Marine Species Monitoring For The U.S. Navy's Mariana Islands Range Complex

ANNUAL REPORT

11 April 2012

Prepared for and Submitted to
National Marine Fisheries Service
Office of Protected Resources

Prepared by
Commander, U. S. Pacific Fleet Environmental Readiness Office
Department of the Navy
In accordance with Letter of Authorization, 09 August 2011

Marine Species Monitoring
For The U.S. Navy's
Mariana Islands Range Complex

ANNUAL REPORT

11 April 2012

Citation for this report is as follows:

DoN 2012. Marine Species Monitoring for the U.S. Navy's Mariana Island Range Complex - Annual Report. 11 April 2012. Department of the Navy, Commander, U.S. Pacific Fleet. Author: Julie Rivers

Appendices by Bio-Waves, Inc, HDR/EOC, NMFS/Pacific Islands Fisheries Science Center, Naval Facilities Engineering Command, Pacific were prepared by the following authors: K. Ampela, S. Coates, T. Dominello, M. Deakos, K. Dunleavy, E. Ferguson, S. Hanser, M. Hill, HDR-EOC, C. Hom-Weaver, A. Ligon, E. Norris, T. Norris, E. Oleson, J. Oswald, M. Richie, M. Richlen, A. Ü, Robert Uyeyama and T. Yack

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report presents data gathered in support of the U. S. Navy's (Navy) Mariana Islands Range Complex (MIRC) Marine Species Monitoring Plan (DoN 2010a, as revised DoN 2011) from 12 Februrary 2011 through 12 February 2012.

The Navy uses the MIRC for at-sea training, as described in the MIRC Environmental Impact Statement (EIS) (DoN 2010b). In support of the MIRC EIS, the National Marine Fisheries Service (NMFS) issued a Biological Opinion (NMFS 2010a) and a five-year Final Rule (NMFS 2010b) for the taking of marine mammals under the Marine Mammal Protection Act (MMPA), with an associated Letter of Authorization (LOA) (NMFS 2010c) to the Commander, U.S. Pacific Fleet (CPF) in August of 2010. The Final Rule and accompanying LOA require the Navy to implement monitoring of marine species as described in annual monitoring plans.

The data collection period for monitoring and reporting is not specifically stated in the MIRC Final Rule as it was for previous range complexes. In order to provide enough time to collect, compile, and validate the range data prior to the 15 April annual report submission date, a data cutoff date of 12 February has been implemented by the Navy. This preparation time is consistent with other authorizations.

Monitoring in the MIRC this period included vessel surveys, deployment of passive acoustic monitoring devices and analysis of acoustic data from a 2007 line transect survey. All metrics committed to in the 2011 Monitoring Plan were met or exceeded.

Based upon lessons learned in the field and input from subject matter experts, monitoring for the next period will retain the overall level of effort but include some new components. The Monitoring Plan for 2012-2015 is included as Appendix E to this document.

LIST OF TABLES (not including Appendices)

INTRODUCTION

Background

The Navy developed the Mariana Islands Range Complex (MIRC) Monitoring Plan (DoN 2010a) to provide marine mammal as required under the Marine Mammal Protection Act (MMPA) of 1972 and the Endangered Species Act (ESA) of 1973. In order to issue an Incidental Take Statement (ITS) for an activity, the National Marine Fisheries Service (NMFS) must set forth "requirements pertaining to the monitoring and reporting of such taking." 50 CFR §216.101(a)(5)(a). A request for a Letter of Authorization (LOA) must include the suggested means of accomplishing the necessary monitoring and reporting that will result in increased knowledge of the species and of the level of taking or effects to populations of marine mammals that are expected to be present. While the ESA itself does not have a specific monitoring requirement, recent biological opinions issued by NMFS have included terms and conditions that require the Navy to implement a monitoring program.

The Draft MIRC Monitoring Plan (submitted to NMFS in September 2009) outlined study questions—similar to those in other range complex monitoring plans—directed at data gathering to determine if there are any adverse effects from Navy training. Field methods proposed in the plan were (1) passive acoustic monitoring, (2) marine mammal observers aboard Navy vessels, (3) near shore visual observers, and (4) collaboration with NMFS during an oceanographic survey. NMFS released the Draft MIRC Monitoring Plan to the public as part of the MMPA Proposed Rule review process; NMFS then provided verbal and e-mail feedback to the Navy based upon this review. NMFS' feedback suggested that although the Navy conducted a four month line-transect survey in 2007 (DoN 2007), the MIRC, unlike other range complexes, is a region where limited data from systematic surveys for marine mammals and sea turtles exist. Therefore, NMFS recommended that the Navy revise the monitoring plan to augment the limited distribution and abundance data for MIRC region.

The Navy incorporated recommendations from NMFS and the public into the Final MIRC Marine Species Monitoring Plan (DoN 2010a). The overall objective of the plan was revised from exercise monitoring to gathering field data that will enable the Navy and NMFS to better understand the distribution and abundance of marine mammals and sea turtles in the MIRC. Methods that were implemented from 2010 through 2012 were (1) analysis of the Mariana Islands Sea Turtle and Cetacean Survey (MISTCS) acoustic data, (2) passive acoustic monitoring and (3) visual surveys. This plan was updated in 2011 as part of the MIRC Annual Marine Species Monitoring Report (DoN 2011).

In 2011, the Navy convened a Scientific Advisory Group to assess the Navy's range complex monitoring plans and provide recommendations for improving them. Subsequently, the Navy solicited more range-specific input from researchers that have conducted field work in the Mariana Islands and Hawaii. This input was used by Navy biologists to build the revised 2012-15 Monitoring Plan (Appendix E)

Integrated Comprehensive Monitoring Program

The Integrated Comprehensive Monitoring Program (ICMP) provides the overarching framework for coordination of the U.S. Navy monitoring program (DoN 2010c). It has been developed in direct response to Navy Range permitting requirements established in the various MMPA Final Rules, ESA Consultations, Biological Opinions, and applicable regulations. As a framework document, the ICMP applies by regulation to those activities on ranges and operating areas for which the Navy sought and received incidental take authorizations.

The ICMP is intended for use as a planning tool to focus Navy monitoring priorities pursuant to ESA and MMPA requirements. Top priority will always be given to satisfying the mandated legal requirements across all ranges. Once legal requirements are met, any additional monitoring-related research will be planned and prioritized using guidelines provided by the ICMP, consistent with availability of both funding and scientific resources. As a planning tool, the ICMP is a "living document." It will be routinely updated as the program matures. Initial areas of focus for maturing the document in 2010/2011 included further refinement of monitoring goals, adding a characterization of the unique attributes associated with each range complex / study area to aid in shaping future monitoring projects, as well as a broader description of the data management organization and access procedures.

The ICMP is evaluated annually through the Adaptive Management Review (AMR) process to: (1) assess progress, (2) provide a matrix of goals for the following year, and (3) make recommendations for refinement and analysis of the monitoring and mitigation techniques. This process includes conducting an annual AMR meeting at which the Navy and NMFS jointly consider the prior year goals, monitoring results, and related science advances to determine if modifications are needed to more effectively address monitoring program goals. Modifications to the ICMP that result from AMR discussions are incorporated by an addendum or revision to the ICMP as needed.

Under the ICMP, monitoring measures prescribed in range/project-specific monitoring plans and Navy-funded research relating to the effects of Navy training and testing activities on protected marine species should be designed to accomplish one or more of the following top-level goals as prescribed in the 2010 ICMP update (DoN, 2010a):

(a) An increase in our understanding of the likely occurrence of marine mammals and/or ESA-listed marine species in the vicinity of the action (i.e., presence, abundance, distribution, and/or density of species).

(b) An increase in our understanding of the nature, scope, or context of the likely exposure of marine mammals and/or ESA-listed species to any of the potential stressor(s) associated with the action (e.g., sound, explosive detonation, or expended materials), through better understanding of one or more of the following: 1) the nature of the action and its surrounding environment (e.g., sound source characterization, propagation, and ambient noise levels); 2) the affected species (e.g., life history or dive patterns); 3) the likely co-occurrence of marine mammals and/or ESA-listed marine species with the action (in whole or part); and/or; 4) the likely biological or behavioral context of exposure to the stressor for the marine mammal and/or ESA-listed marine species (e.g., age class of exposed animals or known pupping, calving or feeding areas).

(c) An increase in our understanding of how individual marine mammals or ESA-listed marine species respond (behaviorally or physiologically) to the specific stressors associated with the action (in specific contexts, where possible, e.g., at what distance or received level).

(d) An increase in our understanding of how anticipated individual responses, to individual stressors or anticipated combinations of stressors, may impact either: 1) the long-term fitness and survival of an individual; or 2) the population, species, or stock (e.g., through effects on annual rates of recruitment or survival).

(e) An increase in our understanding of the effectiveness of mitigation and monitoring measures, including increasing the probability of detecting marine mammals (through improved technology or methodology), both specifically within the safety zone (thus allowing for more effective implementation of the mitigation) and in general, to better achieve the above goals. Improved detection technology resulting from these goals will be rigorously and scientifically validated prior to being proposed for mitigation, and meet practicality considerations (engineering, logistic, fiscal).

(f) A better understanding and record of the manner in which the authorized entity complies with the incidental take authorization and incidental take statement.

OPNAV (N45) is responsible for maintaining and updating the ICMP, as necessary, reflecting the results of future regulatory agency rulemaking, AMRs, best available science, improved assessment methodologies, and more effective protective measures. This is done in consultation with Navy technical experts, Fleet Commanders, and Echelon II Commands as appropriate, and as part of the AMR process.

Report Objective

Design of the Range Complex Monitoring Plans represented part of a new Navy-wide assessment, and as with any new program, there are many coordinating, logistic, and technical details that continue to be refined. The scope of the first generation Range Complex Monitoring Plans in 2008 was to discuss the background for monitoring as well as define initial procedures to be used in meeting study objectives derived from the NMFS-Navy agreements. Monitoring results are presented each year to the NMFS and the next year's monitoring goals established based on the adaptive management process.

Overall, and in support of the above statement, this report has two main objectives:

- Present data and results from the Navy-funded marine mammal and sea turtle monitoring conducted in the Mariana Islands Range Complex from 12 February 2011 to 12 February 2012.

Included in this assessment are reportable metrics of monitoring as requested by NMFS. This Year Two report will focus mostly on summarizing collected data and providing a brief description of the major accomplishments from techniques used this year, while referring to the more technical discussions in various Appendices provided by the scientists who performed the monitoring work in the Range Complexes.

- Continue the adaptive management process by providing an overview of meetings and initiatives over the past year that support proposed revisions to the Navy's 2012 MIRC Monitoring Plans as well as presenting progress made towards development of a Strategic Plan for Navy Monitoring that has been facilitated by establishing a Scientific Advisory Group to review and provide recommendations on the Navy's monitoring program. Proposed changes primarily reflect input received from the scientific community and other stake holders. An overview of the events that have prompted these most recent adaptive management actions is provided in the following sections.

MONITORING IN THE MIRC

Prior to 2007, little information was available on the abundance and density of marine mammals and sea turtles in the MIRC; most of that information came from short surveys (several days) and opportunistic sightings. Eldredge (1991) compiled the first list of published and unpublished records for the greater Micronesia area; that list catalogued 19 marine mammal species. In 2003, Eldredge revised this list from 19 to 13 cetacean species thought to occur around Guam (Eldredge 2003).

The first comprehensive marine mammal and sea turtle survey of the area, MISTCS, was funded by the U.S. Pacific Fleet from January to April 2007 (DoN 2007). The Navy proactively initiated the visual and acoustic survey to gather data to support an analysis of potential effects in the Mariana Islands Environmental Impact Statement (EIS) and associated MMPA and ESA consultations. MISTCS provided the first density estimates for several marine mammal species as well as confirming the presence of sei whales in the MIRC (DoN2007, Fulling et al 2011).

Field efforts increased considerably in 2010 after the completion of the MIRC EIS/OEIS and issuance of the Letter of Authorization (LOA) and Biological Opinion (BiOp). Vessel surveys have been conducted seasonally and passive acoustic monitoring devices have been deployed. Additionally, the acoustic data from MISTCS was more fully analyzed.

Monitoring Objectives

The 2010 and 2011 MIRC monitoring plans (DoN 2010a and 2011) were designed to collect field data to augment the limited distribution and abundance data for marine mammal and sea turtles in the region. Unlike other range complexes, monitoring in the MIRC is not yet focused on effects from Navy training. **Table 1** from the 2011 Monitoring Plan shows the 2011-12 monitoring commitments that were set as goals for this reporting period.

Results of the monitoring are helping to build the scientific baseline for this region as well as supporting the Navy’s next phase of environmental compliance documents.

Table 1. FY11-12 monitoring commitments for the MIRC (from DoN 2011)

Monitoring Technique	Implementation	
Visual Surveys (aerial or vessel)	Conduct summer and winter visual surveys using a small boat and/or airplane around Guam, Tinian, Rota and Saipan in cooperation with NMFS and/or DAWR. Visual surveys would integrate methods such as photo ID that provide data that can be used for distribution and abundance. 45 days total.	Adaptive Management Review (AMR) for Year 3
Acoustic Data Analysis	Analyze existing acoustic data set, which was collected during Navy's 2007 MISTCS survey.	
Passive Acoustics Monitoring (PAM)	Continue recording from PAM devices and begin/conduct data analysis.	

Monitoring Accomplishments

The MIRC monitoring plan made commitments for late FY11 through early FY12. Accomplishments are summarized in **Table 2** and below.

Summary of Monitoring Conducted (February 2011 to February 2012)

- Visual Survey highlights (Full reports in Appendix A and B):

  - Survey teams were in the field for 45 days of non-systematic visual surveys from small boats were conducted for marine mammals and sea turtles around the islands of Rota, Guam, Saipan, Aguijan and Tinian. 6 days on the water were lost due to rough weather conditions.
  - The surveys covered 2,244 nmi of trackline over 276 hours on effort.
  - A total of 47 groups of cetaceans and 6 sea turtles were sighted. Sightings that were identified to species included green sea turtles, bottlenose, pan-tropical spotted, and spinner dolphins; sperm, short-finned pilot, pygmy killer and dwarf sperm whales.
  - 12,612 photographs taken during the surveys have been provided to PIFSC for their photo-identification catalog.

Vessel surveys were conducted in winter and summer with the goal of obtaining observations of seasonal migrants as well as year round odontocetes. Winter surveys proved very challenging with higher seas (winter Beaufort sea state (BSS) >4 - 66% of the time; summer > 4 BSS - 43%Guam, BSS>4 - 48% other islands) reducing survey distance offshore and on the windward sides of the islands. Surveys resulted in zero baleen whales observations, in contrast to the MISTCS results where baleen whales were observed regularly. This may be due to the difference in survey platforms (small vessel versus large vessel), the distance offshore that small vessels can safely survey or something anomalous (e.g. oceanographic conditions, sea surface temperature, etc) in 2007. The Navy is looking forward to the potential for the PAM data analysis to provide more insight into the occurrence of baleen whales.

➢ Mariana Island Sea Turtle and Cetacean Survey (MISTCS) acoustic data analysis highlights (Full report in Appendix C):

- Estimate of minke whale abundance application of distance sampling methodology to towed array passive acoustic detections and line transect observations
- Classification of delphinid whistles to four associated acoustic groups
- Improved detection function for acoustic sperm whale encounters and quantification that the majority of recorded sperm whale codas were from the “normal dialect” or clan of sperm whales
- Comparison of humpback whale song fragments to Hawaii humpback whale song of the same time period
- Characterization of sei whale vocalizations

MISTCS used standard line-transect methodology and PAM using a towed hydrophone array system. The PAM component of the survey was effective in detecting some species humpback whale (*Megaptera novaeangliae)* and minke whale (*Balaenoptera acutorostrata)* that were infrequently (or never) visually detected, and for other species (e.g., sperm whale [*Physter macrocephalus*] and small groups of delphinids), increased detection rates when visual sighting conditions were poor. Recordings of minke whale, sperm whale, sei whale (*Balaenoptera borealis*), humpback whale, and several species of dolphins (including larger delphinids, such as the “blackfish”) were analyzed in detail to provide more comprehensive information on the occurrence and aspects of these species’ ecology and behavior. The main goals of these analyses were to: (1) provide acoustically-derived density estimates when feasible (e.g., minke whales); (2) estimate an acoustically-derived ‘detection function’ (e.g., sperm whales); (3) describe and compare acoustic signals for some species and populations for which limited information is available (e.g., sei whales and humpback whales); and (4) assess the success of automated classification algorithms for several species of delphinids.

➢ Passive Acoustic Monitoring highlights (Full report in Appendix D):

- Four Ecological Acoustic Recorded (EAR) buoys were deployed in September 2011 – two off Guam, one off Saipan and one off Tinian. They will be retrieved during the winter 2012 visual survey and analysis will begin upon retrieval.

Table 2. U.S. Navy-funded marine mammal monitoring accomplishments within the Mariana Islands Range Complex in FY10 and through 12 February 2011.

Field Method	Monitoring Commitment	Total accomplished
Visual surveys	Conduct summer and winter visual surveys using a small boat and/or airplane around Guam, Tinian, Rota and Saipan. Visual surveys would integrate methods such as photo ID that provide data that can be used for distribution and abundance. 45 days total.	45 field days of summer and winter visual surveys using a small boat around Guam, Tinian, Rota, Aguijan and Saipan. 12,612 photographs were collected for use in photoidentification studies.
MISTCS data analysis	Analyze existing acoustic data set from 2007 MISTCS	Analyzed existing acoustic data set from 2007 MISTCS survey.
Passive Acoustic Monitoring	Deploy four passive acoustic monitoring devices around the Mariana Islands that are capable of gathering data throughout the year.	Deployed four passive acoustic monitoring devices around the Mariana Islands for one year.

ADAPTIVE MANAGEMENT AND YEARLY MONITORING COMMITMENTS

MIRC ADAPTIVE MANAGEMENT AND 2012-15 MONITORING PLAN

Adaptive management is an iterative process of optimal decision making in the face of uncertainty, with an aim to reducing uncertainty over time via system monitoring. Within the natural resource management community, adaptive management involves ongoing, real-time learning and knowledge creation, both in a substantive sense and in terms of the adaptive process itself. Adaptive management focuses on learning and adapting, through partnerships of managers, scientists, and other stakeholders who learn together how to create and maintain sustainable ecosystems. Adaptive management helps science managers maintain flexibility in their decisions, knowing that uncertainties exist and provides managers the latitude to change direction will improve understanding of ecological systems to achieve management objectives; and is about taking action to improve progress towards desired outcomes.

A 2010 Navy-sponsored monitoring meeting in Arlington, VA initiated a process to critically evaluate the current Navy monitoring plans and begin development of revisions/updates to both existing region-specific plans as well as the Integrated Comprehensive Monitoring Program (ICMP). Discussions at that meeting as well as the following Navy/NMFS annual adaptive management meeting (Oct 2010) established a way ahead for continued refinement of the Navy's monitoring program. This process included establishing a Scientific Advisory Group (SAG) of leading marine mammal scientists with the initial task of developing recommendations that would serve as the basis for a Strategic Plan for Navy monitoring. The Strategic Plan is intended to be a primary component of the ICMP and provide a “vision” for navy monitoring across geographic regions - serving as guidance for determining how to most efficiently and effectively invest the marine species monitoring resources to address ICMP top-level goals and satisfy MMPA Letter of Authorization regulatory requirements. The objective of the Strategic Plan is to continue the evolution of Navy marine species monitoring towards a single integrated program, incorporating SAG recommendations, and establishing a more transparent framework for soliciting, evaluation, and implementing monitoring work across the Fleet range complexes. The Strategic Plan is currently being developed and will establish the process for soliciting, reviewing, and selecting the most appropriate monitoring projects to invest in across the Navy. It is anticipated that some current efforts will continue but the level of effort and investment may be allocated differently across Navy Ranges.

Originally, five study questions were developed between NMFS and the Navy as guidance for developing monitoring plans (as presented in the Introduction), and all existing range-specific monitoring plans attempted to address each of these study questions. However, the state of knowledge for the various range complexes is not equal, and many factors including level of existing information, amount of training activity, accessibility, and available logistics resources, all contribute to the ability to perform particular monitoring activities. In addition, the Navy monitoring program has historically been compartmentalized by range-complex and focused on effort-based metrics (survey days, trackline covered, etc.).

Navy established the SAG in 2011 with the initial task of evaluating current Navy monitoring approaches under the ICMP and existing LOA’s to develop objective scientific recommendations that would form the basis for the Strategic Plan. While recommendations were fairly broad and not prescriptive from a range complex perspective, the SAG did provide specific programmatic recommendations that serve as guiding principles for the continued evolution of the Navy Marine Species Monitoring Program and provide a direction for the Strategic Plan development. The meeting resulted in refinement of the five study questions of the ICMP into six study goals, as earlier described in detail in the Background section of the Introduction of this report. The SAG also provided three general recommendations that apply broadly across the Navy's monitoring program:

- Transparency, collaboration, and data accessibility;
- Specific Programmatic recommendations in four key areas: (1) overall monitoring objectives and scope; (2) operational methodology; (3) data analysis and integration; and (4) procedural logistics.
- The importance of monitoring the effects of all types of training exercises, including low-frequency active sonar and explosives.

Specific to the MIRC, the SAG recommended a broad suite of monitoring for this area including passive acoustic monitoring, development of local expertise, and non-systematic surveys incorporating biopsy, tagging and photo-identification studies. In June 2011, the Navy hosted a Marine Mammal Monitoring Workshop with guidance and support from NMFS that included scientific experts and representatives of environmental non-governmental organizations (NGOs). The purpose of the workshop was to present a consolidated overview of monitoring activities accomplished in 2009 and 2010 pursuant to the Final Rules currently in place, including the SAG review, outcomes of selected monitoring-related research and lessons learned, and to seek feedback on future directions. A significant outcome of this workshop was to continue consolidating monitoring efforts from individual range complex plans and develop a single Strategic Plan for Navy Monitoring that will improve the return on investment by focusing specific objectives and projects where they can most efficiently and effectively be addressed throughout the Navy range complexes. The Strategic Plan is currently in development and will be incorporated as a primary component of the ICMP.

SAG results, subsequent input from local Hawaii and Marianas researchers and lessons learned from prior monitoring was used by Navy biologists to revise and improve monitoring for MIRC for the remainder of the LOA period while maintaining the same overall level of effort. See Appendix E for revised Monitoring Plan for 2012-15.

Table 3 – Summary of monitoring methods for FY10-15

	FY10		FY11		FY12		FY13		FY14		FY15
Passive Acoustic Monitoring			- Deploy four passive acoustic monitoring devices around the Mariana Islands that are capable of gathering data throughout the year. - Analyze existing acoustic data set which was collected during Navy's 2007 MISTCS survey.		- Deploy four passive acoustic monitoring devices around the Mariana Islands that are capable of gathering data throughout the year. - Analyze data from 4 PAM devices deployed in FY12		- Deploy PAM devices in the Mariana Islands that are capable of gathering data throughout the year. - Opportunistically collect acoustic recordings with a dipping hydrophone during visual survey effort. - Analyze data from PAM devices		- Deploy PAM devices in the Mariana Islands that are capable of gathering data throughout the year. - Opportunistically collect acoustic recordings with a dipping hydrophone during visual survey effort. - Analyze data from PAM devices		Opportunistically collect acoustic recordings with a dipping hydrophone during visual survey effort.
Visual Surveys	- Small boat surveys around Guam, Tinian and Saipan. - Visual observations using marine species observers aboard NMFS/PIFSC oceanographic survey in the Region, as well as during transits between Hawaii and Guam.	ADAPTIVE MANAGEMENT REVIEW (AMR)	Conduct summer and winter visual surveys using a small boat and/or airplane around Guam, Tinian, Rota and Saipan in cooperation with NMFS and/or DAWR. Visual surveys would integrate methods such as photo ID that provide data that can be used for distribution and abundance. 45 days total.	A M R	Conduct summer and winter visual surveys using a small boat and/or airplane around Guam, Tinian, Rota and Saipan in cooperation with NMFS and/or DAWR. Visual surveys would integrate methods such as photo ID that provide data that can be used for distribution and abundance. 45 days total.	A M R	Conduct non-random, non-systematic visual survey or shore based surveys at any time of the year.	A M R	Conduct non-random, non-systematic visual survey or shore-based surveys at any time of the year.	A M R	Conduct non–random, non-systematic visual survey or shore-based surveys at any time of the year.
Biopsy							Purchase biopsy supplies to support biopsy attempts. Archive (preserve, extract DNA, sex) biopsy samples.		Purchase biopsy supplies to support biopsy attempts. Archive (preserve, extract DNA, sex) biopsy samples.		Purchase biopsy supplies to support biopsy attempts. Archive (preserve, extract DNA, sex) biopsy samples.
Satellite tagging							- Purchase satellite tags to support tagging attempts during visual surveys. - Analyze data from satellite tags.		- Purchase satellite tags to support tagging attempts during visual surveys. - Analyze data from satellite tags.		- Purchase satellite tags to support tagging attempts during visual surveys. - Analyze data from satellite tags.
Photo-ID and mark-recapture abundance estimates											Mark-recapture abundance estimate analysis for species with the highest likelihood of generating a statistically significant result.
Sea turtle distribution and density							Either line transect diving surveys or sea turtle tags along with analysis		Either line transect diving surveys or sea turtle tags along with analysis		Either line transect diving surveys or sea turtle tags along with analysis

REFERENCES

DoN 2007. Marine mammal and sea turtle survey and density estimates for Guam and the Commonwealth of the Northern Mariana Islands. Primary authors: Phil Thorson, Greg Fulling, Tom Norris, Candice Hall and Kerry Sawyer. Prepared under contract by Man-Tech SRS Technologies and Geo-Marine for the U.S. Navy, Pacific Fleet, Honolulu, Hawaii.

DoN 2010a. Marine Species Monitoring Plan for the Mariana Islands Range Complex. May 2010. Prepared for NMFS, Protected Resource Division by U.S. Pacific Fleet Environmental.

DoN 2010b. Mariana Islands Range Complex Final Environmental Impact Statement/Overseas Environmental Impact Statement. May 2010.

DoN 2010c. U.S. Navy Integrated Comprehensive Monitoring Program. December 2010 Update. 20 December 2010.

DoN 2011. Marine Species Monitoring Plan for the Mariana Islands Range Complex. 2011 plan submitted as part of the 2011 Annual Marine Species Monitoring for the U.S. Navy's Mariana Islands Range Complex Report. Prepared for NMFS, Protected Resource Division by U.S. Pacific Fleet Environmental.

Eldredge, L. G. 1991. Annotated checklist of the marine mammals of Micronesia. Micronesica 24(2):217-230.

Eldredge, L. G. 2003. The marine reptiles and mammals of Guam. Micronesica 35-36:653-660.

Fulling, G.L., P.H. Thorson, and J. Rivers. 2011. Distribution and abundance estimates for cetaceans in the waters off Guam and the Commonwealth of the Northern Mariana Islands. *Pacific Science.* Vol 65(3):321-343.

Mobley, J.R. 2007. Marine Mammal Monitoring Surveys in Support of Valiant Shield Training Exercises (Aug. 13-17, 2007). Marine Mammal Research Consultants.

NMFS 2010a. Biological Opinion. Issued 16 August 2010 by Endangered Species Division of the Office of Protected Resources, NMFS.

NMFS 2010b. Taking and Importing Marine Mammals; Military Training Activities and Research, Development, Testing and Evaluation Conducted Within the Mariana Islands Range Complex. Final Rule. Vol. 75, No. 148, pp. 45527-45556. 3 August 2010.

NMFS 2010c. Letter of Authorization valid for 12 August 2010 to 11 August 2011.

APPENDIX A –

Guam Marine Species Monitoring Survey – Vessel Based Monitoring Survey, Winter 2011.

GUAM MARINE SPECIES MONITORING SURVEY

VESSEL-BASED MONITORING SURVEYS

WINTER 2011

December 2011

ACRONYMS AND ABBREVIATIONS

CNMI	Commonwealth of Northern Mariana Islands
DON	Department of the Navy
ESA	Endangered Species Act
ft	Feet
km	Kilometer(s)
km^2	Square kilometer(s)
MISTCS	Mariana Islands Sea Turtle and Cetacean Survey
mm	Millimeter(s)
MMPA	Marine Mammal Protection Act
nm	Nautical mile(s)
nm^2	Square nautical mile(s)
NMFS	National Marine Fisheries Service
SPUE	Sightings Per Unit Effort
XBT	Bathythermograph

Table of Contents

Appendix

Figures

Tables

Suggested Citation

HDR. 2011. Guam marine species monitoring survey: Vessel-based monitoring surveys winter 2011. Final Report submitted by HDR to U.S. Navy NAVFAC Pacific. 15 pp.

Introduction

Detailed information is lacking on island-specific use by marine mammals of nearshore and oceanic waters off Guam and Commonwealth of Northern Mariana Islands (CNMI). The U.S. Navy prepared a comprehensive compilation of data and literature concerning the protected and managed marine resources for the Marianas Operating Area (DON 2005). The area assessed was south of Pagan and included the waters off of Guam, Tinian, and Farallon de Medinilla. Prior to 2007, there was little information available on the abundance and density of marine mammals in the Mariana Islands. Most accounts of marine mammal occurrence within the region were opportunistically reported sighting and stranding data (reviewed in DON 2005). The Mariana Islands Sea Turtle and Cetacean Survey (MISTCS) conducted during January-April 2007 in waters around Guam and the Northern Mariana Islands was the first systematic survey effort for marine mammals in this region (DON 2007; Fulling et al. 2011). The surveyed area included waters off Guam and Tinian; however, the northern boundary of the MISTCS survey area was south of Pagan. The U.S. Navy proactively initiated the visual and acoustic survey to gather data to support an analysis of potential effects of U.S. Navy training exercises in the Mariana Islands Environmental Impact Statement and associated Marine Mammal Protection Act (MMPA) and Endangered Species Act (ESA) consultations. Other recent data from this region include marine mammal monitoring efforts associated with U.S. Navy training exercises, south of Saipan and east of Guam and Rota, during August 2007 (e.g., Mobley 2007). Small-boat surveys partially-funded by the U.S. Navy and the National Marine Fisheries Service (NMFS) were conducted around the islands of Guam, Tinian, and Saipan during February-March 2010 (Ligon et al. 2011).

The objective of this current survey effort was to conduct baseline surveys to further document marine mammal and sea turtle occurrence in nearshore waters around the island of Guam. This report presents the results of the Guam Marine Species Monitoring Survey conducted on the *MV Island Girl* from February 17 to March 3, 2011. This survey covered an area of approximately 4,100 square kilometers (km^2)(1,200 square nautical miles ([nm^2]) to document marine mammal and sea turtle distribution around the island of Guam. The approach primarily followed opportunistic survey protocols used in a recent survey around Guam (Ligon et al. 2011), which remained nearshore (within 5.6 kilometers [km] or 3 nautical miles [nm] of the coastline).). The resulting sightings, therefore, consisted of spinner dolphins (*Stenella longirostris*; 7 of 9 sightings) and a mixed group of bottlenose dolphins (*Tursiops truncatus*) and short-finned pilot whales (*Globicephala macrorhynchus*). In addition, one species of sea turtle was observed (green sea turtle, *Chelonia mydas*). Additional lines of effort following standard line-transect protocols were attempted (out to 10 nm from shore) when sea conditions permitted.

Methods

Visual Surveys

The survey was conducted between February 17 and March 3, during which time data collection was maximized to the degree possible. The survey platform, the *MV Island Girl*, is a 12.8 meters (m) (42-foot [ft]) vessel (authorized for use on the windward side of Guam) with an observer height of 5.5 m (18 feet [ft]). Sighting data were collected during daylight hours when weather conditions permitted (such as Beaufort sea states of 0–6 and visibility > 1.9 kilometer [1.0 nm]). The primary approach was to use opportunistic survey methods in order to maximize survey effort during less than ideal weather conditions; systematic line-transect surveys, however, were also used when sea conditions were acceptable (see **Figure 1** for proposed systematic tracklines). The survey was conducted using an observation team of three individuals—two dedicated observers searching with 7x50 hand-held reticled binoculars (port and starboard positions) and the third with unaided eyes and 7x50 hand-held reticled binoculars (centerline position). The third observer served as the data recorder. Five observers rotated through the three observer positions every 2 hours. All marine species observers were experienced with line-transect survey methodology, had experience in identification of subtropical Pacific marine mammal and sea turtle species, were knowledgeable about marine mammal biology and behavior, and had previous experience conducting marine mammal observations from vessels (see **Table 1**).

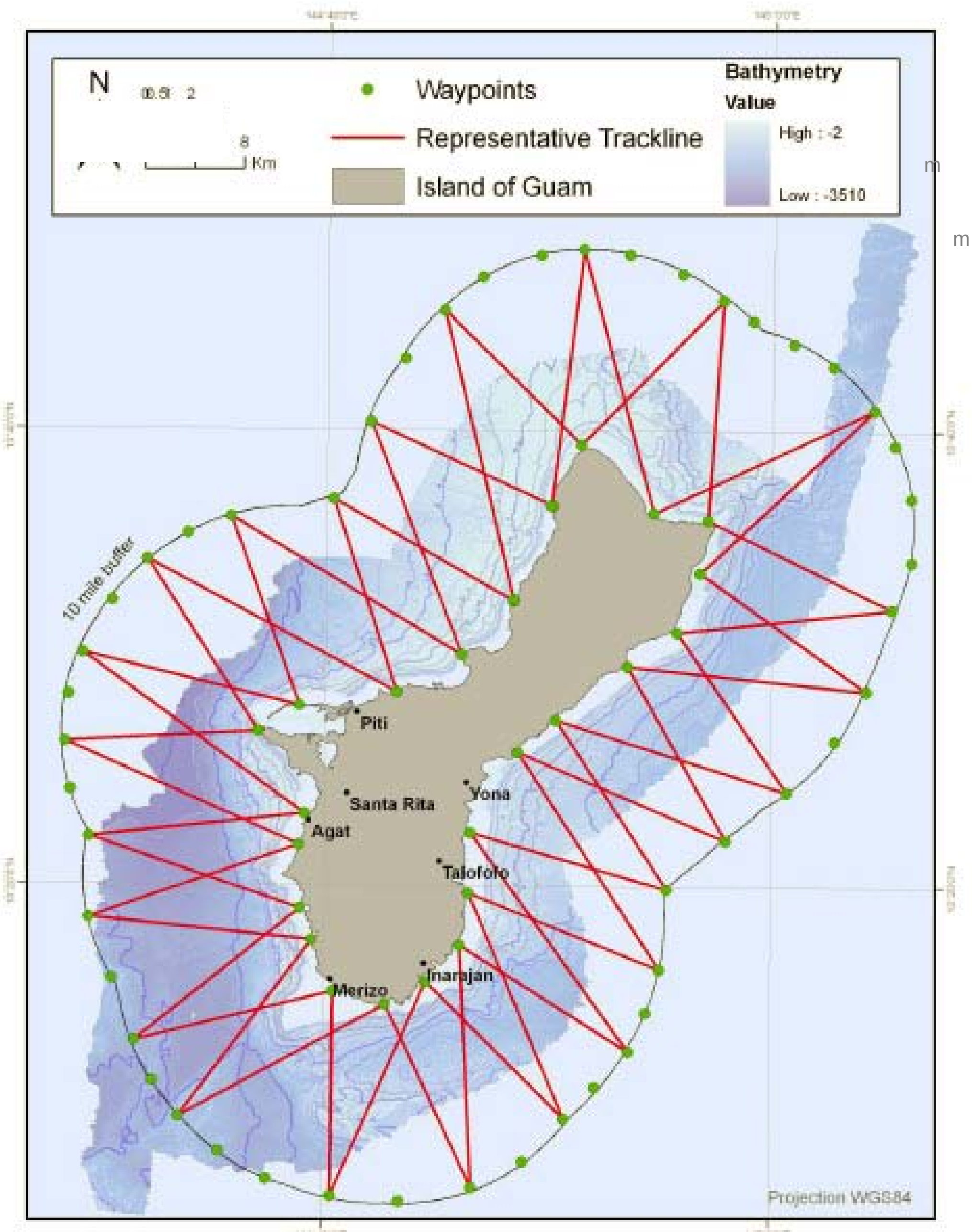


Figure 1: Proposed systematic tracklines. Additional waypoints were inserted in the event that tracklines needed to be adjusted based on weather or sea state.

Table 1: Scientific personnel for survey.

Crew Position	Name	Company
Cruise Leader	Gregory Fulling	HDR
Marine Species Observer	Anne Douglas	Cascadia Research Collective
Marine Species Observer	Kristen Ampela	HDR
Marine Species Observer	Suzanne Yin	HDR
Marine Species Observer Trainee	Jennifer Brown	HDR
Marine Species Observer	Desray Reeb	HDR

A daily watch for opportunistic sightings of marine mammals and sea turtles was maintained on the flying bridge of the *MV Island Girl* (**Figure 2**) during daylight hours (approximately 0700 to 1800). Additional effort was conducted in nearshore areas and within harbors to document sightings of sea turtles and marine mammals. Data for observation conditions, watch effort, sightings, and other required information were entered into a Panasonic Toughbook® notebook computer using the computer program WinCruz. When sightings occurred, photographs of marine species were taken to verify species identification and, if possible, individual identification (marine mammals only). The animals photographed were approached by the *MV Island Girl* during normal survey operations or approached the vessel on their own. Efforts were made to position the vessel to maximize image quality for identification purposes (with respect to lighting, glare, etc.). Photographs were taken using two Canon Digital EOS D7 cameras with 100–400 millimeter (mm) zoom lenses. Camera settings were adjusted, as needed, to produce the highest-quality images possible.

Figure 2. Photo of the MV Island Girl used for the survey.

Oceanographic Data Collection

Oceanographic data were planned to be collected with an expendable bathythermograph (XBT) data acquisition system and XBT hand-held launcher following all marine mammal sightings. However, the XBT to be used on this survey was not functioning and therefore, no oceanographic data were collected.

Data Processing

Tracklines and sightings were entered into GIS, and used to calculate distance and effort (on/off and Beaufort sea states). Bottom depths for sightings were taken from existing GIS data (ARC-GIS Ocean Base map).

Results

Survey Effort

Visual surveys were made over 1024.76 kilometers (km) (552.96 nm) of trackline during 10 survey days for a total of 71.7 hours (see **Table 2** and **Figure 3**). While survey tracklines were planned to surround the entire island, weather conditions constrained the survey effort to the northern and western sections of the island. Beaufort sea states ranged from 2 to 6, with 89 percent of effort taking place in sea states of 3 to 5 (see **Table 3,** and **Figures 4, 5a and 5b**). As shown in Table 3, sightings were made only during Beaufort sea states of 2 to 5.

Table 2: Total daily survey effort in hours, kilometers (km) and nautical miles (nm) by date.

Date	Total Hours	Daily Effort (km)	Daily Effort (nm)
2/17/2011	6:48:50	118.27	63.82
2/18/2011	8:30:01	126.95	68.50
2/19/2011	9:12:22	136.79	73.81
2/20/2011	7:30:59	112.98	60.96
2/21/2011	8:25:05	114.25	61.65
2/22/2011	9:12:14	114.84	61.97
2/23/2011	5:25:26	78.70	42.47
2/24–2/28/11	(no survey due to weather)		
3/1/2011	7:51:17	94.37	50.92
3/2/2011	3:47:22	57.69	31.13
3/3/2011	4:58:24	69.95	37.74
Total	**71:42:00**	**1,024.76**	**552.96**

Table 3: Total survey effort by Beaufort Sea State, including Sightings Per Unit Effort (SPUE).

Beaufort Sea State	Total Effort (km)	Total Effort (nm)	Percentage of Survey Effort	Mammal Sightings	SPUE Mammals (per km)	Turtle Sightings	SPUE Turtles (per nm)
0	0		0.00	0	0 (0 nm)	0	0 (0/nm)
1	0		0.00	0	0 (0 nm)	0	0 (0/nm)
2	91.95	49.62	8.97	4	0.044 (0.081/nm)	1	0.011 (0.020/nm)
3	253.52	136.80	24.74	4	0.016	3	0.002

					(0.029/nm)		(0.022/nm)
4	362.80	195.76	35.40	1	0.003 (0.005/nm)	1	0.005 (0.003/km)
5	297.07	160.30	28.99	0	0 (0 nm)	1	0.003 (0.006/nm)
6	19.42	18.48	1.90	0	0 (0 nm)	0	0 (0/nm)
Total	**1,024.76**	**552.96**	**100.00**	**9**	**0.009 (0.016/nm)**	**6**	**0.006 (0.011/nm)**

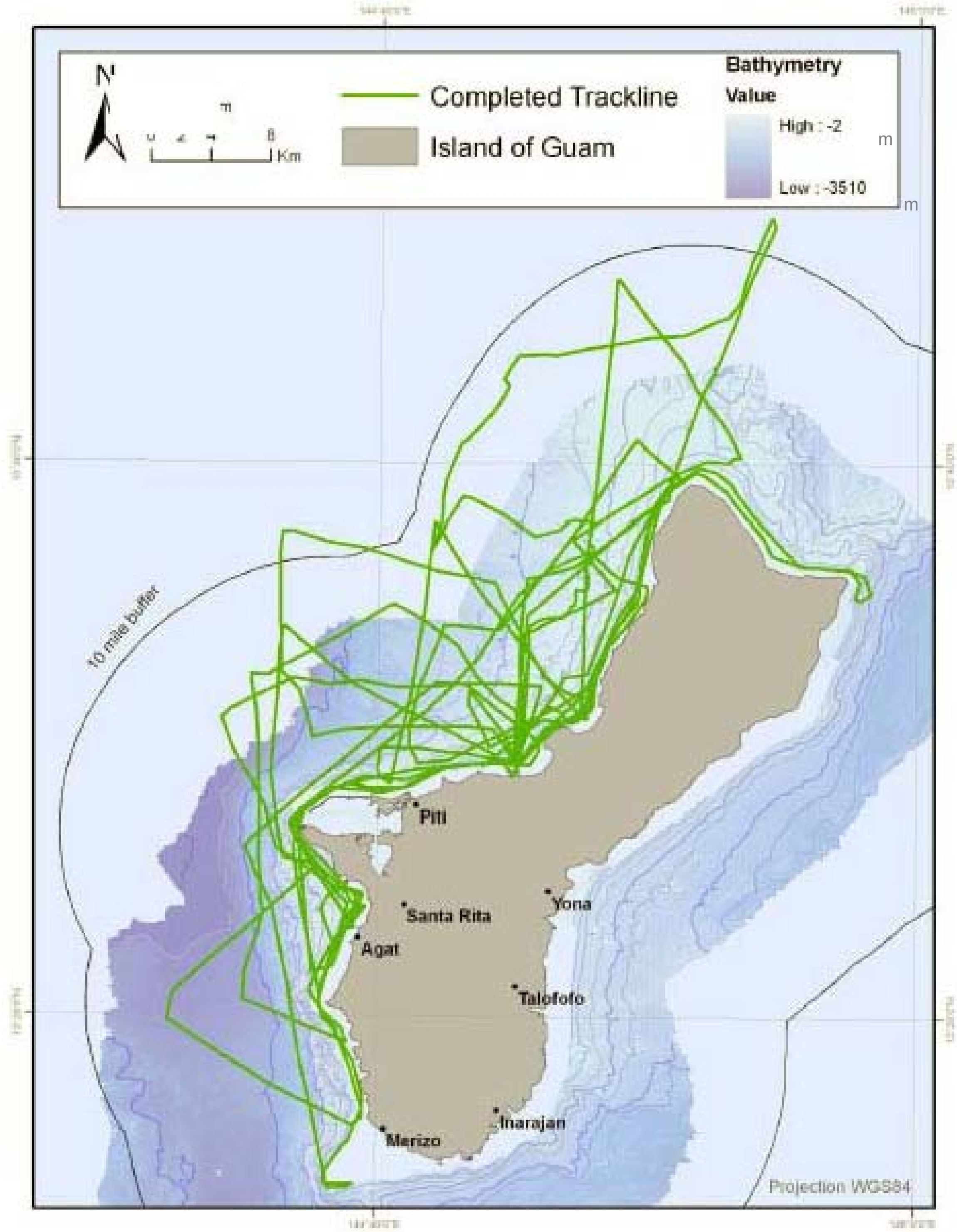


Figure 3: Completed tracklines during the Guam Marine Species Monitoring Survey, Winter 2011.

