-class classifier		6-class classifier		Final classification
			Classified as	Confidence	Classified as	Confidence	
1	11/2/2011	3:45	Bottlenose	1	Spinner	2	Bottlenose or *Stenella*
2	11/2/2011	10:55	*Stenella*	4	Spinner	1	*Stenella*
3	11/9/2011	3:20	Bottlenose	4	Bottlenose	2	Bottlenose
4	11/9/2011	4:25	*Stenella*	3	Spotted	0	*Stenella*
5	11/9/2011	5:35	*Stenella*	3	Bottlenose	1	Bottlenose or *Stenella*
6	11/9/2011	6:25	*Stenella*	3	Spinner	3	Spinner
7	11/19/2011	17:40	Blackfish	2	Blackfish	3	Blackfish
8	11/19/2011	18:40	Bottlenose	1	Bottlenose	1	Bottlenose
9	11/19/2011	20:00	Ambig	n/a	Striped	0	unknown
10	11/22/2011	7:30	Bottlenose	2	Spinner	2	Bottlenose or Spinner
11	11/23/2011	0:25	Rough-toothed	3	Rough-toothed	0	Rough-toothed
12	11/23/2011	3:35	Bottlenose	2	Bottlenose	4	Bottlenose
13	11/23/2011	4:20	Bottlenose	2	Bottlenose	0	Bottlenose or *Stenella*
14	11/23/2011	4:55	*Stenella*	1	Striped	1	unknown
15	11/23/2011	12:45	Blackfish	3	Blackfish	3	Blackfish
16	11/24/2011	4:50	Ambig	n/a	Rough-toothed	0	unknown
17	11/29/2011	20:45	Ambig	n/a	Striped	0	unknown
18	11/29/2011	22:10	*Stenella*	2	Spotted	3	Spotted
19	12/3/2011	5:05	*Stenella*	3	Striped	3	Striped
20	12/3/2011	22:25	*Stenella*	4	Spinner	2	*Stenella*
21	12/6/2011	2:30	*Stenella*	4	Spinner	4	Spinner
22	12/6/2011	3:20	Ambig	n/a	Spinner	2	Spinner
23	12/6/2011	7:10	*Stenella*	3	Spinner	3	Spinner
24	12/7/2011	19:40	*Stenella*	3	Spotted	3	Spotted
25	12/15/2011	23:30	Bottlenose	2	Striped	1	Bottlenose or Striped
26	12/18/2011	0:25	Blackfish	1	Bottlenose	0	Bottlenose or Blackfish
27	12/18/2011	9:45	Bottlenose	2	Striped	1	Bottlenose or Striped
28	12/22/2011	0:25	Bottlenose	2	Bottlenose	1	Bottlenose
29	12/22/2011	21:35	*Stenella*	3	Striped	3	Striped

Id #	Date	Time	4-class classifier		6-class classifier		Final classification
			Classified as	Confidence	Classified as	Confidence	
30	12/25/2011	4:40	Blackfish	2	Blackfish	4	Blackfish
31	12/26/2011	2:50	Bottlenose	2	Bottlenose	0	Bottlenose
32	12/27/2011	4:10	Bottlenose	1	Bottlenose	1	Bottlenose
33	12/29/2011	18:35	Bottlenose	2	Striped	0	Bottlenose
34	1/4/2012	15:45	Blackfish	4	Blackfish	4	Blackfish
35	1/5/2012	1:40	Blackfish	4	Blackfish	4	Blackfish
36	1/7/2012	3:05	Blackfish	4	Blackfish	4	Blackfish
37	1/7/2012	4:10	Ambig	n/a	Bottlenose	0	unknown
38	1/7/2012	19:45	Bottlenose	1	Striped	1	Bottlenose or *Stenella*
39	1/8/2012	7:35	Bottlenose	3	Bottlenose	2	Bottlenose
40	1/8/2012	9:05	*Stenella*	3	Striped	3	Striped
41	1/10/2012	3:20	Ambig	n/a	Striped	2	Striped
42	1/16/2012	20:40	Bottlenose	1	Striped	0	Bottlenose or striped
43	1/16/2012	21:35	Bottlenose	3	Bottlenose	1	Bottlenose
44	1/17/2012	1:05	*Stenella*	1	Bottlenose	0	unknown
45	1/23/2012	2:40	Blackfish	1	Rough-toothed	1	Blackfish or rough-toothed
46	1/24/2012	4:55	Blackfish	4	Blackfish	4	Blackfish
47	1/25/2012	16:05	Blackfish	4	Blackfish	4	Blackfish
48	1/25/2012	19:50	*Stenella*	3	Spinner	3	Spinner
49	1/31/2012	0:20	Bottlenose	2	Striped	2	Bottlenose or *Stenella*
50	2/5/2012	5:35	Bottlenose	1	Striped	0	unknown

Notes:

'Id #' refers to the detection number.

Six-class classifier had a strong-whistle threshold of 0 percent and four-class classifier had a strong-whistle threshold of 45 percent.

'Ambiguous' (Ambig) means that strong whistles were not present in the encounter.

Confidence in the classification was on a 0-4 scale, with 0 being the least confident and 4 being the most confident. Final classification was based on certainty scores and the distribution of tree votes in the six-class and four-class classifiers.

Unknown' means that confidence values were not high enough for a final classification to be made.

19 detections at Schwab North, and these included only four species or species-groups (rough-toothed dolphins, blackfish, *Stenella* species, and bottlenose dolphins). Based on final classifications (**Figure 24c**), blackfish, rough-toothed dolphins and bottlenose dolphins were the most commonly identified species at Schwab North (26 percent, 21 percent and 21 percent of detections, respectively, not including detections that could not be identified as a single species). Bottlenose dolphins and *Stenella* species made up the greatest proportion of detections at Schwab South (20 percent and 28 percent of detections, respectively, not including detections that could not be identified as a single species) (**Figure 25c**). The proportion of schools that were classified as bottlenose dolphins was similar at the two sites. Blackfish and rough-toothed dolphins made up a greater proportion of detections at Schwab North than they did at Schwab South (26 percent of detections vs. 16 percent of detections for blackfish 21 percent of detections vs. 2 percent of detections for rough-toothed dolphins). In contrast, *Stenella* species were more common at Schwab South (28 percent of detections vs. 10 percent of detections). Approximately 10 percent of detections were identified as 'unknown' at each site.

b. Deployment 2

School classifications for Okinawa whistles recorded during Deployment 2 are presented in **Tables 13** (Schwab North) **14** (Schwab South) and **15** (Ie Shima), and the percentages of trees voting for each species are presented in **Appendix C3**. Percentages of detections identified as each species or species-group for Deployment 2 are given in **Figures 24** (Schwab N), **25** (Schwab S) and **26** (Ie Shima). Similar to Deployment 1, there were more detections at Schwab South than at Schwab North (71 vs. 46, respectively). The fewest whistle detections occurred at the Ie Shima recording site (n=30). Most species were detected at all three sites, with the exception of spinner dolphins at Schwab South and spotted dolphins at Ie Shima. However, both of these species are *Stenella* species and could have been present but only identified to the genus level. Based on the final classification results (**Figures 24c, 25c,** and **26c**), blackfish and rough-toothed dolphins represented the largest proportion of detections at all three sites (41–53 percent of detections for the two species combined, not including detections that could not be identified as a single species). Bottlenose dolphins represented about 20 percent of detections at all three sites. For the *Stenella* species class, different patterns were evident at each of the different EAR sites. Spinner dolphins represented a greater proportion of detections at Schwab North than at either of the other two sites (9 percent at Schwab N, 0 percent at Schwab S, 3 percent at Ie Shima, not including detections that could not be identified as a single species). Spotted dolphins were the most common *Stenella* species classified at Schwab South (6 percent of detections), but were not very common at Schwab North (2 percent of detections), and were not identified at Ie Shima. Striped dolphins were the most common *Stenella* species classified at Ie Shima (10 percent of detections), but made up a small proportion of detections at both of the other 2 sites (2 percent at Schwab North and 3 percent at Schwab S). The percentage of detections identified as unknown ranged from 0 percent for Ie Shima to 8 percent for Schwab South.

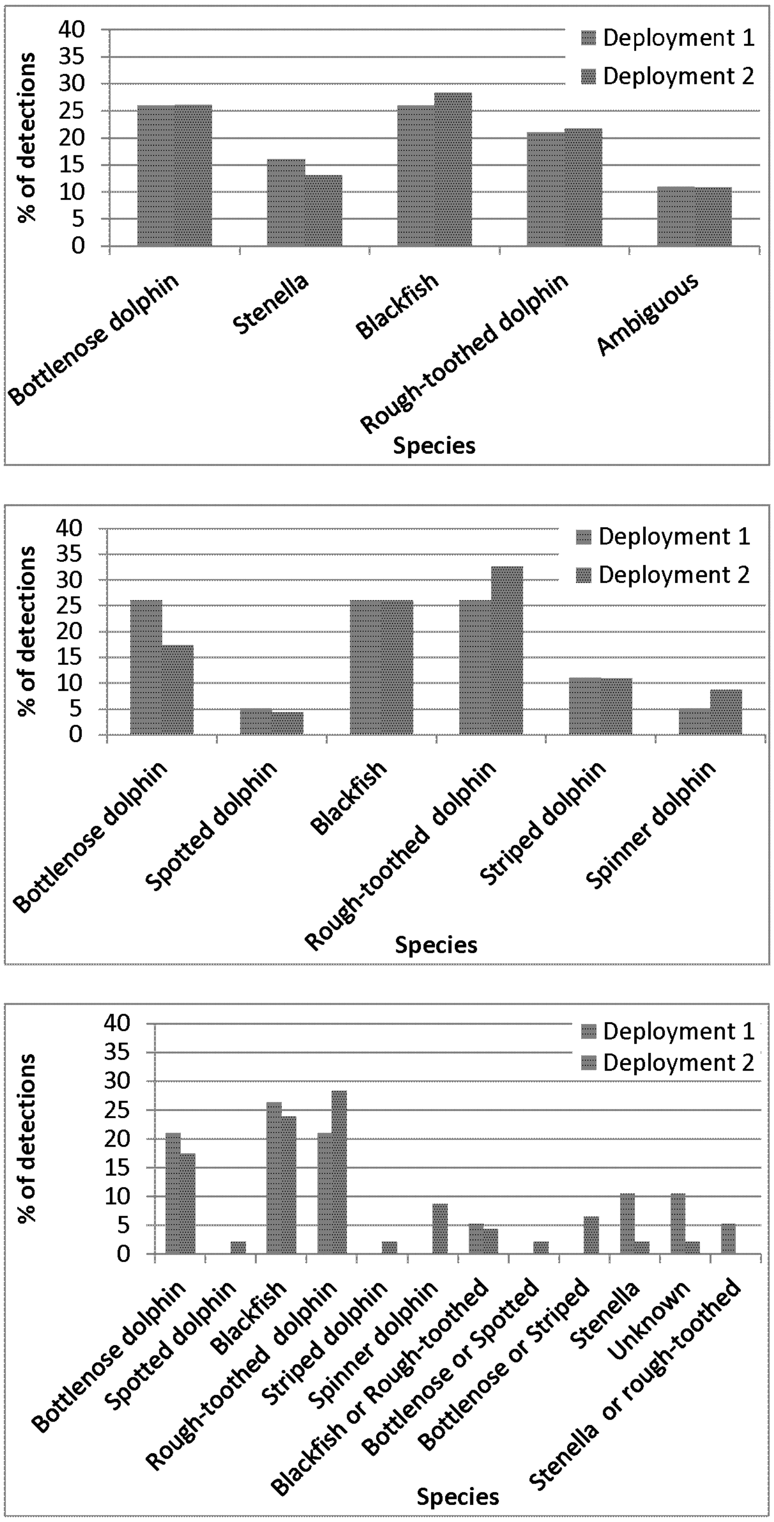
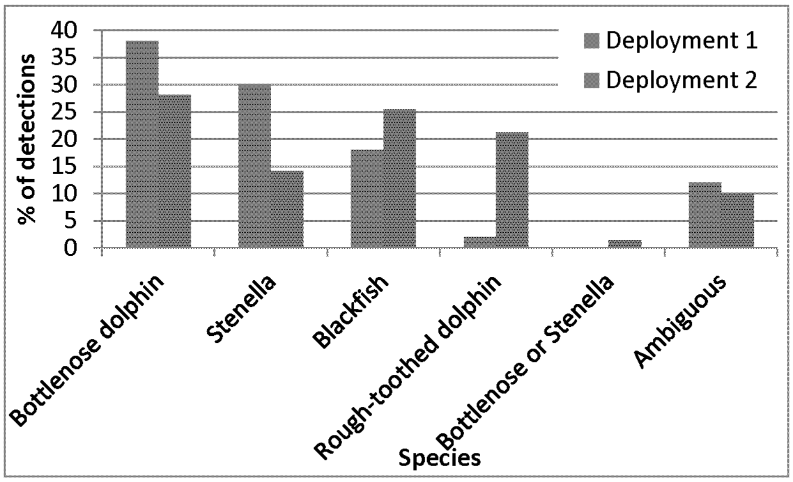
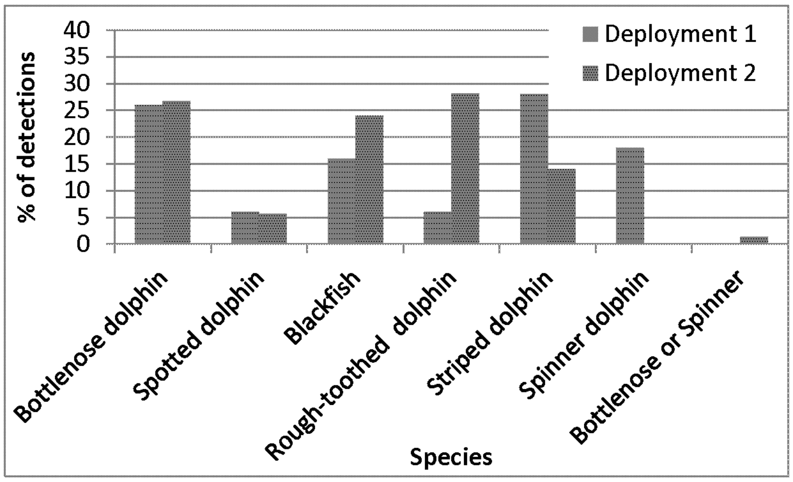


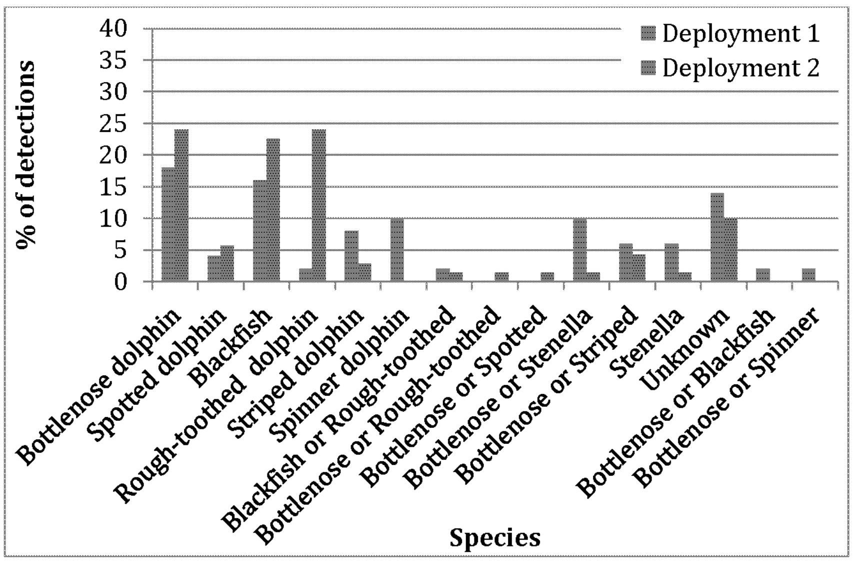
Figure 24. Percentages of detections identified as each species or class for Deployments 1 (blue bars) and 2 (red bars) at Schwab North: a) results from four-class classifier, b) results from six-class classifier, c) final classification based on both classifiers.



a)



b)



c)

Figure 25. Percentages of detections identified as each species or class for Deployments 1 (blue bars) and 2 (red bars) at Schwab South: a) results from four-class classifier, b) results from six-class classifier, c) final classification based on both classifiers.

Table 13. Classification results from six-class classifier and four-class classifier for whistles recorded at Schwab North during Deployment 2.

Id #	date	Time	4-class classifier		6-class classifier		Final classification
			Classified as	Confidence	Classified as	Confidence	
1	3/4/2012	15:40	*Stenella*	4	Striped	1	*Stenella*
2	3/4/2012	18:55	Blackfish	2	Blackfish	4	Blackfish
3	3/5/2012	0:30	Blackfish	4	Blackfish	4	Blackfish
4	3/8/2012	16:50	Blackfish	4	Blackfish	4	Blackfish
5	3/11/2012	11:55	Ambig	n/a	Spinner	2	Spinner
6	3/11/2012	20:40	Bottlenose	2	Striped	1	Bottlenose or Striped
7	3/11/2012	22:55	Bottlenose	2	Striped	1	Bottlenose or Striped
8	3/12/2012	2:05	Rough-toothed	4	Rough-toothed	4	Rough-toothed
9	3/12/2012	14:10	Blackfish	4	Blackfish	4	Blackfish
10	3/17/2012	17:10	*Stenella*	3	Striped	3	Striped
11	3/19/2012	21:05	Rough-toothed	4	Rough-toothed	4	Rough-toothed
12	3/19/2012	23:20	*Stenella*	2	Rough-toothed	2	Unknown
13	3/20/2012	2:35	Bottlenose	3	Bottlenose	3	Bottlenose
14	3/21/2012	6:20	Rough-toothed	3	Rough-toothed	3	Rough-toothed
15	3/22/2012	16:05	Blackfish	4	Blackfish	4	Blackfish
16	3/22/2012	20:45	Bottlenose	1	Bottlenose	4	Bottlenose
17	3/24/2012	0:40	Bottlenose	3	Bottlenose	2	Bottlenose
18	3/25/2012	0:10	Bottlenose	3	Bottlenose	3	Bottlenose
19	4/4/2012	3:45	*Stenella*	3	Spotted	3	Spotted
20	4/5/2012	16:55	Ambig	n/a	Rough-toothed	2	Rough-toothed
21	4/6/2012	2:05	Ambig	n/a	Rough-toothed	2	Rough-toothed
22	4/6/2012	12:40	Blackfish	4	Blackfish	4	Blackfish
23	4/12/2012	21:45	Blackfish	3	Blackfish	3	Blackfish
24	4/13/2012	11:05	Rough-toothed	4	Rough-toothed	4	Rough-toothed
25	4/14/2012	3:50	Blackfish	3	Blackfish	3	Blackfish
26	4/14/2012	23:25	Ambig	n/a	Rough-toothed	2	Rough-toothed