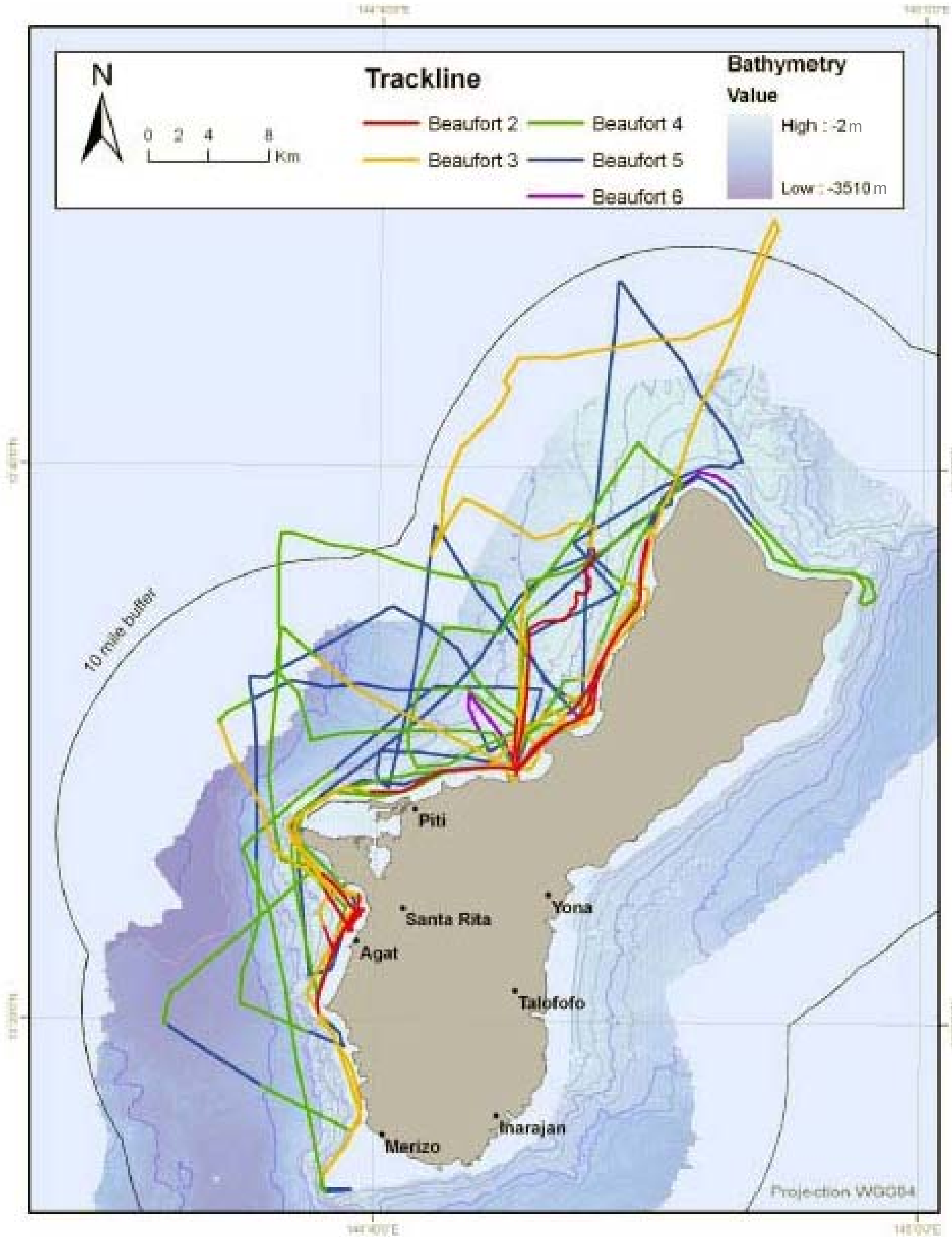


Figure 4: Completed trackline by sea state during the Guam Marine Species Monitoring Survey, Winter 2011.

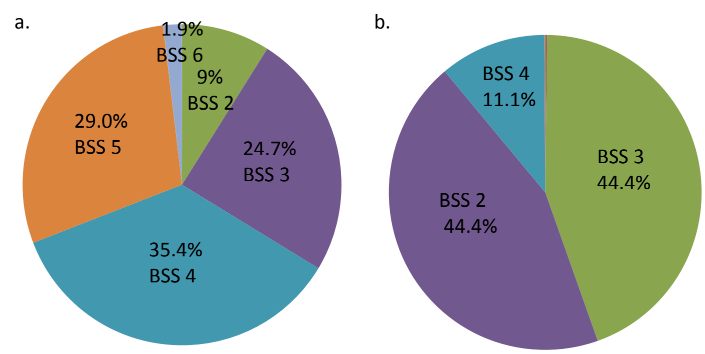


Figure 5a and b: 5a - Percentage of survey effort for Beaufort Sea States 0 -6. 5b - percentage of cetacean sightings by Beaufort Sea State.

Sightings

There were nine cetacean sightings (three identified species) and six sea turtle sightings (one identified species) (see **Table 4** and **Figure 5**). Cetacean sightings consisted of seven groups of spinner dolphins; one mixed-species group of short-finned pilot whales (*Globicephala macrorhynchus*) and bottlenose dolphins (*Tursiops truncatus*); and one unidentified small dolphin. All six sea turtles sighted were green sea turtles (*Chelonia mydas*).

Photographs

During this survey 1,830 photographs were taken of three species of cetaceans (spinner and bottlenose dolphin, and short-finned pilot whales) and one sea turtle (green sea turtle).

Discussion

Due to the size of the survey ship and the sea conditions, the original systematic line transect survey, which would have encompassed all of the area around Guam, was modified to use opportunistic survey in the near shore area out to 5.6 km (3 nm) on the western and northern side of Guam. This opportunistic approach was similar to a previous survey in the Guam area (Ligon et al. 2010). During better conditions the survey would revert back to using the standard line-transect survey protocol out to 18.5 km (10 nm) but still on the western and northern sides of Guam.

Due to weather constraints, the survey could only be made on the northern and western sides of Guam (leeward side), and was conducted in Beaufort sea states of 0-6. Even with restricting the survey to the leeward side of the island, 89 percent of the surveys were conducted in Beaufort sea states of 3-5, and 66.3 percent were in Beaufort sea states of 4 and 5 making sighting conditions difficult. However, despite the high Beaufort sea states, nine cetacean and six sea turtle sightings were made during the 10 day survey.

Species diversity in this near shore survey was not as high as the MISTCS (DON 2007; Fulling et al. 2011), Valiant Shield 2007 (Mobley 2007) or Oleson and Hall (2010) surveys which surveyed beyond 10 nm and farther offshore of Guam into deep water including near the Mariana Trench or remained at sea longer. Lignon et al. (2011) also surveyed the nearshore area of Guam as well as Saipan, and their sightings also included one sperm whale (*Physeter macrocephalus*), several spotted dolphins (*Stenella attenuate*), and spinner dolphins (the primary species sighted in this survey).

Table 4: Summary of sightings and behavioral observations.

Sighting No.	Date	Time (local)	Survey Day	Lat	Long	Species Code	Group Size Best	Group Size High	Group Size Low	Bearing (deg)	Reticle	Bottom Depth (m)	Calves	Behavior	Common Name
-	2/17/11	-	Y												
1	2/18/11	12:05	Y	13.382N	144.642E	SL	35			000	0.50	100–200	No	Resting; slow traveling	Spinner Dolphin
-	2/19/11	-	Y												
2	2/20/11	8:39	Y	13.403N	144.650E	SL	4	5	3	335	0.75	> 100	No	Milling; resting	Spinner Dolphin
3	2/20/11	9:41	Y	13.398 N	144.655E	SL	3	3	3	270	0.20	> 100	Yes	Approached to bowride; tailslaps	Spinner Dolphin
T1	2/21/11	8:37	Y	13.489N	144.763E	CM	1	1	1	335	0.05	> 100		N/A	Green Turtle
4	2/21/11	8:40	Y	13.487N	144.762E	SL	23	35	16	000	0.10	> 100	Yes	Milling; resting	Spinner Dolphin
T2	2/21/11	14:06	Y	13.408N	144.652E	CM	1	1	1	45	0.01	> 100		N/A	Green Turtle
5	2/22/11	8:00	Y	13.569N	144.760E	GM/TT	26	35	16	010	0.60	700–800	Yes	Resting; slow traveling	Short-finned Pilot Whale/ Bottlenose Dolphin
6	2/22/11	15:41	Y	13.514N	144.795E	SL	25	34	17	315	0.10	> 100	Yes	Approached to bowride; tailslaps	Spinner Dolphin
7	2/23/11	12:03	Y	13.513N	144.790E	UND	2	5	1	335	0.30	> 100	N/A	Unidentified Small Dolphin	Unidentified Small Dolphin
T3	2/23/11	12:13	Y	13.511N	144.788E	CM	1	1	1	270	0.03	> 100		N/A	Green Turtle
-	2/24-2/28/11	-	N												
T4	3/1/11	10:37	Y	13.395N	144.655E	CM	1	1	1	000	1.0	> 100		N/A	Green Turtle
8	3/1/11	10:44	Y	13.399N	144.658E	SL	7	8	6	345	0.25	> 100	No	Milling	Spinner Dolphin

Sighting No.	Date	Time (local)	Survey Day	Lat	Long	Species Code	Group Size Best	Group Size High	Group Size Low	Bearing (deg)	Reticle	Bottom Depth (m)	Calves	Behavior	Common Name
9	3/1/11	11:54	Y	13.392N	144.653E	SL	25	32	20	340	0.10	> 100	Yes	Slow traveling	Spinner Dolphin
T5	3/1/11	11:57	Y	13.389N	144.652E	CM	1	1	1			> 100		N/A	Green Turtle
-	3/2/11	-	Y												
T6	3/3/11	9:49	Y	13.517N	144.797E	CM	2	2	2	320	0.02	> 100		N/A	Green Turtle

Note: Sightings are numbered by date and time, cetaceans are represented by a number only and sea turtles with a T before the number. Mean group
Time is Chamorro standard time (UTC/GMT = + 10 hours)

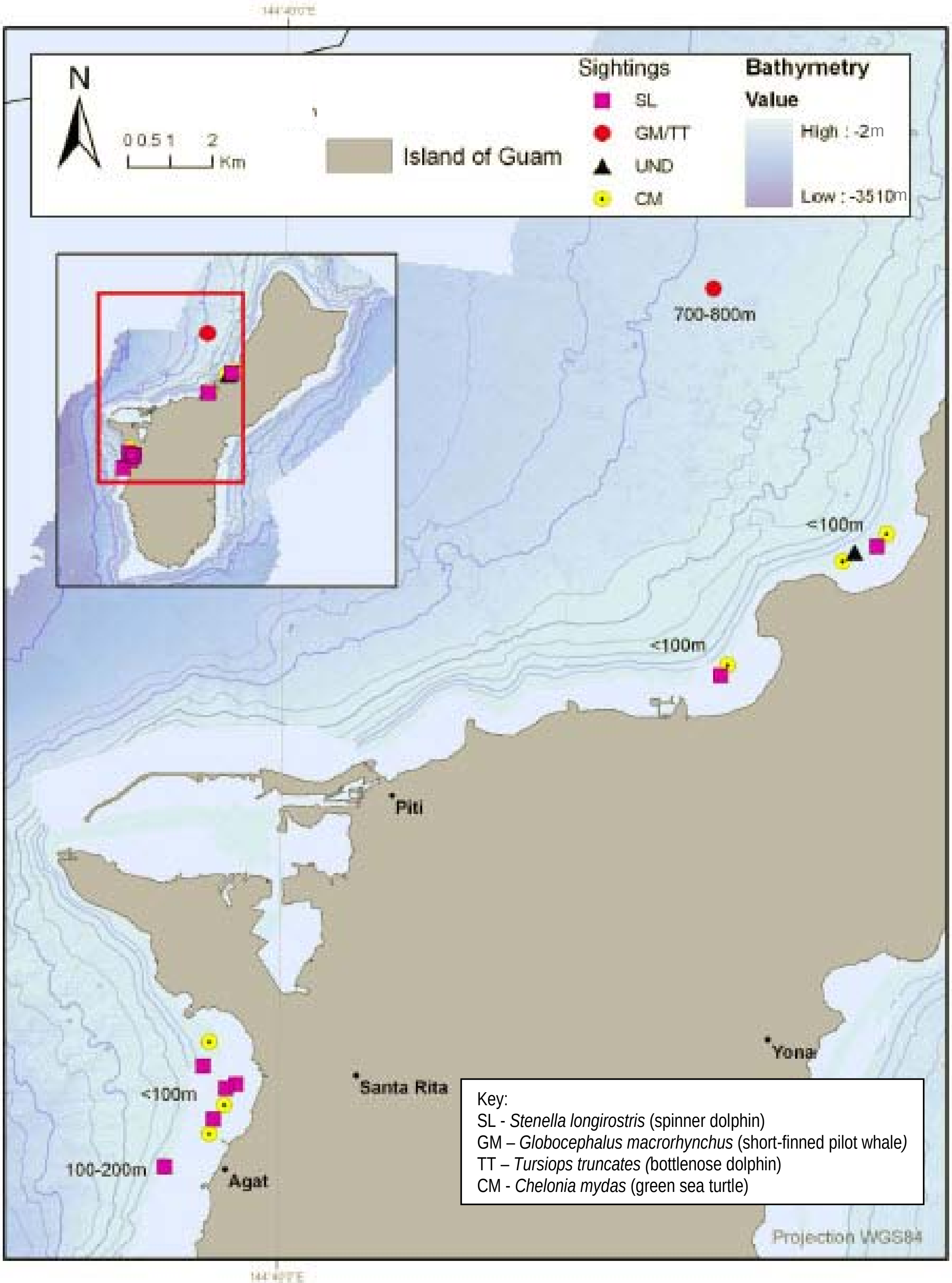


Figure 6: Marine mammal and sea turtle sightings during the Guam Marine Species Monitoring Survey.

Literature Cited

DON (Department of Navy). 2007. Marine mammal and sea turtle survey and density estimates for Guam and the Commonwealth of The Northern Mariana Islands. Final report contract No. N68711-02-D-8043. Prepared for U.S. Navy, Pacific Fleet, Naval Facilities Engineering Command, Pacific, Honolulu, Hawaii. 150 pp. http://www.nmfs.noaa.gov/pr/pdfs/permits/mirc_mistcs_report.pdf

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

Ligon, A.D., M.H. Deakos, and A.C. Ü. 2010. Small-boat cetacean surveys off Guam and Saipan, Mariana Islands, February – March 2010. Report to Pacific Island Fisheries Science Center under Order No. AB133F-10-SE-0930. 34 pp.

Mobley, J.R. 2007. Marine Mammal Monitoring Surveys in Support of "Valiant Shield" Training Exercises (Aug. 13-17, 2007). Report prepared for Environmental Division Commander, U.S. Pacific Fleet.

Oleson, E.M. and M.C. Hill. 2010. 2010 *Report to PACFLT: Report of Cetacean Surveys in Guam, CNMI, and the High-seas*. Prepared for Department of the Navy by National Marine Fisheries Service, Pacific Island Fisheries Science Center, Honolulu, Hawaii. 23pp.

APPENDIX A - Species Photos

Figure 1. Photo of a bottlenose dolphin (*Tursiops truncatus*) and a short-finned pilot whale (*Globocephalus macrorhynchus*) taken from a mixed species group during the Guam 2011 Winter Survey.

Figure 2. Photo of spinner dolphins (*Stenella longirostris*) taken during the Guam 2011 Winter Survey.

Figure 3. Photo of a green sea turtle (*Chelonia mydas*) taken during the Guam 2011 Winter Survey.

Appendix B –
Cetacean Surveys of Guam and CNMI Waters: August – September, 2011

Cetacean Surveys of Guam and CNMI Waters: August – September, 2011

Marie Hill[1,2], Allan Ligon[3], Mark Deakos[3], Adam Ü[4], Erik Norris[2], and Erin Oleson[2]

[1] Joint Institute for Marine and Atmospheric Research,
Research Corporation of the University of Hawaiʻi,
1000 Pope Road
Honolulu, Hawaiʻi 96822, U.S.A.

[2] Pacific Islands Fisheries Science Center,
1601 Kapiʻolani Boulevard, Suite 1000,
Honolulu, Hawaiʻi 96814, U.S.A.

[3] Hawaiʻi Association for Marine Education and Research,
PMB 175, 5095 Napilihau Street 109B,
Lahaina, Hawaiʻi 96761, U.S.A.

[4] 1111 N. Forest Street
Bellingham, WA 98225, U.S.A.

Mission

The Pacific Islands Fisheries Science Center's (PIFSC) Cetacean Research Program (CRP) conducted surveys for cetaceans in the waters surrounding Guam and the Commonwealth of the Northern Mariana Islands (CNMI) (Figure 1) in an effort to further develop a record of cetacean occurrence in the region and to gather photos and biopsy samples for population studies. This project was carried out in partnership with the U.S. Navy Commander, Pacific Fleet by a team of six primary personnel (Table 1).

Methods

Small boat surveys were conducted off of Guam between 26 August and 05 September, 2011 (Tables 2-3, Figure 2). All Guam surveys, except one, were conducted aboard a 9.4 m Bertram Sport Fisherman with flying bridge and twin-diesel inboard engines (*Lucky Strike*). One survey utilized a 7.0 m GlassPro with twin 4-stroke outboard engines (*Anna Marie*). Surveys were conducted off of the southernmost islands of the CNMI (Saipan, Tinian, Aguijan, and Rota) 7- 29 September, 2011 (Table 4, Figures 3-4). During 7-13 and 19-30 September the observer team's research base was located on Saipan. All surveys were conducted aboard a 12.2 m sport-fisher with flying bridge and twin-diesel inboard engines (*Sea Hunter*) and included the waters surrounding Saipan, Tinian, and Aguijan (Figure 3). During 14-19 September surveys were based off of Rota and were conducted aboard a 12.2 m Ocean Alexander Sport-fisher with flying bridge and twin-diesel inboard engines (*Sr. Dung*) in the waters surrounding Rota (Figure 4).

Survey effort was designed to cover representative habitat within the study area and did not conform to systematic (i.e. line-transect) design. Vessel tracks were spread out from day to day to ensure representative survey coverage of the study area, particularly over a wide range of depths, and were also dictated by weather and sea conditions. The survey vessels traveled at a speed of 8-12 knots, depending on the size of the vessel and sea conditions. Between three and seven observers scanned for marine mammals with unaided eye or occasional use of 10x binoculars, collectively searching 360-degrees around the vessel. The primary research team (Tables 1-2) was accompanied by one to four additional individuals. The vessels were operated by locally experienced captains, with knowledge of cetacean sighting locations. In CNMI, both sets of captains allowed primary research team to operate vessel during primary search effort and when approaching cetaceans. On occasion, individuals from Guam and Saipan local field offices of the Pacific Islands Fisheries Science Center, Pacific Islands Regional Office, CNMI Department of Fish and Wildlife, CNMI Coastal Resource Management, and CNMI Division of Environmental Quality assisted the observer team with survey efforts.

All cetacean groups encountered were approached for species confirmation, group size estimates, photo-identification, and biopsy sampling (for assessment of genetic population structure) when possible. Digital SLR cameras with telephoto zoom lenses were used for taking photographs. Photographic efforts were focused on dorsal fin images (for individual identification purposes) and images of the body and head (for assessments of health and scarring). Additional data collected during each sighting included the location, behavior, estimate of calf numbers (when possible), Beaufort sea state, and swell height. Environmental data (e.g., Beaufort sea state, swell height) and effort status were recorded regularly as conditions changed. Global Positioning System (GPS) readings of the vessel's track were automatically recorded once per minute.

Although not requested by the Navy, PIFSC conducted biopsy sampling during the project in order to support their goals of evaluating stock structure. Biopsy sampling was conducted using a Barnett RX-150 crossbow and Ceta-Dart bolts with sterilized, stainless steel biopsy tips (25 mm long x 8 mm diameter). Tissue samples were preserved in a cooler on ice while on the boat. Samples were split in half longitudinally at the end of each field day (with each subsample stored in a different vial) and transferred to a standard refrigerator freezer until the end of the project. Samples were transported, in a cooler with dry ice, on board a commercial airline to Honolulu, HI, USA[1]. One vial of each sample is stored in an -80°C freezer at the Pacific Islands Fisheries Science Center (Honolulu, HI, USA), and the other was submitted (via PIFSC) to the Southwest Fisheries Science Center (SWFSC, La Jolla, CA, USA) for tissue archiving. Samples are archived until adequate numbers are available to assess stock structure or until funding is provided to address other specific questions. Biopsy samples were collected under MMPA permit 14097 issued to SWFSC and CNMI-DFW permit, license no. 02260-11.

Bathymetric datasets, used in displaying and analyzing the depth profiles of our survey effort and sightings, were obtained from two different sources. First, the Pacific Islands Benthic Habitat Mapping Center (PIBHMC) has available high-resolution multibeam color-shaded bathymetry datasets for nearshore waters. There are 5 m grids available for waters inside the 400 m isobath surrounding Guam, Rota, Saipan, Tinian, Aguijan and Marpi Reef. In addition, 60 m grids are available for portions of the waters out to the 3,500 m isobath surrounding Guam; the 2,700 m isobath surrounding Saipan, Tinian, and Aguijan; and the 1,900 m isobath surrounding Rota. The datasets were downloaded as binary ASCII files (.asc) from the School of Ocean and Earth Science and Technology's (University of Hawaii at Manoa) website (http://www.soest.hawaii.edu/pibhmc/pibhmc_cnmi.htm). The second source of bathymetric data was the General Bathymetric Chart of the Oceans (GEBCO) (http://www.gebco.net/data_and_products/gridded_bathymetry_data). A binary ASCII file of the one arc-minute grid was downloaded using the GEBCO Grid Demonstrator software. This dataset was used for displaying the bathymetry beyond the 500 m isobath around all of the islands.

All bathymetry datasets were processed using ArcCatalog 9.3 (ESRI, Redlands, CA). The ASCII files were first converted into raster grids and were then projected in the WGS 1984

[1] Samples collected in the waters of CNMI were inspected by the U.S. Fish and Wildlife Officer on Guam and imported to the US under CITES permit # US774223/9 issued to SWFSC.

UTM Zone 55N coordinate system. Contours were also extracted from the high-resolution PIBHMC grids as shape-files (.shp) and projected. Contour shape files and raster grid datasets were imported into ArcMap 9.3 (ESRI, Redlands, CA). Vessel GPS tracks and sighting locations were also projected in the WGS 1984 UTM Zone 55N coordinate system and then overlaid onto the bathymetric datasets. Depths of sighting locations were determined by joining the sighting locations and the bathymetric raster datasets within ArcMap. If the high-resolution PIBHMC multibeam data were not available for a particular sighting location, then the depth value was either interpolated using the two nearest nautical chart depth soundings (for locations near islands or submerged reefs) or obtained from the GEBCO 1 arc-minute raster dataset (for offshore locations). To analyze the amount of search effort by depth, on-effort times were calculated for depth bins from 0 to 2,200 m in 100 m intervals. In ArcMap, on-effort tracklines were joined to the bathymetric raster datasets and depths were assigned to the trackline points (each representing 1 minute).

Results

Guam Surveys

During eight days, between 26 August and 5 September, nine surveys were completed within the waters surrounding Guam (< 20 km from shore). A total of 968 km were covered with over 66 on-effort hours of survey (Table 3, Figure 2). Most of the surveys (8 out of 9) originated from the Hagatna Boat Basin (13.4781° N, 144.7496° E). One survey, on the final day, originated from Agat Marina (13.3690° N, 144.6507° E). Seventeen (26%) on-effort survey hours were spent inside of the 200 m isobath (Figure 5). The average daily Beaufort sea state ranged from 2.7 to 4.8 (Table 3). More than half (57%, 549 km) of the total on-effort trackline distance was surveyed in Beaufort 1 - 3 conditions, while the remaining 43% (419 km) was surveyed in Beaufort 4 - 5 (Figures 6-7). Preliminary local climatological data from the Guam National Weather Service Office (Station: Guam International Airport) indicate that winds predominated from the WSW with average daily wind speeds ranging from 3 to 11 knots, and maximum wind speeds ranging from 14 to 23 knots (Table 5). During the study period, the swell conditions off the west side of Guam were affected by Typhoon Nanmadol and Severe Tropical Storm Talas. Estimated maximum swell heights reached 5 – 12 ft (Table 3). More than a third (36%, 348 km) of the total on-effort trackline distance was surveyed in swell heights of 6 - 12 ft (Figures 8-9). Four field days (25 August; 2-4 September) were lost due to inclement weather (*i.e.,* high winds and rain).

There were eight cetacean sightings (Figure 2) during the nine surveys off of Guam. The overall sighting rate was 0.83 sightings/100 km of effort. The species included bottlenose dolphins (*Tursiops truncatus*), spinner dolphins (*Stenella longirostris*), pantropical spotted dolphins (*Stenella attenuata*), and short-finned pilot whales (*Globicephala macrorhynchus*). Spinner dolphins were the most frequently encountered species with 4 sightings (50%). An opportunistic off-effort sighting of spinner dolphins was also observed from shore by the research team off Sirena Beach along the northern coast between Ritidian and Pati Points. All sightings of spinner dolphins were in water depths less than 100 m (Table 8). All cetacean sightings were in depths less than 1,000 m (Table 8). A total of 2,185 photos and 21 biopsy samples were collected from the eight cetacean groups (Tables 7-8).

CNMI Surveys

Between 7 and 29 September, a total of 21 cetacean surveys were conducted in the waters surrounding Saipan, Tinian, Aguijan, and Rota. The surveys covered 2,165 km of trackline with 139 on-effort hours (Table 4, Figures 3-4). Fifteen of the surveys originated from the Smiling Cove Marina (15.2173° N, 145.7224° E) on Saipan and covered the waters surrounding Saipan, Tinian, and Aguijan (Figure 3). The remaining six surveys covered the waters surrounding Rota and originated from the Rota West Harbor (14.1349° N, 145.1332° E) (Figure 4). A total of 62 (45%) on-effort survey hours were inside of the 200 m isobath (Figure 5). The average daily Beaufort sea state ranged from 1.5 to 4.7 (Table 4). More than half (52%, 1,126 km) of the total on-effort trackline distance was surveyed in Beaufort 0 – 3 conditions, while 48% (1,040 km) of the trackline was surveyed in Beaufort 4 – 6 conditions (Figures 6-7). Preliminary local climatological data from the National Weather Service Office (Station: Saipan/Isley) indicates that wind direction shifted from the WSW at the beginning of the study period to the ESE at the end (Table 6). Average daily wind speeds ranged from 4 to 13 knots, and maximum wind speeds ranged from 13 to 23 knots (Table 6). The estimated maximum swell heights reached 3 – 6 ft (Table 4). Most (95%, 2,066 km) of the total on-effort trackline was surveyed in swell heights 0 – 4 ft (Figures 8-9).

During the 21 surveys within the CNMI waters (< 35 km from shore) there were 30 on-effort sightings of cetaceans (Tables 7, 9; Figures 3-4). The overall sighting rate was 1.39 sightings/100 km of effort. The species included bottlenose dolphins, spinner dolphins, pantropical spotted, short-finned pilot whales, pygmy killer whales (*Feresa attenuata*), a dwarf sperm whale (*Kogia sima*), and unidentified medium and small delphinids (Tables 7, 9; Figures 3-4). An opportunistic off-effort sighting of short-finned pilot whales was also observed from shore by the research team about 2 km offshore of the Rota West Harbor. Spinner dolphins were the most frequently encountered species with 18 sightings (60%). All spinner dolphin sightings were in waters depths less than 100 m (Table 9). All cetacean sightings were in depths less than 1,000 m except for a single sighting of unidentified small dolphins in 1,500 m deep water off of Rota (Table 9). A total of 8,597 photos and 68 biopsy samples were collected during the study period (Table 7).

Discussion

These surveys represent the second collaborative effort of the PIFSC's CRP and the U.S. Navy Pacific Fleet toward a better understanding of the occurrence and distribution of cetaceans in waters off of Guam and the southernmost islands of CNMI (Saipan, Tinian, Aguijan, and Rota). The U.S. National Marine Fisheries Service (NMFS) and the PIFSC are responsible for the assessment of marine mammal stocks in the Exclusive Economic Zone (EEZ) waters of Guam and CNMI. The U.S. Navy is mandated by the Marine Mammal Protection Act (MMPA) of 1972 and the Endangered Species Act (ESA) of 1973 to monitor cetacean and turtle presence within the Mariana Island Range Complex (MIRC). The first collaborative effort was carried out in February-March, 2010 and included 10 survey days off Guam and 6 off Saipan and Tinian (Oleson and Hill 2010, Ligon *et al.* 2011). These initial surveys are an effort toward creating species inventories and collecting both photo and genetic data to aid in stock structure evaluation. Long-term goals include the evaluation of the population status of each stock. This includes producing population abundance estimates of the island-associated species using mark-recapture techniques.

Guam Surveys

The surveys off Guam were largely confined to the northwestern and northern portions of the island. Both the sea conditions and the harbor location (Hagatna) of the main survey vessel (*Lucky Strike*) played a role in this outcome. Weather patterns far offshore of Guam produced large swells along the western coast during most of the study period. In addition, winds predominated from the southwest and west-southwest (Table 5). Those factors combined to reduce the survey efforts off the southwestern coast of Guam. Effort was made on several days to survey within the lee (on the northeastern side) of the island, however, it was not possible to do so daily because of the transit time to and from the Hagatna Boat Basin. Surveys on these days lasted between 9 and 10 hours, reaching the maximum for the vessel charter agreement and the project budget. One survey track circumnavigated the island close to shore and focused on species typically found in shallow waters < 100 m (*e.g.,* spinner dolphins and bottlenose dolphins). The survey took 9.5 hours with one spinner dolphin encounter off of Inarajan Bay on the southeastern shore (Tables 3, 8; Figure 2). Another survey went up to Rota Bank, approximately 19 km northwest of the island. The captain of the *Lucky Strike* indicated that pantropical spotted dolphins were seen there regularly by fishermen.

Compared to the surveys of 2010, conditions in 2011 were more amenable to working further offshore. The winter in the Marianas is characterized by strong northeast (trade) winds, which were evident during the 2010 surveys (Ligon *et al*. 2011). Most of the 2010 surveys (7 out of 10) were within Agat Bay and along the southwestern shore of the Island. Only one of the current surveys targeted that area because of the wind and sea conditions out of the southwest. Use of the larger vessel (*Lucky Strike*; 9.4 m) in 2011, for all but one survey, facilitated our ability to operate farther offshore and farther from the harbor. The same vessel was used for one of three surveys off the northwest side of the island in 2010. Conditions during those surveys were mostly Beaufort 5+ with swell heights > 3 ft and up to 10 ft (Ligon *et al*. 2011). The summer months are described as typically the calmest in the Marianas, except for periods punctuated by typhoons and tropical storms. During the current surveys, swells produced by a typhoon and tropical storm west of the island affected visibility. The large swells may have contributed to the relatively low sighting rate (0.83 sightings/100 km of effort), which was lower than the adjusted sighting rate of 2010 (0.96 sightings/100 km of effort; Ligon *et al*. 2011). At times, the swell blocked the horizon line even from the observers standing on the flying bridge. The higher sighting rate in 2010 may also have related to the greater effort spent close to shore (< 100 m depth: 16.8 hrs (29.5%) in 2010 vs 13 hrs (19.6%) in 2011 where spinner dolphins regularly occur (Ligon *et al.* 2011).

CNMI Surveys

The survey effort within the CNMI waters was separated into two regions in order to maximize the time spent in the nearshore waters of each island. The proximity of Tinian and Aguijan to Saipan enabled the research team to work from Saipan for an extended period (Tables 2, 4; Figure 3). The distance, by boat, between Saipan and Rota is over 130 km. A daytime (8-10 hour) trip from Saipan to Rota was not logistically viable. Instead, the observer team flew down to Rota from Saipan and worked out of the Rota West Harbor for six days (Tables 2, 4; Figure 4).

During the first two days of surveys off Saipan, Tinian, and Aguijan conditions were ideal for cetacean observations. The Beaufort sea state was low, and the swell was much smaller than the previous period off of Guam (Table 4, Figures 6-9). The first survey was a circumnavigation of the three islands (Saipan, Tinian, and Aguijan), which took 9.5 hours with one spinner dolphin encounter off of Aguijan (Table 4, Figure 3). This was a very similar scenario to the Guam circumnavigation, but the *Sea Hunter* off Saipan was able to cover more ground during the same period of time and was farther offshore (Figure 3). At the end of the first five days of surveys the conditions deteriorated slightly due to localized weather systems that produced wind and rain. Most of the survey effort around the three islands was located off of the west-northwest sides of Saipan and Tinian (Figure 3). The bulk of the surveys (10 out of 16) took place after the team's return from Rota (September 19). Beginning on 16 September winds predominated from the southeast and east at maximum speeds of 15-23 knots (Table 6). During 20-29 September, surveys off the eastern shores of Saipan and Tinian were tight along the coast (Figure 3). Over the entire period working off the three islands spinner dolphins were the most frequently encountered species (10 out of 20 sightings). This was also the case in 2010 when all but one sighting (6 out of 7) were of spinner dolphins (Oleson and Hill 2010, Ligon *et al*. 2011).

The observer team flew to Rota on 13 September and completed a series of six surveys around the island (Table 4, Figure 4) before returning to Saipan on the 19th. All but one of the surveys included a circumnavigation of the island. The circumnavigations took seven to eight hours and each included two cetacean sightings (Table 4, Figure 4). Spinner dolphins were again the most frequently encountered species representing eight out of ten on-effort sightings (80%). These surveys around Rota are the first completed by the PIFSC CRP as no surveys were attempted in 2010.

Some re-sightings of distinctive individuals were noted in the field during the surveys within the CNMI waters. On 9 September, a group of bottlenose dolphins was observed off the southeast side of Saipan. Individuals from that group were observed the following day off the northwest side of Tinian (Table 4, Figure 4). During the surveys off of Rota, individual spinner dolphins with distinctive fins were recognized by observers between sightings. In addition, the off-effort sighting of pilot whales on 16 September, observed from shore, included an adult male with a particularly distinctive fin that was recognized by the team from the on-effort pilot whale sighting of the previous day.

Five submerged, offshore reefs were visited during the study period off Saipan, Tinian, and Rota (Figures 3-4). Two groups of spinner dolphins and a single dwarf sperm whale were encountered at Marpi Reef, 15 km north of Saipan (Figure 3). Two groups of spinner dolphins were also seen at Marpi Reef in 2010 (Oleson and Hill 2010, Ligon *et al*. 2011). Analysis has not yet been done to determine whether any of these are the same individuals. Archiving and development of Guam and CNMI photo-ID catalogs will begin in summer 2012 and will allow for evaluation of animal movements and abundance for commonly seen species.

Acknowledgements

We would like to thank our boat captains and crews: John Eads (Owner/Captain, *Lucky Strike*), Sam Markos (Owner, *Sea Hunter*), Ben Sablan (Captain, *Sea Hunter*), Manny Blas (Captain, *Sea Hunter*), Fidel Mendiola Jr (Owner, *Sr. Dung*), Ramon Castro (Captain, *Sr. Dung*), Ignacio Lizama (Captain, *Sr. Dung*), Allan Ainbinder (Captain, *Anna Marie*). We would also like to thank all of the volunteers that assisted with the surveys and logistical support for this project. This includes: Valerie Brown and Robbie McNulty (PIRO-Guam), Eric Cruz (PIFSC-Guam), Jenn Brown (HDR-Guam), Mark & Lynne Michael (Dive Rota), Mike Tenorio, Trey Dunn and Peter Ruzevich (CNMI-DFW), Rachel Zuecher (CNMI-CRM), Aric Bickel (CNMI-DEQ), and Karri Fisher (CNMI-PSS).

This research was conducted under NMFS Scientific Research MMPA permit no. 14097 (issued to SWFSC) and CNMI Division of Fish and Wildlife permit, license no. 02260-11 issued to A. Ligon. Funding was provided by the U.S. Navy Pacific Fleet.

References

Ligon, A.D., M.H. Deakos, A.C. Ü. 2011. Small-boat cetacean surveys off Guam and Saipan, Mariana Islands, February-March 2010. Report to the Pacific Islands Fisheries Science Center AB133F-10-SE0930. 34 pp.

Oleson, E.M. and M.C. Hill. 2010. Report of cetacean surveys in Guam, CNMI, and the high-seas and follow up on 2009 main Hawaiian Islands cetacean survey. Report to the Pacific Fleet Command. 29 pp.

Tables

Table 1: Personnel, roles and organizations.

Name	Role	Organization
Erin Oleson	Chief Scientist/Marine Mammal Observer	Pacific Islands Fisheries Science Center
Marie Hill	Marine Mammal Observer	Joint Institute for Marine and Atmospheric Research
Allan Ligon	Survey Leader/Marine Mammal Observer	Hawai'i Association for Marine Education and Research
Mark Deakos	Marine Mammal Observer	Hawai'i Association for Marine Education and Research
Adam Ü	Marine Mammal Observer	HDR under contract to NAVFAC Pacific
Erik Norris	Marine Mammal Observer/VOC	NOAA Corps

Table 2: Mission schedule, locations, and personnel.

Dates (2011)	Location	Personnel
24 August – 06 September	Guam	Deakos, Hill, Ligon, Norris, Ü
06 – 13 September	Saipan	Deakos, Hill, Ligon, Norris, Ü
13 – 19 September	Rota	Deakos, Ligon, Norris, Ü
19 – 30 September	Saipan	Deakos, Ligon, Oleson, Ü

Table 3: Guam surveys summary.

Date (2011)	Vessel	# Crew	Harbor	Survey Location Description	Begin On-Effort Time	End On-Effort Time	Total On-Effort Time	On-Effort Distance (km)	Average Beaufort	Maximum Swell Height (ft)
08/26	*Lucky Strike*	6	Hagatna Boat Basin	Hagatna north and east to Katalina Pt.	6:10	14:46	8:36	135	2.7	6
08/27	*Lucky Strike*	7	Hagatna Boat Basin	Guam west side	6:11	14:36	8:25	113	2.9	12
08/28	*Lucky Strike*	6	Hagatna Boat Basin	Hagatna north and east to Hawaii Rock Quarry	6:13	15:36	8:56	123	3.1	8
08/29	*Lucky Strike*	7	Hagatna Boat Basin	Hagatna north to Rota Bank	6:11	15:19	9:08	124	2.9	10
08/30	*Lucky Strike*	7	Hagatna Boat Basin	Guam circumnavigation (counter clockwise)	6:05	15:22	9:13	140	2.7	8
08/31	*Lucky Strike*	6	Hagatna Boat Basin	Guam west side	6:05	11:00	4:54	73	2.6	10
09/01	*Lucky Strike*	6	Hagatna Boat Basin	Hagatna around north to northeast	6:04	14:21	8:11	116	4.6	8
09/05	*Lucky Strike*	6	Hagatna Boat Basin	Hagatna south to Facpi Pt.	6:13	11:47	5:23	88	4.8	7
09/05	*Anna Marie*	3	Agat Marina	Agat south to Cocos	6:38	10:07	3:27	55	4.3	5
						Total:	66:13	968		

Table 4: CNMI surveys summary.

Date (2011)	Vessel	# Crew	Harbor	Survey Location Description	Begin On-Effort Time	End On-Effort Time	Total On-Effort Time	On-Effort Distance (km)	Average Beaufort	Maximum Swell Height (ft)
09/07	*Sea Hunter*	7	Smiling Cove Marina	Saipan-Tinian-Aguijan circumnavigation	6:00	15:23	9:23	159	2.1	4
09/08	*Sea Hunter*	7	Smiling Cove Marina	Saipan-west & north to Marpi Reef	5:59	15:40	9:41	117	1.5	3
09/09	*Sea Hunter*	7	Smiling Cove Marina	Saipan circumnavigation	6:08	12:47	6:31	90	3.4	5
09/10	*Sea Hunter*	7	Smiling Cove Marina	Tinian circumnavigation	5:57	12:53	6:51	99	4.0	6
09/12	*Sea Hunter*	7	Smiling Cove Marina	Saipan-Tinian west side, Coke Reef & 300 Reef	6:11	13:54	7:44	131	3.0	4
09/14	*Sr. Dung*	6	Rota West	Rota circumnavigation	6:56	13:44	6:47	108	3.3	4
09/15	*Sr. Dung*	6	Rota West	Rota circumnavigation	6:58	14:38	7:40	98	3.5	4
09/16	*Sr. Dung*	6	Rota West	Rota west side	13:34	16:56	3:22	80	3.4	3
09/17	*Sr. Dung*	6	Rota West	"Ice Box" Reef & Rota circumnavigation	6:54	15:12	8:18	153	3.7	3
09/18	*Sr. Dung*	6	Rota West	Rota circumnavigation	7:58	15:47	7:49	123	3.9	4
09/19	*Sr. Dung*	5	Rota West	Rota circumnavigation	7:15	11:20	4:05	61	3.3	3
09/20	*Sea Hunter*	7	Smiling Cove Marina	Saipan-Tinian west side	8:07	14:08	6:01	104	3.0	5
09/21	*Sea Hunter*	7	Smiling Cove Marina	Saipan west side	7:00	12:33	5:33	94	4.5	5
09/22	*Sea Hunter*	6	Smiling Cove Marina	Saipan north-west	11:56	16:10	4:14	60	4.4	3
09/23	*Sea Hunter*	7	Smiling Cove Marina	Saipan-Tinian west side	6:57	12:31	5:33	96	3.3	4
09/24	*Sea Hunter*	5	Smiling Cove Marina	Marpi Reef & Saipan west side	7:00	16:07	9:07	143	3.7	5
09/25	*Sea Hunter*	7	Smiling Cove Marina	Saipan circumnavigation - nearshore	7:01	13:15	6:14	85	3.0	4
09/26	*Sea Hunter*	6	Smiling Cove	Saipan-Tinian west side	7:24	11:25	4:01	66	4.7	6

			Marina							
09/27	*Sea Hunter*	8	Smiling Cove Marina	Saipan west side	9:59	13:36	3:38	59	4.6	5
09/28	*Sea Hunter*	6	Smiling Cove Marina	Saipan north-west	7:08	14:06	6:59	118	4.3	4
09/29	*Sea Hunter*	5	Smiling Cove Marina	Tinian circumnavigation	7:01	16:49	9:47	122	3.9	4
						Total:	139:17	2,165		

Table 5: Wind speed and direction on Guam during the 2011 cetacean survey study period. Preliminary local climatological data from the National Weather Service, Guam office (Station: Guam International Airport). Note: Data have not undergone final quality control by the National Climatic Data Center (NCDC).

Month	Day	Average (24 hr) Speed	Max Speed	Direction (2 min deg)
August	26	4.3	14	170
	27	4.5	17	250
	28	4.8	14	280
	29	4.3	16	310
	30	2.9	15	230
	31	4.3	21	260
September	1	11.3	18	280
	2	7.6	23	270
	3	9	21	280
	4	6.8	17	210
	5	5.8	14	240

Table 6: Wind speed and direction on Saipan during the 2011 cetacean survey study period. Preliminary local climatological data from the National Weather Service, Guam office (Station: Saipan/Isley). Note: Data have not undergone final quality control by the National Climatic Data Center (NCDC).

Month	Day	Average (24 hr) Speed	Max Speed	Direction (2 min deg)
September	7	4.8	13	70
	8	3.6	13	70
	9	8.6	17	230
	10	7.3	16	200
	11	6.7	14	170
	12	4.7	8	240
	13	5.9	15	240
	14	6.8	15	290
	15	7.6	15	290
	16	6.9	23	110
	17	6.1	16	150
	18	9.7	18	80
	19	12.8	21	80
	20	8.3	22	110
	21	8.6	22	70
	22	9.2	21	140
	23	8.3	17	130
	24	6.2	15	70
	25	4.7	15	110
	26	10.8	21	120
	27	12.7	23	130
	28	10.2	12	60
	29	8.5	15	100

Table 7: Summary of on-effort cetacean sightings by region and species.

GUAM				
Species Common	Species Scientific	# Sightings	# Photos	# Biopsy Samples
Bottlenose dolphin	*Tursiops truncatus*	1	158	1
Pantropical spotted dolphin	*Stenella attenuata*	2	185	1
Short-finned pilot whale	*Globicephala macrorhynchus*	1	389	7
Spinner dolphin	*Stenella longirostris*	4	732	12
	Total:	8	2,185	21
CNMI				
Species Common	Species Scientific	# Sightings	# Photos	# Biopsy Samples
Bottlenose dolphin	*Tursiops truncatus*	2	516	3
Dwarf sperm whale	*Kogia sima*	1	63	0
Pantropical spotted dolphin	*Stenella attenuata*	1	306	6
Pygmy killer whale	*Feresa attenuata*	1	256	0
Short-finned pilot whale	*Globicephala macrorhynchus*	3	2225	22
Spinner dolphin	*Stenella longirostris*	18	5211	37
Unid. medium delphinid		3	20	0
Unid. small delphinid		1	0	0
	Total:	30	8,597	68
COMBINED				
Species Common	Species Scientific	# Sightings	# Photos	# Biopsy Samples
Bottlenose dolphin	*Tursiops truncatus*	3	674	4
Dwarf sperm whale	*Kogia sima*	1	63	0
Pantropical spotted dolphin	*Stenella attenuata*	3	491	7
Pygmy killer whale	*Feresa attenuata*	1	256	0
Short-finned pilot whale	*Globicephala macrorhynchus*	4	2614	29
Spinner dolphin	*Stenella longirostris*	22	5943	49
Unid. medium delphinid		3	20	0
Unid. small delphinid		1	0	0
	Total:	38	10,782	89

Table 8: Guam cetacean sightings details.

Date (2011)	Sighting #	Species - Common	Species - Scientific	Time	Latitude	Longitude	Depth (m)	Bathymetry Source	Beaufort	Swell Height (ft)	Group Size	# Calves	Behavior	# Photos	# Biopsy Samples
08/27	1	Pantropical spotted dolphin	*Stenella attenuata*	7:14	13.5986	144.7695	740	PIBHMC 5m	3	4-8	4	0	leap/spin; boat approach	0	0
08/27	2	Short-finned pilot whale	*Globicephala macrorhynchus*	7:51	13.5791	144.7501	824	PIBHMC 5m	3	4-8	14	0	slow travel	389	7
08/28	1	Spinner dolphin	*Stenella longirostris*	14:56	13.5159	144.7951	36	PIBHMC 5m	4	4-8	30	1	social; leap/spin	266	2
08/29	1	Spinner dolphin	*Stenella longirostris*	10:10	13.7955	144.9532	74	nautical chart	3	6-10	45	3	mill	428	3
08/29	2	Bottlenose dolphin	*Tursiops truncatus*	11:18	13.7996	144.9539	71	nautical chart	3	6-10	14	2	mill	158	1
08/30	1	Spinner dolphin	*Stenella longirostris*	9:30	13.2720	144.7571	33	nautical chart	3	1-2	40	2	rest	320	3
08/31	1	Pantropical spotted dolphin	*Stenella attenuata*	8:38	13.6099	144.7002	964	GEBCO 1 arc-minute	3	6-8	21	2	feed; fast travel	185	1
09/01	1	Spinner dolphin	*Stenella longirostris*	10:42	13.5630	144.9430	20	PIBHMC 5m	3	1-2	55	2	mill	439	4
09/03	1	Spinner dolphin *	*Stenella longirostris*	13:46	13.6073 *	144.9079 *	~10 *	Estimated *	2	1-3	50	n/a	rest	0	0

* Opportunistic, shore-based spinner dolphin group observed by research team on 09 Sept, 2011. Lat/Long & depth were estimated from sighting location.