Id #	date	Time	4-class classifier		6-class classifier		Final classification
			Classified as	Confidence	Classified as	Confidence	
27	4/15/2012	1:35	Rough-toothed	2	Rough-toothed	3	Rough-toothed
28	4/20/2012	19:50	*Stenella*	3	Spinner	3	Spinner
29	4/23/2012	0:45	Rough-toothed	4	Rough-toothed	4	Rough-toothed
30	4/23/2012	2:10	Blackfish	4	Blackfish	4	Blackfish
31	4/27/2012	16:00	Bottlenose	3	Bottlenose	4	Bottlenose
32	4/28/2012	19:25	Bottlenose	3	Bottlenose	1	Bottlenose
33	5/3/2012	21:35	Bottlenose	3	Bottlenose	3	Bottlenose
34	5/5/2012	8:30	Blackfish	4	Blackfish	4	Blackfish
35	5/8/2012	21:50	Rough-toothed	3	Rough-toothed	2	Rough-toothed
36	5/8/2012	23:05	Blackfish	1	Blackfish	1	Blackfish or Rough-toothed
37	5/9/2012	17:50	Bottlenose	2	Spotted	2	Bottlenose or Spotted
38	5/9/2012	20:45	*Stenella*	3	Spinner	3	Spinner
39	5/10/2012	17:40	Bottlenose	3	Bottlenose	3	Bottlenose
40	5/11/2012	1:50	Rough-toothed	4	Rough-toothed	4	Rough-toothed
41	5/11/2012	3:45	Rough-toothed	1	Rough-toothed	4	Rough-toothed
42	5/13/2012	0:55	Ambig	n/a	Spinner	2	Spinner
43	5/15/2012	22:30	Blackfish	2	Blackfish	3	Blackfish
44	5/16/2012	21:05	Blackfish	2	Rough-toothed	2	Blackfish or Rough-toothed
45	5/19/2012	4:25	Rough-toothed	2	Rough-toothed	2	Rough-toothed
46	2/21/2012	1:30	Bottlenose	2	Striped	2	Bottlenose or Striped

Notes:

'Id # refers to the detection number.

Six-class classifier had a strong-whistle threshold of 0 percent and four-class classifier had a strong-whistle threshold of 45 percent.

'Ambiguous' (Ambig) means that strong whistles were not present in the encounter.

Confidence in the classification was on a 0-4 scale, with 0 being the least confident and 4 being the most confident. Final classification was based on certainty scores and the distribution of tree votes in the six-class and four-class classifiers.

Unknown' means that confidence values were not high enough for a final classification to be made.

Table 14. Classification results from six-class classifier and four-class classifier for whistles recorded at Schwab South during Deployment 2.

Id #	date	Time	4-class classifier		6-class classifier		Final classification
			Classified as	Confidence	Classified as	Confidence	
1	3/4/2012	16:05	*Stenella*	2	Rough-toothed	1	Unknown
2	3/4/2012	17:20	Bottlenose	1	Bottlenose	4	Bottlenose
3	3/4/2012	22:45	Blackfish	2	Bottlenose	1	Unknown
4	3/5/2012	0:05	Bottlenose	4	Bottlenose	1	Bottlenose
5	3/5/2012	1:05	*Stenella*	3	Spotted	3	Spotted
6	3/5/2012	15:10	Bottlenose	4	Bottlenose	4	Bottlenose
7	3/5/2012	18:00	Ambig	n/a	Striped	0	Unknown
8	3/8/2012	17:45	Blackfish	4	Blackfish	4	Blackfish
9	3/9/2012	23:40	Bottlenose	2	Striped	2	Bottlenose or Striped
10	3/11/2012	11:25	Blackfish	4	Blackfish	4	Blackfish
11	3/11/2012	21:50	Bottlenose	3	Bottlenose	4	Bottlenose
12	3/12/2012	4:50	Ambig	n/a	Bottlenose	2	Bottlenose
13	3/12/2012	13:40	Blackfish	4	Blackfish	4	Blackfish
14	3/16/2012	18:30	*Stenella*	3	Spotted	3	Spotted
15	3/16/2012	20:10	*Stenella*	1	Bottlenose	1	Unknown
16	3/19/2012	21:15	Blackfish	3	Blackfish	3	Blackfish
17	3/19/2012	23:30	*Stenella*	3	Striped	3	Striped
18	3/21/2012	6:00	Rough-toothed	4	Rough-toothed	4	Rough-toothed
19	3/22/2012	2:40	Ambig	n/a	Striped	1	Striped
20	3/22/2012	6:25	Rough-toothed	3	Rough-toothed	4	Rough-toothed
21	3/22/2012	15:40	Blackfish	2	Blackfish	3	Blackfish
22	3/22/2012	21:40	Bottlenose	4	Bottlenose	4	Bottlenose
23	3/23/2012	21:15	*Stenella*	3	Spotted	3	Spotted
24	3/23/2012	22:35	Ambig	n/a	Rough-toothed	2	Rough-toothed
25	3/25/2012	0:50	Rough-toothed	3	Rough-toothed	3	Rough-toothed
26	3/25/2012	20:00	Bottlenose	2	Bottlenose	2	Bottlenose
27	3/30/2012	18:40	Bottlenose	1	Bottlenose	1	Bottlenose or Striped
28	3/30/2012	19:55	Bottlenose	3	Bottlenose	3	Bottlenose
29	4/1/2012	22:50	Blackfish	4	Blackfish	4	Blackfish

Id #	date	Time	4-class classifier		6-class classifier		Final classification
			Classified as	Confidence	Classified as	Confidence	
30	4/3/2012	6:35	Blackfish	3	Blackfish	3	Blackfish
31	4/4/2012	3:15	Bottlenose	4	Bottlenose	2	Bottlenose
32	4/6/2012	2:00	Blackfish	4	Blackfish	4	Blackfish
33	4/6/2012	12:35	Blackfish	4	Blackfish	4	Blackfish
34	4/9/2012	17:35	Bottlenose	3	Bottlenose or spinner	1	Bottlenose
35	4/12/2012	23:00	Blackfish	2	Blackfish	2	Blackfish
36	4/13/2012	13:45	Blackfish	2	Rough-toothed	1	Blackfish or Rough-toothed
37	4/14/2012	5:00	Rough-toothed	3	Rough-toothed	3	Rough-toothed
38	4/15/2012	0:40	Blackfish	4	Blackfish	4	Blackfish
39	4/18/2012	17:25	Rough-toothed	4	Rough-toothed	2	Rough-toothed
40	4/23/2012	0:50	Bottlenose	3	Bottlenose	1	Bottlenose
41	4/27/2012	16:45	Blackfish	2	Blackfish	3	Blackfish
42	4/28/2012	18:35	Blackfish	4	Blackfish	4	Blackfish
43	5/1/2012	4:35	Rough-toothed	3	Rough-toothed	4	Rough-toothed
44	5/1/2012	6:10	Rough-toothed	4	Rough-toothed	4	Rough-toothed
45	5/3/2012	17:25	Rough-toothed	4	Rough-toothed	4	Rough-toothed
46	5/3/2012	22:40	Blackfish	1	Blackfish	2	Blackfish
47	5/5/2012	23:00	*Stenella*	3	Spotted	3	Spotted
48	5/6/2012	12:00	Rough-toothed	1	Rough-toothed	3	Rough-toothed
49	5/6/2012	13:30	Bottlenose	4	Bottlenose	1	Bottlenose
50	5/6/2012	17:00	Rough-toothed	3	Rough-toothed	3	Rough-toothed
51	5/6/2012	18:45	Ambig	n/a	Bottlenose	0	unknown
52	5/8/2012	19:40	Bottlenose or *Stenella*	1	Striped	1	Bottlenose or *Stenella*
53	5/8/2012	20:25	Rough-toothed	3	Rough-toothed	3	Rough-toothed
54	5/8/2012	23:25	Ambig	n/a	Striped	0	Unknown

Id #	date	Time	4-class classifier		6-class classifier		Final classification
			Classified as	Confidence	Classified as	Confidence	
55	5/9/2012	21:45	Bottlenose	2	Rough-toothed	1	Bottlenose or Rough-toothed
56	5/10/2012	6:20	Bottlenose	2	Bottlenose	1	Bottlenose
57	5/10/2012	16:45	Rough-toothed	3	Rough-toothed	3	Rough-toothed
58	5/10/2012	20:35	Rough-toothed	3	Rough-toothed	3	Rough-toothed
59	5/10/2012	21:45	Ambig	n/a	Rough-toothed	1	Rough-toothed
60	5/12/2012	13:35	Blackfish	4	Blackfish	4	Blackfish
61	5/12/2012	22:45	*Stenella*	0	Blackfish	2	Unknown
62	5/13/2012	3:55	*Stenella*	3	Striped	1	*Stenella*
63	5/13/2012	5:45	Rough-toothed	4	Rough-toothed	4	Rough-toothed
64	5/14/2012	5:45	*Stenella*	2	Bottlenose	2	Bottlenose or Spotted
65	5/15/2012	21:45	Bottlenose	3	Bottlenose	3	Bottlenose
66	5/16/2012	21:30	Blackfish	4	Blackfish	4	Blackfish
67	5/17/2012	1:40	Bottlenose	2	Striped	0	Bottlenose
68	5/17/2012	22:40	Bottlenose	2	Striped	0	Bottlenose
69	5/20/2012	0:40	Bottlenose	4	Bottlenose	4	Bottlenose
70	5/20/2012	2:00	Bottlenose	2	Striped	2	Bottlenose or Striped
71	5/21/2012	1:15	Rough-toothed	3	Rough-toothed	3	Rough-toothed

Notes:

'Id #' refers to the detection number.

Six-class classifier had a strong-whistle threshold of 0 percent and four-class classifier had a strong-whistle threshold of 45 percent.

'Ambiguous' (Ambig) means that strong whistles were not present in the encounter.

Confidence in the classification was on a 0-4 scale, with 0 being the least confident and 4 being the most confident. Final classification was based on certainty scores and the distribution of tree votes in the six-class and four-class classifiers.

Unknown' means that confidence values were not high enough for a final classification to be made.

Table 15. Classification results from six-class classifier and four-class classifier for whistles recorded at Ie Shima during Deployment 2.

Id #	date	Time	4-class classifier		6-class classifier		Final classification
			Classified as	Confidence	Classified as	Confidence	
1	3/10/2012	6:00	Blackfish	4	Blackfish	4	Blackfish
2	3/12/2012	12:00	Blackfish	4	Blackfish	4	Blackfish
3	3/14/2012	1:00	Rough-toothed	2	Rough-toothed	4	Rough-toothed
4	3/17/2012	3:00	Bottlenose	1	Striped	1	Bottlenose or *Stenella*
5	3/18/2012	23:00	Blackfish	4	Blackfish	4	Blackfish
6	3/20/2012	4:00	Rough-toothed	3	Rough-toothed	1	Rough-toothed
7	3/20/2012	8:00	*Stenella*	3	Spotted	2	*Stenella*
8	3/26/2012	23:00	Rough-toothed	4	Rough-toothed	4	Rough-toothed
9	3/27/2012	3:00	Bottlenose	4	Bottlenose	4	Bottlenose
10	3/31/2012	19:00	*Stenella*	3	Striped	4	Striped
11	4/8/2012	15:00	Blackfish	4	Blackfish	4	Blackfish
12	4/8/2012	19:00	Blackfish	4	Blackfish	4	Blackfish
13	4/11/2012	3:00	*Stenella*	3	Striped	2	Striped
14	4/11/2012	7:00	Bottlenose	2	Striped	1	Striped or Bottlenose
15	4/12/2012	0:00	Bottlenose	0	Blackfish	2	Blackfish or Bottlenose
16	4/15/2012	9:05	Rough-toothed	1	Rough-toothed	2	Rough-toothed
17	4/16/2012	23:05	Blackfish	4	Blackfish	4	Blackfish
18	4/17/2012	1:00	*Stenella*	3	Spinner	3	Spinner
19	4/17/2012	16:00	Rough-toothed	3	Rough-toothed	3	Rough-toothed
20	4/17/2012	20:00	Rough-toothed	3	Rough-toothed	4	Rough-toothed

Id #	date	Time	4-class classifier		6-class classifier		Final classification
			Classified as	Confidence	Classified as	Confidence	
21	4/21/2012	16:00	Rough-toothed	4	Rough-toothed	4	Rough-toothed
22	4/25/2012	15:00	Bottlenose	3	Bottlenose	2	Bottlenose
23	5/1/2012	5:00	Rough-toothed	2	Rough-toothed	3	Rough-toothed
24	5/2/2012	2:00	Ambig	n/a	Bottlenose	2	Bottlenose
25	5/8/2012	4:00	Blackfish	4	Blackfish	4	Blackfish
26	5/9/2012	12:00	*Stenella*	0	Rough-toothed	2	Rough-toothed
27	5/12/2012	17:00	Bottlenose	4	Bottlenose	4	Bottlenose
28	5/12/2012	19:00	*Stenella*	2	Striped	3	Striped
29	5/13/2012	21:25	*Stenella*	3	Striped or spinner	2	*Stenella*
30	5/16/2012	5:00	Bottlenose	3	Bottlenose	2	Bottlenose

Notes:

'Id #' refers to the detection number.

Six-class classifier had a strong-whistle threshold of 0 percent and four-class classifier had a strong-whistle threshold of 45 percent.

Ambiguous' (Ambig) means that strong whistles were not present in the encounter.

Confidence in the classification was on a 0-4 scale, with 0 being the least confident and 4 being the most confident. Final classification was based on certainty scores and the distribution of tree votes in the six-class and four-class classifiers.

Unknown' means that confidence values were not high enough for a final classification to be made.

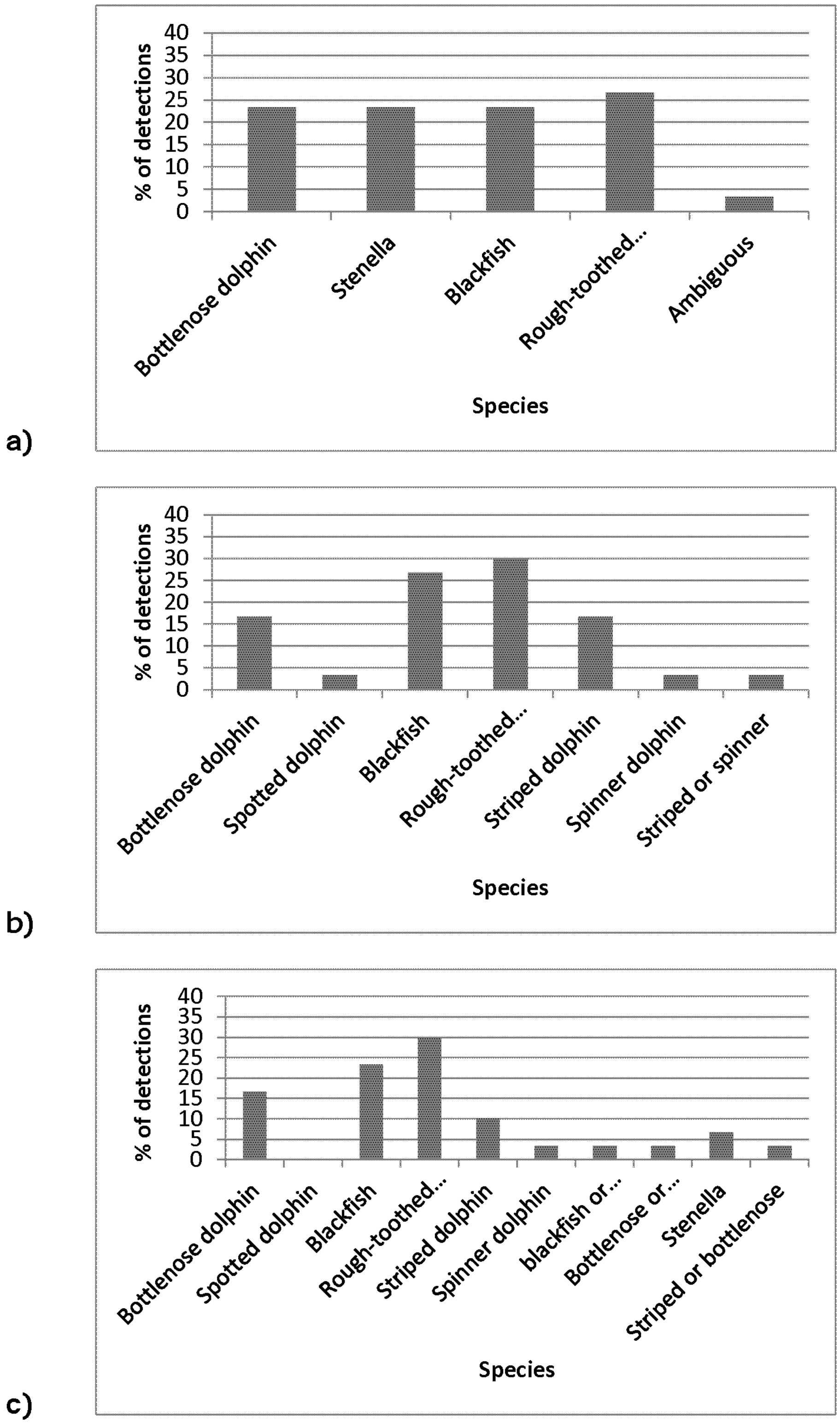


Figure 26. Percentages of detections identified as each species or class for deployment 2 at Ie Shima: a) results from four-class classifier, b) results from six-class classifier, c) final classification based on both classifiers.