Table 9: CNMI cetacean sightings details.

Date (2011)	Sighting #	Species - Common	Species - Scientific	Time	Latitude	Longitude	Depth (m)	Bathymetry Source	Beaufort	Swell Height (ft)	Group Size	# Calves	Behavior	# Photos	# Biopsy Samples
09/07	2	Spinner dolphin	*Stenella longirostris*	11:05	14.8557	145.5823	48	nautical chart	2	3	55	4	mill	619	6
09/08	1	Unid. Medium delphinid	n/a	6:25	15.2682	145.6886	464	PIBHMC ** SMAR 60m	2	2-3	1	0	slow travel	0	0
09/08	2	Short-finned pilot whale	*Globicephala macrorhynchus*	7:07	15.3039	145.7113	570	PIBHMC ** SMAR 60m	1	2-3	34	5	slow travel	437	7
09/08	3	Pygmy killer whale	*Feresa attenuata*	10:58	15.3799	145.8184	563	PIBHMC ** SMAR 60m	1	2-3	6	1	slow travel	256	0
09/08	4	Spinner dolphin	*Stenella longirostris*	11:55	15.4110	145.8704	61	PIBHMC Marpi 5m	0	2-3	42	3	mill	349	2
09/08	5	Dwarf sperm whale	*Kogia sima*	13:23	15.4373	145.8432	673	PIBHMC ** SMAR 60m	0	2-3	1	0	log	63	0
09/09	1	Spinner dolphin	*Stenella longirostris*	6:59	15.2680	145.7790	64	PIBHMC Saipan 5m	3	1	65	2	fast travel	704	7
09/09	2	Bottlenose dolphin	*Tursiops truncatus*	10:05	15.1351	145.7456	34	PIBHMC Saipan 5m	2	2-3	10	0	mill	294	2
09/10	1	Spinner dolphin	*Stenella longirostris*	8:02	14.9790	145.6681	29	PIBHMC Tinian 5m	4	1-2	40	5	leap/spin; boat approach	483	2
09/10	2	Spinner dolphin	*Stenella longirostris*	9:10	14.9202	145.6415	44	PIBHMC Tinian 5m	5	2-3	30	1	boat approach; bow ride	31	0
09/10	3	Bottlenose dolphin	*Tursiops truncatus*	11:14	15.0990	145.6365	61	PIBHMC Tinian 5m	5	2-3	10	0	boat approach; bow ride	222	1
09/12	1	Unid. small delphinid	n/a	10:35	15.2218	145.4556	1,502	GEBCO 1 arc-minute	4	2-4	2	n/a	wag tail leap	0	0
09/14	1	Spinner dolphin	*Stenella longirostris*	6:57	14.1401	145.1307	34	PIBHMC Rota 5m	2	2	8	n/a	n/a	0	0
09/14	2	Spinner dolphin	*Stenella longirostris*	9:51	14.1095	145.1775	46	nautical chart	3	1-2	18	0	slow travel	320	1
09/15	1	Short-finned pilot whale	*Globicephala macrorhynchus*	10:36	14.1136	145.1259	216	PIBHMC Rota 5m	4	2-3	38	1	slow travel	996	9

Date (2011)	Sighting #	Species - Common	Species - Scientific	Time	Latitude	Longitude	Depth (m)	Bathymetry Source	Beaufort	Swell Height (ft)	Group Size	# Calves	Behavior	# Photos	# Biopsy Samples
09/15	2	Spinner dolphin	*Stenella longirostris*	13:31	14.1156	145.1243	97	PIBHMC Rota 5m	4	2-3	13	0	mill	145	3
09/16	1	Short-finned pilot whale *	*Globicephala macrorhynchus*	13:00	14.1510*	145.1240*	188 *	Estimated *	n/a	n/a	30	n/a	slow travel	0	0
09/17	1	Unid. medium delphinid	n/a	7:24	14.0397	145.0372	969	GEBCO 1 arc-minute	3	2	5	n/a	evasive	20	0
09/17	2	Spinner dolphin	*Stenella longirostris*	12:29	14.1953	145.2935	91	PIBHMC Rota 5m	4	2	18	n/a	mill	470	0
09/18	1	Spinner dolphin	*Stenella longirostris*	11:34	14.1839	145.2938	59	nautical chart	5	2-3	24	n/a	mill	343	1
09/18	2	Spinner dolphin	*Stenella longirostris*	13:46	14.1279	145.2310	90	PIBHMC Rota 5m	4	2-3	18	n/a	slow travel	214	2
09/19	1	Spinner dolphin	*Stenella longirostris*	7:34	14.1306	145.1409	71	PIBHMC Rota 5m	2	1-2	28	n/a	rest	263	0
09/19	2	Spinner dolphin	*Stenella longirostris*	9:35	14.1832	145.2947	59	nautical chart	4	2-3	40	n/a	mill	207	1
09/22	1	Pantropical spotted dolphin	*Stenella attenuata*	13:58	15.3052	145.7457	561	PIBHMC** SMAR 60m	4	2-3	40	n/a	slow travel	306	6
09/24	1	Spinner dolphin	*Stenella longirostris*	9:48	15.4328	145.8862	72	PIBHMC Marpi 5m	4	3-4	55	n/a	mill	393	3
09/25	1	Spinner dolphin	*Stenella longirostris*	9:06	15.1926	145.7849	62	PIBHMC Saipan 5m	3	2-3	55	n/a	slow travel	377	6
09/25	2	Spinner dolphin	*Stenella longirostris*	11:29	15.0922	145.7532	91	PIBHMC Saipan 5m	5	2-3	28	n/a	mill	72	3
09/25	3	Spinner dolphin	*Stenella longirostris*	12:18	15.1200	145.6864	66	PIBHMC Saipan 5m	4	2	18	n/a	slow travel	28	0
09/29	1	Unid. small delphinid	n/a	7:25	15.1909	145.6911	26	PIBHMC Saipan 5m	2	1-2	1	n/a	n/a	0	0
09/29	2	Spinner dolphin	*Stenella longirostris*	9:22	14.9878	145.6725	55	PIBHMC Tinian 5m	5	2-3	6	n/a	moderate travel	193	0
09/29	3	Short-finned pilot whale	*Globicephala macrorhynchus*	11:51	15.0219	145.5413	723	PIBHMC ** SMAR 60m	4	1-3	33	n/a	moderate travel	792	6

* Opportunistic, shore-based short-finned pilot whale group observed by research team on 16 Sept, 2011. Lat/Long & depth were estimated from approximated sighting location.

** The bathymetry source SMAR refers to the Southern Marianas 60 m grid and includes the waters surrounding Saipan, Tinian, and Aguijan out to 2,700 m depth in some locations.

Figures

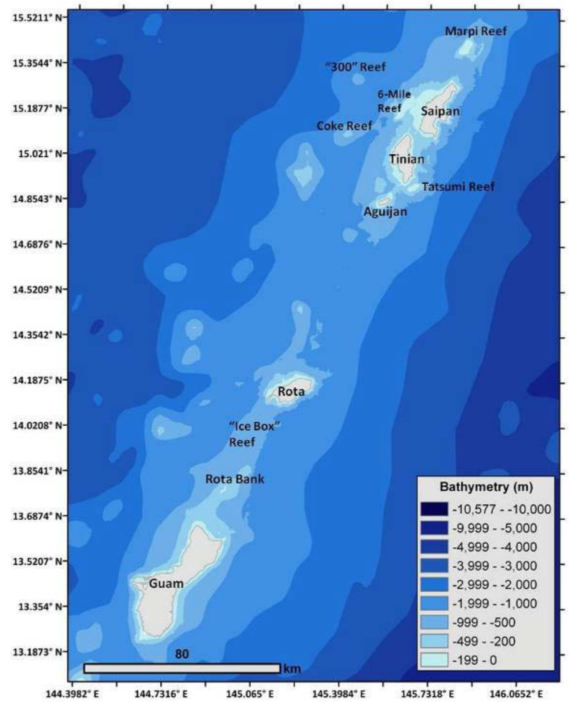


Figure 1: Survey locations of Guam and the Commonwealth of the Northern Mariana Islands displaying bathymetry from all datasets combined in depth bins between 0 and 10,500 m.

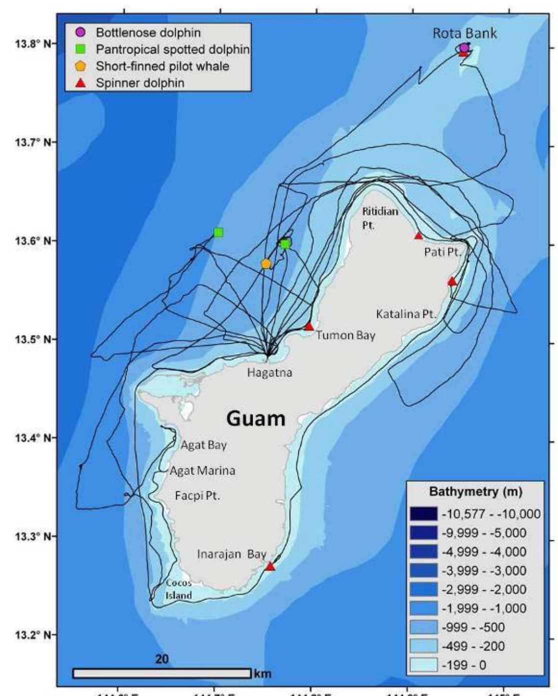


Figure 2: Guam survey tracklines (black lines) and cetacean sightings (26 August – 05 September, 2011). The spinner dolphin sighting shown on the north coast of Guam is a shore-based opportunistic sighting made by the research team.

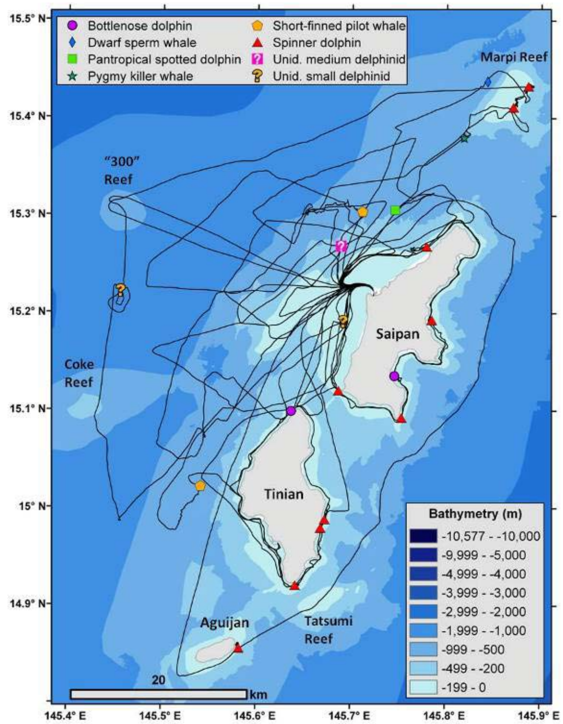


Figure 3: CNMI survey tracklines (black lines) and cetacean sightings around Saipan, Tinian, and Aguijan (7-12 and 20-29 September, 2011).

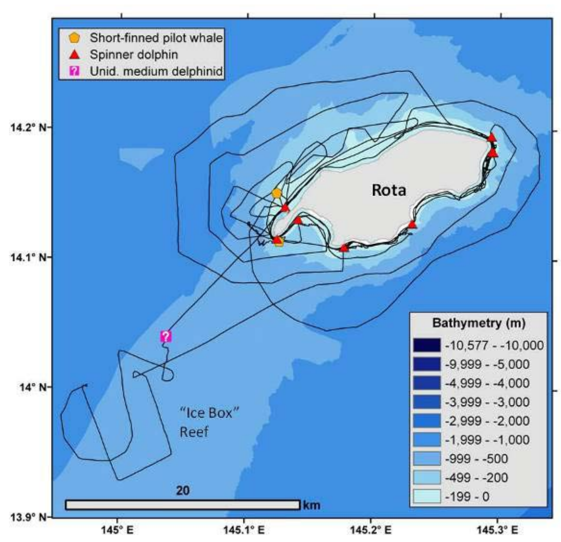


Figure 4: CNMI survey tracklines (black lines) and cetacean sightings around Rota (14-19 September, 2011). The pilot whale sighting shown on the west side of Rota is a shore-based opportunistic sighting made by the research team.

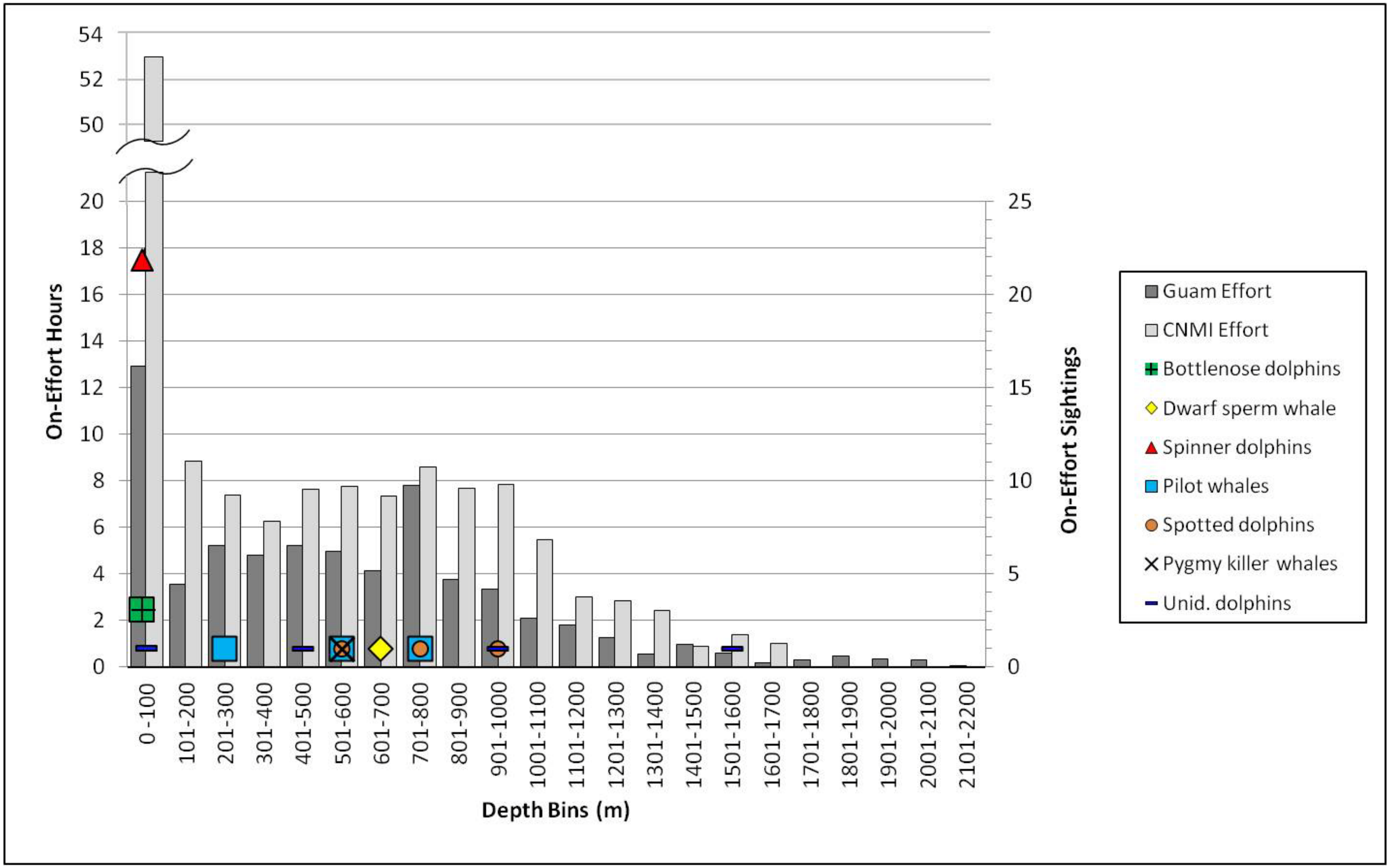


Figure 5: Distribution of sightings and search effort across depth profiles divided into 100 m interval depth bins. Guam total on-effort hours = 66. CNMI total on-effort hours = 139.

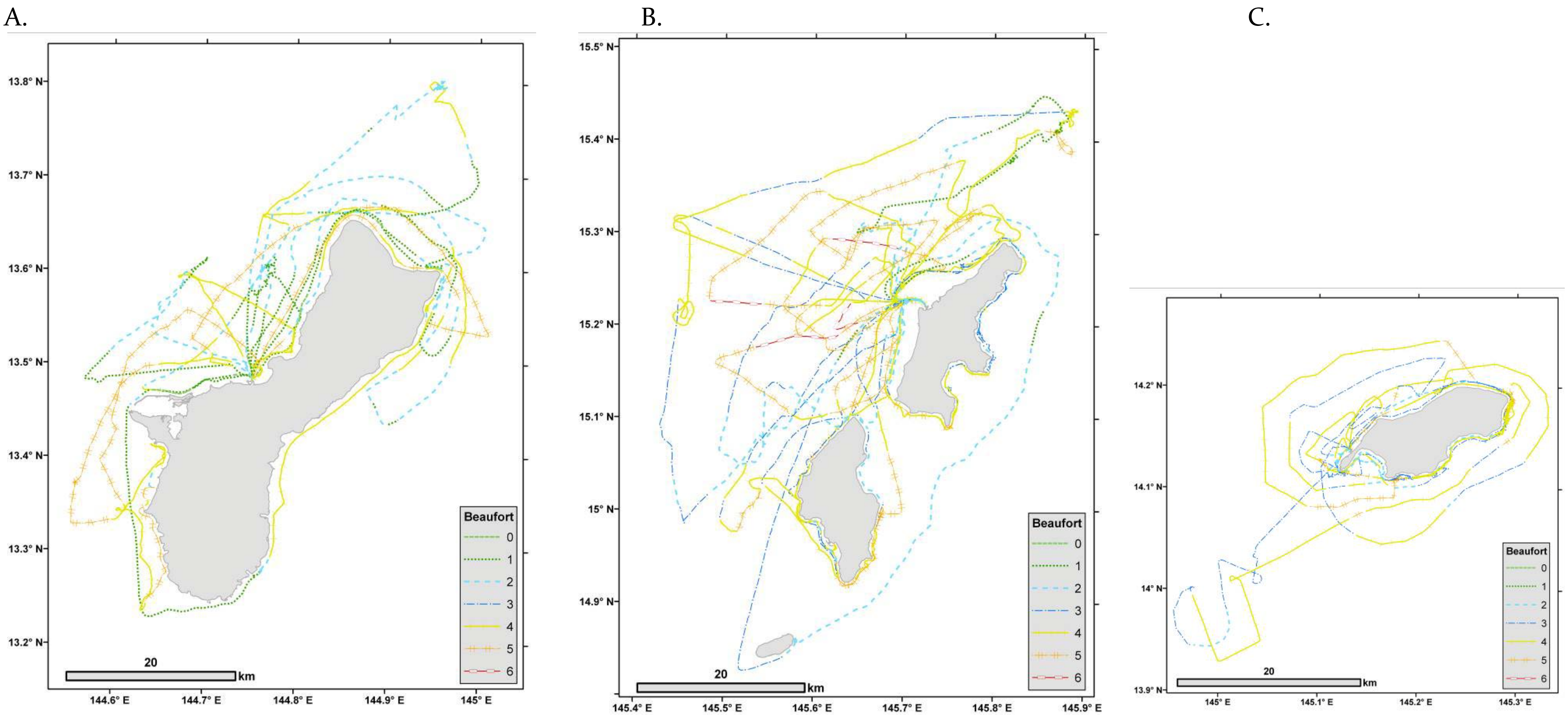
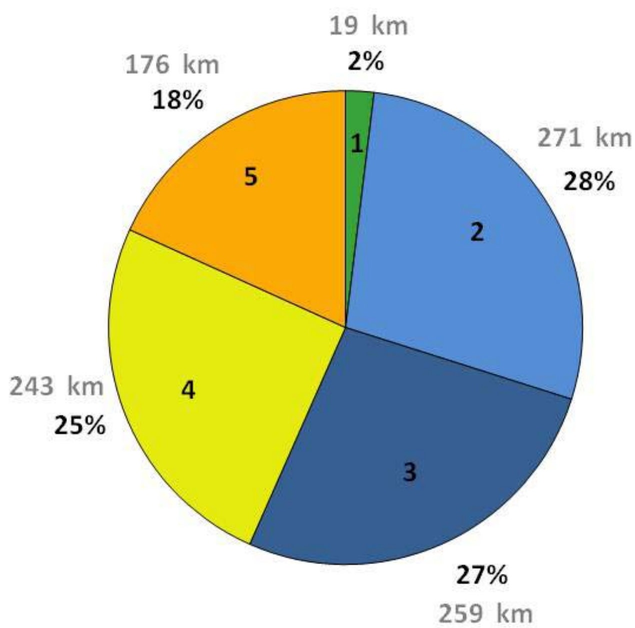


Figure 6: On-effort tracklines by Beaufort sea state in the waters surrounding Guam (A); Saipan, Tinian, and Aguijan (B); and Rota (C).

A.



B.

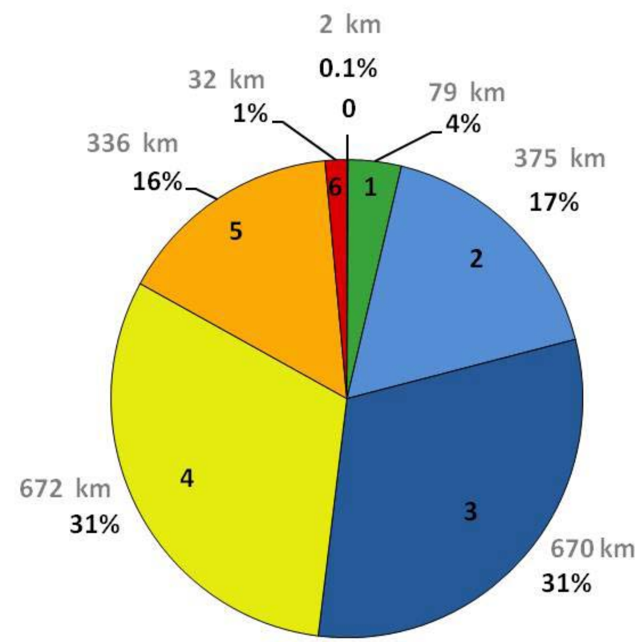


Figure 7: Beaufort sea state as a percentage of the total on-effort trackline distance off (A) Guam (Total trackline distance = 968 km) and (B) Saipan, Tinian, Aguijan, and Rota (Total trackline distance = 2165km).

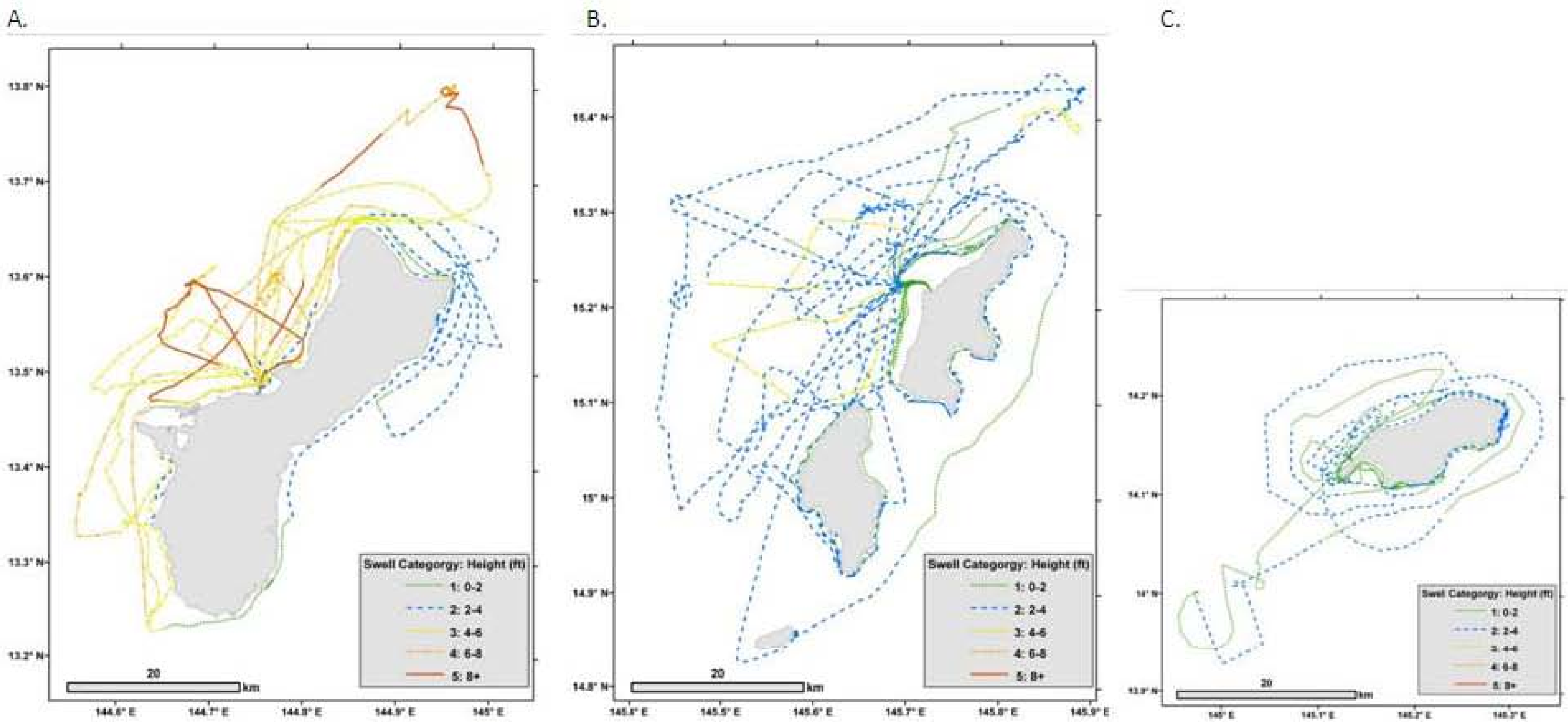


Figure 8: On-effort survey tracklines by swell height in the waters surrounding Guam (A); Saipan, Tinian, and Aguijan (B); and Rota (C).

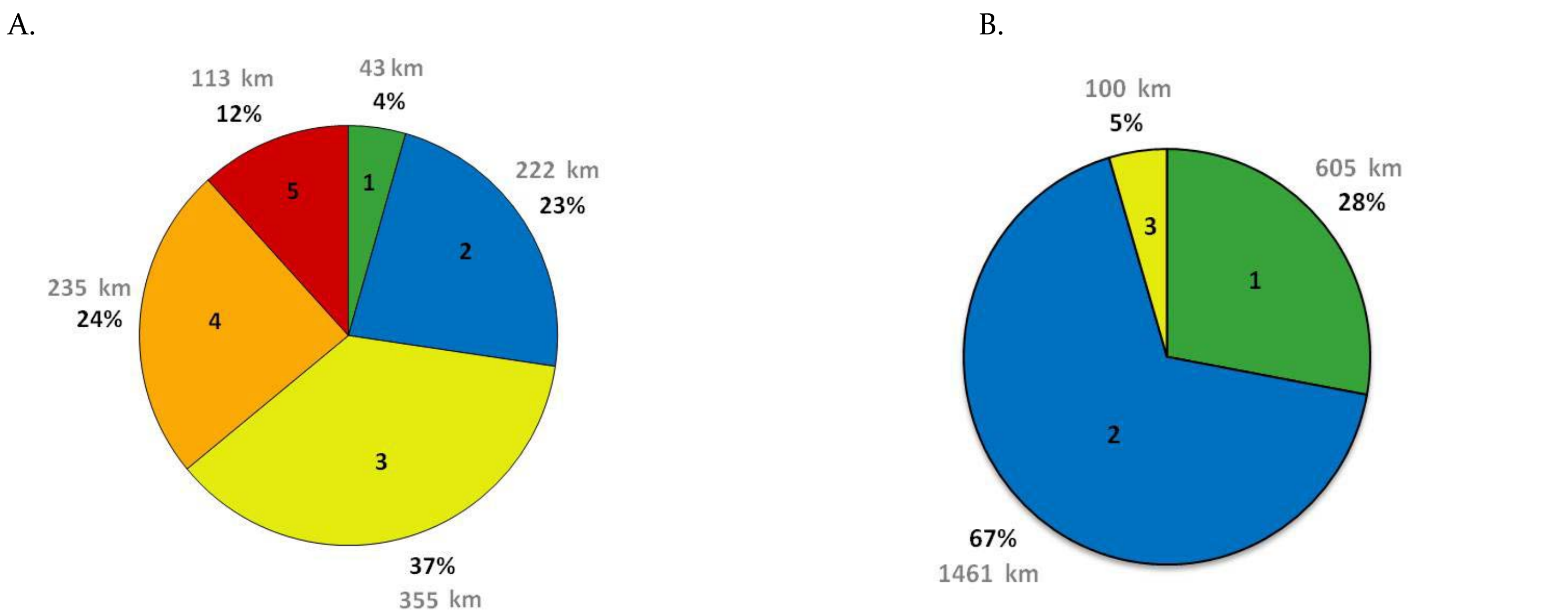


Figure 9: Swell height as a percentage of the total on-effort trackline distance off (A) Guam (Total trackline distance = 968 km) and (B) Saipan, Tinian, Aguijan, and Rota (Total trackline distance = 2165 km). Swell categories- 1: 0-2 ft; 2: 2-4 ft; 3: 4-6 ft; 4: 6-8 ft; 5: 8+ ft.

Appendix C -

Deployment of Four Ecological Acoustic Recorders in the Mariana Islands Range Complex (MIRC), September 2011

Deployment of Four Ecological Acoustic Recorders in the Mariana Islands Range Complex (MIRC), September 2011

Final Report

Contract Number N62470-10-D-3011 CTO KB10

February 2012

Prepared by:

M. Richlen, HDR
K. Ampela, HDR

Prepared for:

U. S. Pacific Fleet

Under contract issued by:

Naval Facilities Engineering Command, Pacific
258 Makalapa Drive, Suite 100
Pearl Harbor, HI 96860-3134

Suggested Citation

DoN (Department of Navy). 2012. Deployment of Four Ecological Acoustic Recorders in the Mariana Islands Range Complex (MIRC), September 2011. Prepared for Naval Facilities Engineering Command, Pacific, Pearl Harbor, HI under Contract No. N62470-10-D-3011, CTO KB10 issued to HDR, Inc

MIRC Passive Acoustic Monitoring Summary

In September of 2011, four passive acoustic monitoring devices were deployed in the Marianas Island Range Complex (MIRC). These Ecological Acoustic Recorders, or "EARs", were developed by Marc Lammers and Whit Au at the University of Hawai'i/Hawai'i Institute of Marine Biology. The dates, locations, and deployments depths for the four instruments are summarized in Table 1. Deployments were made to the northwest and southwest of Guam, one to the north off Saipan, and one to the southwest of Tinian. Deployments were performed by HDR staff in coordination with the University of Hawai'i/Hawai'i Institute of Marine Biology. These instruments were deployed in support of the U.S. Navy's monitoring plan under the MMPA Letter of Authorization (LOA) and permit granted to the Navy by the National Marine Fisheries Service (NMFS) for training using medium-frequency active sonar (MFAS) and underwater explosives in the MIRC. The data generated by these instruments will enable the Navy and NMFS to better understand the distribution and abundance of marine mammals and sea turtles in the Mariana Islands. The monitoring data will be provided to NMFS in the Navy's 2012 year end monitoring report and used by the Navy for analysis in future monitoring years.

The EARs were deployed as bottom mounted autonomous sensors with the aims of reaching between 5 and 6 months of battery life before needing to be refurbished (new batteries and new hard drives). Collection of the hard drives and refurbishment of the devices is expected to occur in the spring of 2012. The recording settings of the EARs can be found in Table 2.

All four instruments were deployed with ORE Edgetech acoustic releases between depths of 820 and 952 meters (Figure 1). After each deployment event, the depth and vertical orientation of each EAR was confirmed by the acoustic release associated with each device. The EARs deployments off Guam were accomplished using a charter dive vessel, the Sun Chaser, a 42-foot Newton (owned and operated by Micronesian Divers Association, Piti, Guam). The vessel used for the Saipan and Tinian EAR deployments was a 32-foot charter fishing vessel, named Mizuwari, built by Hsing Hang Marine (owned and operated by Pelley Boat Charters Inc., Saipan).

Table 1. PAM deployment site information

Site	Latitude	Longitude	Depth	Deployment Date	Begin Recording
Guam North	13 41.781 N	144 45.186 E	820 m	9/5/2011	9/10/2011
Guam South (11 mile reef)	13 13.392 N	144 28.303 E	952 m	9/15/2011	9/16/2011
Saipan	15 27.292 N	145 50.938 E	850 m	9/12/2011	9/12/2011
Tinian	15 04.602 N	145 26.676 E	869 m	9/11/2011	9/12/2011

Table 2. Acoustic recording settings and specifications

Sampling Rate	80 kHz
Recording Time (duration)	30 sec
Recording Period (how often)	360 sec (6 minutes)
Anti-Aliasing filter	90%
Hydrophone sensitivity	Approximately 193 dB re 1μPa
Clock	Local Time
Disk Space	320 GB maximum
Energy Detection	Disabled

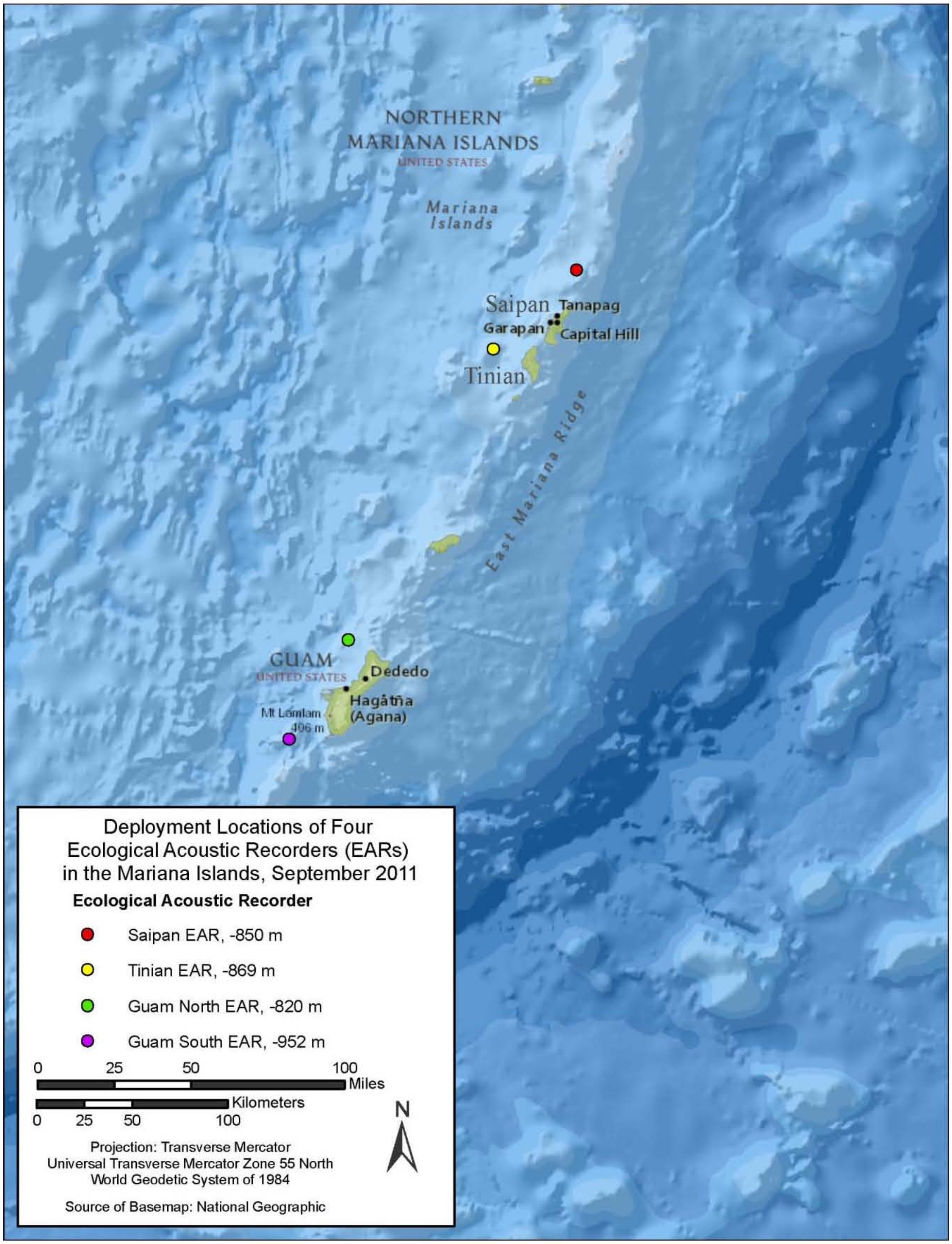


Figure 1. Deployment locations of four ecological acoustic recorders in the Mariana Islands, September 2011

Appendix D –

An Analysis of Acoustic Data from the Mariana Islands Sea Turtle and Cetacean Survey (MISTCS)

An Analysis of Acoustic Data from the Mariana Islands Sea Turtle and Cetacean Survey (MISTCS)

N62470-10D-3011 CTO KB08
Task Order #002, MSA NO. CON-005-4394-009

Prepared for:
Commander, U.S. Pacific Fleet
Pearl Harbor, HI

Submitted to:

NAVFAC Pacific
258 Makalapa Dr.
Suite 100
Pearl Harbor, HI 96860

Prepared by:

Thomas F. Norris, Julie Oswald, Tina Yack,
Elizabeth Ferguson, Cory Hom-Weaver,
Kerry Dunleavy, Shannon Coates
and Talia Dominello.

Bio-Waves Inc.
144 West D St, Suite 20
Encinitas, CA 92024

March 26, 2012

Suggested Citation: Norris, T.F., J. Oswald, T. Yack, E. Ferguson, C. Hom-Weaver, K. Dunleavy, S. Coates, and T. Dominello. 2012. An Analysis of Acoustic Data from the Mariana Islands Sea Turtle and Cetacean Survey (MISTCS). Prepared for Commander, Pacific Fleet, Pearl Harbor, HI. Submitted to Naval Facilities Engineering Command Pacific (NAVFAC), EV2 Environmental Planning, Pearl Harbor, HI, 96860-3134, under Contract No. N62470-10D-3011 CTO KB08, Task Order #002 issued to HDR, Inc. Submitted by Bio-Waves Inc., Encinitas, CA 92024.

Background

During 2007, the first large-scale survey for marine mammals and sea turtles -- the Mariana Islands Sea Turtle and Cetacean Survey (MISTCS) -- was conducted in the Navy's Mariana Islands Range Complex (MIRC; DoN 2007, Fulling et al. 2011). The survey region encompassed approximately 584,800 square kilometers (km2) and was a rectangle bounded by 18° – 10° N and 142° –148° E. The survey used standard line-transect methodology and also included passive acoustic monitoring (PAM) using a towed hydrophone array system. This was the first systematic survey of marine mammals conducted in this region of the North Pacific, and the sei whale (Balaenoptera borealis) that was not considered to likely occur in the area (see DoN 2005) was encountered during MISTCS.

The PAM component of the survey was effective in detecting some species (e.g., humpback whale and minke whale [Megaptera novaeangliae and Balaenoptera acutorostrata, respectively]) that were infrequently (or never) visually detected, and for other species (e.g., sperm whale [Physter macrocephalus] and small groups of delphinids), increased detection rates when visual sighting conditions were poor. More than 65 percent of survey effort was conducted in Beaufort sea states of 5 or higher during the 3-month cruise (DoN 2007). Towed array survey effort was conducted for 70 out of 71 (99 percent) potentially surveyable days at sea for a 762 hours (hrs) and 11,478 kilometers (km) of total acoustic survey effort. This resulted in an average of 10.9 hours /day of acoustic survey effort over the entire survey period. In addition, over 50 sonobuoys were deployed; 36 were monitored and/or recorded successfully. These sonobuoys had a relatively high failure rate since they were acquired for the cruise past their expiration date (battery life). Bioacoustic signals for 12 species of cetaceans were recorded from both the towed array and sonobuoy data. This was the first time they were documented at sea (i.e., other than from stranding records) in the Northern Mariana Islands region for several species.

In this report, we present a detailed analysis of several species of cetaceans that were acoustically detected during the MISTCS. Only preliminary results of these encounters were presented in the cruise report for MISTCS (DoN 2007). Recordings of minke whale, sperm whale, sei whale (Balaenoptera borealis), humpback whale, and several species of dolphins (including larger delphinids, such as the "blackfish") were analyzed in detail to provide more comprehensive information on the occurrence and aspects of these species' ecology and behavior. The main goals of these analyses were to: (1) provide acoustically-derived density estimates when feasible (e.g., minke whales); (2) estimate an acoustically-derived 'detection function' (e.g., sperm whales); (3) describe and compare acoustic signals for some species and populations for which limited information is available (e.g., sei whales and humpback whales); and (4) assess the success of automated classification algorithms for several species of delphinids. This report is divided into five sections: Section 1 is an assessment of the abundance of calling minke whales; Section 2 is a classification of recorded whistles; Section 3 is an evaluation of the sperm whale encounter; Section 4 is an analysis of humpback whale song; and Section 5 addresses sei whale vocalizations.

SECTION 1. An Assessment of the Abundance of Calling Minke Whales Using Towed Array Passive Acoustic Data and Line-transect Methods

1.1 Background

1.2

Although they are one of the most abundant species of baleen whales worldwide, the minke whale is rarely sighted in subtropical and tropical waters. As noted by Rankin and Barlow (2005), minke whales are the smallest of baleen whales and are typically found as individuals or in small groups of two to three. The minke whale produces inconspicuous blows and surfaces for short periods of time. High sea states also reduce the probability of sighting minke whales. Other factors that are not yet understood may also be driving the low sighting rates in these waters. Like most baleen whales, the minke whale is believed to migrate to warm waters in the winter and spring, probably to engage in reproductive activities. Before MISTCS, winter/spring distribution and abundance of minke whales in the subtropical waters of the Western North Pacific was relatively unknown. Based on the Navy's Marine Resources Assessment (MRA) for the Mariana Islands (DoN 2005), minke whale occurrence was considered to be 'rare' in the Mariana Islands Range Complex (MIRC). In fact, prior to the MISTCS, there were no verified records for this species in the MIRC and surrounding regions, even though the MIRC is within the known distribution range for this species. The MRA states that "there is a low or unknown occurrence of the minke whale from the coastline (excluding harbors and lagoons) to seaward of the Marianas study area and vicinity" (DoN 2005). Since the MISTCS, there have been a few additional acoustic detections, mostly in the vicinity of the Marianas Trench, using sonobuoys and towed hydrophone array methods similar to those used on the MISTCS (Oleson and Hill 2010).

During the 2007 MISTCS survey, there were 29 'unique acoustic detections' of minke whales, five of which were acoustically localized (see Figure 4-4 and Table 3-8 in DoN 2007). A type of call known as the 'boing' that is unique to minke whales, was used to determine the presence of minke whales (Rankin and Barlow 2005). Boings are complex amplitude modulated calls that last 3 to 5 seconds with a peak frequency near 1.5 kilohertz (kHz). For MISTCS, unique acoustic detections were considered to be independent encounters with animals (i.e., different animals). Both quantitative information, such as bearing angles and time interval between detections, and qualitative information such as relative amplitude of calls and the degree differences in bearing angles were used to determine unique detections. Five acoustic localizations that were made during the survey were included in the 29 unique detections; however, the remaining 24 detections did not include localizations. Because of the limited number of localizations, and the lack of analytical tools available at the time for post-processing of acoustic detections of minke whales, abundance estimates were not calculated in the final cruise report (DoN 2007) nor in subsequent analyses of abundance (Fulling et al. 2011).

Line-transect survey and analytical methods are relatively well developed for estimating abundance of marine mammals using visual sighting data (Holt 1987). These methods are based on a broader theory known as Distance Sampling (Buckland et al. 2001). Line-transect methods assume accurate measurements of the perpendicular distances of animals from the survey-track, although they are relatively robust to some types of measurement error (Marques 2007). These distances, and other data, are used to estimate a detection function, which is one of the main components of the abundance estimation formula. The detection function describes the decreasing probability of sightings (or acoustic localizations) as a function of increasing perpendicular distance from the survey trackline (i.e., fewer animals are detected as one 'looks' further out from the trackline).

The same analytical approach that is used for visual-based line transect surveys can be applied to acoustic data collected from marine mammals using a towed hydrophone array. To do this requires acoustic localization of individuals or groups of calling animals in order to obtain the perpendicular distances from the trackline that are used to model the detection function. A method of localization known as 'target motion analysis' (originally developed by the Navy to track submarines and ships) is commonly used to localize marine mammals with a towed hydrophone array (Leaper et al. 1992; Barlow and Taylor 2005). This method estimates the location of a 'target' using successive bearings (Figure 1-1). Target motion analysis assumes that animals are calling often, are solitary (or occur in small, tightly clustered groups) and are stationary (or move slowly relative to the survey vessel speed). This approach has been used with dipole towed hydrophone arrays to locate sperm whales and small porpoises acoustically for line-transect abundance estimation (Barlow and Taylor 2005; Gerrodette et al. 2011). To our knowledge, this approach has never been applied to estimate baleen whale abundance from towed arrays, although alternative approaches have been described for blue and fin whales (Balaenoptera musculus and Balaenoptera physalus, respectively) (Clark and Fristrup 1996). We use an approach similar to that of Barlow and Taylor (2005) (without group size estimation from visual data) to estimate the density and an abundance of calling minke whales in the MIRC area. The caveats and assumptions for this approach will be discussed in relation to our preliminary findings.