Section 5 Discussion

For both deployments, there were a greater number of detections at Schwab South compared to Schwab North. This result may be explained by the fact that the EAR deployed at Schwab South was in deeper water than the EAR at the Schwab North site. In the eastern tropical Pacific Ocean (ETP), *Stenella* species such as striped dolphins and some populations of spotted and spinner dolphins (e.g., offshore spotted dolphins, whitebelly spinner dolphins) tend to have distributions that are further offshore (Au and Perryman 1985, Reilly 1990). In the North Pacific, rough-toothed dolphins are generally considered to be associated with deep water (Gannier and West 2005, Baird et al. 2008); however, Baird et al. (2008) found evidence of site fidelity in rough-toothed dolphins around the Hawaiian Islands. It is possible that rough-toothed dolphins were detected more commonly at Schwab North due to similar site fidelity patterns.

Two of the most commonly identified species or class at all sites during both deployments were blackfish and bottlenose dolphins. Rough-toothed dolphins also made up a large proportion of detections (with the exception of Schwab South, deployment 1). There are a large number of sighting and stranding records around Okinawa for species within the blackfish group (false killer whales, pilot whales, and melon-headed whales) (ex. Uchida 1985, 2005), and bottlenose dolphins have also been recorded in some stranding, sighting and capture records from Okinawa (Uchida 1985, 2005). These records support the results of the classification analysis reported here. While there are few sighting and stranding records for rough-toothed dolphins off of Okinawa, Uchida (1994) reported that rough-toothed dolphins were 'often' sighted in these waters. Rough-toothed dolphins made up a relatively large proportion of acoustic detections at most sites during both deployments, with the exception of Schwab South, Deployment 1. Only 2 percent of detections were identified as rough-toothed dolphins during Deployment 1, in contrast to 24 percent at the same site during Deployment 2. The percent of detections identified as rough-toothed dolphins was also higher during Deployment 2 at Schwab North, although the difference was not as pronounced (21 percent Deployment 1, 28 percent Deployment 2). Because the EAR at Ie Shima failed to record data during deployment 1, it is not possible to determine whether the same trend was evident at that site.

Pantropical spotted dolphins are considered to be one of the most common species off Okinawa (Uchida 1994); however, this species made up a very small proportion of detections at Schwab North and Schwab South (0–6 percent) and was not identified at all at Ie Shima. It is possible that these locations are not preferred habitat for spotted dolphins. It is important to note, however, that whistle detections classified as '*Stenella* species,' 'unknown,' or spinner dolphins may, in fact, be spotted dolphins. Spotted dolphin whistles in the test dataset were misclassified as spinner dolphins 27 percent of the time (**Table 8**). In order to more accurately classify whistles to species, the classifiers should be augmented and tested using more visually validated data from the waters around Okinawa. With more accurate acoustic classifiers, it will be possible to obtain a more complete understanding of species occurrence in this area.

Results from Deployment 1 and Deployment 2 showed similar trends; however, there were some important differences. While deployment durations were similar, there were more detections during Deployment 2 at both Schwab North and Schwab South. There were almost 2.5 times more detections at Schwab North and almost 1.5 times more detections at Schwab South during Deployment 2. In addition to a greater number of detections, there was also greater species diversity at Schwab North during Deployment 2. During Deployment 1, only four species or classes were detected (rough-toothed dolphins, blackfish, *Stenella* species and bottlenose dolphins). During Deployment 2, all seven species or classes were detected. While this is an interesting trend, it is important to note that the species not detected during Deployment 1 were all members of the *Stenella* group. The proportion of detections identified as *Stenella* was higher during deployment 1 and this may have been due to the presence of spotted, striped and/or spinner dolphins. This result highlights the importance of collecting more visually validated data in order to increase our ability to identify whistles to species rather than class.

Because the EAR at Ie Shima did not record during Deployment 1, it is not possible to examine ‘seasonal’ (November–February vs. March–May) trends in species occurrence at this site. The Ie Shima acoustic data do; however, provide an interesting geographic comparison. The EAR at the Ie Shima site was deployed at a similar depth to Schwab South (approximately 400 m), while Schwab North was deployed in shallower water (128 m). The Ie Shima site is also on the opposite side of Okinawa from Schwab North and Schwab South (**Figure 2**). Despite the differences in depth and location, blackfish, bottlenose dolphins and rough-toothed dolphins were the most commonly identified species at all three sites. There were, however, some differences within the *Stenella* species, with striped dolphins being most common at Ie Shima, spinner dolphins most common at Schwab North and spotted dolphins most common at Schwab South. These may be real differences reflecting different habitat use and behavior among species; however, caution should be taken in interpreting these results. A small percentage of detections were classified as ‘*Stenella*’ for each site. The ability to identify these *Stenella* detections to species may strengthen the observed trends or it may weaken them. For example, if the detections identified as ‘*Stenella*’ at Ie Shima are all actually spinner dolphins, then spinner dolphins would be at least as common at that site as striped dolphins.

As highlighted in the paragraph above, both classifiers used to identify the Okinawa whistles contained some classes composed of several species (e.g., the ‘blackfish’ class and the ‘*Stenella*’ class). Although it is more desirable to classify whistles to the species level, combining species that are misclassified as each other improves the performance of the classifier and makes it possible to classify whistles produced by the remaining species more accurately. The blackfish class, in particular, has been shown to be a particularly effective grouping based on percentage of correct classification scores and error reduction scores. The current classifier contains all of the blackfish species that have been reported in the waters surrounding Okinawa, with the exception of the pygmy killer whale (*Feresa attenuata*). Based on previous work, it is likely that whistles produced by pygmy killer whales would be classified as blackfish using the current classification system.

Bio-Waves, Inc. created random-forest classifiers to identify whistles recorded during the Mariana Islands Sea Turtle and Cetacean Survey (DoN 2007). Similar to the waters surrounding Okinawa, little is known about the occurrence of marine mammals in the waters around the Mariana Islands. MISTCS 2007 was the first systematic line-transect visual and acoustic survey in the waters around Guam and the Mariana Islands (DoN 2007, Fulling et al. 2011). During this survey, some of the acoustic detections did not have concurrent visual observations, so ROCCA's classifier was applied in order to identify these detections to species or class. The results of the ROCCA classifier provided a more complete picture of the distribution of marine mammals than could be gained based on visual observations alone. The classifier that was used to identify MISTCS acoustic-only detections contained a blackfish class that was made up of whistles recorded from pilot whales and false killer whales in the tropical Pacific Ocean. During MISTCS, one school of melon-headed whales was detected both acoustically and visually. When the whistles recorded during this detection were run through the ROCCA classifier, the acoustic detection was correctly classified as blackfish. This suggests that the blackfish class could possibly be considered representative of whistles from other species of blackfish and not only applicable to pilot whales and false killer whales. The whistles recorded during the encounter with melon-headed whales had similar characteristics to those recorded from pilot whales and false killer whales (i.e., the whistles were relatively low in frequency [< 9Hz], had few inflection points and steps, and had a narrow frequency range). It is important to note, however, that this is based on whistles measured from only a single school of melon-headed whales. Additional, visually-confirmed acoustic detections of this and other blackfish species (e.g., pygmy killer whale) are necessary in order to determine if these results will hold true for other species of blackfish.

The four-class classifier used to identify Okinawa whistles also contained a combined *Stenella* species class. These species were combined based on classification errors in the seven-species random forest analysis (**Table 7**). Almost all classification errors for spotted dolphins resulted in detections classified as striped or spinner dolphins. Most misclassified striped dolphin detections were classified as spotted dolphins, and most spinner dolphin detections that were misclassified were classified as striped dolphins. In the tropical Pacific, whistles produced by these species have very similar frequency and duration characteristics (Oswald et al. 2007). Frequency characteristics are particularly important in the random-forest classifier used here, so these similarities make it difficult to distinguish among these species. Bottlenose dolphin whistles have similar frequency characteristics to *Stenella* species, but their whistles are, on average, almost twice as long as the whistles produced by *Stenella* species (Oswald et al. 2007).