1.2 Methods

Details on the towed-array system are presented in DoN (2007). All channels of analog acoustic data from the hydrophones were passed through a low-pass filter system (Alligator Technologies, AAF-1 model) with a 48 kHz corner frequency (for anti-aliasing). A tunable high pass filter (Krohn-Hite model 3382) was used to reduce flow and self-vessel noise thereby increasing the effective dynamic range of the system. Corner frequencies of the high pass filter were set between 100 Hz and 500 Hz, depending on noise conditions. A PC digital audio interface (MOTU Traveler Model) was used to digitized the filtered hydrophone signals (@ 96 kHz sample rate) and pass them to a desktop computer via a fire-wire cable.

Towed hydrophone array recordings were analyzed using the program Boinger, which was a MATLAB program developed by St. Andrews University and Bio-Waves Inc. under Office of Naval Research (ONR) sponsorship (Norris et al. 2011). The purpose of using Boinger was to review and re-process all boings recorded and detected in the field and use automatic detection methods during post-processing in order to localize minke whales better. The resulting distances from the trackline were then imported into a program (e.g., Distance) for line-transect abundance estimation. Modifications were made to the existing version of Boinger, so that the Microsoft Access database (Whaletrack II) used during MISTCS survey to datalog and map acoustic data could be used as one of the main inputs for localization analysis. Acoustic .wav files recorded in the field from the two-element towed array were also used as inputs. Other modifications to Boinger were made to allow input of boings that were automatically detected by post-processing files using Ishmael software (using automatic boing detectors developed by D. Mellinger, Oregon State University/Pacific Marine Environmental Laboratory). Ishmael is a bio-acoustic data-acquisition, display and processing program that can be used in the field and for post processing data from hydrophone arrays (Mellinger 2001).

The modified version of Boinger used in this study allowed a data analyst to quickly review and analyze acoustic data from MISTCS by sequentially processing each boing detected and saving results and localization maps for further review (Figures 1-2A to 1-2C). In addition, other features such as the Dominant Signal Component (DSC) and the cross-correlation function were reviewed by the data analyst in order to attempt to differentiate multiple individuals when they occurred. The DSC is the peak frequency of a particular frequency band in the call. The cross correlation function is used to calculate the bearing between the two hydrophones in the array (Mellinger 2001). The output of Boinger included times, geo-referenced positions of localizations, the perpendicular distance of acoustic localizations to the ship trackline and maps of the ship track and localizations (Figure 1-2C).

The automated boing detector was run on all .wav files recorded during the MISTCS cruise using the program Ishmael. All automated detections were visually reviewed and confirmed by a trained data analyst to identify and remove false detections. The verified detections were then imported into the database that Boinger reads to locate boings from the .wav files. The outputs of the detector included the filename and the relative times of the detections.

Both the detections of boings made in real-time (i.e., during the survey) using the program Ishmael, and the automatic detections made during post-processing were used as inputs to Boinger. These data were processed by data analysts who reviewed and saved all possible localizations. All localizations were ranked based on a variety of qualitative and quantitative characteristics, including the quality of the localization, the number of bearing lines used in a localization, the level of clustering of DSC values from the bearings used, and the 'tightness' of the convergence of the bearing lines. This information was saved to a spreadsheet. Maps of localizations were saved and printed out for a final review by a senior data-analyst (T. Norris) for a final decision on whether or not to include in the line-transect analysis.

Due to the linear configuration of the towed hydrophone array, there is a left/right ambiguity inherent in the localization. Because the ship was not usually traveling in a perfectly straight line and the array was always streaming directly behind the ship (i.e., coincident with the ship-track), the left and right side perpendicular distances from the trackline to the localizations were not always the same. In these cases, the mean of the two distances was used as an approximation of the true distance. In cases in which the ship turned or deviated significantly from the planned ship track, it was sometimes possible to resolve which side the animal was on (e.g., when bearing lines converged only to one side). In such cases, only the perpendicular distance for the localization on the 'good' side was used.

The perpendicular distances estimated using Boinger were used as inputs to the distance sampling analysis program Distance (Version 6; Thomas et al. 2010a). Distance was used to estimate detection functions, encounter rates, effective strip widths and ultimately, the density and abundance of calling minke whales in the MISTCS study area using the line-transect formula for density (modified for abundance below) from Buckland et al. (2001):

$$\hat{N} = \frac{nsA}{2wL\hat{P}_a\hat{g}_0}$$

The fixed (known) variables in this equation are:

A = area of the MISTCS survey area (584,800 km2)
L = total length of on-effort trackline surveyed (6,324 km)
n = number of animals acoustically localized (30)

The estimated variables are:

w = strip width surveyed on each side of the survey trackline (i.e., the truncation distance)
Pa = the average probability of detecting an animal between 0 and w.

Variables and function with assumed values:

s = animal group or cluster size for this study s is assumed to equal 1.
g(0) = the probability of detecting an animal at distance = 0 (i.e., on the trackline) - for this study, g(0) is assumed to equal 1.

(Deviations from the assumptions will be addressed in the discussion).

Given that S and g(0) = 1, the formula can be simplified to:

$$\hat{N} = \frac{nA}{2wL\hat{P}_a}$$

Before models were tested in Distance, frequency histograms of the perpendicular distances were inspected to determine if there were any problems with the data. Various cut points for the histograms were tried in combination with 'right truncation' to eliminate 'outliers' (i.e., detections that did not contribute to the overall expected shape of the function) and improve the fit and, therefore, the robustness of the model. 'Left truncation' was applied at various distances to remove localization data near the trackline, but based on visual inspection of the histograms and advice by outside experts on Distance Sampling (e.g., L. Thomas, CREEM, St. Andrews, UK) 1 km was chosen as the appropriate distance for left truncation. This step was taken to reduce the bias associated with possible reduction in vocalization rates near the trackline (Thomas et al. 2010b). The rationale for this step will be explained in greater detail in the discussion.

Final models were chosen based on a comparison of the Akaike Information Criteria (AIC) value for various models, as well as the coefficient of variation (CV) of the abundance estimate (lower was considered better for both). AIC measures the relative fit for different models (Buckland et al. 2001).

Abundance and density (abundance divided by the total study area sizes) were estimated after selection of the best model for the detection function. CVs and Confidence Intervals (CIs) were automatically calculated in Distance using the analytical method.

1.3 Results

The Ishmael automatic detector and Boinger program were used to efficiently review over 700 hrs of recordings from MISTCS. After post-processing the data using Boinger, 30 localizations were estimated. This total consisted of 25 more localizations than originally were made in-situ during the cruise. A map of localization indicates that most detections were distributed near, but not in, the deepest regions of the Mariana Trench (Figure 1-3).

Inspection of the frequency histograms of the perpendicular sighting distances reveals a decrease in detection near the trackline (Figure 1-4). Two scenarios were modeled for the detection function: 1.) Animal movement away from the trackline and; 2) Vocal rate reduction near the trackline.

For Scenario #1 (animal movements away from the trackline), a Uniform Key function with a Cosine Series expansion model was chosen as the best fit (Figure 1-5A). No right or left truncation was used but 4-km cut-points for the histograms were manually selected. The abundance estimate for calling animals in the MISTCS study area was 333 (95 percent C.I. 201 – 552) calling animals. This estimate assumes that all animals calling remain present when the vessel passes nearby, but that animals just redistribute relative to the trackline.

For Scenario #2 (reduction in vocal rates near the trackline), a Uniform Key function with a Cosine Series expansion model was also chosen. In this model, 5 percent of the largest values (at the far right on the histogram) were truncated as well as all values less than 2 km on the left side of the histogram (Figure 1-5B). This was necessary to reduce any bias in the overall detection function shape that was caused by animals that were present, but not vocalizing due to some effect caused by presence of the research vessel. The abundance estimate for the MISTCS study area for Scenario #2 was 540 (95 percent C.I. 299 – 975) calling animals (Table 1-1). This estimate assumes some animals go undetected (or under-detected) as the vessel passes nearby, and thus attempts to correct for this by removing those animals (distributed near the trackline) from the detection function analysis.

1.4 Discussion

Presently there are no estimates for minke whale abundance or density in the MIRC or surrounding areas in the tropical western North Pacific. Because there were no sightings made of minke whales during MISTCS, minke whales were not included in the recent abundance estimates resulting from this effort (Fulling et al. 2011). Due to the elusive nature of minke whales in subtropical waters and the poor sighting conditions that are pervasive in the MIRC area, it is unlikely there will ever be enough sightings to estimate minke whale abundance using visual data.

Several caveats and deviations from the assumptions required for line-transect sampling methods and data analysis should be considered before using these data. First, it is clear that g(0), the probability that all animals on the trackline are detected, is not equal to one (i.e., some animals on or very near the trackline are not being counted). This is apparent based on visual inspection of the first bin (1 km) of the histogram of perpendicular localization distances from the tracklines (Figure 1-4). This fundamental assumption of line-transect methods must be met for abundances to be considered unbiased (Buckland et al. 2001). However, in practice this assumption is often violated (e.g., due to animal responses to the survey platform or inability to see some animals on the trackline) or ignored resulting in the true population being underestimated.

The reduced numbers of localizations near the trackline is likely caused by three (non-mutually exclusive) possibilities:

1. Acoustic methods are negatively biased with respect to their ability to detect and localize animals near the trackline (due to a directional beam-pattern for the array).

2. Animals are moving away from the survey vessel when it is nearby (i.e., evasive movements).

3. Animals are reducing their vocalization rates when the vessel is nearby.

The first possibility can occur due to what is known as 'end-fire' for towed hydrophone arrays. End-fire is a reduction in sensitivity in regions directly in front of and behind the hydrophone array (i.e., along the axis of the cable). It is usually caused by a receiving beam pattern for the hydrophone array elements that is not omni-directional. This is often the case for cylindrical elements that are often used in towed hydrophone arrays. In addition, physical obstruction of sound waves can be caused by the hydrophone cable, components in the hydrophone array, the research vessel or bubbles generated by cavitation from the propeller of the research vessel. The result of these obstructions is that the hydrophone does not have a clear path to 'look' directly forward and/or backward. This occurs for most towed hydrophone arrays, but generally is limited to small angles (less than 10 -15 degrees) along the axis of the hydrophone array (Rankin et al. 2008). This situation can easily be corrected for in the analysis (via left truncation of data) if the angles, or regions, of poor localizations are known or can be estimated.

The second possibility occurs when animals avoid the vessel when it is nearby. This possibility is difficult to verify without being able to track animals. Preliminary analysis of acoustic data collected from minke whales using fixed seafloor hydrophones at the Pacific Missile Range Facility (PMRF) in Hawaii indicated that at least some animals moved away from a relatively quiet motor-sailing vessel used to conduct surveys in the area (S. Martin, SPAWAR Systems Center Pacific, San Diego, CA, unpublished data). Further information is needed to verify this effect. Fortunately, line transect methods are relatively robust to this effect as the detection function can account for movement of animals away from the trackline if the effect on the frequency histogram distribution of perpendicular distances is not too severe.

The third possibility, a reduction in vocalization rates when the vessel is nearby, is one that we consider very likely to be occurring. However, this possibility is difficult to assess without being able to track animals when they reduce or cease vocalizing. This situation can be problematic for line-transect abundance estimation because it results in an underestimate of animals. However it can be corrected for by 'left truncating' the perpendicular distance (localization) data. Collecting data to verify this possibility will probably require tagging animals and tracking them at the same time. Alternatively, vocalization rates could be compared before, during, and after the vessel passes animals that were initially vocalizing, assuming they do not move away. We have analyzed some preliminary towed array data that indicate a decrease in vocalization rates, but the situation appears to be complex (Norris et al. 2011).

Even with these caveats, we believe that the abundance estimates we present here are relevant because some of the issues and biases can be addressed. For example, left truncation of the histogram of distance data can reduce or eliminate the bias associated with a reduction in vocalization rates (Thomas 2010b). Evasive movements can be examined with existing seafloor hydrophone data and more detailed analysis of towed-hydrophone array data. Or additional acoustic data could be collected from sonobuoys and/or fixed seafloor hydrophones with sufficient temporal and spatial coverage to track and monitor vocalization rates of individuals as the survey vessel passes nearby. Tracking data collected using either passive acoustic methods or via electronic tagging might also provide information on vocalization rates that can be used for correction factors. This situation is not as problematic as it seems as many line-transect surveys have some biases that must be accounted for or considered (e.g., for many species $g(0) \neq 1$) and solutions to these problems exist (e.g., Schweder et al. 1996).

For the purposes of this analysis, we assumed that the group size of all acoustic localizations was equal to one. There is only limited evidence to confirm this, but based on our experience detecting and tracking numerous species we believe this assumption to be valid. Vocalizations almost never overlap and when they occur closely in time (e.g., within a few seconds of another call) the second individual is usually several hundreds to thousands of meters away. Similar results have been determined based on passive acoustic tracking of multiple individuals from the PMRF hydrophone arrays (S. Martin, SPAWAR Systems Center Pacific, San Diego, CA, pers. comm.). It is possible (even likely) that non-vocalizing individuals are associated with or occur nearby vocalizing individuals, but this effort does not attempt to assess or correct for the occurrence of non-vocalizing animals. Future efforts in which animals are tagged or tracked might allow this possibility to be studied, but this was well beyond the scope of the current study.

Other issues that should be examined are the segmentation of tracklines (in the case of MISTCS, due in part by bad weather and sea conditions disrupting effort). Density surface modeling might be a more effective type of line-transect estimation if the segmentation is too severe or if the effort is biased (Buckland et al. 2004). Density surface modeling treats the encounter rate component in the distance formula as a model based problem, as compared to the design-based approach that is used in conventional distance sampling, as we did in this study. Other methods of modeling abundance and distribution that include covariates and habitat features might improve the accuracy of estimates or allow predictive assessments of occurrence, distribution and habitat preference. Acoustic data will be essential for such efforts, since it is unlikely that sufficient visual data will ever be available for minke whales.

1.5 Conclusions and Recommendations

The estimates provided in this report are probably biased but we consider these limitations acceptable given the alternative (i.e., no estimates for minke whales in the study site). Coefficients of Variation for both scenario estimates were under 30 percent, which is substantially lower than those for density estimates of all other species in the same area that were made using visual data (e.g., most CVs were greater than 50 percent for estimates in Fulling et al. 2011). We would recommend using the lower estimate (i.e., scenario #1 estimates) for any management needs concerning permitting for takes or deleterious impact as this is the more conservative estimate. For management needs, modeling impacts, or other effects on minke whales, we would recommend using the larger (i.e., scenario #2 estimates) as this would provide the most conservative approach.

Future efforts should examine vocalization rates as this is perhaps the main variable that affects the population estimates provided here. For example, gender biases relative to vocalization rates of minke whales are unknown, but might be expected to favor, or be exclusively limited to, males given what is known about other species in the genus Baleanoptera (e.g., blue and fin whales). Given that we think that the MISTCS study area is likely to be a wintering area, it is important to collect more information about these poorly understood aspects of minke whale biology. Finally, the effects of survey vessel noise and other anthropogenic noise (e.g., sonar and explosive noise) need to be studied further in order to obtain better population estimates and understand if noise is negatively affecting this elusive and acoustically sensitive species.

Any plans to conduct future surveys and monitoring should also consider how to optimize collection of passive acoustic data. Vessel types for towed array surveys should be an important consideration during survey planning. For example, any survey planning to incorporate passive acoustic methods (i.e., either towed arrays and/or sonobuoys) should use a vessel that is quiet and preferably diesel-electric powered. The quality of the electrical power source for the acoustic research equipment should also be considered. If AC power onboard the survey vessel is not ‘clean,’ then a high-quality inverter connected to an isolated battery bank should be considered, or alternatively, audio equipment should be directly powered via DC current using batteries. A small, high quality generator dedicated to powering only the acoustic equipment is another alternative.

If autonomous recording devices are used, their placement should consider the distribution of minke whales as determined from this and future studies. Finally, efforts to improve and automate analysis of passive acoustic data, for detection, localization, and data analysis should be undertaken to improve the efficiency and accuracy of data analysis. For example, the program Boinger should be developed further to make it more efficient and effective for post processing data. This would include allowing more information to be used to asses if different animals are being localized; e.g., by colorizing bearing based on DSC values, providing animation or playback capabilities, and providing semi-automatic bearing and localization capabilities. The cost of developing automated programs is relatively small relative to the cost of collecting and post-processing data in real-time.

For visually elusive species like the minke whale, passive acoustics is probably the only method available to effectively survey the population and obtain abundance estimates, even if for the time being it might only represent a proportion of the overall population. Future studies undoubtedly will shed light on aspects such as vocalization rates and the effects of the survey vessel on the behaviors of minke whales. Additionally, passive acoustic data collection will be one of the few methods that will be able to effectively survey, monitor, and assess effects of man-made activities on marine mammals in remote areas such as MIRC and will likely be an important component for any such efforts.

1.6 Tables and Figures

1.6.1 Tables

Table 1-1. Summary statistics for acoustic-based abundance/density estimate for calling minke whales using the software program Distance.

The two scenarios are the same as presented in the results; Scenario #1 assumes animal movement away from the trackline. In this scenario neither right nor left truncation is done. Scenario #2 assumes a reduction in vocal rates near the trackline. In this scenario left truncation (at 1 km) is done to remove any bias due to the lower probability of detecting animals close to (< 1km) the trackline. (Details of analysis 36 and 37 available in Distance project folder.)

Scenario	N	95 percent CI	D	Percent CV	d.f.
#1 (analysis 36)	345	208-572	.0005923	25	29.26
#2 (analysis 37)	394	238-652	0.000676	25	29.07

1.6.2 Figures

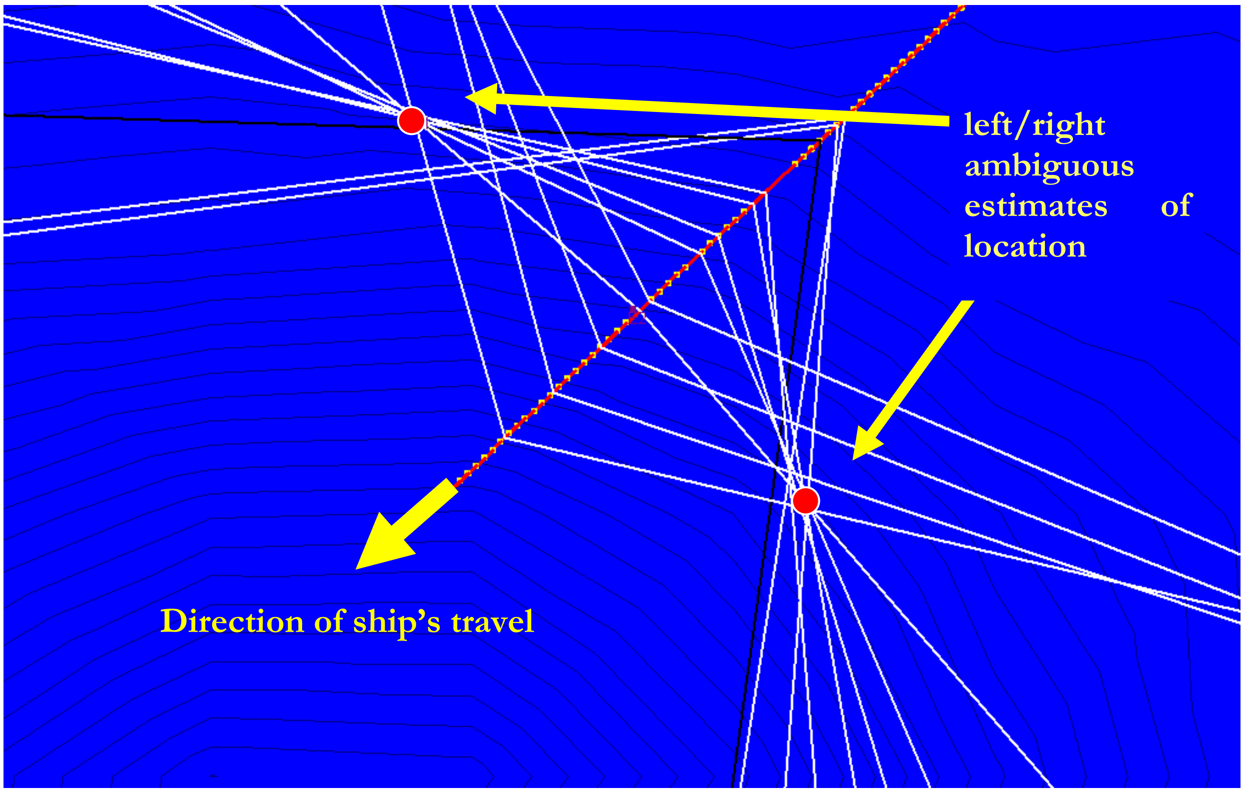


Figure 1-1. An example of the 'target motion analysis' method of localization used for minke whales.

Sequential bearing lines from the towed hydrophone array to a vocalizing animal converge as the vessel passes the animal. This method assumes that the animal is relatively stationary compared to the vessel speed. Also note the left/right ambiguity caused by the linear configuration of the hydrophone array.

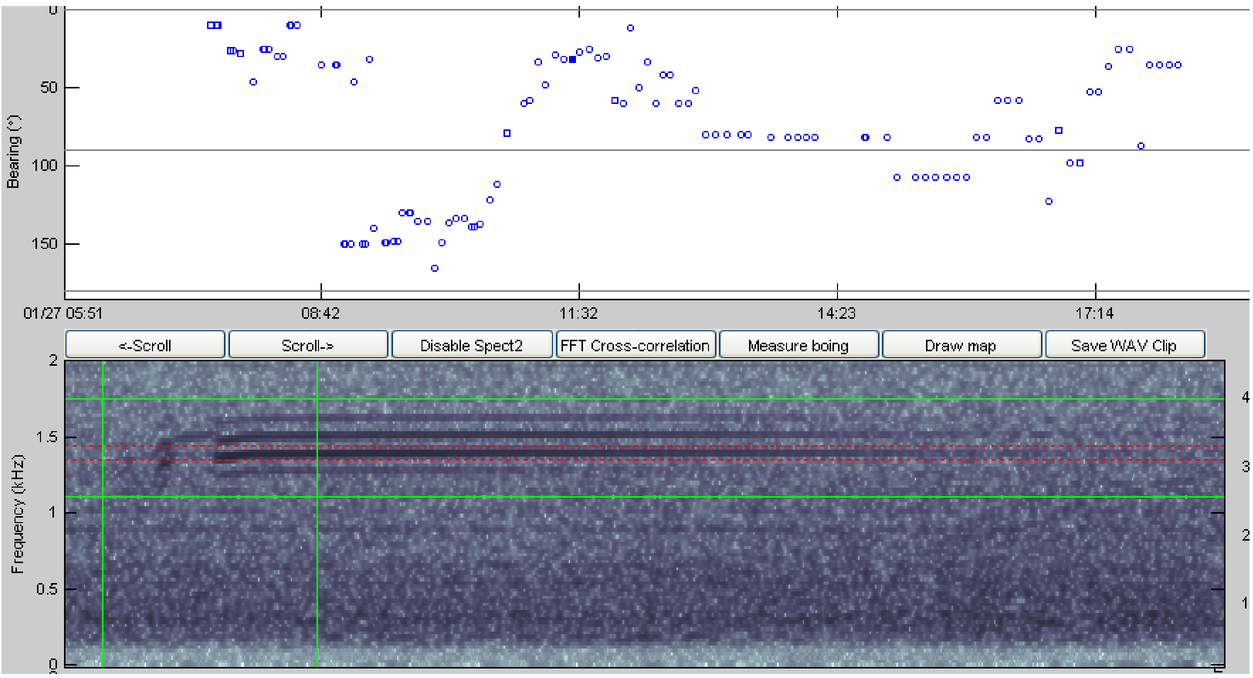


Figure 1-2A. Example of a bearing vs. time display (top panel) and a spectrogram vs. time display (bottom panel).

The top panel depicts a series of boings over time (in this case about 18 minutes) and the bottom pane is an individual boing that is being processed in *Boinger*. Boings are selected by clicking on open circles in top panel (imported from Ishmael's auto-detection output) which results in *Boinger* loading the corresponding boing from a .wav file. The data analyst then moves the horizontal green lines to window the appropriate part of the boing to measure the FFT cross-correlation (used to calculate the bearing); and the horizontal green lines to measure the DSC of the boing. The tabs at the top of the spectrogram depict the different measurements and other options possible in Boinger. The Dominant signal component is the peak frequency of the signal that occurs within the band of the 2 horizontal green lines. The broken red lines indicate the expected range of the DSC value to allow the user to decide if there is an 'unusual' DSC present.

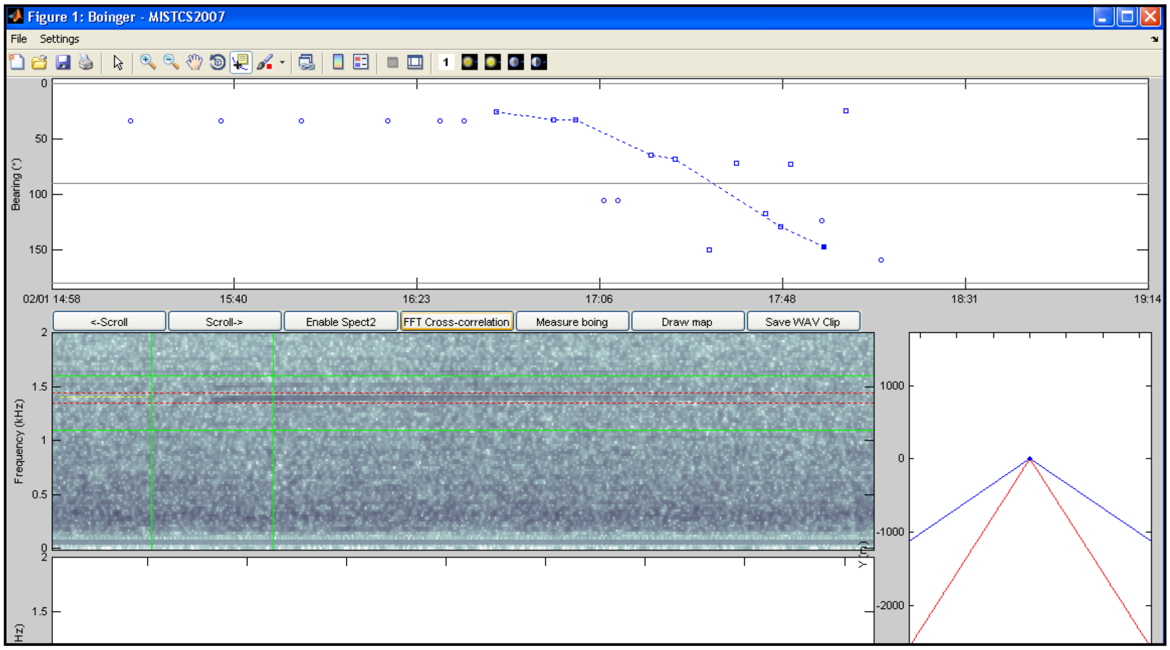


Figure 1-2B. An example of a good bearing vs. time track (top panel) for an individual whale that is being localized.

The bearing for the last boing (solid blue square inside yellow circle in top panel) is plotted in blue on the panel on the lower right. This panel depicts the bearing measurement made in the field (red lines) and the one made using *Boinger* (blue lines). Once the bearing is reviewed and compared to the bearings obtained in the field, the data analyst can then save the bearing and plot it on a map to localize the calling animal (see next figure).

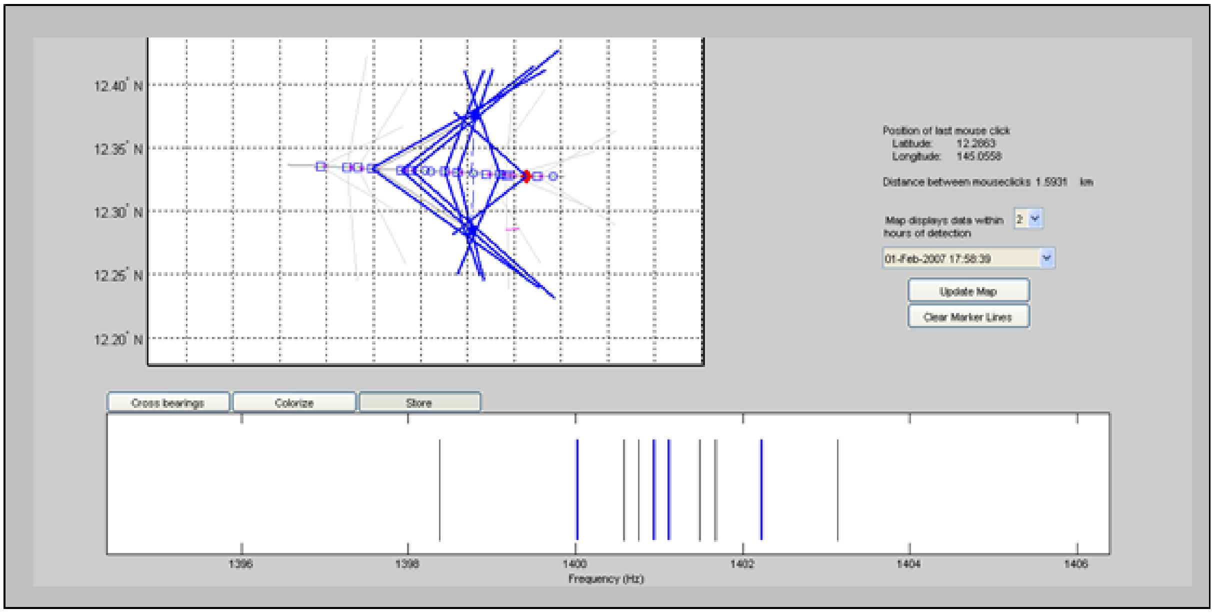


Figure 1-2C. Example of a good localization (top panel).

DSC values (bottom panel) of bearings used in the localization are depicted by the blue vertical lines which in this case are clustered within a few Hertz (Hz) of each other, indicating that boings that are being used for localization bearings are likely from the same animal. There are likely several vertical lines overlaid on top of each other, thus not the same number of blue lines in the bottom panel as bearing lines in the top map.

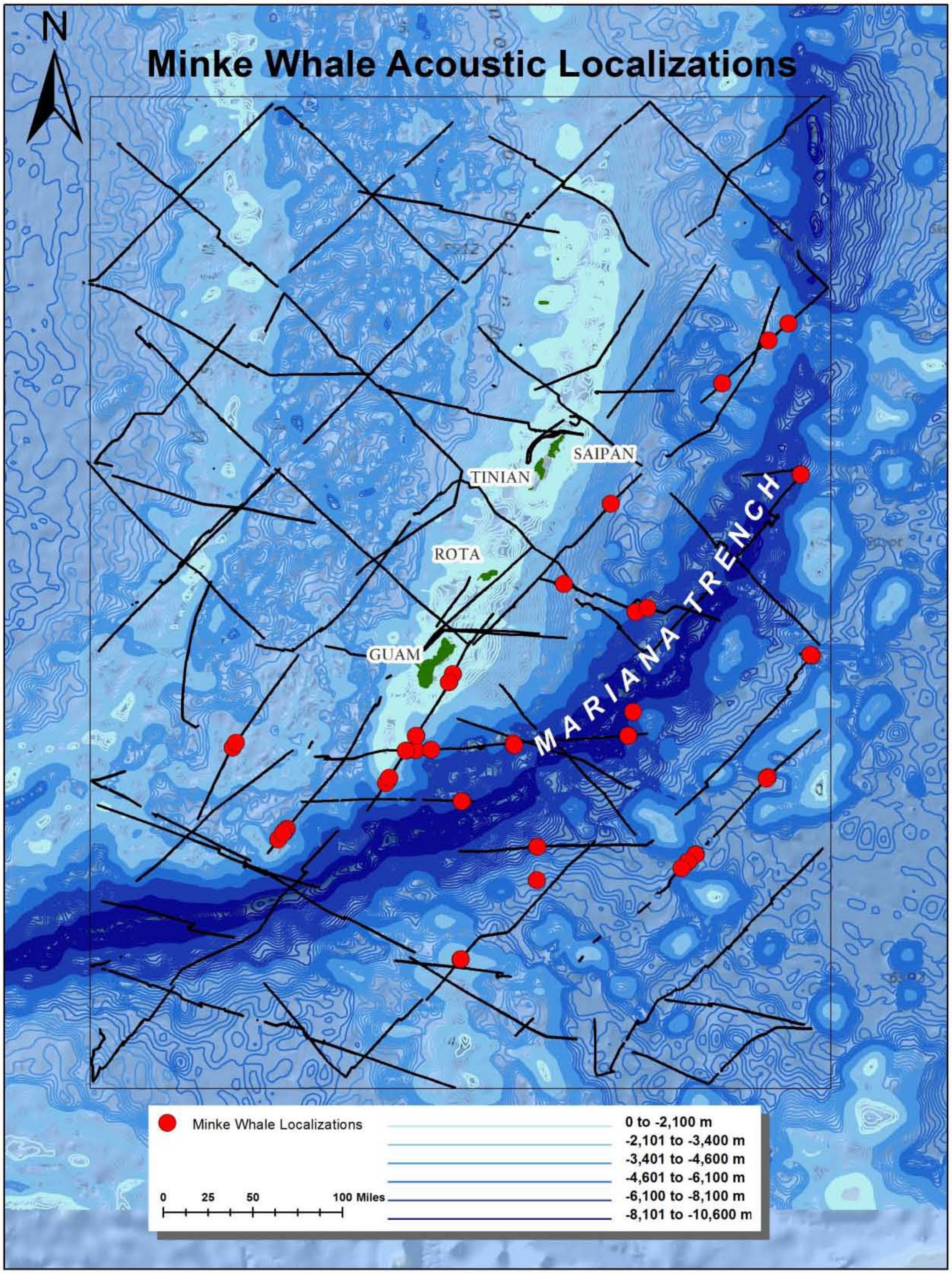


Figure 1-3. Map of the MISTCS study area (gray box) with ship tracks (dark blue segments) of minke whale post-processed acoustic localizations.

Left-right ambiguous localizations are indicated by a pair circles with both port (red) and starboard (green) locations.

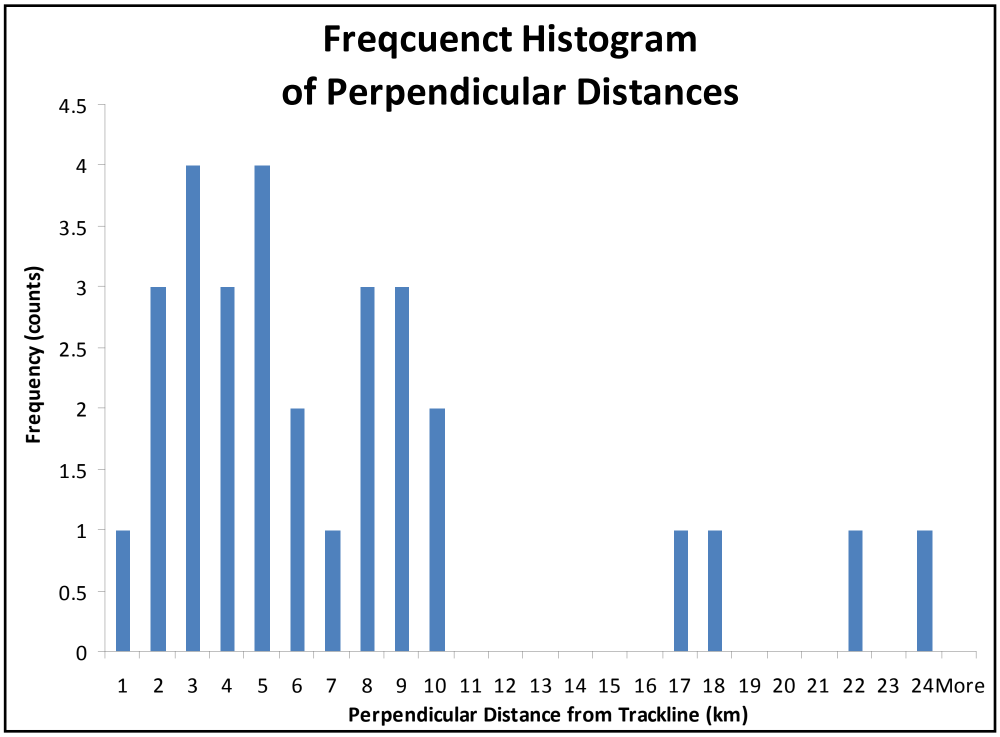


Figure 1-4. Histogram of distances of localization perpendicular to the trackline (1 km bins).

Note the significant reduction in localizations that occur in the first bin (1 km). This indicates that animals are either avoiding the vessel as it approaches, or are reducing (or ceasing) vocalizations.

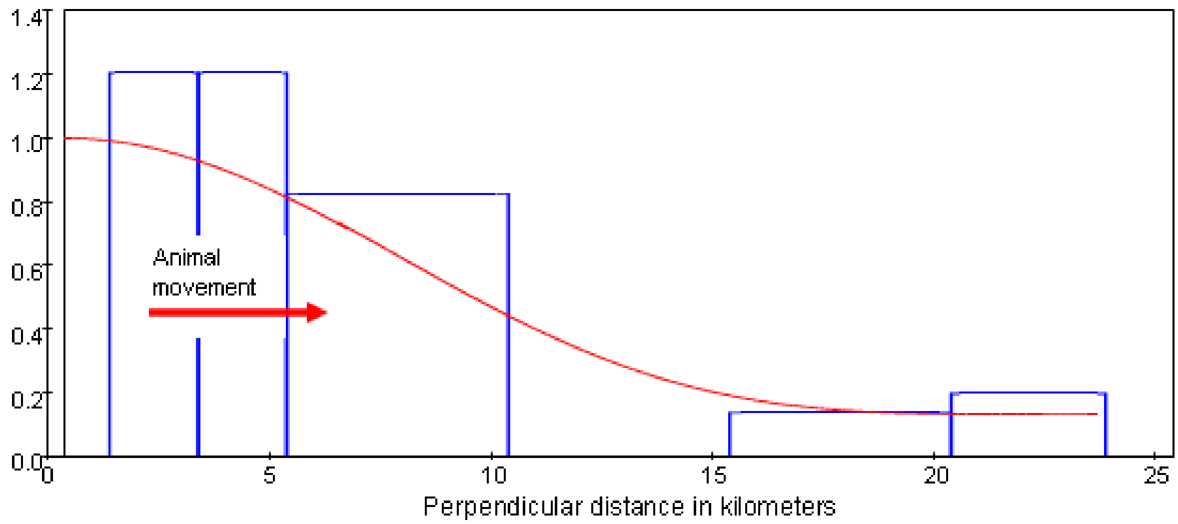


Figure 1-5A. Probability of detection (vertical axis) and detection function modeled for Scenario #1 which assumes evasive movement away from (research vessel at) trackline.

Best fit was the Uniform Key function plus a Cosine Series expansion. No truncation was used. (analysis #36 in *Distance* Project Folder)

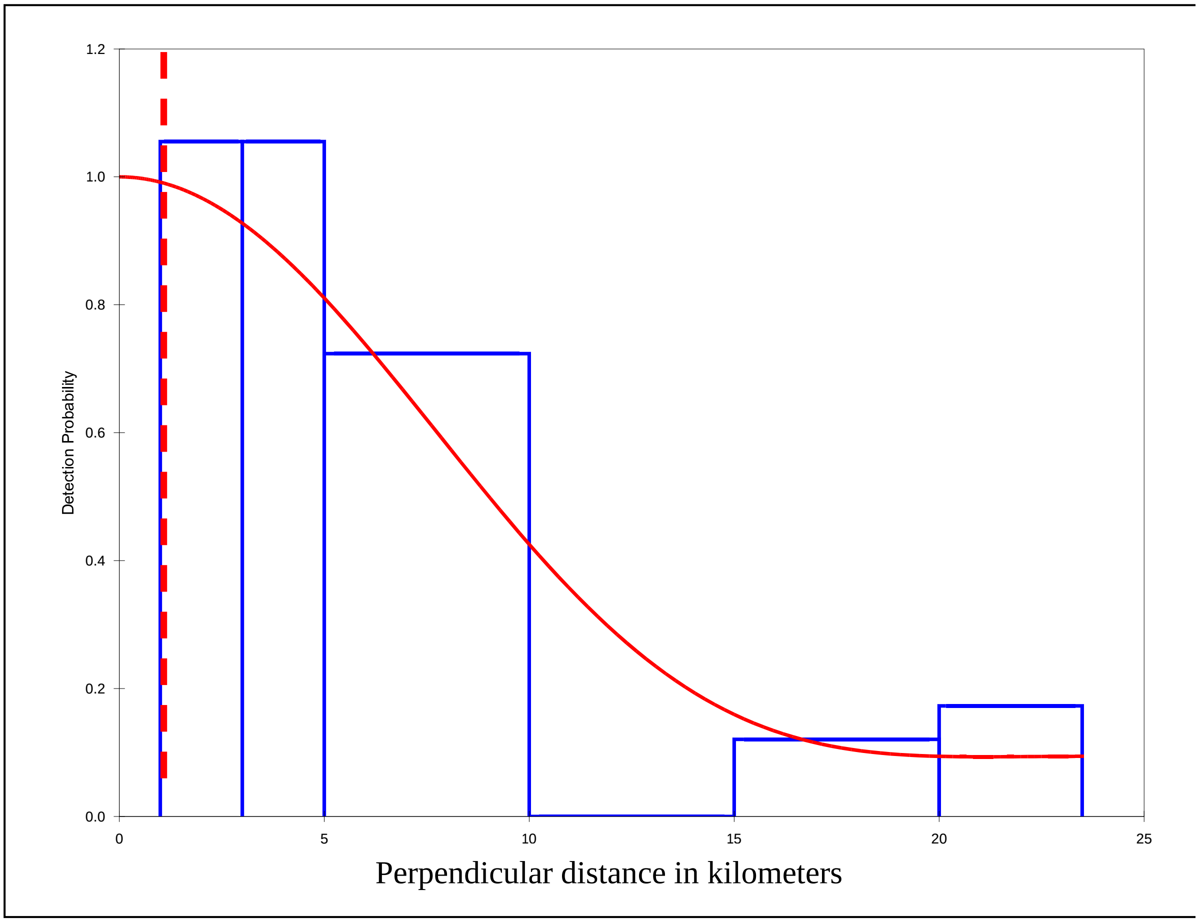


Figure 1-5B. Probability of detection (vertical axis) and detection function modeled for scenario #2.

This scenario assumes a reduction in calling behavior (probably due to the vessel) near the trackline. Best fit was the Uniform Key Function plus Cosine series expansion. Left truncation was used at 1 km to remove bias due to reduced calling rates. Dashed red line indicates right truncation point. (Analysis # 37 in *Distance* project folder)

1.7 Literature Cited

Barlow, J. and B.L. Taylor. 2005. Estimates of sperm whale abundance in the northeastern temperate Pacific from a combined acoustic and visual survey. *Marine Mammal Science*. 21(3):429-445.

Buckland, S.T., D. Anderson, K. Burnham, J. Laake, D.L. Borchers, and L. Thomas. 2004. *Advanced Distance Sampling*. Oxford University Press, New York.

Buckland, S.T., D. Anderson, K. Burnham, J. Laake, D.L. Borchers, and L. Thomas. 2001. Introduction to Distance Sampling: Estimating abundance of biological populations. Oxford University Press, Oxford..

Clark, C.W. and K.M. Fristrup. 1996. 'Whales '95: A combined visual and acoustic survey of blue and fin whales off Southern California. *Reports of the International Whaling Commission* 47:583–600.

Department of the Navy (DoN). 2005. *Marine resources assessment for the Marianas Operating Area--Final report*. Contract number N62470-02-D-9997, CTO 0027. Pacific Division, Naval Facilities Engineering Command, Pearl Harbor, HI. https://portal.navfac.navy.mil/portal/page/portal/navfac/navfac_ww_pp/navfac_hq_pp/navfac_environmental/mra

Department of the Navy (DoN). 2007. *Marine mammal and sea turtle survey and density estimates for Guam and the Commonwealth of The Northern Mariana Islands*. Final Report contract No. N68711-02-D-8043. Prepared for U.S. Navy, Pacific Fleet, Naval Facilities Engineering Command, Pacific, Honolulu, Hawaii. http://www.nmfs.noaa.gov/pr/pdfs/permits/mirc_mistcs_report.pdf

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

Gerrodette, T., B.L. Taylor, R. Swift, S. Rankin, A.M. Jaramillo-Legorreta, and L. Rojas-Bracho. 2011. A combined visual and acoustic estimate of 2008 abundance, and change in abundance since 1997, for the vaquita, *Phocoena sinus*. *Marine Mammal Science* 27(2):E79-E100.

Holt, R.S. 1987. Estimating density of dolphin schools in the eastern tropical Pacific Ocean by line transect methods. *Fishey Bulletin* 85(3):419-434.

Leaper, R., O. Chappell, and J. Gordon. 1992. The development of practical techniques for surveying sperm whale populations acoustically. *Reports of the International Whaling Commission* 42:549–560.

Marques, T.A. 2007. Incorporating measurement error and density gradients in distance sampling surveys. Unpublished Ph.D. thesis, University of St. Andrews.

Martin, S.W., T.A. Marques, L. Thomas, R.P. Morrissey, S. Jarvis, N. DiMarzio, D. Moretti, and D. Mellinger. In Press. Estimating minke whale (Balaenoptera acutorostrata) boing sound density using passive acoustic sensors. *Marine Mammal Science.*

Mellinger, D.K. 2001. *Ishmael 1.0 User's Guide*. NOAA Technical Memorandum OAR-PMEL-120. National Oceanic and Atmospheric Administration, Pacific Marine Environmental Laboratory, Seattle, WA.