When interpreting the results of the classification analysis, it is important to remember that classifiers are not perfect. Correct classification scores ranged from 42 percent to 91 percent for the six-class classifier and from 50 percent to 93 percent for the four-class classifier. Classification errors do occur, however, and without visually validated acoustic data from Okinawa, it is not possible to evaluate the prevalence of such errors. The use of 'certainty scores' was meant to provide some guidance as to how much confidence to place in each classification, but in order to gain more insight into possible errors, it will be necessary to test the classifiers on visually validated recordings collected around Okinawa. In addition, it is important to note that the classifiers used in this study were created using data collected in the tropical Pacific and around the Mariana Islands. Geographic variation has been found in the whistles of some species (e.g., Atlantic spotted dolphins, bottlenose dolphins, Baron et al. 2008, Indo-Pacific bottlenose dolphins, Morisaka et al. 2005, pilot whales, Rendell et al. 1999, bottlenose dolphins, Ding et al. 1995). The addition of MISTCS data to the classifier may have captured some of the geographic variability in whistles; however, the MISTCS dataset is small, not every species is represented, and nothing is known about the degree of geographic variation in whistles throughout the Pacific Ocean. It is possible that a classifier created using whistles collected in the Okinawa study area would produce better results.

Another factor to bear in mind when evaluating classifications is that the current classifier does not contain whistles from every species that has been reported in the waters surrounding Okinawa. Species such as pygmy killer whales, Risso's dolphins, and Fraser's dolphins are not included in the classifier data set due to low sample sizes of whistles available. Ideally, a classifier trained and tested using recordings made around Okinawa and including validated sounds from all species found in these waters would be used to identify whistles recorded off Okinawa. Due to low densities of animals and logistic difficulties inherent to conducting visual and acoustic surveys in this area, it may be difficult to obtain the sample sizes necessary to train and test an effective and efficient classifier. As a first step, it would be wise to collect a smaller sample of whistles from these animals and compare them to whistles of the same species recorded in different areas. This type of analysis requires a smaller sample size than is necessary for training and testing a classifier and would be useful for evaluating how accurately a classifier created using eastern tropical Pacific data can predict species in recordings collected around Okinawa.

Currently, it is not possible to identify mixed-species schools using ROCCA. Mixed-species schools can be relatively common. For example, during a visual and acoustic marine mammal abundance survey in the eastern tropical Pacific Ocean, 28 percent of sighted schools were mixed-species schools, with spotted, spinner and bottlenose dolphins being the species most commonly found in these schools (Oswald et al. 2008). In the Okinawa analysis, several detections from each location and deployment were identified as one species or another (ex. Table 14, id#55: bottlenose or rough-toothed). It is possible that these detections were not one species *or* another, but one species *and* another. It is also possible that some detections that were identified as one species actually contained more than one species. To our knowledge, no work has been done on the acoustic identification of mixed-species schools. It would be valuable to analyze whistles recorded during mixed-species encounters in order to develop methods for identifying these schools as such.

It is also important to bear in mind the definition of 'acoustic detection' as used in this study. Acoustic detections were based on elapsed time between whistles, and a new acoustic detection was delineated when 30 minutes or more had elapsed between measured whistles. Thirty minutes was chosen based on the fact that delphinids are generally quite mobile. We assumed that if 30 minutes had passed between whistles, one school had left the area and another had entered. However, it is possible that the whistles were all produced by one school that simply stopped whistling for a period of time. In addition, because only the three 30-sec files containing the most acoustic energy within an hour were examined, it could not be determined whether the break between measured whistles was an actual cessation in whistling, or whether the whistling continued between measured whistles, but at a lower level. In fact, due to the programmed EAR duty cycle (30 seconds of recording every 5 minutes), it was not possible to determine whether there was a true cessation of whistling in between recordings. The trade-off between the length of deployment that is possible and the types of questions that can be addressed using the resulting data is important to consider when determining duty cycles for acoustic monitoring projects. Because of this fact, while 'acoustic detection' was used as a proxy for independent schools, it is more accurately thought of as a discrete set of whistle events. One school may be represented by two or more different acoustic detections. While examining additional files in order to determine true breaks between whistling bouts could provide some insight, it would still be impossible to determine whether breaks represented one school leaving and another arriving, or simply one school remaining in the area, but not whistling for a period of time.

Although caution must be taken in interpreting the results of this analysis, the findings presented here shed light on species occurrence in the Okinawa study area. The ability to identify species based on their whistles provides information that can be used to plan future vessel surveys, aerial surveys, and locations of fixed PAM installations. Furthermore, predictive habitat and spatial models could benefit from any additional information about the distribution and occurrence of delphinids in the Okinawa study area. Finally, the development of a classifier specific to the study area would provide an effective tool that can be used to analyze data collected in the future using passive acoustic methods, especially fixed PAM installations and recorders, as these recordings rarely have visual observations associated with them. The ability to identify species on recordings that do not include concurrent visual observations will allow species occurrence and distribution data to be collected in a more comprehensive, efficient and cost effective way.

5.1 Recommendations for Future Work

The results of these analyses have provided a first look into the relative acoustic occurrence of delphinid species in the ocean waters around Okinawa. Here, we present recommendations for future work that will improve our understanding of the spatial and temporal distribution of delphinid species in this area.

Visually-validated acoustic data should be collected in the waters surrounding Okinawa. We recommend conducting combined visual and acoustic surveys that incorporate towed hydrophone arrays and/or sonobuoys. When developing classifiers, it is critical to use recordings that have been identified to species with certainty. When multiple schools of cetaceans are present in an area, it is necessary to localize the sounds being detected in order to determine which school is producing those sounds. Both towed hydrophone arrays and sonobuoys provide the capability to localize sounds and are therefore preferred methods for collecting visually-validated acoustic recordings.

With sufficient visually-validated acoustic data recorded in the waters surrounding Okinawa one could test the accuracy of ROCCAs current classifier and augment the classifier to improve classification success and reduce the need for grouping species. The ability to acoustically identify individual species will allow a more detailed examination of temporal and spatial differences in habitat use by delphinids around Okinawa. This type of examination would help one to determine the relative importance to delphinids of different locations around Okinawa and aid in Navy planning and mitigation efforts. Ideally, enough data should be collected to allow the development of a classifier specific to Okinawa. This could take considerable time and effort, so a first step would be to collect enough data to allow evaluation of the existing classifier. Effort should also focus on collecting recordings from species that are not currently included in the classifier due to small sample sizes (e.g., pygmy killer whales, Risso's dolphins, Fraser's dolphins).

It would also be valuable to analyze a large dataset of whistles recorded from mixed-species schools of dolphins in order to develop methods for identifying mixed-species schools in addition to single-species schools. The ability to identify mixed-species schools would increase the accuracy of analyses and would also provide a much more complete understanding of species occurrence and habitat use.

In this study, only the three 30-sec files containing the most acoustic energy within an hour were analyzed, and schools were defined based on an inter-whistle interval of 30 minutes or less. We recommend performing a sensitivity analysis to examine how changing these analysis parameters might influence the results.

Finally, we recommend collecting additional data using seafloor acoustic recorders such as the EAR. These types of recorders allow long time-series of data to be collected in remote areas. Sample sizes for many species in the current dataset are small, making it difficult to generalize the results to other areas and times. In addition to increasing sample size, the collection of additional acoustic data from autonomous recorders over ecologically meaningful temporal and spatial scales would allow seasonal and spatial comparisons of species occurrence. We recommend that acoustic data be collected at several locations around Okinawa so that more detailed geographic comparisons of species occurrence can also be conducted. Additional methods, such as towed hydrophone arrays, sonobuoys and dipping hydrophones should be used to increase the geographic and temporal scope of acoustic data collected in the waters surrounding Okinawa.

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APPENDIX C1
Variables Measured from Whistles

Variable	Explanation
begsweep	slope of the beginning sweep (1 = positive, -1 = negative, 0 = zero)
begup	binary variable: 1=beginning slope is positive, 0=beginning slope is negative
begdwn	binary variable: 1=beginning slope is negative, 0=beginning slope is positive
endsweep	slope of the end sweep (1 = positive, -1 = negative, = 0 zero)
endup	binary variable: 1=ending slope is positive, 0=ending slope is negative
enddwn	binary variable: 1=ending slope is negative, 0=ending slope is positive
harms	binary variable: 1=harmonics are present, 0=harmonics are absent
beg	beginning frequency (Hz)
end	ending frequency (Hz)
min	minimum frequency (Hz)
dur	duration (seconds)
range	maximum frequency - minimum frequency (Hz)
max	maximum frequency (Hz)
meandc	mean duty cycle (Measured from the waveform. Proportion of time that the signal exceeds a threshold amplitude)
meandc_quart	mean duty cycle of the first quarter of the whistle
meandc_2quart	mean duty cycle of the second quarter of the whistle
meandc_3quart	mean duty cycle of the third quarter of the whistle
meandc_4quart	mean duty cycle of the fourth quarter of the whistle
mean freq	mean frequency (Hz)
median freq	median frequency (Hz)
std freq	standard deviation of the frequency (Hz)
spread	difference between the 75th and the 25th percentiles of the frequency
quart freq	frequency at one quarter of the duration (Hz)
half freq	frequency at one half of the duration (Hz)
threequart	frequency at three quarters of the duration (Hz)
centerfreq	(minimum frequency+(maximum frequency-minimum frequency))/2
rel bw	relative bandwidth: (max freq - min freq)/center freq
maxmin	max freq/min freq
begend	beg freq/end freq
cofm	coefficient of frequency modulation: take 20 frequency measurements equally spaced in time, then subtract each frequency value from the one before it. COFM is the sum of the absolute values of these differences, all divided by 10000

Variable	Explanation
tot step	number of steps (10% or greater increase or decrease in frequency over 2 contour points)
tot inflect	number of inflection points (changes from positive to negative or negative to positive slope)
max delta	maximum time between inflection points
min delta	minimum time between inflection points
maxmin delta	max delta/min delta
mean delta	mean time between inflection points
std delta	standard deviation of the time between inflection points
median delta	median of the time between inflection points
mean slope	overall mean slope
mean pos slope	mean positive slope
mean neg slope	mean negative slope
mean absslope	mean absolute value of the slope
posneg	mean positive slope/mean negative slope
perc up	percent of the whistle that has a positive slope
perc dwn	percent of the whistle that has a negative slope
perc flt	percent of the whistle that has zero slope
up dwn	number of inflection points that go from positive slope to negative slope
dwn up	number of inflection points that go from negative slope to positive slope
up flt	number of times the slope changes from positive to zero
dwn flt	number of times the slope changes from negative to zero
flt dwn	number of times the slope changes from zero to negative
flt up	number of times the slope changes from zero to positive
step up	number of steps that have increasing frequency
step dwn	number of steps that have decreasing frequency
step.dur	number of steps / duration
inflect.dur	number of inflection points / duration

APPENDIX C2
Percentages of Trees Voting for Each Species in the Four-Class Classifier and Six-Class Classifier – Deployment 1

Schwab North

id #	# whistles	# strong whistles	% tree votes, 4-class				% tree votes, 6-class					
			Bottlenose	*Stenella*	Blackfish	Rough-toothed	Bottlenose	Spotted	Blackfish	Rough-toothed	Striped	Spinner
1	12	8	35	44	10	11	18	11	16	13	23	19
2	2	0	0	0	0	0	20	18	18	19	18	7
3	8	3	7	29	7	57	12	12	17	31	15	13
4	25	13	39	37	10	14	24	12	11	15	31	8
5	26	21	11	13	54	22	12	8	42	21	8	8
6	5	3	21	20	32	27	15	11	28	20	17	9
7	4	4	83	15	1	1	45	11	3	1	19	22
8	11	6	24	53	8	15	17	17	9	18	15	23
9	1	1	4	9	81	5	8	5	71	11	1	4
10	29	28	11	9	65	16	12	3	60	16	3	5
11	1	1	9	18	22	50	14	5	11	36	16	19
12	9	4	47	25	7	21	25	15	8	20	18	14
13	4	3	47	38	8	7	27	14	20	5	18	18
14	5	2	17	20	16	47	18	9	13	34	15	12
15	6	4	36	28	27	10	25	10	25	14	19	8
16	7	2	17	43	7	33	16	12	9	34	15	14
17	1	0	0	0	0	0	13	23	16	7	20	21
18	11	7	10	12	58	20	15	14	35	19	8	10
19	3	2	10	9	18	63	13	10	18	43	9	7

Note: 'Id #' refers to the detection number.

US00009391

Schwab South

id #	# whistles	# strong whistles	% tree votes, 4-class				% tree votes, 6-class					
			Bottlenose	*Stenella*	Blackfish	Rough-toothed	Bottlenose	Spotted	Blackfish	Rough-toothed	Striped	Spinner
1	2	2	63	36	0	1	34	15	0	1	10	40
2	4	3	32	50	13	5	14	28	12	4	13	29
3	3	3	65	34	0	1	38	7	2	1	15	38
4	1	1	23	74	1	1	17	33	3	1	32	15
5	4	4	38	52	3	7	30	17	3	9	25	17
6	1	1	30	67	2	1	14	31	1	0	8	45
7	2	2	27	20	38	15	20	7	42	8	11	11
8	9	6	43	38	6	14	30	12	8	13	26	11
9	2	0	0	0	0	0	22	13	7	6	31	21
10	2	1	54	44	0	2	22	9	8	2	11	49
11	2	2	23	17	13	47	30	9	11	32	13	5
12	4	3	38	31	6	25	35	20	4	17	16	9
13	2	1	49	46	2	3	29	24	3	8	27	10
14	4	4	34	34	7	25	20	11	11	20	24	15
15	2	1	13	15	54	19	9	17	40	26	4	4
16	1	0	0	0	0	0	22	16	8	24	18	12
17	1	0	0	0	0	0	17	9	9	14	26	25
18	2	2	46	52	1	2	29	42	1	1	10	18
19	1	1	32	67	0	1	20	16	2	1	33	27
20	3	1	4	74	14	8	21	9	8	8	23	30
21	5	5	25	73	1	1	17	11	2	1	32	39
22	1	0	0	0	0	0	29	22	6	4	5	35
23	1	1	33	56	2	9	12	16	3	2	8	59
24	1	1	21	78	1	0	7	55	6	1	25	6
25	5	3	47	30	7	16	24	10	12	18	27	10
26	5	2	22	16	33	29	22	15	21	14	15	12
27	7	6	51	36	3	10	30	12	4	6	31	17
28	4	2	46	29	8	17	24	11	19	11	19	16
29	2	2	19	79	1	2	17	9	1	1	39	33
30	9	7	11	21	40	28	10	14	37	21	9	10
31	3	1	46	23	7	24	24	14	12	16	23	11
32	6	3	35	31	7	28	28	13	12	24	17	6

Id #	# whistles	# strong whistles	% tree votes, 4-class				% tree votes, 6-class					
			Bottlenose	*Stenella*	Blackfish	Rough-toothed	Bottlenose	Spotted	Blackfish	Rough-toothed	Striped	Spinner
33	10	8	52	35	6	7	28	18	4	7	28	15
34	8	7	10	4	59	27	8	4	58	22	3	5
35	9	9	10	10	50	30	14	6	39	25	7	9
36	4	4	8	7	69	16	9	2	74	12	2	1
37	2	0	0	0	0	0	24	13	13	19	20	11
38	6	3	44	40	5	11	26	13	11	12	29	9
39	1	1	58	38	1	3	36	15	0	0	12	36
40	1	1	15	82	1	2	18	24	3	2	45	8
41	1	0	0	0	0	0	19	8	9	18	39	8
42	4	4	44	35	11	10	25	14	11	7	26	17
43	2	2	56	19	9	16	32	11	13	12	29	4
44	5	2	38	44	4	14	23	13	6	23	21	15
45	11	6	19	9	36	36	16	9	28	32	10	5
46	8	7	12	5	57	26	9	5	59	20	3	4
47	8	8	11	5	63	22	8	4	69	15	2	2
48	1	1	31	64	1	4	11	37	0	1	3	47
49	2	2	50	45	1	3	24	12	2	3	33	26
50	9	6	39	18	8	35	20	9	7	28	29	7

Note: 'Id #' refers to the detection number.

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APPENDIX C3
Percentages of Trees Voting for Each Species in the Four-Class Classifier and Six-Class Classifier – Deployment 2

Schwab North

id #	# whistles	# strong whistles	% tree votes, 4-class				% tree votes, 6-class					
			Bottlenose	*Stenella*	Blackfish	Rough-toothed	Bottlenose	Spotted	Blackfish	Rough-toothed	Striped	Spinner
1	8	6	28	50	9	13	18	14	10	17	24	17
2	6	3	30	12	42	16	23	11	32	21	6	7
3	10	8	8	13	55	24	8	10	48	19	8	7
4	6	3	7	8	55	30	10	10	38	21	6	15
5	1	0	0	0	0	0	5	7	16	16	16	40
6	3	3	65	25	3	7	34	14	2	4	35	11
7	5	4	50	21	16	13	24	16	8	12	27	13
8	3	3	10	34	4	52	10	10	5	57	12	6
9	5	3	12	6	59	23	13	8	40	26	8	5
10	1	1	31	66	0	3	25	4	1	2	38	30
11	5	3	31	11	9	49	19	10	10	37	16	8
12	1	1	13	53	5	29	20	7	5	32	20	16
13	1	1	75	14	5	6	56	12	4	6	17	5
14	1	1	23	21	9	47	18	5	16	28	21	12
15	5	5	9	12	65	14	10	2	70	11	4	3
16	5	5	35	30	10	25	37	20	6	17	15	5
17	2	2	55	40	2	3	33	9	1	2	30	25
18	1	1	49	42	1	8	34	16	2	2	22	24
19	1	1	38	58	1	3	22	43	1	1	25	8
20	1	0	0	0	0	0	22	6	18	31	15	8
21	2	0	0	0	0	0	23	7	10	31	16	13
22	8	5	14	8	46	32	13	7	38	28	7	7
23	1	1	8	3	61	28	7	4	59	27	2	1
24	3	3	30	23	6	41	27	10	4	37	14	8
25	1	1	10	8	52	30	7	1	49	28	3	12
26	2	0	0	0	0	0	14	8	28	36	9	5
27	5	5	13	5	39	43	13	12	27	36	7	5