Norris, T., R. Atunes, M. Oswald, S. Martin, V. Janik, M. Oswald, and L. Thomas. 2011. A semi-automated, interactive tool for review of acoustic detection and localization data collected during towed hydrophone array surveys for line-transect density estimation. *Abstracts of the Fifth International Workshop on Detection, Classification, Localization, and Density Estimation of Marine Mammals using Passive Acoustics, 22-25 August 2011, Mount Hood, Oregon.*

Oleson E.M. and M.C. Hill M. C. 2010. *2010 Report to PACFLT: Report of cetacean surveys in Guam, CNMI, and the high-seas*. Prepared for Department of the Navy by National Marine Fisheries Service, Pacific Island Fisheries Science Center, Honolulu, HI.. http://www.nmfs.noaa.gov/pr/pdfs/permits/navy_mirc_monitoring2011.pdf

Rankin, S. and J. Barlow. 2005. Source of the North Pacific 'boing' sound attributed to minke whales. *Journal of the Acoustical Society of America* 118(5):3346-3351.

Rankin, S., J, Barlow, and J. Oswald. 2008. *An assessment of the accuracy and precision of localization of a stationary sound source using a two-element towed hydrophone array*. NOAA Technical Memorandum NMFS-SWFSC-416. National Marine Fisheries Service, La Jolla, CA.

Schweder, T., G. Hagen, J. Helgeland, and I. Koppervik. 1996. Abundance estimation of northeastern Atlantic minke whales. *Reports of the International Whaling Commission* 46:391-405.

Thomas, L., S.T. Buckland, E.A. Rexstad, J. L. Laake, S. Strindberg, S. L. Hedley, J. R.B. Bishop, T. A. Marques, and K. P. Burnham. 2010a. *Distance* software: Design and analysis of Distance Sampling surveys for estimating population size. *Journal of Applied Ecology* 47:5-14.

Thomas, L., V. Janik, and T.F. Norris. 2010b. *The ecology and acoustic behavior of minke whales in the Hawaiian and Pacific islands*. Office of Naval Research Year-end report. Award Number: N000140910489. Submitted to Office of Naval Research, Arlington, VA.

SECTION 2. Classification of Whistles Recorded During the MISTCS 2007 Cetacean Survey

2.1 Background

The sounds produced by delphinids are varied and can be divided into three general categories: echolocation clicks, burst pulses and whistles. Echolocation clicks are short, broadband pulses that are used for navigation and object discrimination (Au 1993). These pulses have peak frequencies that vary from tens of kHz to well over 100 kHz (Norris and Evans 1966; Au 1980). Burst pulses are broadband click 'trains' with very short inter-click intervals. These clicks are repeated at such high rates that the click train, rather than the individual clicks, is audible (Watkins 1967, Herzing 2000). Burst pulses are thought to play a role in both social interactions and echolocation tasks. 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 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). Whistles are thought to function as social signals (Janik and Slater 1998, Herzing 2000, Lammers et al. 2003).

Due to the relatively long duration and frequency modulated nature of whistles, many features can be measured from these types of signals. Whistles are thought to be social signals and therefore have the potential to carry important information. In addition, whistles are relatively omni-directional and their mid- to high- fundamental frequencies (ranging from approximately 5 to 25 kHz) generally propagate well underwater (Rankin et al. 2008). These characteristics make whistles well-suited for studies of species-specific traits and, in particular, for acoustic species identification. The identification of delphinid species using whistles is a topic that is receiving more attention as passive acoustic methods have come into widespread use and acceptance 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).

Recently, Oswald et al. (2007) developed software called Real-time Odontocete Call Classification Algorithm (ROCCA) that allows for the acoustic identification of delphinid whistles occurring in the eastern tropical Pacific (ETP) Ocean. The original classification algorithm used in ROCCA included visually validated acoustic recordings from eight species, was based on linear discriminant function analysis (DFA) and classification and regression tree analysis (CART), and correctly classified 46 percent of schools to species (Oswald et al. 2007). Recent modifications to ROCCA include the use of a random forest analysis in place of DFA and CART. The development of ROCCA is discussed in further detail in **Section 2.2.1** of this report. A near-real-time version of ROCCA has recently been incorporated into the bio-acoustic software program PAMGUARD (Gillespie et al. 2008). This software can be used for real-time acoustic monitoring and post-processing of marine mammal acoustic data.

During a combined visual and acoustic cetacean abundance survey that took place in the waters around Guam and the Northern Mariana Islands (DoN 2007), whistles were frequently detected. These acoustic detections were not always coupled with visual observations. As a result, many acoustic detections were not identified to species. This survey took place in a very large area that is difficult to study due to its remote location and its poor sighting conditions as a result of high Beaufort sea state. Therefore, very little data exist on the occurrence and distribution of delphinids in this study area. The ability to acoustically identify species (or any taxonomic level) that were not sighted (referred to in this report as 'non-sighted acoustic detections') will provide important information regarding the occurrence and distribution of delphinid species in the MISTCS study area. This information can then be used to help assess habitat characteristics, general patterns of distribution, population characteristics, and responses to possible anthropogenic impacts such as naval training exercises.

In this study, we developed a random forest classifier for whistles recorded using a towed hydrophone array during the MISTCS. A Random Forest is a collection of decision trees. Each tree is grown using binary partitioning of the data, based on the value of one variable at each branch or node. 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 (Breiman 2001). Each whistle is run through every tree in the forest, and is then classified as the species that the greatest number of trees 'voted' for. We applied this classifier to the acoustic detections that were not visually sighted during the cruise.

2.2 Methods

2.2.1 Random Forest classification models

The ETP whistle classification algorithms used by ROCCA were created using random forest classification models. Several random forest classification models were created using a database of 1,864 whistles (**Table 2-1**) recorded during five combined visual and acoustic cetacean abundance surveys in the ETP and the waters surrounding the Hawaiian Islands (HI). These five month surveys included *STenella* Abundance Research (STAR) surveys in 2000, 2003, and 2006, Hawaiian Islands Cetacean and Ecosystem Assessment Survey (HICEAS) in 2002, and Pacific Islands Cetacean and Ecosystem Assessment Survey (PICEAS) in 2005 (**Figure 2-2**). As HICEAS and PICEAS were located more in the central than eastern Pacific, the combined dataset will be referred to as the ETP/HI in this report for convenience. See Oswald et al. (2007) for detailed survey methods.

To create classifiers, whistles produced during visually validated, single species encounters were detected manually by a trained bio-acoustic technician (ROCCA does not currently contain an automated whistle detector). The technician noted the start time of all whistles occurring during each acoustic encounter. If more than 35 whistles occurred during an acoustic encounter, 35 of the whistles were randomly selected for analysis. This was done to reduce the risk of over-sampling groups or individuals. ROCCA was then used to extract time-frequency contours from the selected whistles and then to measure 56 features from each contour (in addition to containing classification algorithms, ROCCA also has the capability to extract and measure time-frequency contours from tonal signals), as described in Oswald et al. (2007). The 56 features measured automatically from each whistle contour using ROCCA are described in

Appendix A. Descriptive statistics for a subset of these variables are presented in **Table 2-2**. The 56 measured features were collectively grouped into "feature vectors" for each whistle. These feature vectors were then used to create several different random forest classification models. The first model classified all whistles down to species. Subsequent models were based on groups of species (ex. 'blackfish', '*Stenella* species,' etc.). Species were grouped based on the confusion matrix produced by the first random forest model. For each classification model, different subsets of the 56 features were tested to find the feature vector that yielded the best tradeoff between the number of features included and the percentage of whistles correctly classified.

To create the random forest models, the data were first 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 determine the number of trees and the feature set to use for each model, a random forest analysis was repeated 100 times on the sub-sampled data. The output for each analysis included out-of-bag error estimates (Breiman 2001) for forests consisting of 1 up to 1,000 trees. To calculate out-of-bag error, each tree was grown using approximately two-thirds of the data. The remaining one-third of the data was used as test data. These test data were the 'out-of-bag' data and were used to evaluate the performance of the tree. The out-of-bag error estimates were averaged over all 100 runs to create a plot as shown in **Figure 2-3**. The point at which the out-of-bag error curve began to asymptote was considered to be the number of decision trees to include in the random forest because after this point, little gain was made in classification success with the addition of more trees.

Another output of the random forest analysis is the Gini variable importance index (Breiman 2001). The Gini variable importance index provides a measure of how strongly each variable contributes to the model predictions. The optimal subset of variables to include in each random forest was determined based on this importance index. Variable importance was averaged over all 100 runs described above. Different sets of variables were tested for each random forest model based on the variables that were shown to be most important to the model predictions.

Once the number of trees and the set of variables to include had been determined for a random forest model, all of the data were randomly divided into two equal subsets. One subset was used to train the random forest model and the other was used to test it. The datasets were then switched so that each dataset was used as both a test and a training dataset, and every whistle in the full dataset was classified. Data were divided such that all whistles from a single acoustic detection were in only one subset. This avoided whistles produced by one group or 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" if the percentage of trees voting for the predicted class exceeded a user-determined 'strong whistle threshold' (Oswald et al. 2011). Any whistle that was not strongly classified was omitted from the analysis. The choice of 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 strong whistle threshold was determined individually for each random forest model that was tested and ranged from 35 to 50 percent.

Several random forest models were created and tested. The first model classified whistles to species. Eight species were included in this model (false killer whale [*Pseudorca crassidens*], short-finned pilot whale [*Globicephala macroryhnchus*], bottlenose dolphin, pantropical spotted dolphin [*Stenella attenuata*], spinner dolphin [*Stenella longirostris*], striped dolphin [*Stenella coeruleoalba*] and short-beaked common dolphin [*Delphinus delphis*]). These species were included based on a list of species expected to occur in waters off Guam and the Mariana Islands (Fulling et al. 2011). Although short-beaked common dolphins are considered rare in the MISTCS study area, it is important to include them in the classifier. If not included, this species would be missed altogether and it would be impossible to investigate their occurrence in the MISTCS study area. Based on the confusion matrix produced by the eight species model, several other models were also tested. These included, but were not limited to:

1. A model that grouped false killer whales and short-finned pilot whales into a 'blackfish' class and classified all others to species.
2. A model that contained a blackfish class, a 'medium-sized delphinid' class (bottlenose and pantropical spotted dolphins) and classified the others to species.
3. A model that contained a blackfish class, a medium-sized delphinid class, a small delphinid class (spinner, striped and short-beaked common dolphins) and a rough-toothed dolphin class.

Classification success of each random forest model was evaluated by examining the percentage of individual whistles and overall detections that were correctly classified (by reference to visual species identifications), as well as the 'error reduction' provided by each classification model. Error reduction provides an unbiased measure of the performance of the classifier and is calculated as follows:

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

It 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 chance 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.

Patterns in misclassifications were also evaluated by examining confusion matrices for each classifier. Confusion matrices were created based on strongly classified whistles only. Two confusion matrices were produced; one for individual whistles and one for overall detections. Detections were classified based on the percentage of trees voting for the predicted species for all whistles combined within that detection.

2.2.2 Classification of MISTCS whistles

Whistle contours recorded during both sighted and non-sighted acoustic detections that were made using a towed hydrophone array during MISTCS were extracted and measured using ROCCA. Only detections (both sighted and non-sighted) that occurred more than 3 nautical miles (NM) from any other visual or acoustic detection were included in the analysis. This helped to ensure that the whistles analyzed were produced by the school in question and not by any other school in the area. Whistles recorded during MISTCS in the waters around Guam and the Northern Mariana Islands, where species identity was confirmed visually, were used to test the accuracy of the different classifiers created using ETP data. Acoustic detections that were not coupled with visual sightings or observations (non-sighted acoustic detections) were then run through the most accurate classifier in order to determine which species, or groups of species, were detected acoustically but not visually during the MISTCS.

2.3 Results

2.3.1 MISTCS whistle classification

Whistles were recorded during a total of 80 acoustic detections. Of these, 36 (45 percent) detections were matched to visual sightings (**Table 2-3, Figure 2-4**) and 44 (55 percent) were acoustic-only detections (**Figure 2-5**). A total of 1,122 whistles were measured from acoustic-only detections, ranging from 1 to 50 whistles per detection. Summary statistics describing the whistles of species that were detected both visually and acoustically are provided in **Table 2-4**, where the variables included were chosen to allow comparisons with previously published research.

2.3.2 Random Forest analysis

The confusion matrices for the eight-species random forest model created using ETP/HI data are shown in **Table 2-5**. 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 (ex. false killer whales and short-finned pilot whales). In an attempt to classify the greatest number of taxa to species, different models were tested, each containing a greater number of species groupings (see **Tables 2-6 to 2-8** for examples). Correct classification scores for these models are given in **Tables 2-6 to 2-8**. The model consisting of four classes (blackfish, medium-sized delphinids, small delphinids, and rough-toothed dolphin), 500 trees, and a strong whistle cutoff of 50 percent gave the best results (**Table 2-8**). Overall, 70 percent of detections were correctly classified using this model, compared to 50 percent, 52 percent, and 53 percent for the eight, seven and six class models, respectively. For all models, different feature vectors were tested based on the variable importance scores. In all cases, using all 56 variables gave the best classification results.

2.3.3 Classification of whistles recorded during MISTCS

When the whistles from the MISTCS acoustic detections that included visual confirmation of species identity (**Figure 2-4**) were run through the four different random forest models created from the ETP data, the model consisting of four classes (small delphinids, medium-sized delphinids, blackfish, and rough-toothed dolphin) gave the highest correct classification scores (**Table 2-9**). Consequently, this was the model used to classify whistles recorded during non-sighted acoustic detections (**Figure 2-5**). The percentage of trees voting for each species provides a measure of the certainty of the classification, with 25 percent expected to "vote" for each class based on chance alone. The percentage of trees voting for the predicted class ranged from 38 percent to 93 percent (**Table 2-10**). This was significantly greater than chance alone for every detection (chi-square test, $p<0.001$), suggesting that classifications were made based on real differences in the classes and not simply based on chance alone. Our confidence in the predicted species increases with the percentage of trees voting for that species. Based on our experience with this type of analysis, we consider a prediction to be relatively certain when the percent of trees voting for the predicted species is greater than 60 percent.

Another measure of the certainty of the classification is the distribution of tree votes among species. If the percentage of trees votes are similar for more than one class (e.g.,. if 45 percent of trees voted for 'medium delphinid' and 38 percent of trees voted for 'small delphinid'), the classification can be considered less certain than if the votes are overwhelmingly in favor of a single species or class. When more than 60 percent of trees voted for the predicted species, it was rare that another species had a similar percentage of tree votes (**Table 2-10**). All blackfish and rough-toothed dolphin classifications were considered relatively certain, based both on the percent of trees voting for the predicted species and on the distribution of tree votes. Sixty percent of small delphinid classifications and one out of the three medium delphinid classifications were considered relatively certain based on the distribution of tree votes among species (**Table 2-10**).

Over half (56 percent) of non-sighted detections were classified as blackfish (**Figure 2-6**). The next most common predicted class was small delphinids. Both medium-sized delphinids and rough-toothed dolphins were also represented in the non-sighted detection subsample. Two of the non-sighted acoustic detections could not be classified because they each contained only one whistle of sufficient quality for analysis, and that whistle did not meet the strong whistle cutoff threshold when it was run through the classifier.

2.4 Discussion

Correct classification scores were higher overall for the four-class random forest model (**Table 2-8**) than they were for the eight-class random forest model (**Table 2-5**). This is partially due to there being fewer categories in the four-class random forest model. The likelihood of correct classification simply by chance alone increases as the number of classes decreases. However, the improvement is also partially because the classes in the four-class random forest model were created based on confusion matrices. Species that were commonly confused as each other were grouped into classes (such as 'blackfish' or 'small delphinid'). Eliminating these sources of confusion led to improved classification success. For example, the confusion matrix in **Table 2-5a** shows that for short-finned pilot whales, 37 percent of whistles were correctly classified as short-finned pilot whales, while 49 percent of whistles were misclassified as false killer whales. Short-finned pilot whale whistles were rarely classified as anything else. Similarly, 70 percent of false killer whale whistles were correctly classified and 21 percent of false killer whale whistles were misclassified as short-finned pilot whales. These misclassifications are likely due to the similar frequency characteristics in whistles produced by these two species (**Table 2-2**). Short-finned pilot whale and false killer whale whistles are also less complex than many whistles produced by other species (i.e. the whistles have few inflection points and steps, and cover a narrow frequency range). The fact that these two species were most commonly misclassified as each other led to grouping them into one 'blackfish' class in subsequent classification models. Grouping these species into a 'blackfish' class also makes sense evolutionarily, as false killer whales and short-finned pilot whales are more closely related to each other than they are to the other delphinids included in the random forest.

Other species groupings included a 'small delphinid' class and a 'medium delphinid' class. The small delphinid class included spinner, striped and short-beaked common dolphins, and these species were commonly misclassified as one another. All of the species within the small delphinid class had similar frequency characteristics, likely leading to some of the confusion among these classes. Spinner and striped dolphins are in the same genus (*Stenella*), which may contribute to similarity among their whistles, but more research needs to be done before this can be stated conclusively. Spinner dolphin whistles were especially likely to be misclassified as not only striped and short-beaked common dolphins, but also as bottlenose, pantropical spotted, and rough-toothed dolphins (**Table 2-5**). Spinner, bottlenose, and pantropical spotted dolphins are the three species in the analysis with the highest maximum frequencies. As maximum frequency was the most important variable in the random forest, similar maximum frequencies explain at least some of the misclassification among these species. The fact that spinner dolphin whistles were also misclassified as rough-toothed dolphins is a little more difficult to explain. Qualitatively, rough-toothed dolphins commonly produce whistles with relatively flat slopes and several steps. Spinner dolphins also occasionally produce whistles that fit that description. It is possible that these whistles are distinctive to rough-toothed dolphins and when another species produces them, they are automatically classified as rough-toothed dolphin whistles. This would be an interesting and valuable avenue of future research.

The two species in the 'medium delphinid' class (bottlenose and pantropical spotted dolphins) had similar minimum and maximum frequencies and similar body sizes. Ding et al. (1995a) and Matthews et al. (1999) both found a negative correlation between body length and frequency characteristics of whistle contours for nine odontocete species. Frequency variables were important features in all of the random forest classifiers tested in this study, and so grouping species based on body size seemed reasonable. Based on the Gini variable importance index, maximum frequency was one of the most (if not the most) important variables in all of the random forest models tested here. Other frequency variables also ranked near the top of the variable importance index, including: mean frequency, center frequency, beginning and ending frequency and frequency at one-fourth, one-half, and three-fourths of the duration. Other variables that were consistently important in the random forest were variables related to the slope of the whistle, such as mean slope, and mean negative slope.

It is interesting to note that although rough-toothed dolphins were not grouped with any other species in any model, the percentage of their whistles correctly classified was higher for the four class random forest than it was for the eight class random forest. This is likely because most misclassified rough-toothed dolphin whistles were misclassified in the eight-class model as either short-finned pilot whales or false killer whales (**Table 2-5a**). Grouping short-finned pilot whales and false killer whales into one 'blackfish' class resulted in a more distinct class, as evidenced by the high correct classification score for this class. The increased distinctiveness of this class also resulted in fewer rough-toothed dolphin whistles being misclassified as blackfish.

Correct classification scores were generally higher for detections than they were for individual whistles. This was especially true for short-beaked common dolphins, where 22 percent of individual whistles were correctly classified compared to 40 percent of detections (**Table 2-6**). This can be explained by the method used to classify detections. For individual whistles, the whistle was classified as the species that the greatest number of trees voted for. To classify a detection, the number of trees voting for each species was summed over all of the whistles within that detection. For short-beaked common dolphins, the number of votes for the correct species was often lower than, but still close to, the number of votes for the predicted species. The predicted species varied, however, from whistle to whistle. Because of this, when votes were summed over all whistles, short-beaked common dolphin had the highest number of votes more often than it did for individual whistles.

Most (56 percent) of the non-sighted acoustic detections that occurred during the MISTCS were classified as blackfish. Based on results from the ETP training dataset (95 percent of blackfish schools classified correctly, **Table 2-8**) and on results of running MISTCS-sighted acoustic detections through the four-class random forest model (100 percent of blackfish schools classified correctly, **Table 2-9b**), we have a high degree of confidence in the non-sighted blackfish classifications.

During the MISTCS, one school of melon-headed whales (*Peponocephala electra*) was sighted and after running the whistles recorded during that sighting through the four-class random forest model, the acoustic detection was correctly classified as blackfish. This suggests that the blackfish class could be considered representative of whistles from other species of blackfish and not only applicable to short-finned pilot whales and false killer whales. The whistles recorded during the encounter with melon-headed whales had similar characteristics to those recorded from short-finned pilot whales and false killer whales (i.e., the whistles were relatively low frequency, had few inflection points and steps, and had a narrow frequency range). However, it is important to note that this analysis is based on only one detection of a group of melon-headed whales. Additional visually-confirmed acoustic detections of this and other blackfish species (e.g., pygmy killer whale, *Feresa attenuata*) are necessary in order to determine if these results will hold for other species of blackfish.

It is plausible that most non-sighted acoustic detections were blackfish, as these species often travel in small sub-groups and surface inconspicuously (Barlow and Rankin 2007), making them difficult to detect visually in high Beaufort sea states such as those often encountered during MISTCS. In addition, blackfish are very active acoustically (Barlow and Rankin 2007) and produce whistles that are relatively low frequency and, thus, propagate efficiently under water. All of these characteristics of blackfish whistles make them well suited to acoustic detection and classification methods. During two unrelated visual and acoustic cetacean surveys by the National Oceanic and Atmospheric Administration (NOAA) that took place within the Hawaiian Exclusive Economic Zone (EEZ) and adjacent waters south to Palmyra and Johnston atolls, there were twice as many acoustic detections of false killer whales as there were visual detections (Barlow et al. 2004, 2008; Barlow and Rankin 2007, Barlow et al. 2008).

The percentages of schools correctly classified in both the ETP test data and the MISTCS sighted acoustic detection dataset were not quite as high for the other three classes (small delphinids, medium delphinids and rough-toothed dolphins) as they were for the blackfish class. However, they were all significantly greater than expected by chance alone (**Tables 2-8 and 2-9b**). In addition, the proportion of trees voting for the predicted class was significantly greater than chance for every non-sighted acoustic detection (**Table 2-10**). Based on this and on the distributions of tree votes among species, we believe that the non-sighted acoustic detection classification results can be considered very reliable for these groups as well.

It is important to note that the classifier used to identify whistles recorded in the waters surrounding Guam and the Northern Mariana Islands was created using data collected in the ETP and the waters surrounding the Hawaiian Islands. Geographic variation has been found in the whistles of some species (e.g., Baron et al. 2008, Morisaka et al. 2005, Rendell et al. 1999, Ding et al. 1995b), and so it is possible that a classifier created using whistles collected in the MISTCS study area would produce better results. We were unable to fully test the classifier on whistles collected during MISTCS because not every species included in the classifier was represented in the dataset of MISTCS recordings with visual confirmation of species identity (as expected, short-beaked common dolphins were not observed). In addition, species that were represented in the MISTCS dataset had relatively small sample sizes (i.e. independent detection events). Because of this, we were unable to statistically compare the descriptive statistics presented for the ETP and MISTCS datasets. Such a comparison would provide another means for evaluating how accurately a classifier created using ETP data can predict species in recordings collected around Guam and the Northern Mariana Islands. Larger sample sizes would produce results that could be generalized with a higher degree of confidence.

While classifying whistles to a group of species such as ‘small delphinid’ or ‘blackfish’ is useful, it would be beneficial to be able to classify whistles to species with a high degree of confidence. Extensive work has been conducted to develop species-specific classifiers for delphinid whistles (e.g., Matthews et al. 1999, Rendell et al. 1999, Oswald et al. 2007, Roch et al. 2007, Gannier et al. 2010). To create a species-specific classifier for the MISTCS study area would require visually validated recordings from every whistling species that could be encountered in this area. A large enough sample size to provide both training and test data would also be required. In addition, although the set of variables used to classify whistles to four classes worked well, these may not be the optimal variables for classifying whistles to species. Additional or alternate variables that can be measured from tonal signals should be explored in order to find a set that may allow for more detailed classification. Variables related to the relative intensities of different frequencies may prove useful, as well as variables that describe the overall form of an acoustic encounter (such as the number of whistles recorded, the amount of overlap among whistles in the time domain, and the time between subsequent whistles).

2.5 Conclusions and Recommendations

Of all of the classifiers that were tested, the four-class (small delphinids, medium delphinids, blackfish, rough-toothed dolphins) classifier produced the best results. When this classifier was applied to non-sighted acoustic detections that occurred during MISTCS, most (56 percent) were classified as blackfish. The ability to identify detections that did not have concurrent visual observations makes it possible to obtain information that has been unavailable until now on the distribution and occurrence of species.

While the results of this study provide important information, the ability to identify detections to species, rather than to groups such as “small delphinids” or “blackfish” would be advantageous. In addition, while we were able to test the classifier on some species recorded in the Guam/Mariana Islands study area, we were not able to test it on every species, as visually validated recordings do not exist for every species that may be encountered in the study area. The inability to fully test the classifier on data collected in this study area leaves gaps in our knowledge. With additional visually validated recordings from the Guam and Mariana Islands study area, we would be able to fully test the ETP/HI classifier and determine whether it is truly applicable to these data. In addition, the collection of visually validated data would allow us to include whistles from this study area into the ETP/HI classifier, or if necessary, to create an entirely new classifier containing only whistles from this study area. Comparisons of the whistles produced by species found in both the ETP/HI and the Guam/Mariana Islands study area would also allow us to determine whether a new classifier needs to be created. When the classifier can be fully tested and optimized, it will provide a tool for analyzing data collected using towed hydrophone arrays, seafloor mounted acoustic recorders and sonobuoys. 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.

Future research should include efforts to improve the performance of the classifier. Several approaches should be investigated. First, an examination of the characteristics of whistles that are strongly classified for each species could illuminate variables that are important and distinctive to different species. Similarly, an investigation of whistles that are weakly classified could highlight problems and provide insight into why misclassifications occur. Second, additional or alternate features should be explored for inclusion in the classification analysis. The feature vector used here may not be the optimal vector for classification of delphinid whistles. Other variables such as amplitude of whistles, density of whistles and overlap among whistles could provide greater separation among species. In addition, analysis methods other than spectrographic analysis (such as wavelet analysis) could provide entirely different feature vectors that may provide greater classification success. Finally, alternate classification methods should be explored. The use of classification algorithms such as artificial neural networks, hidden Markov models and support vector machines in conjunction with, or instead of, random forests could lead to higher correct classification scores.

Although it was not possible to classify all whistles to species, even classifying them to broader categories has provided new and important information that is useful in understanding the occurrence and distribution of cetaceans in the MISTCS study area. Due to the remote location of this study area, as well as the challenging visual survey conditions typically encountered in the region, there is a paucity of information on species occurrence and distribution. The ability to identify the presence of “small delphinids,” “medium delphinids,” “blackfish,” and rough-toothed dolphins 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 MISTCS study area. Finally, this project represents a step forward in the development of a classifier specific to the MISTCS study area. A classifier specific to this area will 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 that are associated with them.

2.6 Tables and Figures

2.6.1 Tables

Table 2-1. Number of whistles and number of schools that whistles were recorded from for each delphinid species in the ETP whistle dataset.

Species	# of whistles	# of schools
Bottlenose dolphin (*Tursiops truncatus*)	155	8
Short-beaked common dolphin (*Delphinus delphis*)	226	20
False killer whale (*Pseudorca crassidens*)	309	9
Short-finned pilot whale (*Globicephala macrorhynchus*)	109	12
Pantropical spotted dolphin (*Stenella attenuata*)	297	18
Rough-toothed dolphin (*Steno bredanensis*)	145	12
Striped dolphin (*Stenella coeruleoalba*)	452	36
Spinner dolphin (*Stenella longirostris*)	170	15

Table 2-2. Summary statistics (means and standard deviations) for a subset of the variables measured from whistles recorded in the ETP.

The variables included in this table were chosen to allow comparison with previous research. Frequency variables are given in Hz and duration is in seconds.

Species		Begin Hz	End Hz	Minimum (Min) Hz	Maximum (Max) Hz	Frequency Range	Duration	# of Steps	# of Inflection Points
Short-finned pilot whale	Mean	5466.4	6879.6	4673.3	7867.5	3194.2	0.5	0.3	0.9
	SD	3347.4	4466.5	2444.5	4831.0	3328.9	0.3	1.1	2.0
False killer whale	Mean	5902.5	6463.1	5423.2	7132.0	1708.8	0.4	0.0	0.9
	SD	1387.7	1599.2	1220.0	1627.2	1343.3	0.2	0.1	0.9
Pan tropical spotted dolphin	Mean	10106.3	15345.6	8496.3	18119.9	9624.2	0.7	2.7	1.1
	SD	4214.9	5938.1	2582.5	5147.9	5334.1	0.4	3.5	1.2
Striped dolphin	Mean	11439.1	12268.1	8870.6	15279.9	6408.2	0.6	1.7	1.6
	SD	4096.9	3476.2	2308.1	3414.9	3250.8	0.3	2.6	2.3
Spinner dolphin	Mean	12975.3	13674.6	10688.1	16307.8	5625.8	0.6	0.9	1.7
	SD	4706.2	4719.5	3326.1	4815.4	3859.2	0.4	1.8	2.9
Rough-toothed dolphin	Mean	7885.4	8234.8	6631.9	9764.7	3132.9	0.7	1.5	3.0
	SD	3156.2	2806.4	2157.5	2824.3	1919.0	0.3	1.9	2.9
Bottle-nose dolphin	Mean	12298.4	11486.2	8446.0	16998.9	8550.8	0.9	1.2	2.0
	SD	5765.3	5484.3	2666.0	5561.1	5357.2	0.6	2.3	2.0
Short-beaked common dolphin	Mean	12333.6	12484.6	8677.9	15590.6	6915.0	0.7	2.1	1.8
	SD	4996.2	4539.5	2756.7	4606.0	4126.0	0.4	2.5	2.0

Table 2-3. Number of acoustic detections in the MISTCS study area that were matched with visual observations by species, as well as the number of whistles measured for each species.

Species	# of detections	# of whistles measured
Short-finned pilot whale	2	67
False killer whale	8	400
Melon-headed whale	1	50
Pantropical spotted dolphin	12	199
Striped dolphin	9	257
Spinner dolphin	1	50
Rough-toothed dolphin	1	4
Bottlenose dolphin	2	57

Table 2-4. Summary statistics (means and standard deviations) for a subset of the variables measured from whistles recorded during MISTCS sighted acoustic detections.

The variables included in this table were chosen to allow comparison with previous research. Frequency variables are given in Hz and duration is in seconds

Species		Begin Hz	End Hz	Min Hz	Max Hz	Frequency Range	Duration	# of Steps	# of Inflection Points
Short-finned pilot whale	Mean	5100.3	5360.5	4556.0	5937.0	1381.1	0.4	0.1	1.0
	SD	3784.9	3386.7	3305.3	3677.5	1442.8	0.2	0.4	1.3
False killer whale	Mean	6823.1	7098.5	6041.1	7916.1	1875.0	0.4	0.2	2.3
	SD	1710.8	1963.4	1511.3	1751.5	1592.8	0.2	0.6	2.5
Melon-headed whale	Mean	8737.5	8852.8	7394.1	10042.5	2648.4	0.5	0.3	1.7
	SD	3396.1	3608.6	2914.3	3558.9	2186.5	0.3	1.2	1.6
Pantropical spotted dolphin	Mean	10905.2	13797.5	9741.5	16393.1	6651.5	0.6	0.1	1.1
	SD	3995.1	5894.5	3078.3	6431.2	4922.0	0.3	0.3	1.2
Striped dolphin	Mean	9669.6	11024.9	8301.6	12612.3	4310.7	0.6	0.3	1.7
	SD	3645.1	4450.1	2596.1	4773.8	3604.8	0.3	1.2	2.0
Spinner dolphin	Mean	14085.9	13605.9	11281.9	20037.2	8755.3	0.9	0.0	1.9
	SD	3831.0	3818.2	2569.3	2959.5	3189.5	0.3	0.1	1.6
Rough-toothed dolphin	Mean	4921.9	5355.5	4722.7	5578.1	855.5	0.1	0.3	0.5
	SD	597.8	594.6	508.3	357.0	505.4	0.0	0.5	0.6
Bottle-nose dolphin	Mean	8718.8	9024.7	8278.1	9409.1	1131.0	0.5	0.0	2.1
	SD	3093.1	3124.1	2888.1	3267.0	766.0	0.2	0.0	1.7

Table 2-5. Confusion matrices (percentages of classification) for (a) individual whistles and (b) detections.

Percent of whistles or detections correctly classified are in bold and underlined. Eight-species random forest model was trained and tested using ETP data, and consisted of 800 trees and 56 variables. Results are based on a strong whistle threshold of 35 percent.

Actual species	% classified as								
	Bottle-nose dolphin	Short-beaked common dolphin	False killer whale	Spotted dolphin	Pilot whale	Rough-toothed dolphin	Striped dolphin	Spinner dolphin	n
(a). Individual Whistles									
Bottlenose dolphin	**<u>51</u>**	4	3	20	2	7	5	8	74
Short-beaked common dolphin	8	**<u>40</u>**	2	11	0	11	7	21	63
False killer whale	1	2	**<u>70</u>**	0	21	4	0	2	98
Spotted dolphin	16	20	3	**<u>42</u>**	0	1	4	14	81
Short-finned pilot whale	1	1	49	1	**<u>37</u>**	3	5	3	98
Rough-toothed dolphin	3	3	13	0	10	**<u>65</u>**	3	3	68
Striped dolphin	0	18	3	5	0	6	**<u>58</u>**	10	73
Spinner dolphin	12	18	5	17	3	12	13	**<u>20</u>**	76
(b). Detections									
Bottlenose dolphin	**63**	12	12	0	0	0	0	13	8
Short-beaked common dolphin	6	**41**	0	12	0	6	18	17	17
False killer whale	0	0	**89**	0	11	0	0	0	9
Pantropical spotted dolphin	13	13	7	**47**	0	0	0	20	15
Short-finned pilot whale	0	8	58	0	**26**	8	0	0	12
Rough-toothed dolphin	9	0	9	0	9	**64**	9	0	11

Striped dolphin	0	25	4	8	0	13	**42**	8	24
Spinner dolphin	15	15	0	8	8	8	15	**31**	13

Table 2-6. Percent of individual whistles and detections that were correctly classified and error reduction analysis using ETP test data.

The random forest consisted of 7 classes, 700 trees and 56 variables. The 'blackfish' class contained false killer whales and short-finned pilot whales. Correct classification scores were calculated using a strong whistle threshold of 35 percent. Overall, 48 percent of individual whistles and 52 percent of detections were correctly classified using this model. Correct classification expected by chance was 14.3 percent.

Species	% of whistles correctly classified	Error reduction	n	% of detections correctly classified	Error reduction	n
Bottlenose dolphin	53	45	104	63	57	8
Short-beaked common dolphin	22	9	87	40	30	18
Blackfish	87	85	142	84	81	19
Pantropical spotted dolphin	43	34	92	50	42	16
Rough-toothed dolphin	63	57	106	67	62	12
Striped dolphin	43	34	90	41	31	31
Spinner dolphin	28	16	123	21	8	14

Table 2-7. Percentages of individual whistles and detections that were correctly classified and error reduction using ETP test data.

The random forest consisted of 6 classes, 700 trees and 56 variables. The 'blackfish' class contained false killer whales and short-finned pilot whales, the 'medium-sized delphinid' class contained bottlenose and pan-tropical spotted dolphins. Correct classification scores were calculated using a strong whistle threshold of 35 percent. Overall, 52 percent of individual whistles and 53 percent of detections were correctly classified using this model**.** Correct classification expected by chance was 16.7 percent.

Species	% of whistles correctly classified	Error reduction	n	% of detections correctly classified	Error reduction	n
Medium-sized delphinids	54	45	104	52	42	25
Short-beaked common dolphin	28	14	112	47	36	19
Blackfish	84	81	141	100	100	18
Rough-toothed dolphin	68	62	111	50	40	12
Striped dolphin	47	36	100	44	33	32
Spinner dolphin	30	16	125	25	10	12

Table 2-8. Percentages of individual whistles and detections that were correctly classified and error reduction using ETP test data.

The random forest consisted of 4 classes, 500 trees and 56 variables. The "blackfish" class contained false killer whales and pilot whales, the "medium-sized delphinid" class contained bottlenose and pan-tropical spotted dolphins and the 'small delphinids' class contained spinner, striped and short-beaked common dolphins. Correct classification scores were calculated using a strong whistle threshold of 50 percent. Overall 72 percent of individual whistles and 70 percent of schools were correctly classified using this model. Correct classification expected by chance was 25 percent.

Species	% of whistles correctly classified	Error reduction	n	% of detections correctly classified	Error reduction	n
Medium-sized delphinids	62	49	115	60	47	25
Small delphinids	62	49	122	57	43	47
Blackfish	91	88	128	95	93	19
Rough-toothed dolphin	71	61	101	67	56	12

Table 2-9. Correct classification scores (percent cc = percent correctly classified) and error reduction (error reduct) for individual whistles and detections recorded during acoustic detections that had visual confirmation of species identity.

Results are given for individual whistles ("whistles" columns) and overall acoustic detections ('detections' columns) a) the eight class random forest model contained eight species and correct classification expected by chance was 12.5 percent. The seven-class model contained six species and a 'blackfish' class and correct classification expected by chance was 14.3 percent. b) The six class model contained four species, a blackfish class and a "medium-sized delphinid" class and correct classification expected by chance was 16.7 percent. The four class model contained blackfish, medium-sized delphinids, small delphinids and rough-toothed dolphins and correct classification expected by chance was 25 percent.

a) Eight and seven class random forest model.

Species	Eight class model						Seven class model					
	whistles			detections			whistles			detections		
	% cc	error reduct	n	% cc	error reduct	n	% cc	error reduct	n	% cc	error reduct	n
Bottlenose dolphin	8	-5	37	0	0	2	9	-6	46	0	0	2
Short-beaked common dolphin	n/a	0	0	n/a	n/a	0	n/a	n/a	0	n/a	n/a	0
False killer whale	60	54	287	100	100	8	see blackfish class					
Pantropical spotted dolphin	37	28	154	58	52	12	22	9	172	36	25	11
Short-finned pilot whale	70	66	60	100	100	2	see blackfish class					
Rough-toothed dolphin	0	0	3	0	0	1	0	0	4	0	0	1
Striped dolphin	8	-5	128	13	0.5714	8	34	23	193	56	49	9
Spinner dolphin	32	22	37	0	0	1	33	22	46	0	0	0
Blackfish	n/a	n/a	n/a	n/a	n/a	n/a	69	64	456	100	100	11
Medium delphinid	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Small delphinid	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

b) Six and four class model.

Species	Six class model						Four class model					
	whistles			detections			whistles			detections		
	% cc	error reduct	n	% cc	error reduct	n	% cc	error reduct	n	% cc	error reduct	n
Bottlenose dolphin	see medium delphinid class						see medium delphinid class					
Short-beaked common dolphin	n/a	n/a	0	n/a	n/a	0	see small delphinid class					
False killer whale	see blackfish class						see blackfish class					
Spotted dolphin	see medium delphinid class						see medium delphinid class					
Pilot whale	see blackfish class						see blackfish class					
Rough-toothed dolphin	0	0	4	0	0	1	0	0	4	0	0	1
Striped dolphin	21	5	159	44	33	9	see small delphinid class					
Spinner dolphin	32	18	75	50	40	2	see small delphinid class					
Blackfish	73	68	376	100	100	10	74	65	388	100	100	11
Medium delphinid	29	15	191	54	45	13	38	17	222	57	43	14
Small delphinid	n/a	n/a	n/a	n/a	n/a	n/a	42	23	233	60	47	10

Table 2-10. Predicted species and the percentages of trees voting for each class for non-sighted acoustic detections.

Predicted species based on the four-class random forest model with a 50 percent strong whistle threshold. "Ambig" means that the detection could not be classified because there were no strong whistles present. Detection ID is the identification number assigned to the acoustic detection during MISTCS. The class receiving the highest percent of tree votes is indicated in bold. Cases where the classification can be considered relatively certain are highlighted in yellow or blue. Yellow denotes cases where the percent of tree votes is greater than 60 percent and blue denotes cases where the classification can be considered relatively certain based on the distribution of tree votes. Codes in the "predicted species" column are: Md = medium-sized delphinid, Sd = small delphinid, Bf = blackfish, and Sb = rough-toothed dolphin.

Detection id	# whistles	# strong whistles	Predicted species	% tree votes			
				Medium delphinid	Small delphinid	Black-fish	Rough-toothed dolphins
A007_S999	30	27	Bf	2.8	4.4	**81.5**	11.3
A015_S999	5	5	Sb	5.9	23.2	9.4	**61.6**
A019_S999	15	14	Bf	0.4	1.0	**90.1**	8.4
A020_S999	20	9	Md	**45.6**	38.5	4.3	11.6
A023_S999	21	19	Sd	40.3	**55.5**	0.3	4.0
A025_S999	16	9	Sd	20.4	**38.1**	30.5	11.0
A027_S999	30	22	Sd	23.3	**39.4**	7.0	30.3
A036_S999	10	6	Sd	40.5	**46.3**	1.6	11.6
A037_S999	1	0	Ambig	0.0	0.0	0.0	0.0
A042_S999	1	1	Bf	26.2	14.4	**50.4**	9.0
A043_S999	10	5	Sb	6.9	27.8	20.8	**44.6**
A044_S999	30	30	Bf	1.5	2.3	**78.8**	17.4
A047_S021	48	39	Bf	3.9	7.4	**71.2**	17.5
A049_S026	25	20	Bf	8.1	21.7	**50.5**	19.7
A052_S999	30	27	Bf	3.3	5.3	**69.4**	22.0
A056_S999	7	5	Bf	22.1	14.7	**57.3**	6.0
A059_S999	9	7	Sb	4.9	14.3	18.4	**62.5**
A065_S999	50	42	Bf	4.0	10.0	**56.7**	29.3
A085_S042	50	45	Bf	3.9	4.9	**73.8**	17.4
A086_S999	30	15	Sd	32.0	**53.1**	6.9	8.0

Detection id	# whistles	# strong whistles	Predicted species	% tree votes			
				Medium delphinid	Small delphinid	Black-fish	Rough-toothed dolphins
A099_S999	18	10	Sd	30.8	**59.0**	2.1	8.1
A100_S999	50	41	Bf	3.0	6.0	**72.5**	18.5
A101_S999	50	19	Sd	33.8	**57.1**	1.5	7.6
A102_S999	30	22	Bf	4.0	3.8	**79.2**	13.0
A104_S999	48	38	Bf	2.8	4.3	**79.0**	13.9
A112_S999	30	23	Sd	22.9	**45.9**	11.4	19.8
A126_S999	16	14	Bf	2.1	3.6	**81.0**	13.3
A127_S074	30	23	Bf	2.1	4.1	**79.5**	14.2
A129_S999	7	3	Bf	5.3	5.5	**73.7**	15.6
A136_S089	50	45	Bf	2.6	4.2	**76.7**	16.5
A149_S999	14	11	Sd	36.4	**50.4**	8.3	4.9
A168_S999	9	6	Sb	3.1	20.5	5.3	**71.1**
A169_S999	4	4	Md	**63.3**	35.4	0.2	1.1
A180_S999	50	41	Bf	3.5	4.5	**76.8**	15.3
A187_S999	8	8	Bf	0.4	3.6	**76.2**	19.9
A194_S999	13	6	Bf	7.8	11.6	**53.4**	27.2
A196_S999	17	17	Bf	4.9	8.6	**79.8**	6.7
A205_S999	50	44	Bf	4.0	5.2	**66.8**	24.0
A212_S999	50	38	Bf	3.4	6.4	**73.5**	16.7
A999_S028	1	0	Ambig	0.0	0.0	0.0	0.0
A999_S053	3	3	Bf	0.6	0.6	**93.3**	5.5
A999_S999a	14	12	Bf	2.7	4.5	**78.6**	14.3
A999_S999b	9	9	Bf	6.2	10.5	**61.3**	22.0
A999_S999c	30	25	Sd	27.5	**52.2**	8.6	11.7
A999_S999d	19	17	Md	**52.6**	42.0	1.3	4.1

2.6.2 Figures

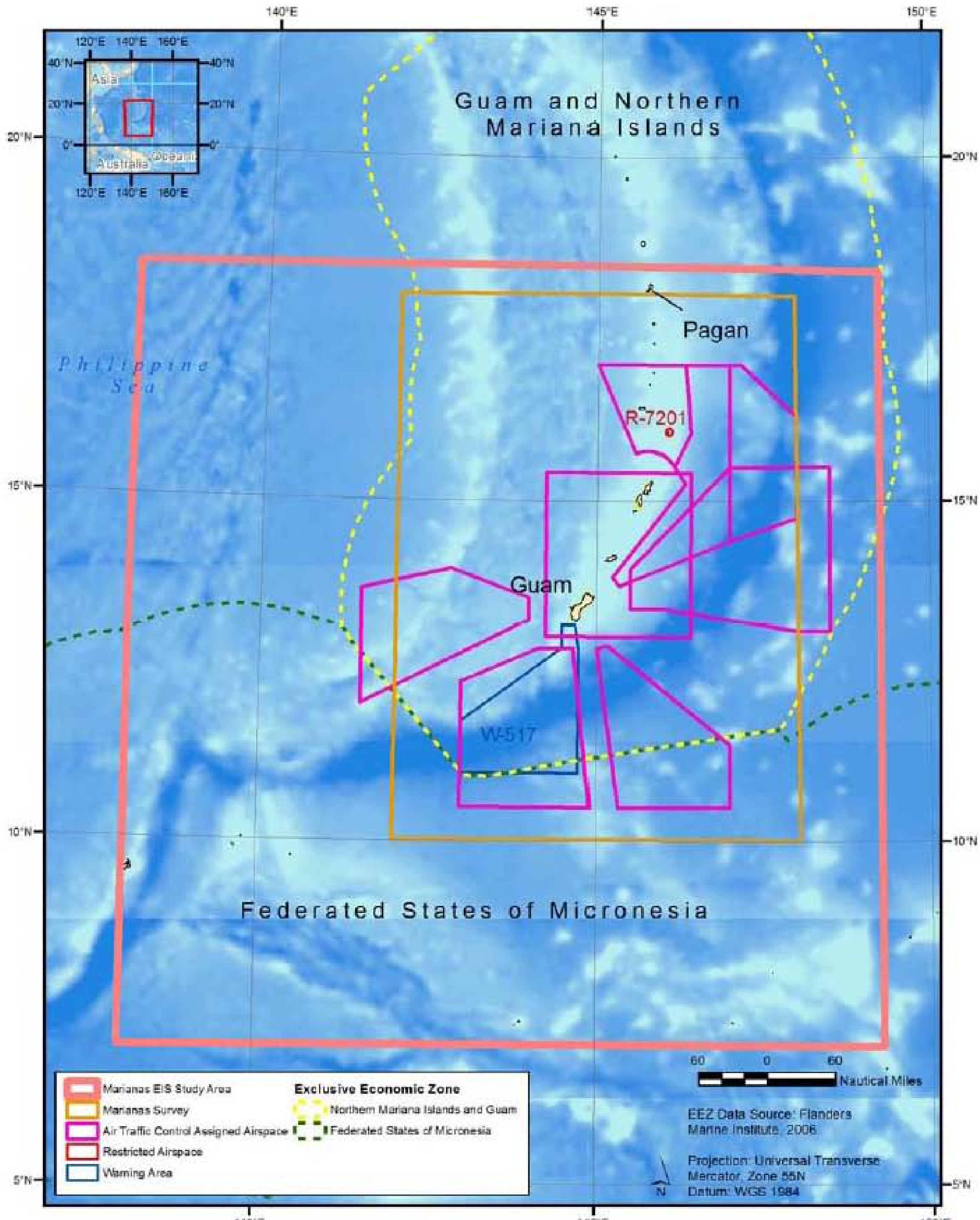


Figure 2-1. MISTCS study area (tan colored box) and Mariana Island EIS study area (peach colored box) including the Commonwealth of the Northern Mariana Islands (from Don 2007).