id #	# whistles	# strong whistles	% tree votes, 4-class				% tree votes, 6-class					
			Bottlenose	*Stenella*	Blackfish	Rough-toothed	Bottlenose	Spotted	Blackfish	Rough-toothed	Striped	Spinner
28	2	2	18	71	4	7	17	15	4	8	16	40
29	4	3	15	7	32	46	12	10	18	38	6	16
30	5	3	13	14	47	26	19	7	41	24	7	2
31	5	5	41	23	14	22	36	15	9	15	21	4
32	2	1	61	22	4	13	25	13	6	18	23	15
33	1	1	75	17	3	5	41	13	2	4	24	16
34	5	4	11	6	54	29	14	9	43	24	4	6
35	8	4	24	7	28	41	18	12	22	29	12	7
36	8	8	10	7	44	39	9	5	37	36	7	6
37	1	1	59	35	3	3	26	38	1	3	24	8
38	1	1	33	66	1	0	12	20	0	0	16	52
39	1	1	84	15	0	1	56	8	1	0	6	29
40	4	3	18	15	17	50	18	12	14	34	12	10
41	7	5	13	10	38	39	15	9	23	31	12	10
42	1	0	0	0	0	0	13	14	1	29	4	39
43	2	2	6	6	75	13	8	4	67	16	2	3
44	2	1	6	4	57	33	13	6	31	38	7	5
45	3	3	18	4	37	41	13	6	33	35	6	7
46	3	3	63	26	3	8	31	12	4	2	40	11

Note: 'Id #' refers to the detection number.

Schwab South

id #	# whistles	# strong whistles	% tree votes, 4-class				% tree votes, 6-class					
			Bottlenose	Stenella	Blackfish	Rough-toothed	Bottlenose	Spotted	Blackfish	Rough-toothed	Striped	Spinner
1	4	1	21	56	14	9	21	20	10	27	17	5
2	6	3	36	33	18	13	34	17	10	10	18	11
3	4	2	26	23	41	10	28	9	10	11	22	20
4	4	3	46	37	5	12	29	10	4	10	26	21
5	2	2	24	59	10	7	30	39	4	6	18	3
6	8	6	57	22	5	16	39	13	7	15	19	7
7	1	0	0	0	0	0	21	18	13	18	22	8
8	10	10	8	10	58	24	8	4	54	24	4	6
9	2	2	55	37	2	6	21	26	2	2	37	12
10	8	6	5	8	66	21	13	5	50	21	5	6
11	3	2	48	26	4	22	33	14	9	19	19	6
12	1	0	0	0	0	0	39	4	12	25	15	5
13	8	7	21	18	44	17	17	12	33	16	9	13
14	1	1	23	74	2	1	21	42	0	0	14	23
15	5	3	14	41	29	16	24	14	19	17	17	9
16	2	2	11	10	61	19	10	8	57	18	3	4
17	1	1	19	71	1	9	12	16	1	4	48	19
18	4	3	15	9	29	47	11	7	20	36	12	14
19	4	0	0	0	0	0	18	17	10	15	26	14
20	3	1	14	5	18	63	15	10	17	42	9	7
21	2	2	24	30	36	10	14	10	39	6	16	15
22	7	4	49	26	8	17	31	13	8	15	21	12
23	1	1	40	59	0	1	30	36	0	0	10	24
24	1	0	0	0	0	0	19	14	11	31	20	5
25	1	1	22	11	17	50	20	5	19	34	13	9
26	2	2	39	27	11	23	31	17	8	16	18	10
27	7	2	40	35	7	18	27	13	9	19	24	8
28	2	1	66	19	2	13	38	10	4	17	18	13
29	3	3	12	10	63	15	16	4	59	12	4	5
30	1	1	13	7	57	23	11	17	40	19	6	7
31	6	5	52	44	2	2	32	12	1	7	17	31
32	7	6	7	9	64	20	9	9	56	19	3	4
33	5	5	14	7	62	17	12	6	55	17	5	5
34	3	3	72	25	1	2	35	12	3	2	13	35
35	4	4	14	8	42	36	10	9	37	36	6	2

id #	# whistles	# strong whistles	% tree votes, 4-class				% tree votes, 6-class					
			Bottlenose	Stenella	Blackfish	Rough-toothed	Bottlenose	Spotted	Blackfish	Rough-toothed	Striped	Spinner
36	7	7	11	6	49	34	9	9	29	31	8	14
37	1	1	19	21	4	56	20	7	6	49	16	2
38	5	3	13	6	53	28	10	7	36	29	7	11
39	10	10	11	7	38	44	10	6	32	35	7	10
40	3	1	50	30	8	12	29	9	7	17	28	10
41	2	2	27	12	42	19	29	6	37	18	9	1
42	7	6	11	6	62	21	14	5	48	21	5	7
43	4	2	10	7	36	47	8	8	31	39	9	5
44	3	3	13	5	4	78	6	1	7	71	9	6
45	3	3	6	4	5	85	4	3	3	82	4	4
46	7	6	11	15	38	36	8	9	39	30	6	8
47	1	1	36	47	6	11	23	39	1	3	19	15
48	2	2	16	7	38	39	14	3	27	44	5	7
49	4	3	47	16	4	33	28	9	4	24	23	12
50	1	1	5	16	13	66	9	5	3	65	10	8
51	1	0	0	0	0	0	27	9	12	16	25	11
52	3	3	36	36	11	17	21	16	14	10	22	17
53	1	1	18	24	6	52	18	9	5	48	18	2
54	4	0	0	0	0	0	24	8	9	24	27	8
55	2	2	45	10	10	35	30	13	4	35	10	8
56	4	2	47	45	2	6	27	15	11	15	25	7
57	1	1	8	13	8	71	8	2	11	61	14	4
58	1	1	18	6	30	46	7	4	27	39	14	9
59	1	0	0	0	0	0	17	16	17	26	15	9
60	4	3	10	5	69	16	13	3	58	17	5	4
61	5	2	17	34	30	19	22	13	30	21	7	7
62	3	2	41	53	2	4	16	20	5	6	28	25
63	4	4	11	8	27	54	11	8	19	51	3	8
64	2	2	31	51	9	9	35	24	6	6	13	16
65	2	1	56	41	1	2	34	11	6	9	23	17
66	8	8	9	6	56	29	8	7	49	23	5	8
67	5	3	46	20	11	23	22	14	11	20	27	6
68	3	2	51	23	12	15	27	5	22	7	28	11
69	6	3	55	17	2	26	31	10	8	25	19	7
70	2	1	62	28	3	7	32	7	1	6	40	14
71	1	1	22	14	10	54	18	3	12	44	15	8

Note: 'Id #' refers to the detection number.

Ie Shima

id #	# whistles	# strong whistles	% tree votes, 4-class				% tree votes, 6-class					
			Bottlenose	Stenella	Blackfish	Rough-toothed	Bottlenose	Spotted	Blackfish	Rough-toothed	Striped	Spinner
1	10	9	8	6	66	20	8	2	61	21	3	5
2	10	10	6	6	69	19	5	3	71	16	2	3
3	3	3	25	10	26	39	12	9	24	32	13	10
4	3	3	47	45	3	5	22	33	1	2	34	8
5	11	11	9	6	61	24	7	3	65	19	2	4
6	2	1	11	31	8	50	16	13	10	25	22	14
7	1	1	31	47	7	15	29	34	6	8	19	4
8	3	3	10	6	39	45	8	11	24	42	8	7
9	3	3	73	8	8	11	50	12	4	7	20	7
10	6	4	34	43	9	14	21	14	6	13	36	10
11	8	7	8	6	74	12	11	2	68	12	3	4
12	4	4	5	6	87	2	4	1	87	3	4	1
13	2	2	33	58	3	6	18	14	3	6	32	27
14	2	2	52	38	4	6	37	9	2	3	40	9
15	3	2	33	14	30	23	16	14	32	24	10	4
16	6	6	9	7	40	44	8	4	39	41	1	7
17	9	9	12	6	73	9	16	4	63	11	3	3
18	1	1	18	63	6	13	15	16	12	5	10	42
19	1	1	9	12	31	48	13	11	12	46	6	12
20	3	2	10	4	9	77	15	5	7	43	23	7
21	4	3	7	4	27	62	8	9	17	57	3	6
22	2	2	45	28	3	24	29	12	5	20	20	14
23	1	1	16	28	8	48	16	12	7	45	17	3
24	1	0	0	0	0	0	37	8	9	22	19	5
25	7	7	13	5	68	14	14	2	64	16	2	2
26	1	1	18	23	10	50	18	5	7	44	19	7
27	4	3	59	28	8	5	37	17	5	5	28	8
28	1	1	45	49	2	4	24	21	1	2	39	13
29	1	1	35	64	1	0	18	11	1	0	35	35
30	2	2	60	36	2	2	32	15	2	1	30	20

Note: 'Id #' refers to the detection number.

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