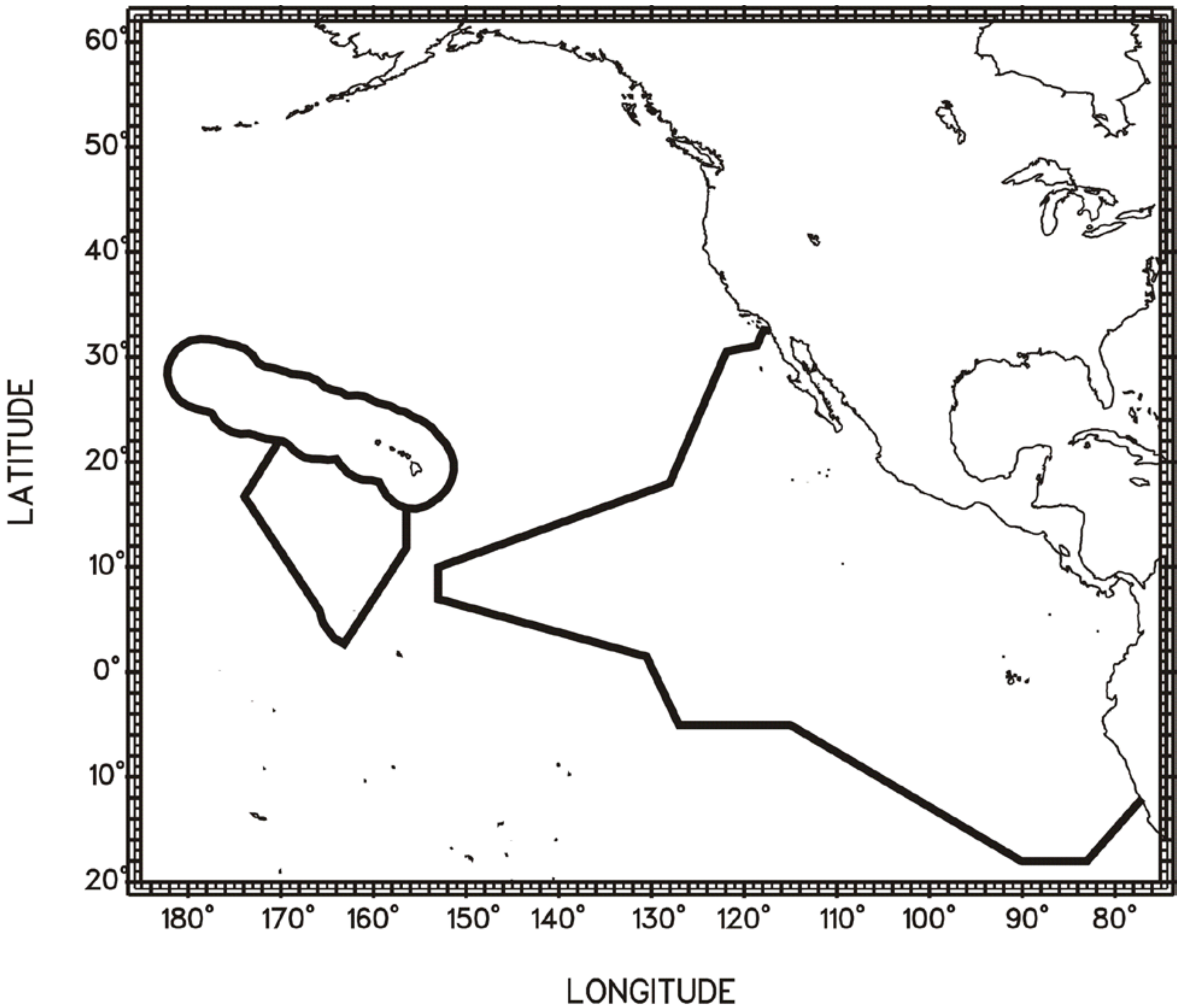


Figure 2-2. Pacific Ocean study area boundaries for the STAR 2000, 2003, and 2006, HICEAS 2002 and PICEAS 2005 visual and acoustic marine mammal abundance surveys.

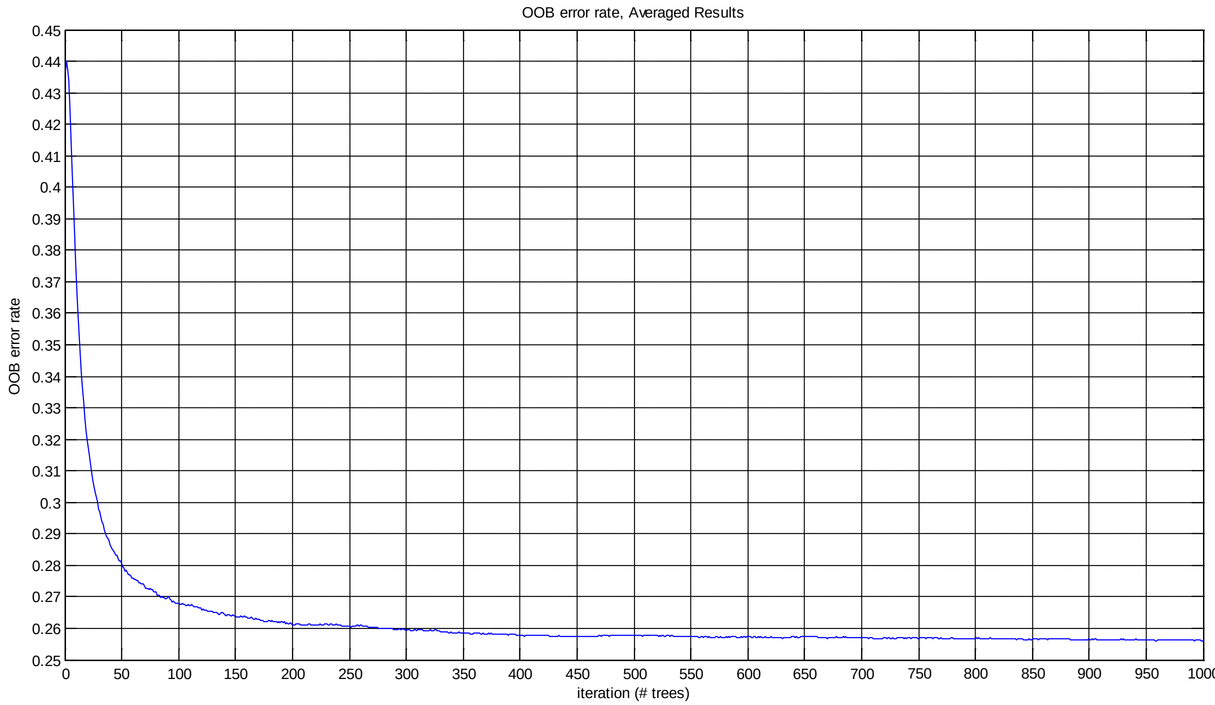


Figure 2-3. Out-of-bag error rate vs. number of trees in the random forest.

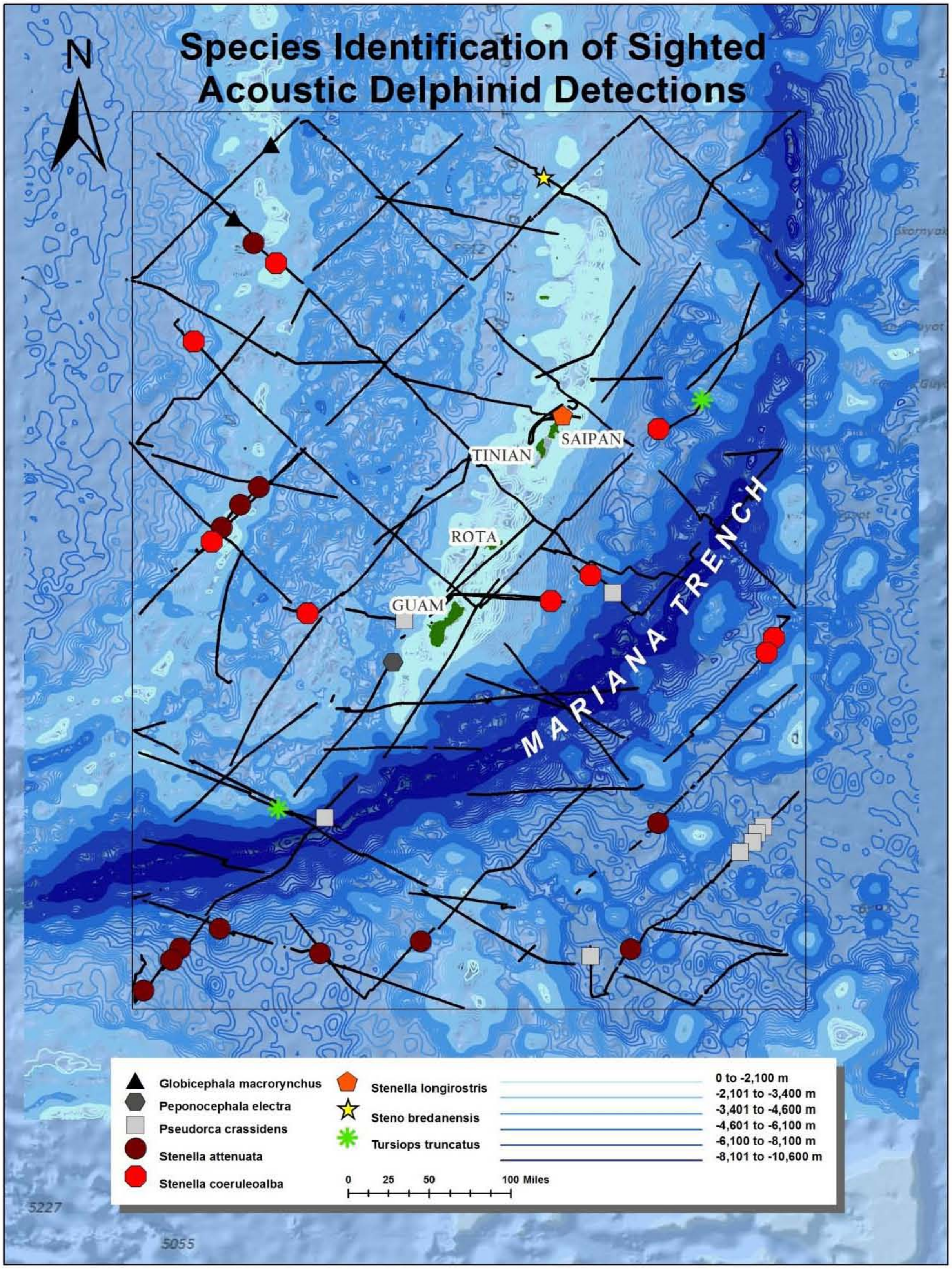


Figure 2-4. Sighted delphinid detections.

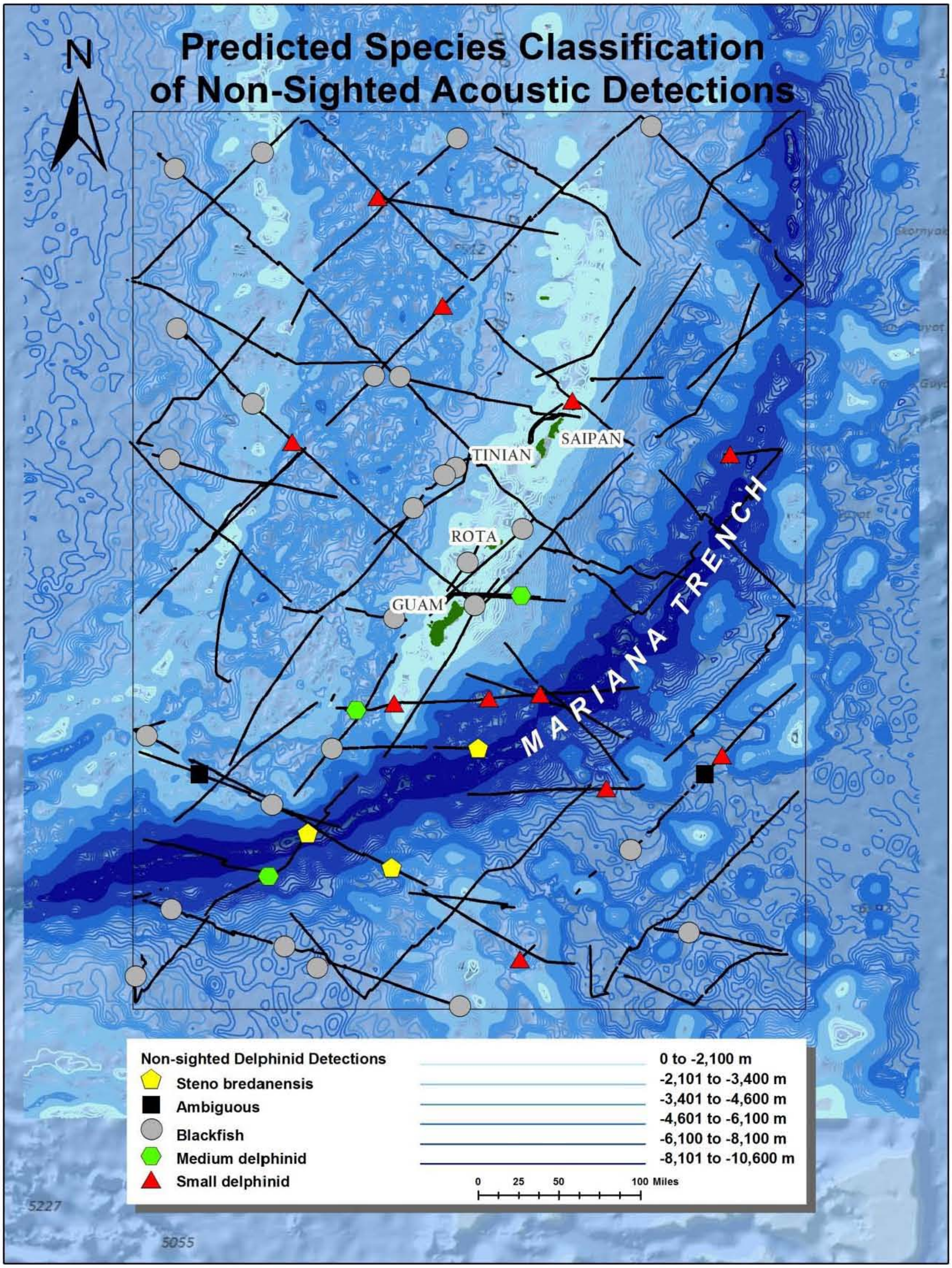


Figure 2-5. Predicted delphinid detections.

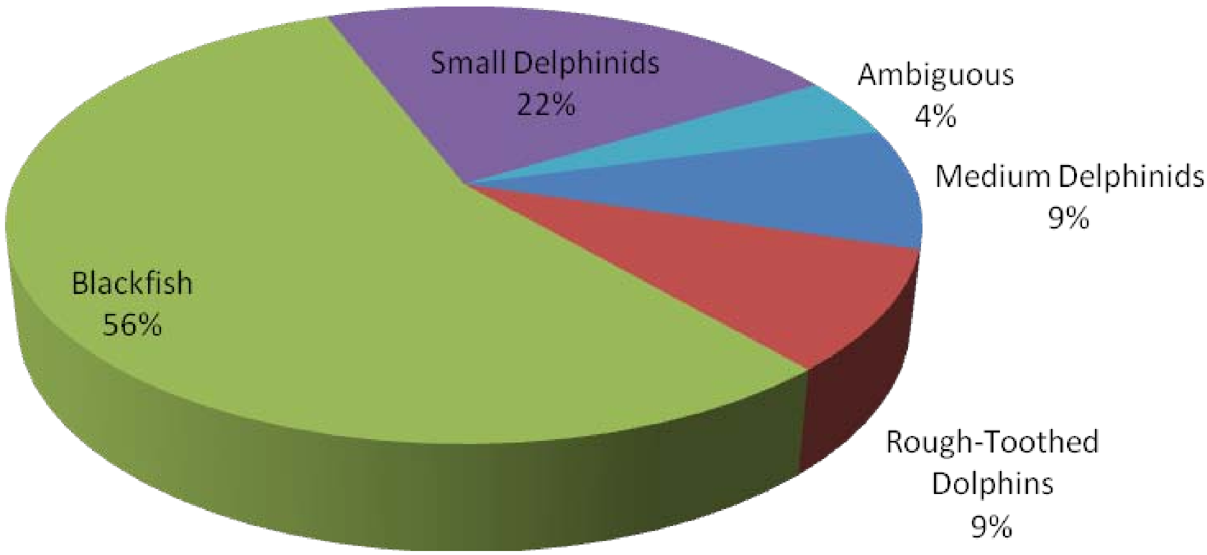


Figure 2-6. Distribution of species predictions for non-sighted acoustic detections. Predicted species are based on the four-class random forest model with a 50 percent strong whistle threshold. "Ambiguous" means that the detection could not be classified because there were no strong whistles present.

2.7 Literature cited

Au, W.W.L. 1980. Echolocation signals of the Atlantic bottlenose dolphin (*Tursiops truncatus*) in open waters. Pages 251-282 in: R.G. Busnel and J.F. Fish, eds. *Animal sonar systems*., eds. Plenum Press, New York.

Au, W.W.L. 1993. *The sonar of dolphins*. Springer-Verlag, New York.

Bachorowski, J. and M.J. Owren. 1999. Acoustic correlates of talker sex and individual talker identity are present in a short vowel segment produced in running speech. *Journal of the Acoustical Society of America* 106:1054-1063.

Barlow, J. and S. Rankin. 2007. *False killer whale abundance and density: Preliminary estimates for the PICEAS study area south of Hawaii and new estimates for the US EEZ around Hawaii*. Southwest Fisheries Science Center Administrative Report LJ-07-02. National Marine Fisheries Service, La Jolla, CA.

Barlow, J., S. Rankin, E. Zele, and J. Appler. 2004. *Marine mammal data collected during the Hawaiian Islands Cetacean and Ecosystem Assessment Survey (HICEAS) conducted aboard the NOAA ships* McArthur *and* David Starr Jordan, *July-December 2002*. NOAA Technical Memorandum NMFS-SWFSC-362. National Marine Fisheries Service, La Jolla, CA.

Barlow, J., S. Rankin, A. Jackson, and A. Henry. 2008. *Marine mammal data collected during the Pacific Islands Cetacean and Ecosystem Assessment Survey (PICEAS) conducted aboard the NOAA ship* McArthur II, *July – November 2005*. NOAA Technical Memorandum NMFS-SWFSC-420. National Marine Fisheries Service, La Jolla, CA.

Baron, S.C., A. Martinez, L.P. Garrison, and E.O. Keith. 2007. Differences in acoustic signals from delphinids in the western North Atlantic and northern Gulf of Mexico. *Marine Mammal Science* 24:42-56.

Breiman, L. 2001. Random forests. *Machine Learning*. 45:5-32.

Ding, W., B. Würsig, and W. Evans. 1995a. Comparisons of whistles among seven odontocete species. Pages 299-323 in R.A. Kastelein and J.A. Thomas, eds. *Sensory systems of aquatic mammals*. R.A. Kastelein and J.A. Thomas, eds. .DeSpil Publishers, Woerden, The Netherlands.

Ding, W., B. Würsig, and W. Evans. 1995b. Whistles of bottlenose dolphins: Comparisons among populations. *Aquatic Mammals* 21:65-77.

Gannier, A., S. Fuchs, P. Quèbre, and J.N. Oswald. 2010. Performance of a contour-based classification method for whistles of Mediterranean delphinids. *Applied Acoustics* 71(11):1063-1069.

Gillespie, D., J. Gordon, R. McHugh, D. McLaren, D. Mellinger, P. Redmond, A. Thode, P. Trinder, and X. Y. Deng. 2008. PAMGUARD: Semiautomated, open source software for real-time acoustic detection and localization of cetaceans. *Proceedings of the Institute of Acoustics* 30(5). .

Herzing, D.L. 2000. Acoustics and social behavior or wild dolphins: Implications for a sound society. Pages 225-272 in W.W.L. Au, A.N. Popper, and R.R. Fay, eds. *Hearing by whales and dolphins*. Springer-Verlag, New York.

Janik, V.M. and P.J.B. Slater. 1998. Context-specific use suggests that bottlenose dolphin signature whistles are cohesion calls. *Animal Behaviour* 56:829-838.

Lammers, M.O., W.W.L. Au, and D.L. Herzing. 2003. The broadband social acoustic signaling behavior of spinner and spotted dolphins. *Journal of the Acoustical Society of America* 114:1629-1639.

Matthews, J.N., L.E. Rendell, J.C.D. Gordon, and D.W. MacDonald. 1999. A review of frequency and time parameters of cetacean tonal calls. *Bioacoustics* 10:47-71.

Mellinger, D.K. 2001. Ishmael 1.0 User's Guide. NOAA Technical Memorandum OAR PMEL-120. National Oceanic and Atmospheric Administration, Pacific Marine Environmental Laboratory, Seattle, WA.

Morisaka, T., M. Shinohara, F. Nakahara and T. Akamatsu. 2005. Geographic variations in the whistles among three Indo-Pacific bottlenose dolphin *Tursiops aduncus* populations in Japan. *Fisheries Science* 71:568-576.

Norris, K.S., and W.E. Evans. 1966. Directionality of echolocation clicks in the rough-tooth porpoise, *Steno bredanensis* (Lesson). Pages 305-316 in W.N. Tavolga, ed. *Marine Bio-Acoustics. Volume 2*. Pergamon Press, New York.

Oswald, J.N., S. Rankin, and J. Barlow. 2004. The effect of recording and analysis bandwidth on acoustic identification of delphinid species. *Journal of the Acoustical Society of America.* 116:3178-3185.

Oswald, J.N., S. Rankin, J. Barlow, and M.O. Lammers. 2007. A tool for real-time acoustic species identification of delphinid whistles. *Journal of the Acoustical Society of America*. 122:587-595.

Rankin, S., J.N. Oswald, and J. Barlow. 2008. Acoustic behavior of dolphins in the Pacific Ocean: implications for using passive acoustic methods for population studies. Canadian Acoustics. 36:88-92.

Rendell, L.E., J.N. Matthews, A. Gill, J.C.D. Gordon, and D.W. MacDonald. 1999. Quantitative analysis of tonal calls from five odontocete species, examining interspecific and intraspecific variation. *Journal of Zoology*. 249:403-410.

Roch, M.A., M.S. Soldevilla, J.C. Burtenshaw, E.E. Henderson, and J.A. Hildebrand. 2007. Gaussian mixture model classification of odontocetes in the Southern California Bight and the Gulf of California. *Journal of the Acoustical Society of America*. 121:1737-1748.

Tyack, P.L. and C.W. Clark. 2000. Communication and acoustic behavior of dolphins and whales. Pages 156-224 in W.W.L. Au, A.N. Popper, and R.R. Fay, eds. *Hearing by whales and dolphins*.. Springer-Verlag, New York.

Watkins, W.A. 1967. The harmonic interval: Fact or artifact in spectral analysis of pulse trains. Pages 15-64 in W.N. Tavolga, ed. *Marine bio-acoustics*. Pergamon Press, New York..

2.8 Appendix A – Variables measured by ROCCA

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
tot step	number of steps (10 percent 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

Variable	Explanation
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

SECTION 3. Evaluation of Sperm Whale Encounters During the MISTCS 2007 Cetacean Survey

This report section was not included because of several inconsistencies that were identified during the internal review that could not be addressed in time for the public release of this document. We are addressing these issues and will release this section of the report at a later time.

The primary goal of post-processing reanalysis of acoustic data gathered during the MISTCS (DoN 2007) was to conduct an analysis of acoustic localizations for sperm whale encounters. A secondary goal of the post-processing effort was to locate and characterize sperm whale codas detected during the cruise to provide insight to the population structure of sperm whales in the MISTCS study area.

3.1 Coda Analysis

Sperm whale codas were identified through both aural and visual review of sperm whale acoustic detections using Adobe-Audition and XBAT software. Coda types were identified and categorized based on classifications commonly used in peer-reviewed literature. Coda types were assigned to an event based on most frequently occurring type of coda during that event period.

Codas were detected in 13 out of 60 (22 percent) of sperm whale acoustic ‘encounters’ identified in the MISTCS 2007 acoustic field data. Comparison of codas from these encounters to those described in the literature revealed that the majority (85 percent) were “regular” coda types. One event included “short” codas, and two of the coda events contained relatively similar numbers of “+1” and “regular” types, so these were considered ambiguous.

The three different codas found in the MISTCS dataset are known to be used by sperm whale clans in other geographic regions in the North and eastern South and Central Pacific, primarily off the Galapagos Islands and off Chilean waters. The occurrence of a "short" clan off of the Mariana Islands extends the documented range of clan type to the western Pacific region. This information can be used to better characterize putative stock structure of sperm whales in the Mariana Islands region.

3.2 Localization and Detection Function Analysis

Recordings were initially reviewed using the MATLAB program Triton to create Long Term Spectral Averages (LTSA’s) to identify periods of likely sperm whale clicks and click events. Identified periods were further reviewed by data analysts using XBAT software in order to obtain start and end periods for sperm whale acoustic encounters.

A total of 103 sperm whale acoustic encounters were localized using the semi-automated post-processing methods described above. Of these, 91 were determined to be of sufficient quality to include in subsequent analysis. There were 54 encounters consisting of ‘regular’ type clicks (ICI < 2 sec) and 37 encounters characterized by ‘slow’ type clicks.

Each sperm whale acoustic encounter period was post-processed using an automated click classifier configured using PAMGUARD software (Gillespie et al. 2008).

Click files were obtained using this method and were further processed using Rainbow Click software (Gillespie and Leaper 1997) to provide time/bearing and map displays of clicks, which were used to create a track of individual animals (events) for each encounter period Rainbow Click was used. Each event was logged to an Access database. Detection events were classified into click type categories based on two types of Inter-Click-Intervals (ICI) -- “Regular” (ICI < 2 sec) or “Slow” (ICI > 2 sec) as commonly defined in other studies. These data were then processed using custom MATLAB code to estimate perpendicular distances from the trackline for each animal/event using a least squares fit to estimate the point of the localization. All detection events were compiled into a database, and histograms were created of the perpendicular distance from the trackline for both “Regular” and “Slow” event categories. Histograms were reviewed for a qualitative assessment before detection functions were generated.

Perpendicular distance and transect length data were imported into the program *Distance* (6.0 release 2; Thomas et al. 2010) which was used for estimating the best detection function. Several models were compared for best fit to the probability distribution of distances from the trackline, with the best fit determined by the lowest AIC and CV values. Models were fit to perpendicular distance data for all clicks combined, regular clicks only, and slow clicks only. Because abundance estimation was beyond the scope of this study, only the detection functions were estimated.

A total of 103 sperm whale acoustic encounters were localized using the semi-automated post-processing methods described above. Of these, 91 were determined to be of sufficient quality to include in subsequent analysis. There were 54 encounters consisting of ‘regular’ type clicks (ICI < 2 sec) and 37 encounters characterized by ‘slow’ type clicks. Five percent of the Distance data was right-truncated before fitting the detection function. Using the *Distance* software, the Hazard Rate ‘key function’ models with a series expansion was determined to best fit the perpendicular distance data for both the regular and slow clicks localization events. AIC values were similar for the different models used however the Hazard Rate model for both click types had the lowest AIC scores.

Post-processing of the towed array acoustic data from MISTCS resulted in many more localizations than were obtained in real-time. Of the 61 sperm whale acoustic encounters in the field, only 25 localizations were made *in situ*, whereas the post-processing analysis resulted in 91 distinct localizations of individual sperm whales, resulting in a 72.5 percent increase in unique localizations. These data should allow an improved spatial analysis of sperm whale distribution in the MIRC region.

Based on a preliminary and qualitative assessment of the geographic position of localizations, the distribution of sperm whales appeared clustered in three main regions of the study area, the northeast, central and southwest portions, respectively, with a few others in the trench and offshore regions. The central cluster may reflect a preference by some animals to inhabit waters near islands. Because groups in the central cluster produced codas that are commonly used by social groups, it is likely that groups found in this area consist of matrilineal social units. Further spatial and habitat analysis and modeling (e.g. density surface models and generalized additive models) can be used to further elucidate these patterns.

Future effort should focus on a stratified analysis of the localization-distance data. Based on the large number of acoustic localizations that were obtained in post-processing, a more precise estimate of abundance than that obtained using only visual detections (as in by Fulling et al. [2011]) should be possible by reducing the variance in the encounter rate and by obtaining a better (e.g. stratified) estimate of the detection function for usual and slow clicking groups. There are two reasonable approaches to obtaining new abundance estimates that we recommend: 1) an acoustic-only approach to estimating abundance, and 2) a combined visual and acoustic abundance estimate using both data-sets. Both of these can be compared to the visual-based estimates produced by Fulling et al. 2011 to determine the most reliable estimate. It is recommended that bio-statisticians with expertise in line-transect methods (e.g., scientists from St Andrew's CREEM or the NMFS-Southwest Fisheries Science Center) advise on any further analysis of these data.

SECTION 4. Humpback Whale Song Review and Comparison

4.1 Introduction

Humpback whales (*Megaptera novaeangliae*) were once very abundant in the North Pacific but were decimated to just over a thousand animals after years of commercial whaling (Gambell 1976; Johnson and Wolman 1984). Based on records from whaling logbooks from the 1750s to early 1900s numerous whales were taken from the Mariana Islands (**Figure 4-1;** Townsend 1935). Since this time, there have been very limited reliable reports of humpback whales in the Northern Mariana Island area. The Mariana Islands MRA states that 'there is a low or unknown occurrence of humpback whales from the coastline (excluding harbors and lagoons) in the Mariana study area and vicinity (DoN 2005). Darling and Mori (1993) conducted a limited survey listening for humpback whales off Saipan and concluded that 'humpback whales were not seen regularly so far south.' They interviewed residents and cited a newspaper article in which a group of three animals was photographed off Saipan in February 1991, indicating that the winter range may extend into this region. There have been just a handful of other sightings of humpback whales in the Northern Mariana Islands in the past 20 years, including a cow/calf pair off Rota and a group of six at the entrance to Apra Harbor, the main harbor in Guam. All these sightings occurred in January and February from the early to mid 1990s (Eldredge 2003) suggesting that this indeed is a winter/spring breeding area.

During the MISTCS line-transect survey, humpback whale songs were acoustically detected on several days over the course of the 3-month survey period (DoN 2007). A night-time acoustic survey off the islands of Saipan and Tinian on 18 February 2007 resulted in an acoustic localization of a singing animal and eventually led to a visual encounter of several animals soon after daybreak (DoN 2007; Morse et al. 2007). Identification photographs were taken and behavioral observations were made of animals in what appeared to be a surface active group as evidenced by tail-slapping, breaching, and chin-slapping behaviors (DoN 2007; Fulling et al. 2011).

This report presents the findings of a more thorough review of humpback song detections, with an emphasis on those that were recorded off Saipan and Tinian as those were the best quality recordings available. A main goal was to do a comparison of these songs with humpback whale songs recorded in Hawaii during a similar time period in the same season.

4.2 Methods

Towed hydrophone array and sonobuoy recordings were made during the winter/spring MISTCS line-transect cruise (for a detailed description of methods, see DoN 2007). Acoustic detection records were compiled from the MISTCS cruise final report and the original acoustic field database. Audio recordings were reviewed aurally (headphones) and visually (scrolling spectrographic display) to identify recordings the presence of humpback whale songs.

.Wav files were reviewed by examining spectrograms using both Adobe Audition and Triton software. To facilitate processing efficiency and optimize frequency settings for the review, all recordings were down-sampled from 96 kHz to 10 kHz. Triton software (www.cetus.ucsd.edu) was used to create long-term spectral averages (LTSAs) of .wav files using 5-second time bins and 10 Hz frequency bins. LTSA files were reviewed by an experienced bioacoustician to identify humpback whale songs for periods in which they were noted in the database and final MISTCS report. Periods with possible song were then reviewed in greater detail using the 'expand' feature in Triton's LTSA to view the corresponding .wav files as a spectrogram (900 FFT points, 60 percent overlap, maximum frequency=2,500 Hz). Sound files were also using the spectral display (i.e. spectrogram; 512 FFT size) display in Adobe Audition. A qualitative 1-5 scale was used to rank the song quality (1=low quality song and 5=high quality song) and background noise intensity (1=low background noise and 5=high background noise). Start and end times of song periods were logged in Triton. The dates and time periods were imported from Triton into an Excel spreadsheet. The relative quality of the songs, and relative level of background noise of all songs (as 10minute .wav files), file names and other relevant information was saved in an Excel spreadsheet to provide a summary of information.

Representative examples of each phrase type that could be qualitatively identified by the data analyst were clipped and saved as .wav files. Spectrograms for each phrase type were made using the same settings (5-sec time bins and 10 Hz frequency bins, with a 10 kHz sampling rate and 900 FFT) so that they could be visually compared (**Figure 4-2**).

The same procedure was conducted for phrases from a sample of humpback whale song (courtesy of Adam Pack, University of Hawaii, Hilo) recorded on 18 February 2007 from the main Hawaiian Island of Maui (**Figure 4-3**). Humpback whale song phrases from MISTCS were then qualitatively compared to those from Hawaii to identify which phrase types were common (**Figure 4-4**).

4.3 Results

Over 120 hours of recordings were reviewed from over 12 days of effort in which humpback whale songs (or possible humpback whale songs) were noted in the acoustic logs. From these recordings, humpback whale songs were identified on 5 separate days, for a total of approximately 5.5 hours of song. The periods of song were then plotted on a map of the survey area to show relative location of the singers (**Figure 4-5**). Of the songs reviewed, approximately 1.5 hours were of sufficient quality for comparative analysis. Much of the data recorded were of too low quality (i.e., low signal/noise) that they were not useful for comparison to the Hawaii song sample (**Table 4-1**).

Only two phrase types from the MISTCS cruise were identifiable (**Figures 4-6 and 4-7**). Unfortunately, the song sample from Hawaii had severe clipping (i.e. the sound levels exceeded the recording system dynamic range resulting in artifacts in the recording e.g. **Figure 4-4**), which resulted in difficulty in identifying the phrase types. In spite of these issues, we were able to identify one phrase type that was shared between the MISTCS Saipan/Tinian sample and the Maui, Hawaii sample (**Figure 4-3**).

Also of interest, we noted the occurrence of mid-frequency sonar activity (14 February 2007) during one of the periods in which humpback song was also recorded. Upon a more detailed review of the spectrograms, it was evident that the sonar signals overlapped with humpback whale songs units during the sonar activity (**Figure 4-8**). No further review of these data was conducted.

4.4 Discussion

Due to low signal-to-noise ratios, the song samples from the MISTCS were not of sufficient quality to identify more than a few phrases types making a comprehensive comparison to songs from other areas less meaningful. Furthermore, the song sample obtained from the Main Hawaiian Islands included sections with 'clipped' signals resulting in occasional artifacts in the spectrograms of phrase types. For some signals, this made qualitative assessment of phrase types difficult. In spite of these difficulties, we were able to identify two phrase types from the MISTCS recordings made off Saipan/Tinian one of which was similar to a phrase types identified from the songs recorded off the Hawaiian island of Maui. This suggests at least some acoustic interchange is occurring between Hawaii and the Mariana Islands. This result is not unexpected because, humpback whales in the North Pacific are believed to consist of one population with animals mixing on the breeding areas, but maintaining some fidelity and segregation at coastal feeding areas in the north (Calambokidis et al. 2008).

Singing and surface active behaviors such as tail slapping and chin breaching that were observed during the visual encounter near Saipan are common for humpback whales inhabiting winter breeding areas. The occurrence of singing and surface active behaviors we observed during the mid-February encounter suggests that the nearshore waters around Tinian and Saipan were being used by at least a few humpback whales that were engaging in courtship behaviors. This might implicate the Northern Mariana Islands as a possible winter breeding area. At one time, humpbacks were relatively common in the Northern Mariana Islands region during winter and spring, as is evident from the records of whaling kills (Townsend 1935). Based on the limited, but new information collected during the MISTCS cruise, it is possible that humpback whales are now re-occupying a former breeding site. However, additional effort to monitor singing activity and the occurrence of surface active groups is needed to verify this.

Interestingly, Calambokidis et al. (2008) suggested the likely existence of an undiscovered wintering area used by whales that feed in the Bering Sea, off the Aleutian Islands and off the Commander Islands. Based on long-term acoustic monitoring of humpback whale songs, some researchers have suggested that the Northwestern Hawaiian Islands could be this undiscovered area (Lammers et al. 2011). Alternatively, it is also possible that the Mariana Islands, Micronesia, the Philippines and other subtropical islands in the western Pacific that remain poorly surveyed could be part of this undiscovered wintering area.

From 2000 to 2003, small vessel surveys were conducted in the Philippines to investigate the current status of humpback whales in the area, and their relationship to other humpback whale populations in the western and central North Pacific (Acebes et. al. 2007). The study site was located in the Babuyan Islands, north of Luzon Island. Recordings of songs and other data were collected during the survey. A comparison of song themes from the Philippines to those recorded in Hawaii indicated that nine unique themes were identified in songs from both Hawaii and the Philippines, with seven of these themes common in both regions. The similarity of song suggests that humpback whales in the Philippines mix, at least to some degree, in order to exchange song information with whales in Hawaii. It might be expected that a similar level of mixing is occurring between the Mariana Islands, Hawaii and Philippines, however, better samples of songs will be needed to confirm this.

Results of the recent Structure of Populations, Levels of Abundance and Status of Humpback Whales in the North Pacific (SPLASH) photographic-identification study indicate that the western-most feeding and wintering areas are distinct from the rest of the North Pacific (Calambokidis et al. 2008). The results also suggest that there is a very low level of interchange between Asian wintering or feeding areas and those in the central and eastern North Pacific (Calambokidis et al. 2008). However, a few occurrences of animals moving between islands of Hawaii; the Revillagigedos and mainland coast of Mexico; and Ogasawara and Okinawa, Japan have been documented during these photographic identification studies (Calambokidis et al. 2008). Fluke photographs from MISTCS were compared to the SPLASH database; however, no matches were made (Rivers et al. 2007).

4.5 Conclusions and Recommendations

Vessel-based surveys conducted in 2010-2011 jointly by the Navy and NMFS have not resulted in any humpback whale sightings (Oleson and Hill 2010; HDR 2011; Ligon et al. 2011; Hill et al. 2012). In addition, acoustic data have been collected from autonomous acoustic recording devices, but these data are still being analyzed. Additional PAM, especially in nearshore areas of the Northern Mariana Islands (e.g., Guam, Saipan and Tinian) is needed to collect better quality samples of humpback whale song. Acoustic monitoring of humpback whale songs can provide remotely collected information on the relative abundance, seasonal trends, migration routes and important breeding habitat for humpback whales in the Northern Mariana Islands region. Autonomous recorders, sonobuoys, and towed array monitoring all have the capability to provide this information (Norris et al. 1999; Au et al. 2000; Lammers et al. 2011).

High-quality recordings of individual humpback whale songs are necessary in order to compare humpback whale songs from the Marianas Islands to songs from other areas. This type of analysis will provide indication of movements of animals and more importantly exchange of cultural information between areas (Cerchio et al. 2001; Darling and Sousa-Lima 2005). Garland et al. (2011) recently demonstrated that song information can be spread rapidly in a unidirectional manner over ocean-basin wide scales. Identifying the level and rate of song exchange is important for identifying and better defining stocks of this depleted species of whale that appears to be re-inhabiting areas impacted by whaling activities.

Finally the effects of Navy activities and sonar on humpback whales acoustic behaviors should be examined. An occurrence of mid-frequency active sonar activity recorded simultaneously with humpback whale singing was identified during our review of songs (**Figure 4-8**). Low frequency active (LFA) sonar has been observed to affect humpback whale songs (Miller et al. 2000), and we have observed and recorded at least one occurrence in which a singing humpback whales ceased singing during the onset of intense mid-frequency sonar near PMRF (T. Norris, Bio-Waves, unpublished data). In several other cases no changes in singing behaviors were observed when sonar intensity was low or infrequent. Autonomous recorder data is most likely to pick up sonar events and these data should be analyzed to give an indication of whether and how sonar might affect humpback whale singing behaviors and relative occurrence.

4.6 Acknowledgements

We would like to acknowledge Laura Morse, Alyson Azzara for their efforts at sea and with preliminary data analysis. Adam Pack (University of Hawaii-Hilo) provided the humpback song sample from Hawaii. The observer and marine mammal survey team from MISTCS provided field assistance locating and photographing animals in the surface-active group encountered off Saipan/Tinian.

4.7 Tables and Figures

4.7.1 Tables

Table 4-1. Summary of Humpback Song Detections and Relevant Attributes

Date (all 2007)	Total Song/Day (hh:mm:ss)	Leg	Song Detection ID #*	Mean Song Quality**	Mean Noise**
7 Feb	1:13:05	II	TA 67	3.05	3
14 Feb	1:23:00	II	TA 97	2.26	3
17 Feb	0:22:50	II	TA 110	3.5	3.75
18 Feb	1:45:05	II	TA 213***	3.38	3.06
18 Feb	0:24:00	II	SB 214***	4.33	4
2 Apr	0:29:00	II	TA 201	1.91	4
Totals	**05:37:00**	n/a	**Means**	**3.07**	**3.46**

*TA=Towed Array, SB=Sonobouy

** Refer to methods for ranking system

*** Detection #SB214 is most likely the same animal(s) as detection as TA213

4.7.2 Figures

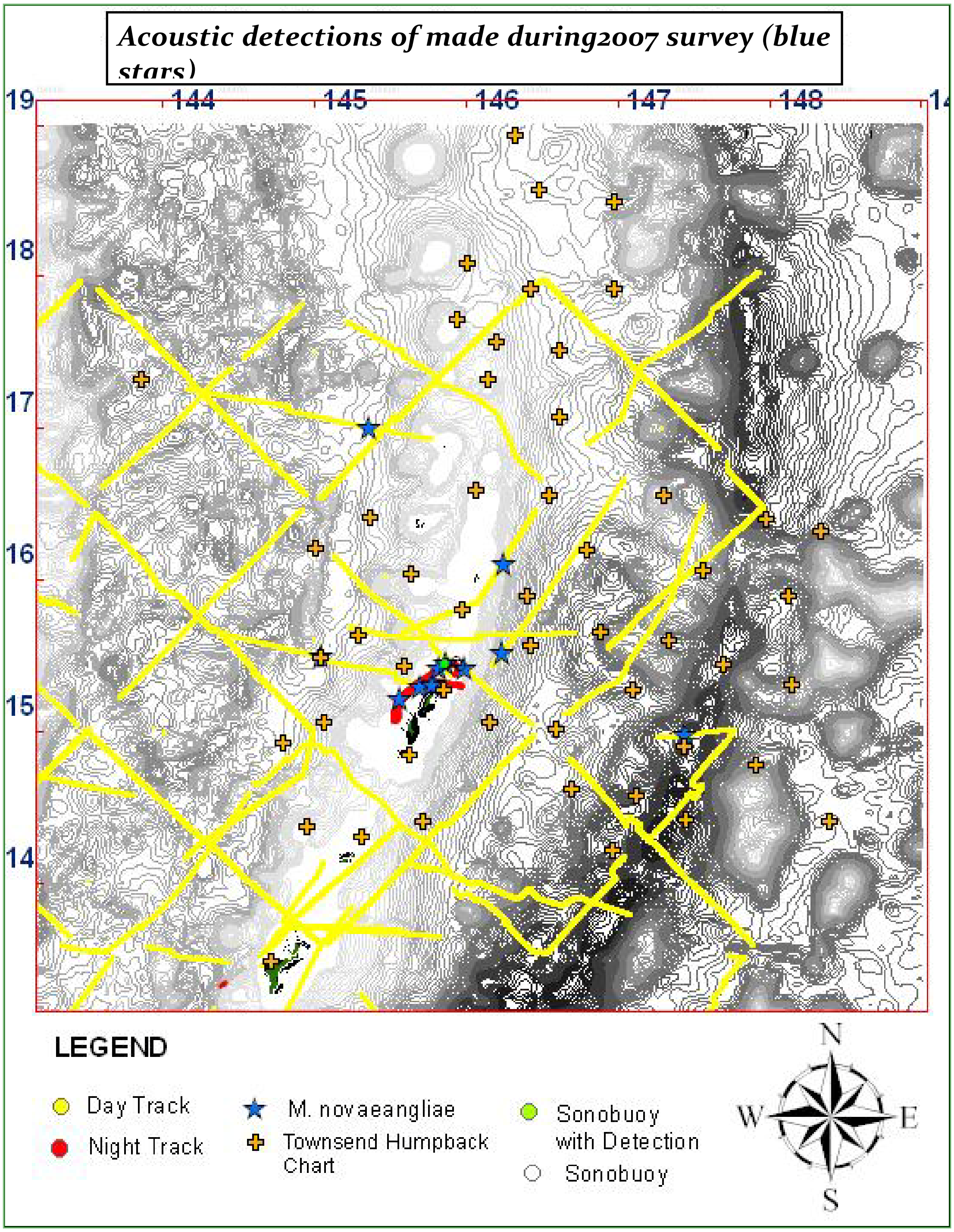


Figure 4-1. Locations of humpback whale kills (orange crosses) from 1750s-1920s (adapted from Townsend 1935) overlaid on the MISTCS study area with survey trackline (yellow) and humpback whale song acoustic detections by towed hydrophone array (blue stars) and sonobuoys (green star).

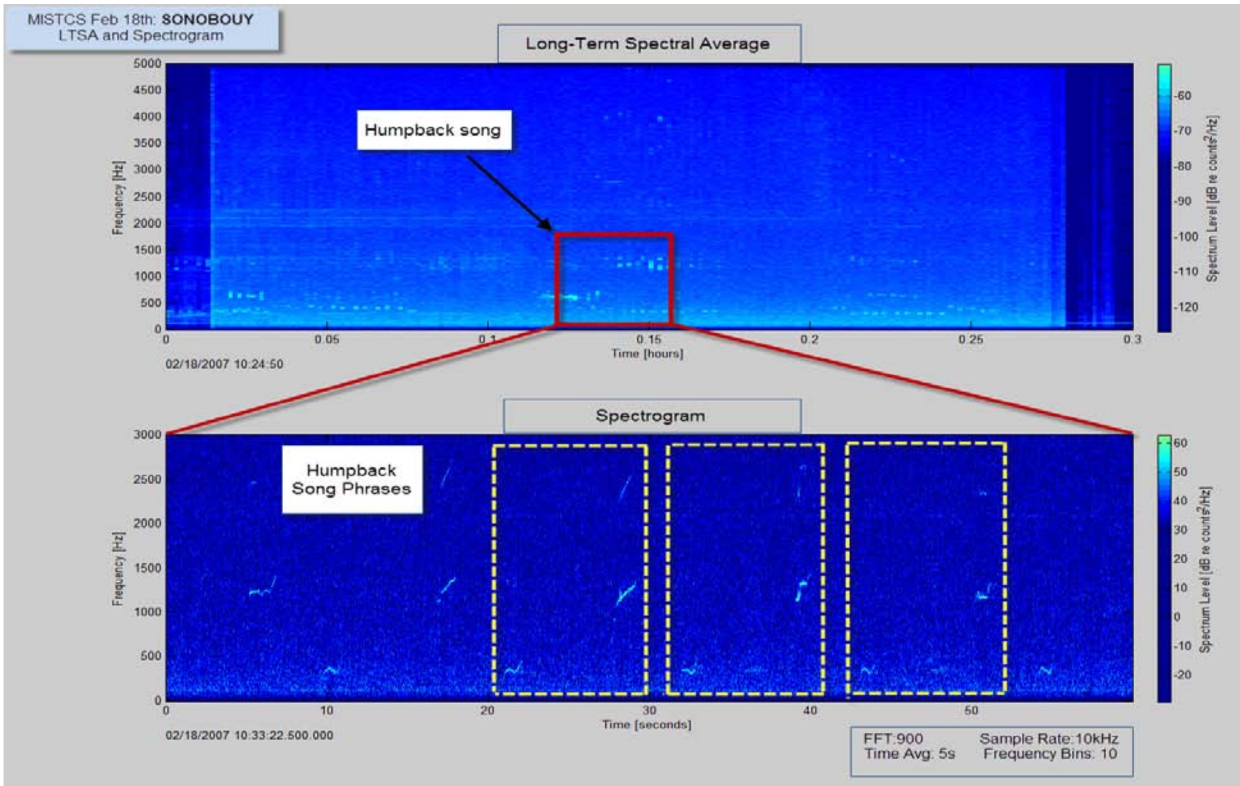


Figure 4-2. LTSA (top panel) and a corresponding spectrogram of boxed (red) selection (bottom panel).

The three boxes (broken yellow line) indicate a single phrase type.

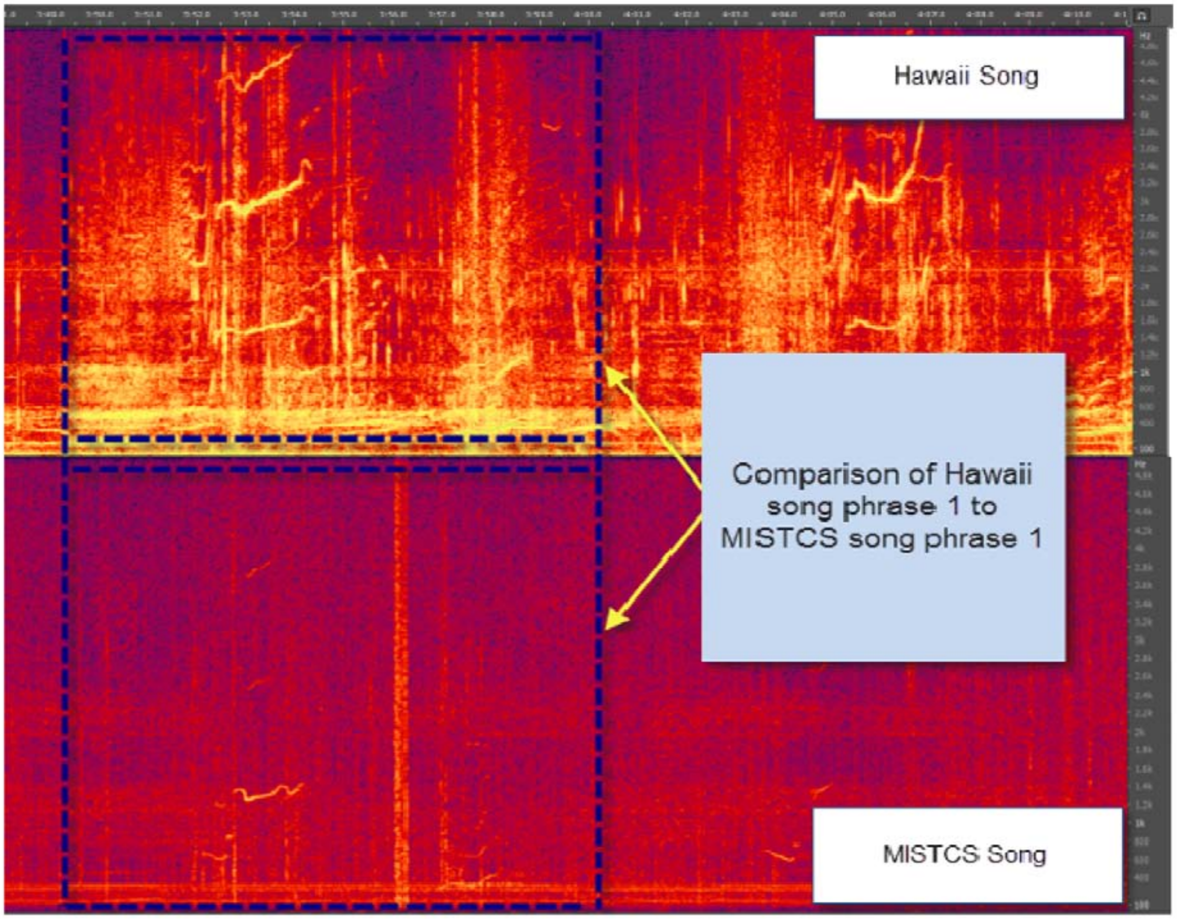


Figure 4-3. Song Comparison: Hawaii song phrase (top), MISTCS song phrase (bottom).

Due to quality issues with both the Hawaii song (with more than one animal singing, and clipping of .wav form), and the MISTCS song (poor signal-to-noise ratio), this was the only shared phrase type that we could identify for both locations.

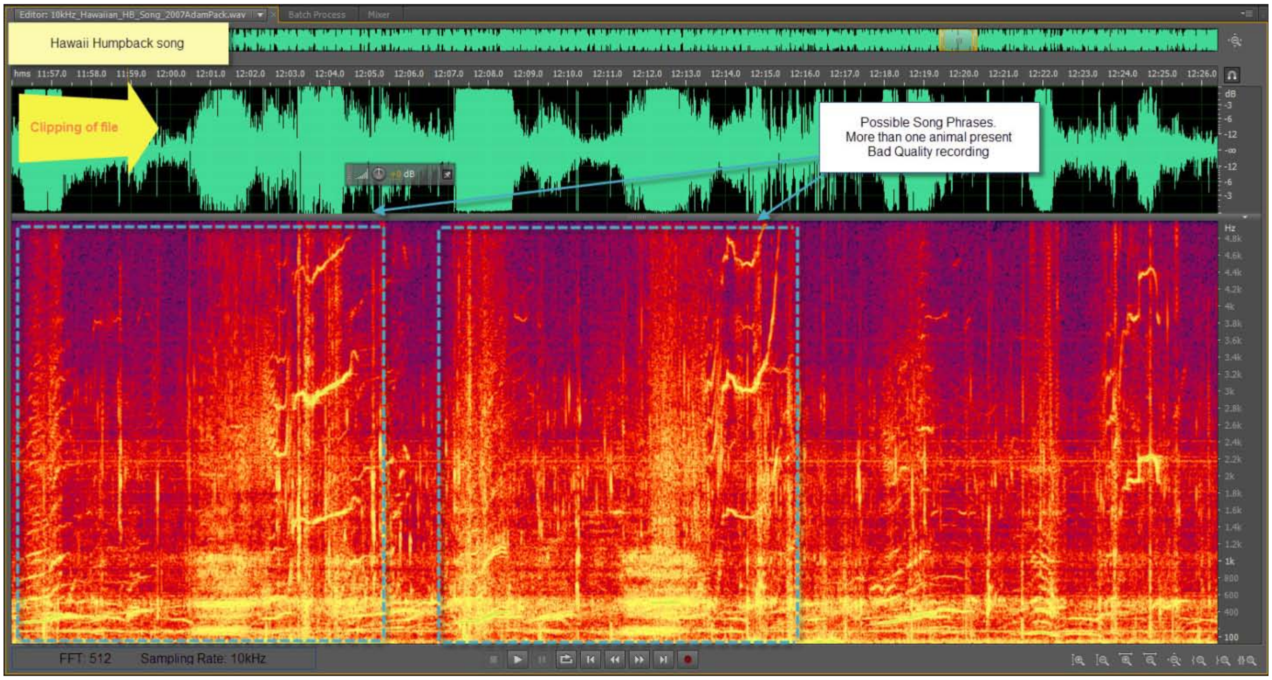


Figure 4-4. Hawaii humpback whale song spectrogram.

Poor quality recording due to clipping of .wav form. Two animals present making it difficult to distinguish individual phrase types.

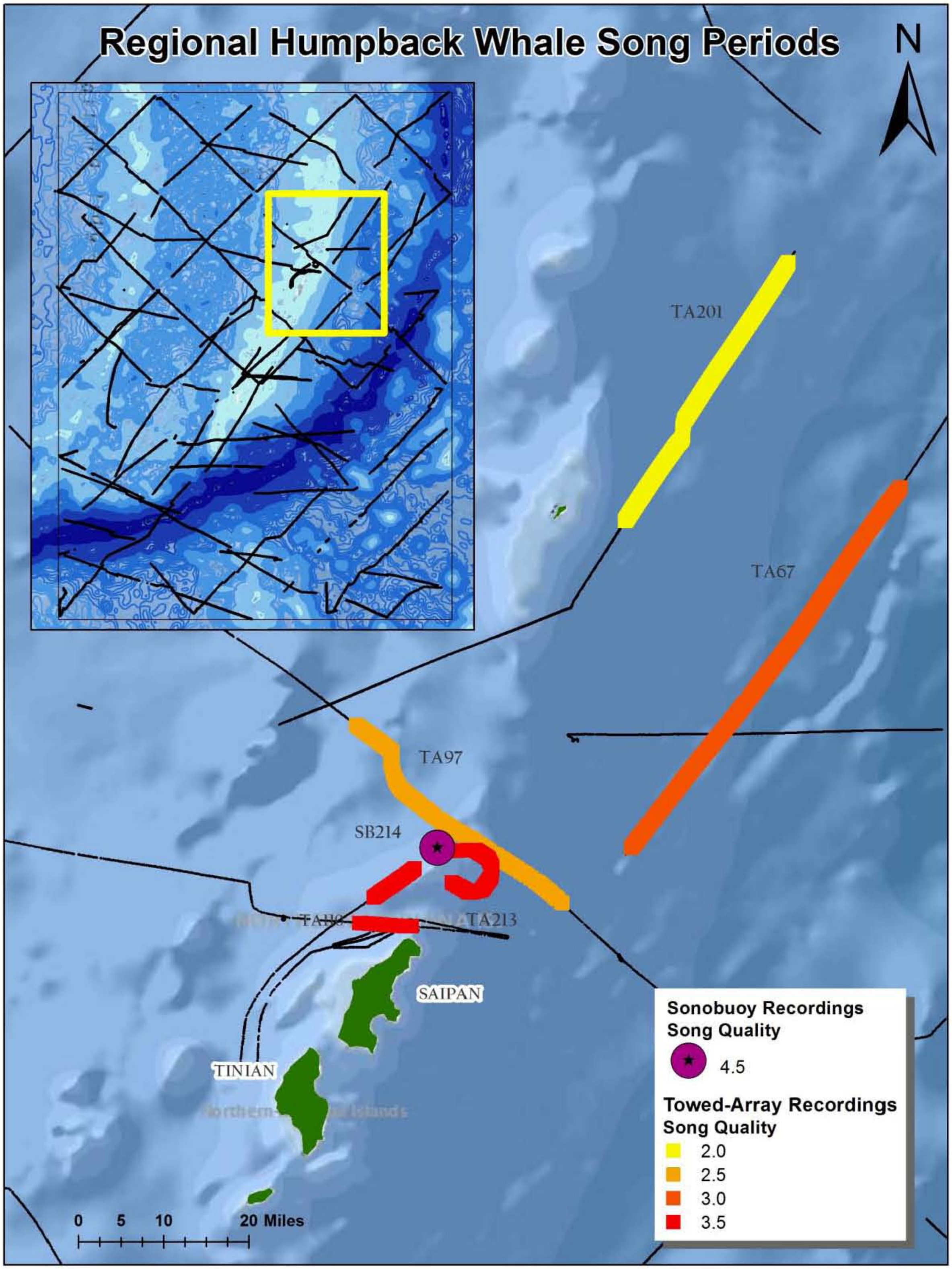


Figure 4-5. Map of humpback whale song intensity and locations near Saipan and Tinian Islands.

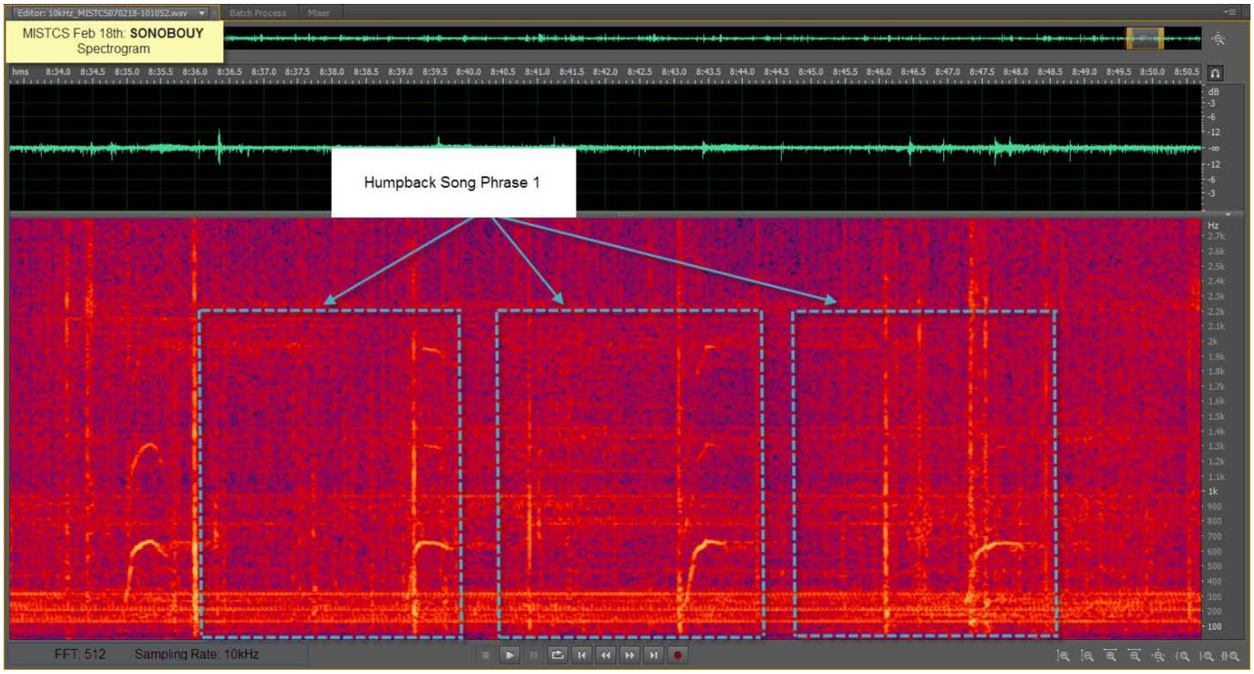


Figure 4-6. Spectrogram of humpback whale song phrase type # 1 from MISTCS. (sonobouy recording)

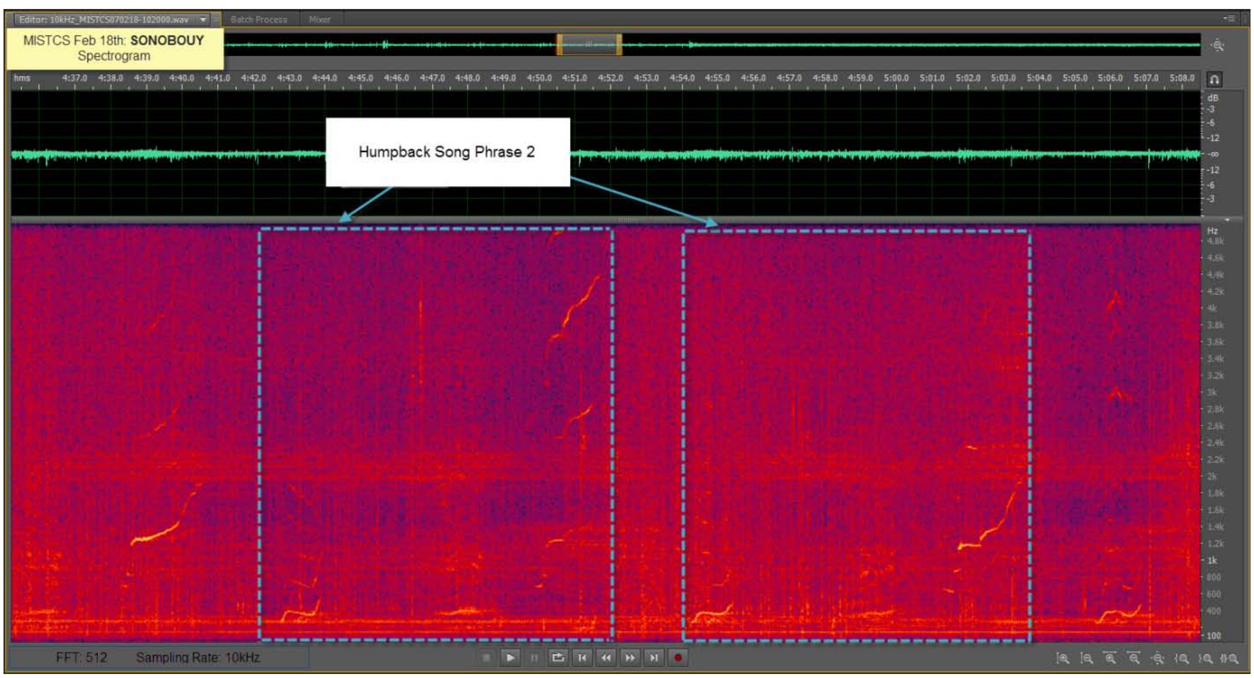


Figure 4-7. Spectrogram of humpback whale song phrase type # 2 from MISTCS. (sonobouy recording)

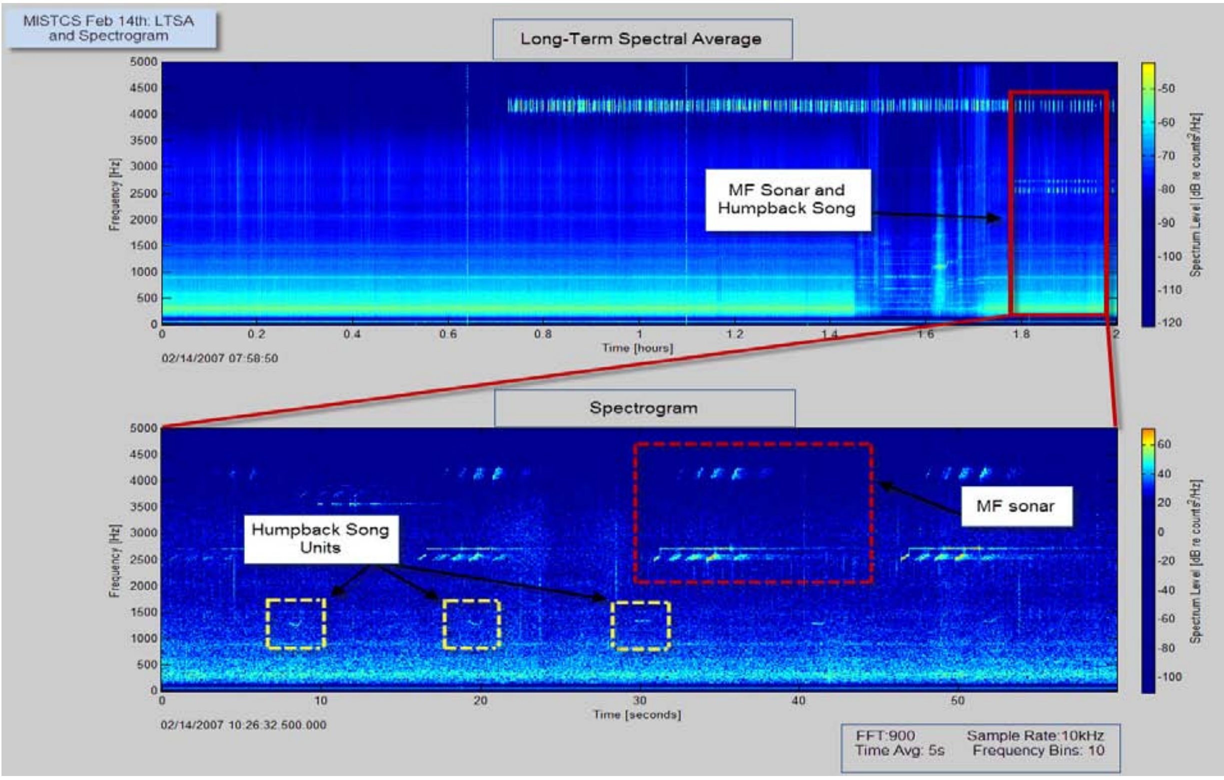


Figure 4-8. LTSA (top panel) and corresponding spectrogram of selection (bottom panel) depicting mid- frequency sonar and concurrent humpback whale song.

4.8 Literature Cited

Acebes, J.M., J.D. Darling, M. Yamaguchi. 2007. Status and distribution of humpback whales (*Megaptera novaeangliae*) in northern Luzon, Philippines. *Journal of Cetacean Research* 9 (1):37-43.

Au, W.W.L. J. Mobley, W.C. Burgess, M.O. Lammers, and P.E. Nachtigall. 2000. Seasonal and diurnal trends of chorusing humpback whales wintering in waters off Western Maui. *Marine Mammal Science* 16(3):530-544.

Calambokidis, J., E.A. Falcone, T.J. Quinn, A.M. Burdin, P.J. Clapham, J.K.B. Ford, C.M. Gabriele, R. LeDuc, D. Mattila, L. Rojas-Bracho, J.M. Straley, B.L. Taylor, J. Urbán, D. Weller, B.H. Witteveen, M. Yamaguchi, A. Bendlin, D. Camacho, K. Fl, and N. Maloney. 2008. *SPLASH: Structure of populations, levels of abundance and status of humpback whales in the North Pacific*. Final report for Contract AB133F-03-RP-00078. Prepared by Cascadia Research, Olympia, WA.

Cerchio, S. 2001. Temporal and geographical variation in songs of humpback whales, *Megaptera novaeangliae*: Synchronous change in Hawaiian and Mexican breeding assemblages. *Animal Behaviour* 62(2):313-329.

Clapham, P.J. 1992. Age at attainment of sexual maturity in humpback whales, *Megaptera novaeangliae*. *Canadian Journal of Zoology* 70 (7):1470-1472.

Darling, J.D. and K. Mori. 1993. Recent observations of humpback whales (*Megaptera novaeangliae*) in Japanese waters off Ogasawara and Okinawa. *Canadian Journal of Zoology* 71(2):325-333.

DoN (Department of the Navy). 2005. *Marine resources assessment for the Marianas Operating Area--Final report*. Contract number N62470-02-D-9997, CTO 0027. Pacific Division, Naval Facilities Engineering Command, Pearl Harbor, HI.

DoN (Department of the Navy). 2007. *Marine mammal and sea turtle survey and density estimates for Guam and the Commonwealth of The Northern Mariana Islands*. Final report contract No. N68711-02-D-8043. Prepared for U.S. Navy, Pacific Fleet, Naval Facilities Engineering Command, Pacific, Honolulu, HI. http://www.nmfs.noaa.gov/pr/pdfs/permits/mirc_mistcs_report.pdf

Eldredge, L.G. 2003. The marine reptiles and mammals of Guam. *Micronesica* 35-36:653-660.

Fulling, G.L., P.H. Thorson., and J. Rivers. 2011. Distribution and abundance estimates for cetaceans in the waters off Guam and the Commonwealth of the Northern Mariana Islands. *Pacific Science* 65(3):321-343.

Gambell, R. 1976. World whale stocks. *Mammal Review* 6(1):41-53.

Garland, E.C., A.W. Goldizen, M.L. Rekdahl, R. Constantine, C. Garrigue, N.D. Hauser, M.M. Poole, J. Robbins, and M.J. Noad. 2011. Dynamic horizontal cultural transmission of humpback whale song at the ocean basin scale. *Current Biology* 21(8):687-691.

HDR. 2011. *Guam Marine Species Monitoring Survey, vessel-based monitoring surveys, Winter 2011*. Draft Report. Prepared for U.S. Navy, Pacific Fleet, Naval Facilities Engineering Command, Pacific, Honolulu, HI

Hill, M., A. Ligon, M. Deakos, A. Ü, E. Norris, and E. Oleson. 2012. *Cetacean surveys of Guam and CNMI waters: August - September, 2011*. PIFSC Data Report DR-12-002. Pacific Islands Fisheries Science Center, National Marine Fisheries Service, Honolulu, HI.

Johnson, J.H. and A.A. Wolman. 1984. The humpback whale, *Megaptera novaeangliae*. *Marine Fisheries Review* 46(4):30-37.

Lammers M.O., P.I. Fisher-Pool, W.W.L Au, C.G. Meyer, K.B. Wong, and R.E. Bernard. 2011. Humpback whale *Megaptera novaeangliae* song reveals wintering activity in the Northwestern Hawaiian Islands. *Marine Ecology Progress Series* 5:247-260.

Ligon, A.D., M.H. Deakos, and A.C. Ü. 2011. Small-boat cetacean surveys off Guam and Saipan, Mariana Islands, February-March 2010. Report to the Pacific Islands Fisheries Science Center under Contract AB133F-10-SE0930.

Miller, P.J., N. Biassoni, A. Samuels, and P.L. Tyack. 2000. Whale songs lengthen in response to sonar. *Nature* 405: 903.

Morse, L., T.F. Norris, A. Azzara, and A. Pack. 2007. First recordings of humpback whale songs in the Northern Mariana Islands. *Abstracts, Seventeenth Biennial Conference on the Biology of Marine Mammals, 29 November-3 December 2007, Cape Town, South Africa*.

Norris, T.F., M. McDonald, and J. Barlow. 1999. Acoustic detections of singing humpback whales (*Megaptera novaeangliae*) in the eastern North Pacific during their northbound migration. *Journal of the Acoustical Society of America* 106(1):506-514.

Oleson, E. and M. C. Hill (2010). *2010 report to PACFLT: Report of cetacean surveys in Guam, CNMI, and the high-seas*. Prepared for Department of the Navy by National Marine Fisheries Service, Pacific Island Fisheries Science Center, Honolulu, Hawaii.

Rivers, J., G.L. Fulling, P. Thorson and C. Oedekoven. 2007. Humpback whale (*Megaptera novaengliae*) fluke photographs from the Northern Mariana Islands compared with other geographic areas. *Abstracts, Seventeenth Biennial Conference on the Biology of Marine Mammals, 29 November03 December 2007, Cape Town South Africa*.

Townsend, C.H. 1935. The distribution of certain whales as shown by logbook records of American whaleships. *Zoologica* 19(1):3-50.

SECTION 5. Characterization of Sei Whale Vocalizations from MISTCS 2007 Encounters

5.1 Introduction

The sei whale is a cosmopolitan pelagic species found in subtropical, temperate, and sub-polar oceanic waters worldwide (Horwood 1987). Individuals are thought to occur primarily in deep water along slopes and shelf breaks (Horwood 1987). Little is known about the distribution and movement of this species and the population has not been defined adequately. For management purposes, in western and Hawaiian U.S. territorial waters, the sei whale is divided into two stocks: the Hawaiian Stock and the Eastern North Pacific Stock (NMFS 2011). The last population estimate for sei whales in the North Pacific of 42,000 was conducted over 30 years ago and used a variety of different methods based on the history of whale catches and trends in sighting rates for sei whales in the North Pacific (Tillman 1977). There have not been any direct estimates of sei whale abundance in the entire (or eastern) North Pacific based on sighting surveys. A 2002 shipboard line-transect survey of the entire Hawaiian Islands EEZ resulted in a summer/fall abundance estimate of 77 (CV=1.06) sei whales (Barlow 2003). The sei whale is currently listed as endangered under the ESA and the International Union for Conservation of Nature’s Red List. A final recovery plan was recently released (NMFS 2011). The recovery plan proposes a three-tiered recovery strategy including: 1) continuation of international whaling regulation; 2) determination of population size, population trends, and population structure using opportunistic data combined with PAM; and 3) continuation of stranding response and affiliated data collection (NMFS 2011).

The sei whale is one of the least studied species of the genus *Balaenoptera*, thus little is known about their vocal behavior. Sei whale vocalizations have been described in only a handful of peer-reviewed publications (**Table 5-1**). Vocalizations have been described for sei whale encounters in four geographic regions: the Antarctic Peninsula (Gedamke and Robinson 2010; McDonald et al. 2005), Nova Scotia (Knowlton et al. 1991; Thompson et al. 1979), the Hawaiian Islands (Rankin et al. 2007; Smultea et al. 2010), and New England (Baumgartner and Fratantoni 2008; Baumgartner et al. 2008). Call descriptions have ranged from 40 to 3,500 Hz in frequency and 1.0 to 1.5 sec in duration. Sei whale vocalizations recorded from off the New Jersey coastline tended to consist of low frequency (<100 Hz) downsweeps and chirps (Newhall et al. 2009). Off the coast of eastern Canada, frequency-modulated sweeps and pulses have been described (Knowlton et al. 1991; Thompson et al. 1979). The frequency range of these calls extends from the low hundreds of Hz to mid-frequency values from 1.5 to 3 kHz. The only description of calls available in the Hawaiian Islands region is of a low frequency (<100 Hz) downsweep (Rankin and Barlow 2007) similar to some calls characterized from the Atlantic Ocean (Newhall et al. 2009; Baumgartner et al. 2008). The most dynamic documented vocalizations are those collected in the Southern Ocean; these calls range from 170 to 700 Hz and consist of a "frequency stepping" that was encountered in both studies (Gedamke and Robinson 2010; McDonald et al. 2005). There is no description of sei whale vocalizations recorded in the western Pacific Ocean, which is likely due to the elusive behavior of the species and limited survey effort in this region.

Several species of baleen whale were encountered during MISTCS, including Bryde's, sei and humpback whales, in addition to sightings of several unidentified species (DoN 2007). Through an extensive literature review, we determined that the characteristics of vocalizations from these other species were distinctly different from those of sei whale calls described in the literature. In addition to known species, we also investigated the recently recognized species known as Omura's whale (*Balaenoptera omurai*). *Balaenoptera omurai*, formerly classified as a small Bryde's, is now considered a separate species in the family Balaenopteridae (Wada et al. 2003). When originally classified (based on skeletal morphology), specimens collected from the Solomon Islands and Eastern Indian Ocean were treated as a small form of Bryde's whale, because of a relatively reduced body size at sexual maturity when compared with measurements of known Bryde's whale. This smaller type is found in and around the coastal southeastern North Pacific waters. Because this is a newly distinguished species, there are no known acoustic recordings of Omura's whale. Because the habitat of Omura's whale overlaps with other species in the family Balaenopteridae, more research is needed to be able to differentiate its distinct vocal repertoire.

Sei whale occurrence had not been previously confirmed in the MIRC prior to MISTCS 2007 (DoN 2005), however, during MISTCS, this species was the second-most frequently observed species (DoN 2007, Fulling et al. 2011). During the MISTCS, three sightings of sei whales were recorded, during which simultaneous acoustic detections of calls were made from the towed array (**Table 5-2**). The acoustic detections occurred after visual observers initially sighted the animals (and in some cases, the survey vessel approached the whales to verify species identity). Calls were produced sporadically and call durations were brief (generally < 2 sec). No sightings or acoustic detections of other species were made in the two hours preceding or following these events, except in one instance where an unidentified rorqual was sighted at a distance of > 3 km. Sixteen visual detections of sei whale were documented throughout MISTCS, although no real-time acoustic detections were attributed to 13 of these encounters by bioacousticians on-effort. The goal of this analysis was to review acoustic recordings taken during the MISTCS cruise to: (1) characterize calls of sei whales, which occurred during sightings of sei whales; (2) evaluate calls that occurred during sightings of undetermined species that could have been sei whales; and (3) compare sei whale calls described in the literature from other geographic areas to calls measured in this study.

5.2 Methods

Known acoustic detections that were associated with sightings (n=3) were reviewed to determine if an automated detector could be developed to post-process the acoustic dataset. Spectrogram template detectors for three call types were developed using XBAT software (www.xbat.org) and tested on a subsample (n=5) of sonobuoy recordings. Due to the diverse nature of sei whale vocalizations recorded during MISTCS, a detector (which in XBAT is designed to be used with stereotyped calls) was not feasible to implement. Therefore, all towed-array and sonobuoy recordings with associated sei whale visual sightings were reviewed by an experienced bio-acoustician both aurally, with headphones, and visually by inspecting a spectrographic display. XBAT software was used to review and annotate all recordings. For visual sei whale detections that were not accompanied by acoustic detections in the field, we reviewed the 30 minutes of acoustic data prior to and after each sighting to look for calls. This review was only conducted for sei whale sightings that existed independently from sightings of other species (*n*=10). Additionally, we reviewed all sonobuoy recordings (*n*=33) to look for sei whale vocalizations.

Sei whale calls were logged and clipped into short .wav files using XBAT. Clipped .wav files were then decimated to 12 kHz using *Adobe Audition* software. Decimation is a process in which the sample rate of the signal is reduced to allow quicker analysis and better frequency resolution at lower frequencies in the spectrogram. After files were decimated they were loaded into *Osprey*, a custom MATLAB program that is used to automatically measure a suite of variables from marine mammal calls (Mellinger and Bradbury 2007). All calls were assigned a quality value (1-3) subjectively, based on their signal-to-noise ratio (SNR) with 1 = the lowest SNR and 3 = the highest SNR. In Osprey, a measurement box was drawn around the call to extract and calculate a variety of frequency, time, and amplitude measurements (**Figure 5-1**). Measurements were then logged to a database for further analysis. Several variables were selected to characterize the vocalizations (low frequency [Hz], upper frequency [Hz], duration[s], bandwidth [Hz], peak frequency [Hz] and signal to noise [SNR; dB]). These measurements were based on the entire signal included in the measurement box. *Osprey* also identifies and logs the low and high frequency as the upper and lower limits of the selection box, which we used to approximate the range of frequency represented by the calls. Calls with extremely poor quality were excluded from the analysis. Calls associated with sighting (S) #063 all occurred within an hour of another distant unidentified rorqual. Although we are not able to definitively claim that the calls are from S#063, these calls were detected within 20 minutes of the sei whale being sighted 50 m from the ship; the relative intensity and SNR of the calls thus lead us to believe that it was associated with the closer sei whale detection rather than the unidentified rorqual detected 30 minutes after calls and 3.7 km away from the ship. As calls were reviewed, they were assigned to a subjective call type category based on their spectrographic representation - Type 1A, 1B, 2, 3, 4, 5A, 5B and 6, respectively. These call types were then compared to those described in the sei whale literature (**Table 5-1**).

5.3 Results

Thirty-two calls were identified and analyzed from towed-hydrophone array and sonobuoy recordings; all calls identified from the towed-hydrophone array were associated with a sighting (*n*=6). Calls identified from sonobuoy recordings were attributed to sei whales if a possible sei whale was detected prior to or during deployment and/or the call matched a type identified from the review of the towed-hydrophone array recordings (**Table 5-2**). Several calls identified from both towed-hydrophone array and sonobuoy recordings were not measured due to poor quality, often caused by engine noise and/or electrical interference on the audio signal. The geographic locations of all sei whale encounters categorized as combined acoustic and visual (*n*=6), visual only (*n*=10), or sonobuoy detections (*n*=5) are shown in **Figure 5-2**. The call types (Type 1 through 6) were used to categorize all sei whale vocalizations from the dataset. Between one and 10 calls were assigned to each representative type (**Table 5-3**). The suite of measurements are described for each call type in **Tables 5-4 to 5-10** and visually represented in spectrograms in **Figures 5-3 to 5-20**.

- Type 1 A calls (*n*=7) were characterized by their slight frequency-modulated (FM) downsweep and had a mean minimum frequency of 834 Hz, a mean maximum frequency of 1,517 Hz, a mean duration of 0.8 sec, a mean bandwidth of 682 Hz, and a mean peak frequency of 991 Hz.
- Type 1 B calls (*n*=2) were comprised of calls with a slight (FM) downsweep centered around 1 kHz and a mean minimum frequency of 914 Hz, a mean maximum frequency of 1,078 Hz, a mean duration of 0.3 sec, a mean bandwidth of 164 Hz, and a mean peak frequency of 1,031 Hz.
- Type 2 calls (*n*=2) are FM short signals, with a mean minimum frequency of 949 Hz, a mean maximum frequency of 1,640 Hz, a mean duration of 0.2 sec, a mean bandwidth of 691 Hz, and a mean peak frequency of 1,042 Hz.
- Type 3 and Type 4 calls only contained one representative each. Both are longer tonal signals that are described in greater detail in the discussion.
- Type 5A and 5B are complex frequency ‘stepped’ signals that either increase or decrease, respectively, in frequency as a function of duration. Type 5A calls (*n*=3) had a mean minimum frequency of 863 Hz, a mean maximum frequency of 1,582 Hz, a mean duration of 0.3 sec, a mean bandwidth of 718 Hz, and a mean peak frequency of 1,047 Hz. Type 5B calls (*n*=8) had a mean minimum frequency of 826 Hz, a mean maximum frequency of 1,642 Hz, a mean duration of 0.6 sec, a mean bandwidth of 897 Hz, and a mean peak frequency of 902 Hz.
- Type 6 calls (*n*=4) were characterized by slight upsweeps and had a mean minimum frequency of 850 Hz, a mean maximum frequency of 1,125 Hz, a mean duration of 0.4 sec, a mean bandwidth of 275 Hz, and a mean peak frequency of 973 Hz.

5.4 Discussion

The MISTCS 2007 sei whale encounters occurred primarily in the central and southern region of the study area, ranging from the island of Tinian to the southeast corner of the study area. A higher concentration was found in the southeast corner and along the Mariana Trench (**Figure 5-2**). The 32 sei whale vocalizations recorded during the survey included acoustic characteristics not previously described elsewhere. The distinctive features of the recorded calls were difficult to measure due to their variability and the poor signal-to-noise quality of some of the recordings at the relevant frequencies. The spectrograms of these calls still provide qualitative representation of call characteristics which might be more diagnostic than quantitative measurements, therefore, both are provided.

Post-processing of the sei whale calls successfully allowed us to identify and attribute three additional sei encounters with acoustic detections (N=7 calls). Additionally, review of the sonobuoy recordings provided an additional three sei whale encounters and seven attributed calls. These were probably missed during the real-time monitoring probably because so little is known of sei whale vocal behavior, and bio-acousticians in the field did not know what types of calls to look for. This review will be useful to other researchers who will be collecting acoustic data, or have recordings from this area and can now search for the calls types described here.

Sei whale calls from this survey were categorized into eight 'unique types' previously discussed. Type 1A calls were grouped based on their slight FM downsweep from approximately 1,000 to 840 Hz. These calls generally included a second, less intense downsweep in the band between 2.5 and 2 kHz (**Table 5-4, Figures 5-3 to 5-7**). Similar to these calls were Type 1B vocalizations, which consisted of a slight downsweep centered at 1 kHz. There was not a secondary band present in this call type (**Table 5-5, Figures 5-8 and 5-9**). While the literature describes downsweep calls that occur in association with sei whale vocalizations, those were frequencies below 100 Hz (Baumgartner et al. 2008; Baumgartner and Fratantoni 2008; Newhall et al. 2009; Rankin and Barlow 2007).

Call type 2 is a short, frequency modulated call that occurs between 1,000 and 1,200 Hz that does not appear similar in spectrographic representation or contour to other documented calls (**Table 5-6, Figure 5-10**).

Call type 3 is represented by only one call and contains three (possibly harmonic) segments between 900 and 3,200 Hz (**Table 5-7, Figure 5-11**). These segments consist of an approximate 1-second long tonal element immediately followed by a short (>.0.5-seconds) frequency modulated element. This call is similar in frequency range with the calls described off Nova Scotia.

Call types 5A and 5B are complex vocalizations that contain overlapping frequency "steps" centered at one or more frequencies. These calls were separated into two groups because type 5A increases from low to higher frequencies, whereas 5B decreases in frequency (**Tables 5-8 and 5-9**, **Figures 5-13 to 5-19**). All of these calls are centered at approximately 1,000 Hz with some of the bands extending to 3,500 Hz. Although the frequency range of the Type 5A and 5B calls do not coincide with those encountered in the Southern Ocean, the qualitative characteristic of the frequency "stepping" is evident; Type 5A and 5B calls are somewhat similar to the frequency range of those collected off Nova Scotia. It should be noted that the frequency stepping in these calls contains more overlap and frequency modulation than those described in the Southern Ocean.

Finally, Type 6 calls represent a more 'stereotypical baleen whale call' as it consists of a slight upsweep from 850 to 1,100 Hz (**Table 5-10, Figure 5-20**). Upsweeps are not mentioned in the literature, although they are typical of calls from other baleen whale species (e.g., fin whales, etc.)

The MISTCS 2007 dataset contained extensive electrical noise (due to a short in the main power system that was providing power to the acoustic system). This was especially true in the beginning of Leg I when the majority of sei whale calls were recorded. This noise was particularly strong in the low frequency range (below 500 Hz), which precluded localization of calls in the field or post-processing. This might have also resulted in missed detections of calls below approximately 500 Hz, or mischaracterization of calls with energy below 500 Hz during the survey. Although localizations were not possible during the survey, we still have high confidence that the calls analyzed here were produced by sei whales because they all occurred coincident to, or within a short time period of, visually confirmed sei whales, and no other visual or acoustic encounters were made within approximately 5 km during the relevant time period.

5.5 Conclusions and Recommendations

The vocalizations described here include call characteristics that have not been previously described from recordings of sei whales in other regions. It is recommended that these findings be submitted for a peer-reviewed publication. Our findings indicate greater variability in the vocal repertoire of sei whales than previously documented. These descriptions should aid in the analysis of other passive acoustic data, especially those collected remotely without associated visual information, such as from autonomous recorders, gliders, and seafloor hydrophones. Additional research is required to obtain a better understanding of the vocal repertoire of sei whales both in the Marianas and in other areas in the North and western North Pacific. Additional effort should be directed toward obtaining validated recordings of sei whales, behavioral information related to calls rates and call types, and if possible photo-identification and genetic (i.e., biopsy) samples. Future research including combined acoustic, behavioral, genetic and sighting data collection may lead to a better assessment of stock structure, distribution and abundance in the western North Pacific Ocean. Additionally, it may be possible to dedicate further effort to development of automated detectors for each call type, but it was not feasible for this effort due to small sample size.

5.6 Tables and Figures

5.6.1 Tables

Table 5-1. Summary of known sei whale studies and vocal descriptions compiled from literature reviews.

Location	Study Period	General Description	Frequency Range & Call Duration	Methods	Author
Cape Cod, MA	2006-2007 (Spring)	Low frequency, downsweeps, single calls, pairs and triplets occasionally detected	<100 Hz, 82 to 34 Hz over 1.4 s	Autonomous recorders (MARUs), 70 hrs of visual and acoustic observations. Used synthetic kernel for auto detections. Localized w/in 3 km.	Baumgartner et al. 2008
SW Gulf of Maine	May 2005 (Feeding)	Low frequency, downsweeps, single calls, pairs and triplets occasionally detected	<100 Hz, 82 to 34 Hz over 1.4 s	Array of autonomous ocean gliders	Baumgartner and Fratantoni 2008
Southern Ocean near Antarctic Peninsula	2003 (summer)	Low freq, tonal, FM, broadband calls; "growls" or "whooshes". Multi-part frequency step in-between. No temporal pattern in calling.	200-700Hz: avg freq 433 ± 192 Hz, over 0.45 s	Seafloor recorders in 3,000 m of water, 2 sonobuoys (DIFAR/Omni). DIFAR 305 m, omni at 27 m. Photo ID within 200 m of ship.	McDonald et al. 2005
Mid-Atlantic continental shelf off New Jersey coast	2006	Low freq, downsweep chirps	NA	Hydrophones on vertical array from 13 m to bottom	Newhall et al. 2009
North of Hawaiian Islands	November 2002	Low freq, Downsweep	Call 1: 100-44 Hz over 1.0s Call 2: 39-21 Hz over1.3s	NA	Rankin and Barlow 2007
B/W Nova Scotia and Newfoundland	NA	Mid freq, Long bursts	1.5-3.5 kHz: 0.7s long bursts of 7-10 metallic pulses (peak freq=3kHz)	NA	Thompson et al. 1979

Antarctic Peninsula	Jan – Feb 2006	Frequency "stepping" from 170-570 Hz	170 – 570 Hz	Acoustic sonobuoy survey	Gedamke & Robinson, 2010
SW Nova Scotia	1986-1989 (Fall)	Mid freq	1.4-2.6 s midfreq vocals, consisted of 2 bouts of 10-20 freq-modulated 1.5-3.5kHz sweeps separated by 0.4-1 s	32 opportunistic recording sessions	Knowlton et al. 1991

Table 5-2. Summary of all calls identified in association with either a visual sighting, or unique acoustic detection.

Quality is a relative measure based on a scale of 1 through 3 with 1 being the lowest SNR and 3 being the highest.

Date	Array/SB	Visual ID	Clip_ID	Quality	Preliminary Type
1/20/2007	Array	S#003 & Acoustic	20070120_8_3_0005.wav	3	1A
1/20/2007	Array	S#003 & Acoustic	20070120_8_3_0006.wav	2	2
1/20/2007	Array	S#003 & Acoustic	20070120_8_3_0007.wav	2	1A
1/20/2007	Array	S#003 & Acoustic	20070120_8_3_0008.wav	2	3
1/20/2007	Array	S#003 & Acoustic	20070120_8_3_0010.wav	1	1B
1/20/2007	Array	S#003 & Acoustic	20070120_8_3_0012.wav	1	1B
1/20/2007	Array	S#003 & Acoustic	20070120_8_3_0016.wav	2	1A
1/20/2007	Array	S#003 & Acoustic	20070120_8_3_0017.wav	2	1A
1/20/2007	Array	S#003 & Acoustic	20070120_8_3_0018.wav	1	6
1/21/2007	Array	S#005 & Acoustic	MISTCS_20070121_0001.wav	2	4
2/19/2007	Array	S#063 & Acoustic	MISTCS_20070219_0001.wav	3	5B
2/19/2007	Array	S#063 & Acoustic	MISTCS_20070219_0002.wav	2	5A
2/19/2007	Array	S#063 & Acoustic	MISTCS_20070219_135738_0001.wav	2	1A
2/19/2007	Array	S#063 & Acoustic	MISTCS_20070219_140000_0001.wav	1	5A
2/19/2007	Array	S#063 & Acoustic	MISTCS_20070219_140000_0002.wav	1	5B
2/19/2007	Array	S#063 & Acoustic	MISTCS_20070219_140000_0003.wav	2	5A
2/19/2007	Array	S#063 & Acoustic	MISTCS_20070219_140000_0004.wav	1	5B
2/19/2007	Array	S#063 & Acoustic	MISTCS_20070219_141000_0002.wav	2	5B
2/19/2007	Array	S#063 & Acoustic	MISTCS_20070219_141000_0003.wav	2	5B
3/26/2007	Sonobuoy	No Sighting	070326_0026_010652.826.wav	1	6
3/26/2007	Sonobuoy	No Sighting	070326_0034_012142.927.wav	2	No Match
4/8/2007	Sonobuoy	No Sighting	070408153100_0001_000754.342.wav	2	1A
4/9/2007	Sonobuoy	Possible S#143	070409_142800_0001_000050.933.wav	1	1A
4/9/2007	Sonobuoy	Possible S#143	070409_142800_0004_001103.022.wav	1	6
4/9/2007	Sonobuoy	Possible S#143	070409_142800_0005_002339.586.wav	1	1A

4/10/2007	Sonobuoy	No Sighting	070410_195000_0013_000630.017.wav	1	6
2/1/2007	Array	S#030	Sei Whale 134848_0001_000018.726.wav	1	1A
2/1/2007	Array	S#030	Sei Whale 135000_0001_000048.741.wav	2	1A
2/1/2007	Array	S#030	Sei Whale 135000_0002_000124.997.wav	2	2
2/20/2007	Array	S#068	Sei Whale_0001_000610.223.wav	2	5B
2/21/2007	Array	S#073	Sei Whale_0001.wav	2	5B
2/21/2007	Array	S#073	Sei Whale_0002.wav	1	5B

Table 5-3. Summary of the number of clipped sei whales calls classified to one of eight qualitative types (1A – 5B).

The total number of clipped calls measured and the number of calls that were associated with a sighting are given for all calls and each type, respectively.

Sei Whale Call Summary		
Category	Total Samples	Total Associated with Sighting
All	32*	25
Type 1A	10	7
Type 1B	2	2
Type 2	2	2
Type 3	1	1
Type 4	1	1
Type 5A	3	3
Type 5B	8	8
Type 6	4	1

*One call could not be matched to a type

Table 5-4. Measurements of sei whale calls categorized as "Type 1A".

The statistical average, median, standard deviation (Std. Dev.) and 10-90th percentile values are provided for each of the six descriptive measures.

Type 1A				
Measurement	Mean	Median	Std. Dev.	10-90th Percentile
Minimum Frequency (Hz)	835.0	867.2	145.7	(666.8 - 954.5)
Maximum Frequency (Hz)	1517.0	1230.5	527.5	(1051.2 - 2240.6)
Duration (s)	0.8	0.6	0.5	(0.34 - 1.7)
Bandwidth (Hz)	682.0	503.9	531.8	(70.3 - 1333.6)
Peak Frequency (Hz)	991.4	1019.5	69.0	(890.6 - 1057.0)
SNR (dB)	15.3	16.1	2.8	(11.9 - 18.7)

Table 5-5. Measurements of sei whale calls categorized as "Type 1B".

The statistical average, median, Std. Dev. and 10-90th percentile values are provided for each of the six descriptive measures.

Type 1B				
Measurement	Mean	Median	Std. Dev.	10-90th Percentile
Minimum Frequency (Hz)	914.1	914.1	49.7	(885.9 - 942.2)
Maximum Frequency (Hz)	1078.1	1078.1	49.7	(1050.0 - 1106.3)
Duration (s)	0.3	0.3	0.1	(0.22 - 0.29)
Bandwidth (Hz)	164.1	164.1	0.0	(164.1 - 164.1)
Peak Frequency (Hz)	1031.3	1031.3	33.1	(1012.5 - 1050.0)
SNR (dB)	11.9	11.9	2.2	(10.7 - 13.2)

Table 5-6. Measurements of sei whale calls categorized as "Type 2".

The statistical average, median, Std. Dev. and 10-90th percentile values are provided for each of the six descriptive measures.

Type 2				
Measurement	Mean	Median	Std. Dev.	10-90th Percentile
Minimum Frequency (Hz)	949.2	949.2	66.3	(911.7 - 986.7)
Maximum Frequency (Hz)	1640.6	1640.6	778.9	(1200.0 - 2081.3)
Duration (s)	0.2	0.2	0.0	(0.18 - 0.21)
Bandwidth (Hz)	691.4	691.4	712.6	(288.3 - 1094.5)
Peak Frequency (Hz)	1043.0	1043.0	49.7	(1014.8 - 1071.1)
SNR (dB)	14.1	14.1	2.6	(12.6 - 15.6)

Table 5-7. Measurements of sei whale calls categorized as "Types 3 and 4".

The measured values are provided for each of the six measures.

Measurement	Type 3	Type 4
Minimum Frequency (Hz)	832.0	714.8
Maximum Frequency (Hz)	3035.2	1160.2
Duration (s)	1.9	3.5
Bandwidth (Hz)	2203.1	445.3
Peak Frequency (Hz)	937.5	890.6
SNR (dB)	19.1	14.5

Table 5-8. Measurements of sei whale calls categorized as "Type 5A."

The statistical average, median, standard deviation (std. dev.) and 10-90th percentile values are provided for each of the six descriptive measures.

Type 5A				
Measurement	Mean	Median	Std. Dev.	10-90th Percentile
Minimum Frequency (Hz)	863.3	855.5	13.5	(855.5 - 874.2)
Maximum Frequency (Hz)	1582.0	1535.2	564.0	(1141.4 - 2041.4)
Duration (s)	0.3	0.3	0.1	(0.23 - 0.37)
Bandwidth (Hz)	718.8	679.7	551.8	(285.9 - 1167.9)
Peak Frequency (Hz)	1046.9	1054.7	35.8	(1017.2 - 1073.4)
SNR (dB)	14.6	15.4	2.7	(12.3 - 16.5)

Table 5-9. Measurements of sei whale calls categorized as "Type 5B".

The statistical average, median, Std. Dev. and 10-90th percentile values are provided for each of the six descriptive measures.

Type 5B				
Measurement	Mean	Median	Std. Dev.	10-90th Percentile
Minimum Frequency (Hz)	826.2	843.8	55.8	(764.1 - 876.6)
Maximum Frequency (Hz)	1642.1	1546.9	705.8	(1037.7 - 2294.5)
Duration (s)	0.6	0.6	0.2	(0.39 - 0.78)
Bandwidth (Hz)	815.9	773.4	728.0	(165.2 - 1453.1)
Peak Frequency (Hz)	902.3	896.5	14.0	(890.6 - 917.6)
SNR (dB)	16.9	17.4	3.5	(12.6 - 20.39)

Table 5-10. Measurements of sei whale calls categorized as "Type 6".

The statistical average, median, Std. Dev. and 10-90th percentile values are provided for each of the six descriptive measures.

Type 6				
Measurement	Mean	Median	Std. Dev.	10-90th Percentile
Minimum Frequency (Hz)	849.6	873.0	76.8	(776.9 - 903.5)
Maximum Frequency (Hz)	1125.0	1119.1	131.5	(1007.8 - 1246.9)
Duration (s)	0.4	0.2	0.3	(0.16 - 0.66)
Bandwidth (Hz)	275.4	234.4	98.3	(217.9 - 365.6)
Peak Frequency (Hz)	972.7	984.4	40.6	(935.2 - 1000.8)
SNR (dB)	9.6	9.8	2.3	(7.37 - 11.57)

5.6.2 Figures

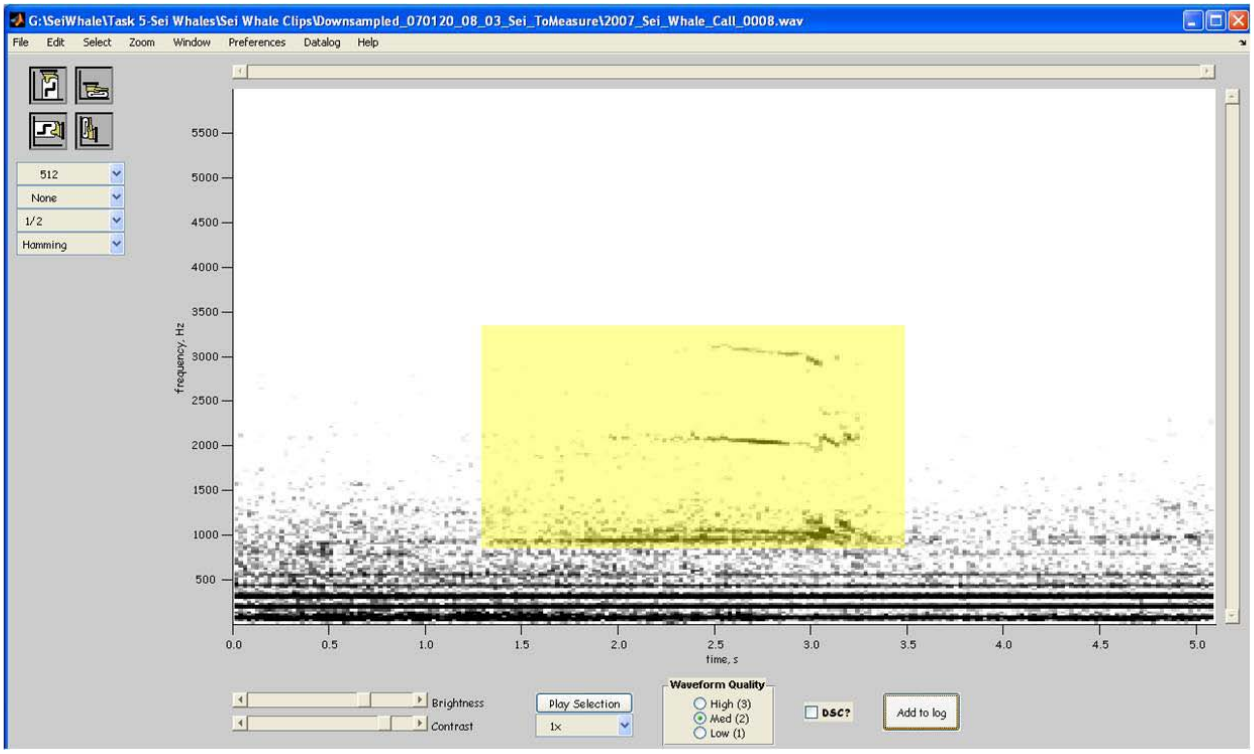


Figure 5-1. An example of a measurement box for a sei whale call in *Osprey*.

The spectrographic display shows frequency (Hz) along the y-axis and time (sec) along the x-axis with amplitude reflected as color intensity. The dark bands along the bottom of the figure are attributable to electric noise present in the system.

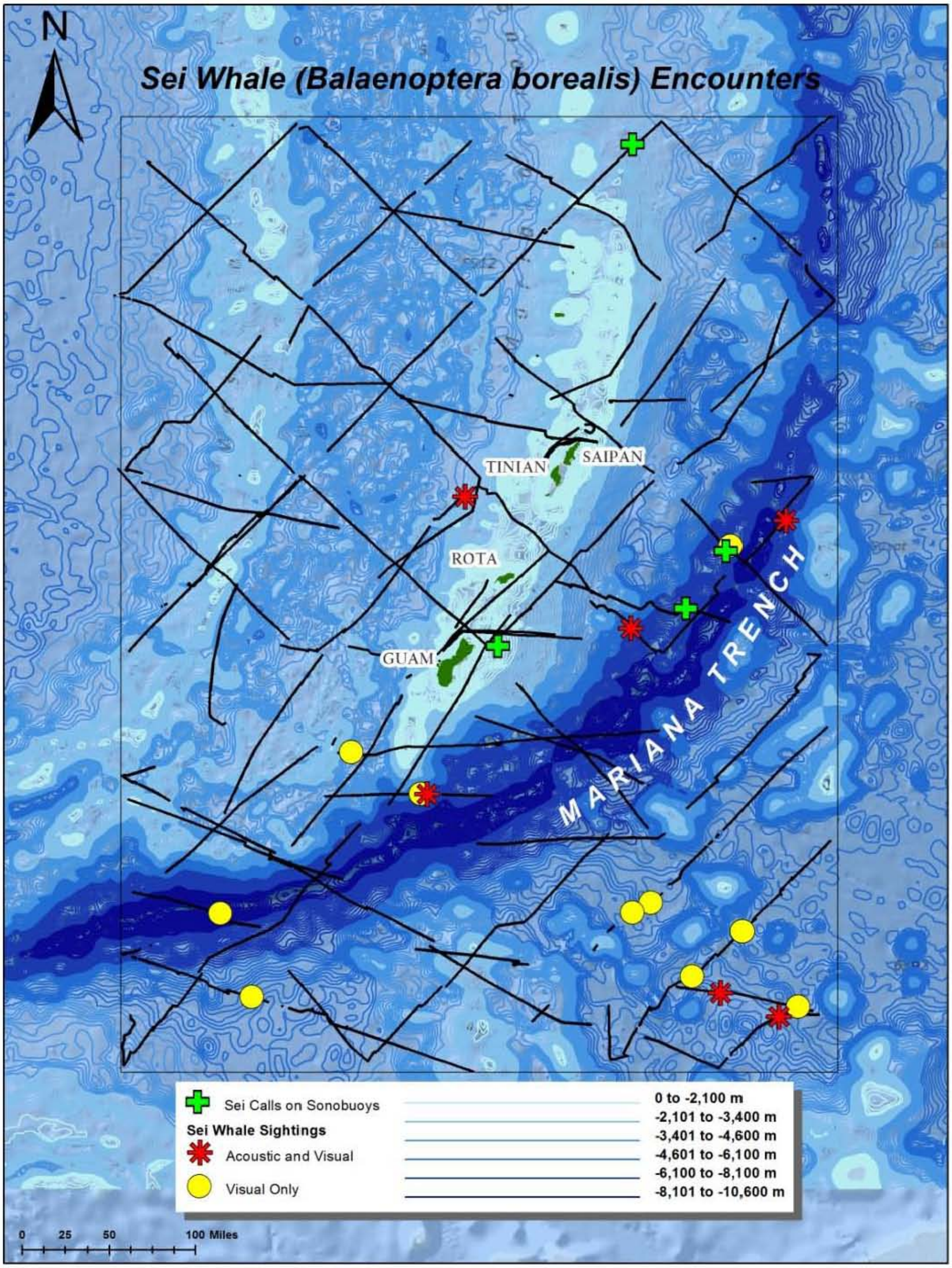


Figure 5-2. Locations of MISTCS 2007 sei whale encounters categorized as combined acoustic and visual (red star), visual only (yellow circle) or sonobuoy (green cross)

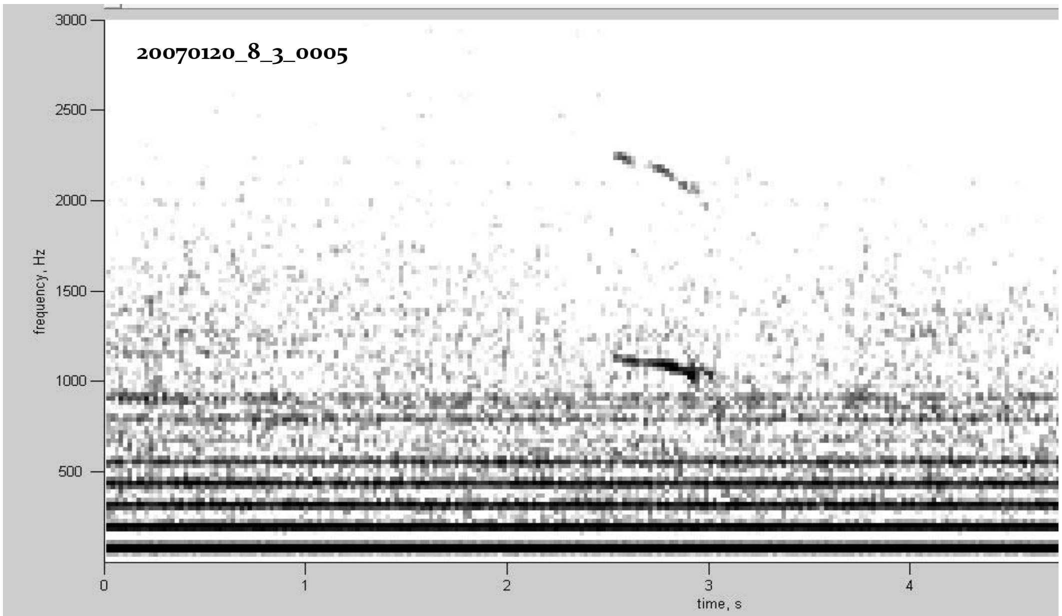


Figure 5-3. Example of Type 1A sei whale call spectrographic display showing frequency (Hz) along the y-axis and time (sec) along the x-axis with amplitude reflected as color intensity.

The dark horizontal banding pattern is due to electrical noise from the research vessel's power supply. This noise only occurred during the beginning of the first leg, when, unfortunately, most of the recordings of sei whale calls were made.

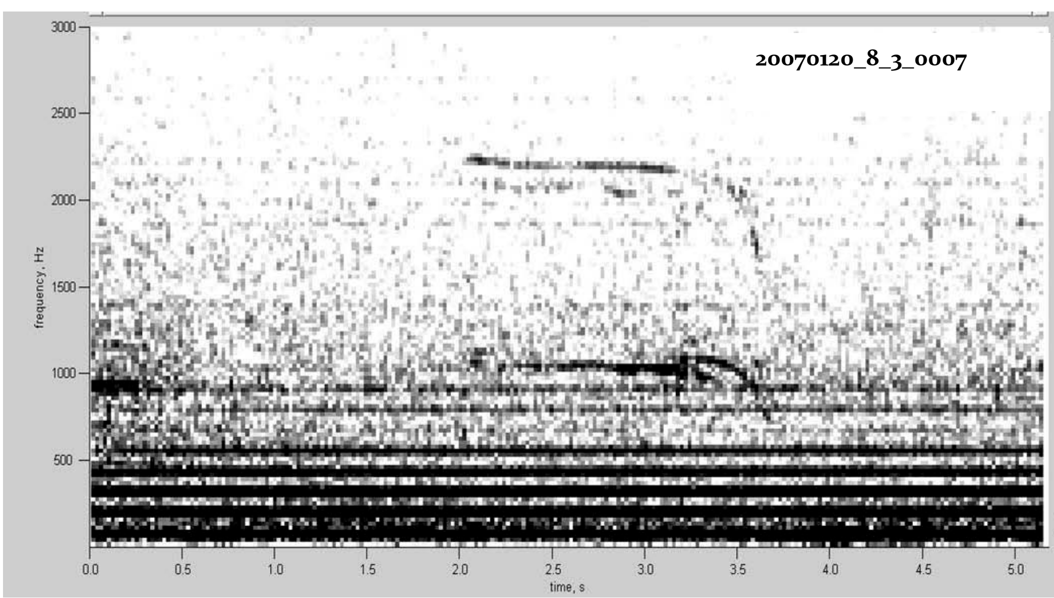


Figure 5-4. Example of Type 1A sei whale call spectrographic display showing frequency (Hz) along the y-axis and time (sec) along the x-axis with amplitude reflected as color intensity

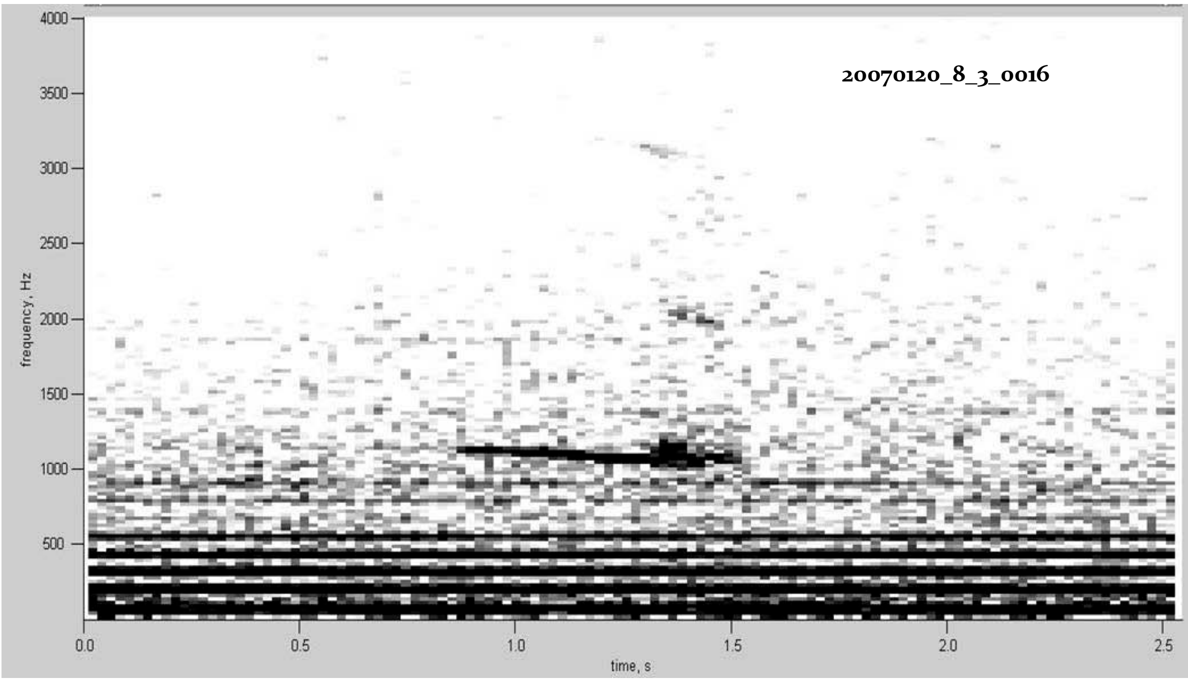


Figure 5-5. Example of Type 1A sei whale call spectrographic display showing frequency (Hz) along the y-axis and time (sec) along the x-axis with amplitude reflected as color intensity

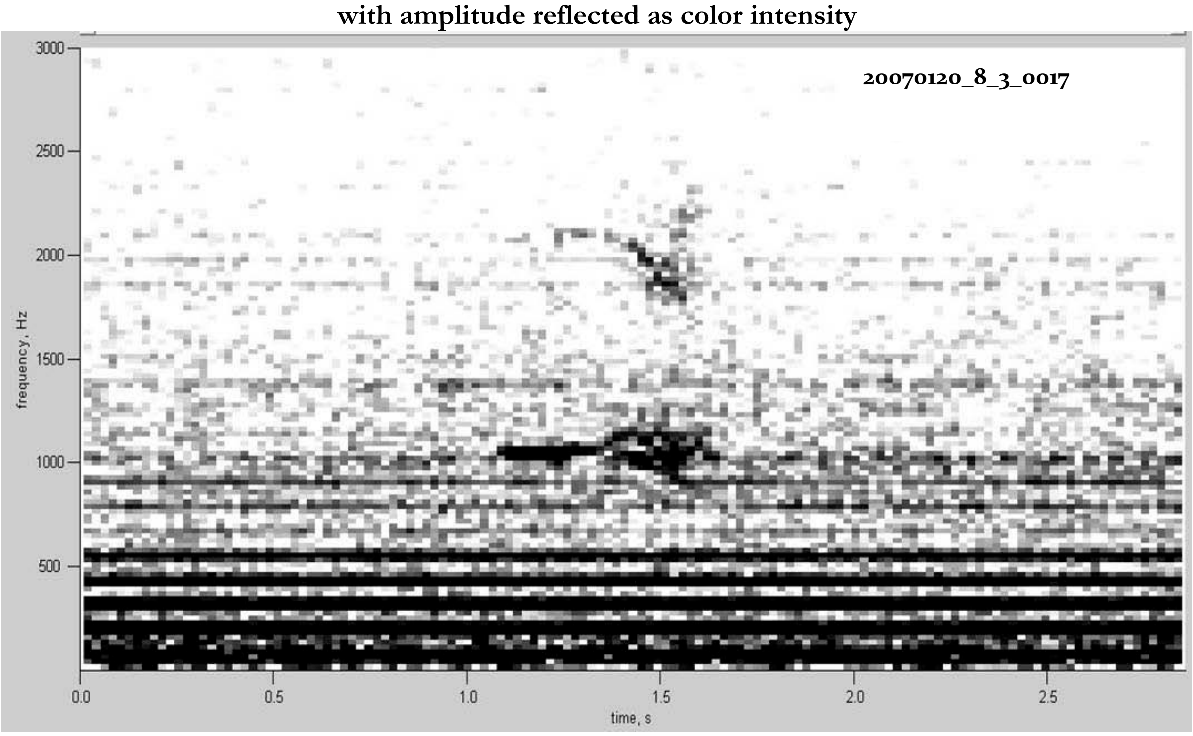


Figure 5-6. Example of Type 1A sei whale call spectrographic display showing frequency (Hz) along the y-axis and time (sec) along the x-axis with amplitude reflected as color intensity

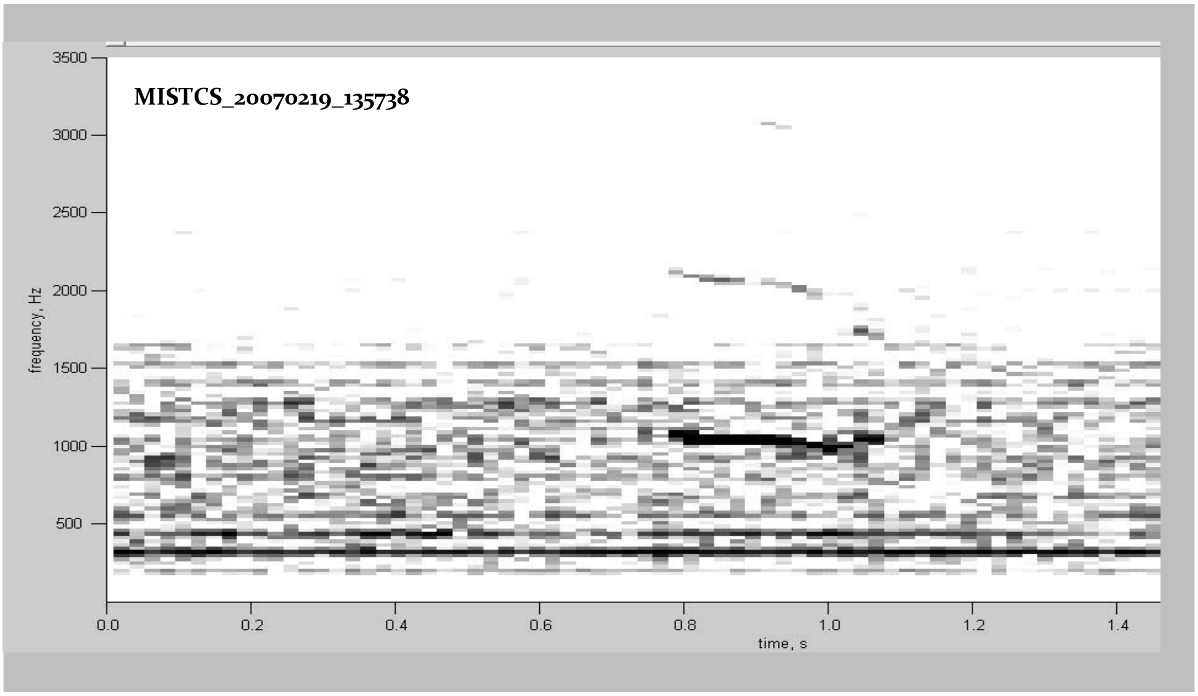


Figure 5-7. Example of Type 1A sei whale call spectrographic display showing frequency (Hz) along the y-axis and time (sec) along the x-axis with amplitude reflected as color intensity

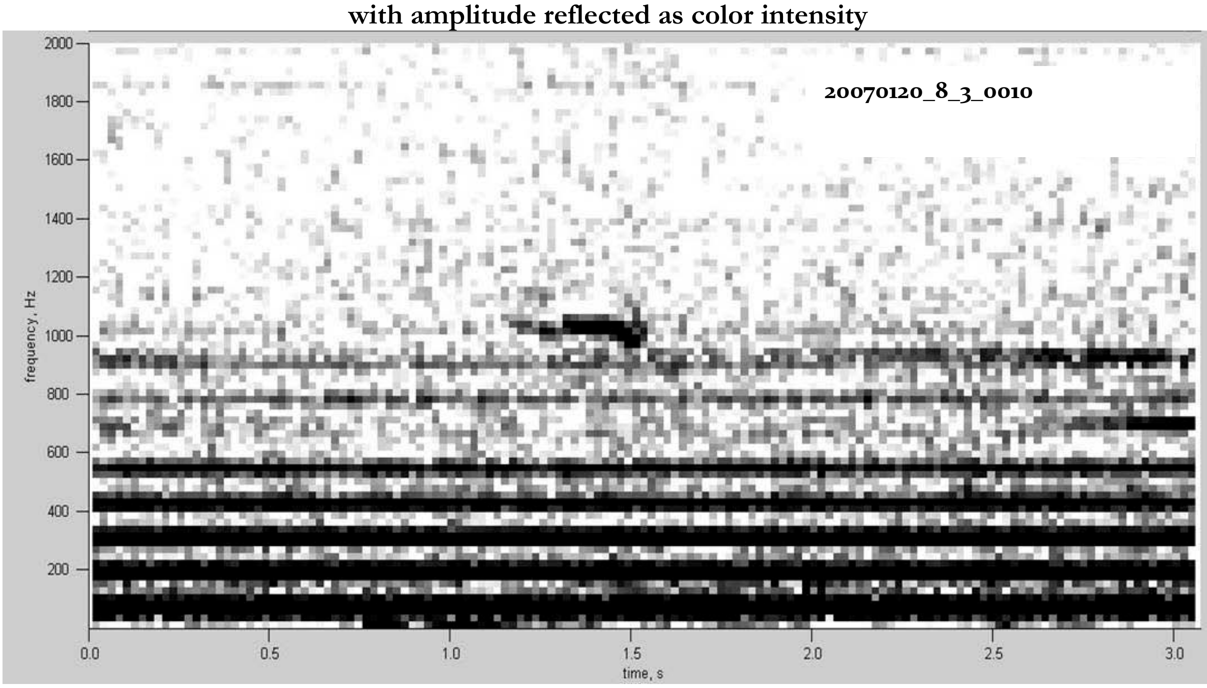


Figure 5-8. Example of Type 1B sei whale call spectrographic display showing frequency (Hz) along the y-axis and time (sec) along the x-axis with amplitude reflected as color intensity

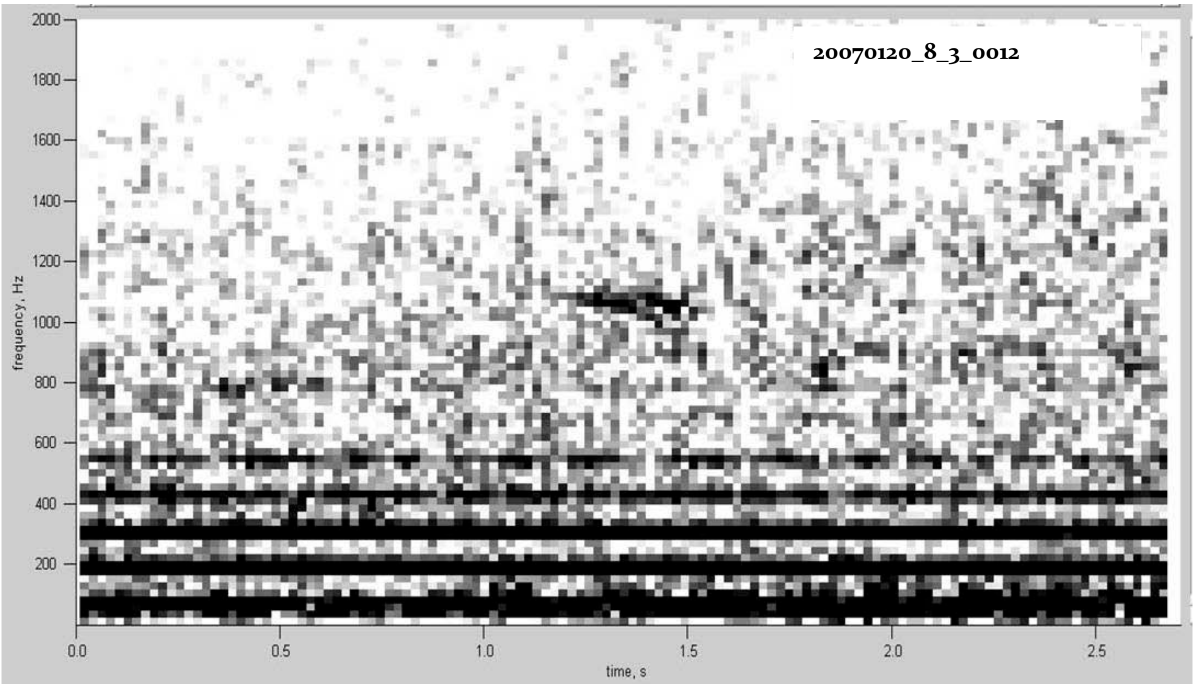


Figure 5-9. Example of Type 1B sei whale call spectrographic display showing frequency (Hz) along the y-axis and time (sec) along the x-axis with amplitude reflected as color intensity

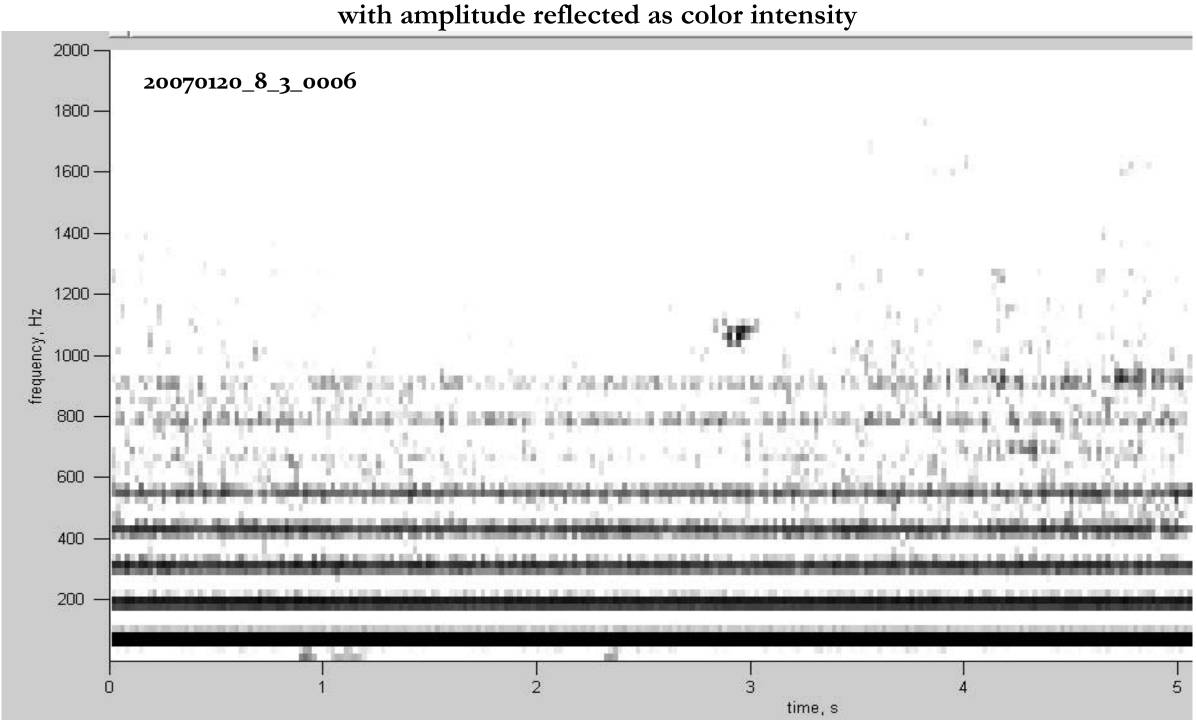


Figure 5-10. Example of Type 2 sei whale call spectrographic display showing frequency (Hz) along the y-axis and time (sec) along the x-axis with amplitude reflected as color intensity

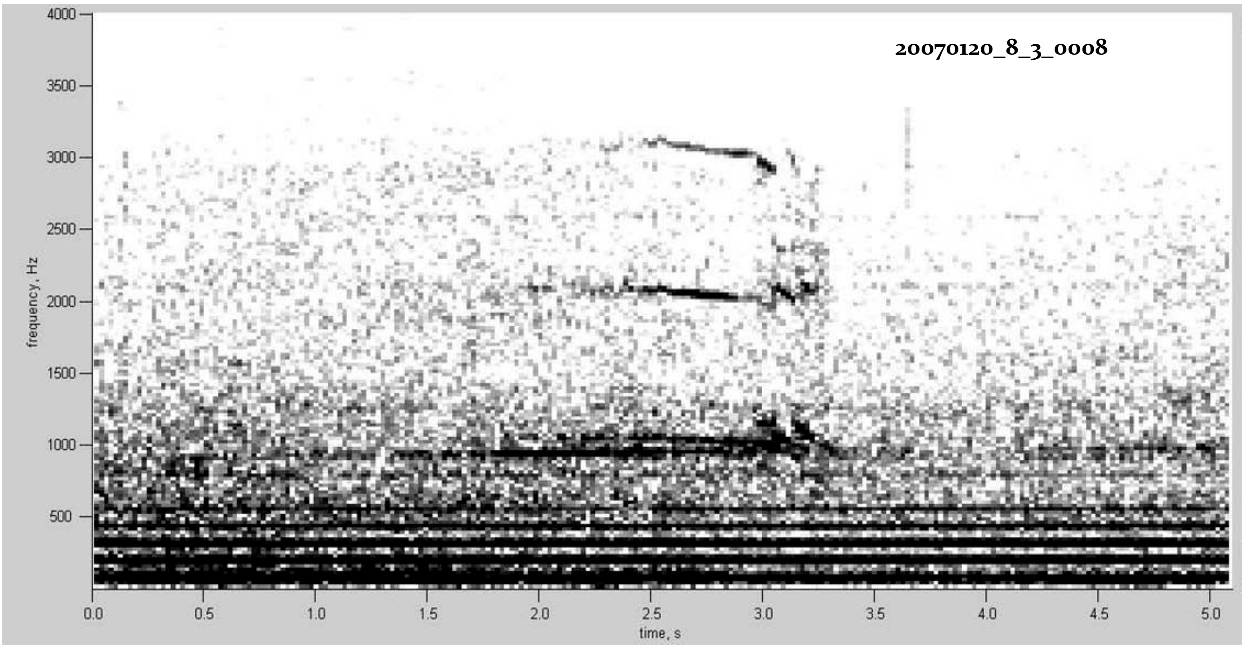


Figure 5-11. Example of Type 3 sei whale call spectrographic display showing frequency (Hz) along the y-axis and time (sec) along the x-axis with amplitude reflected as color intensity

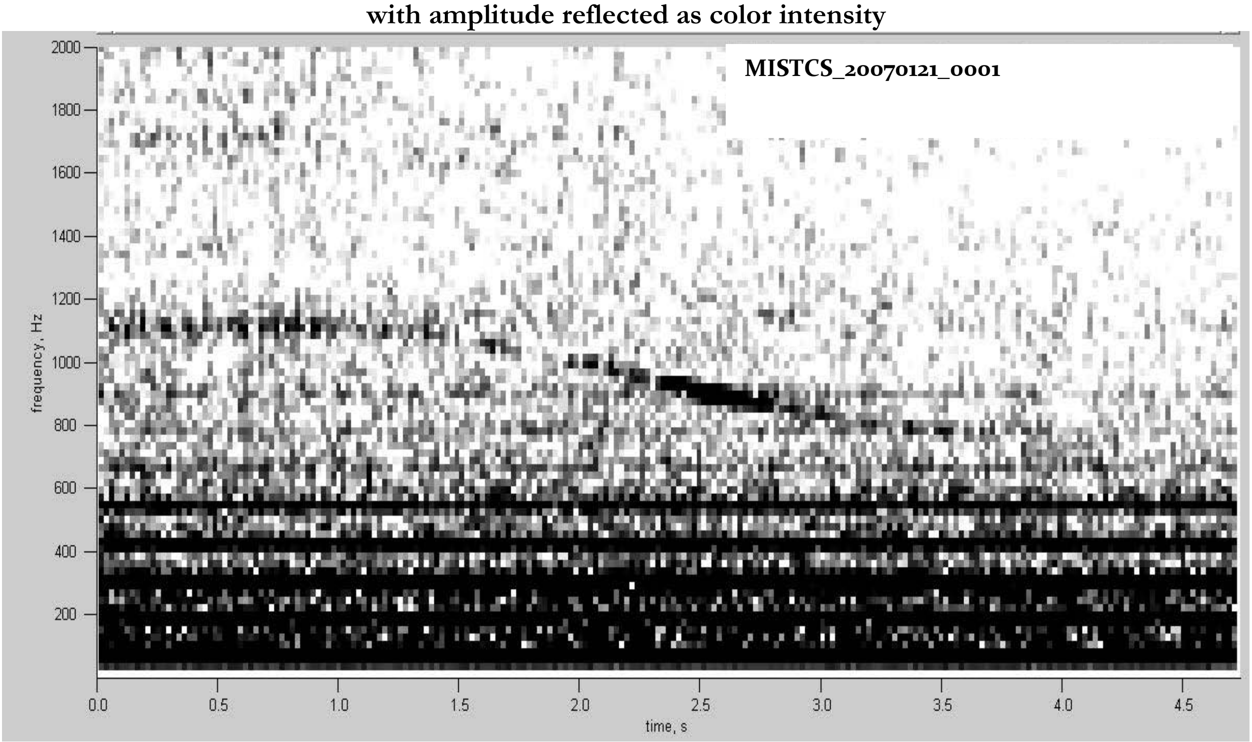


Figure 5-12. Example of Type 4 sei whale call spectrographic display showing frequency (Hz) along the y-axis and time (sec) along the x-axis with amplitude reflected as color intensity

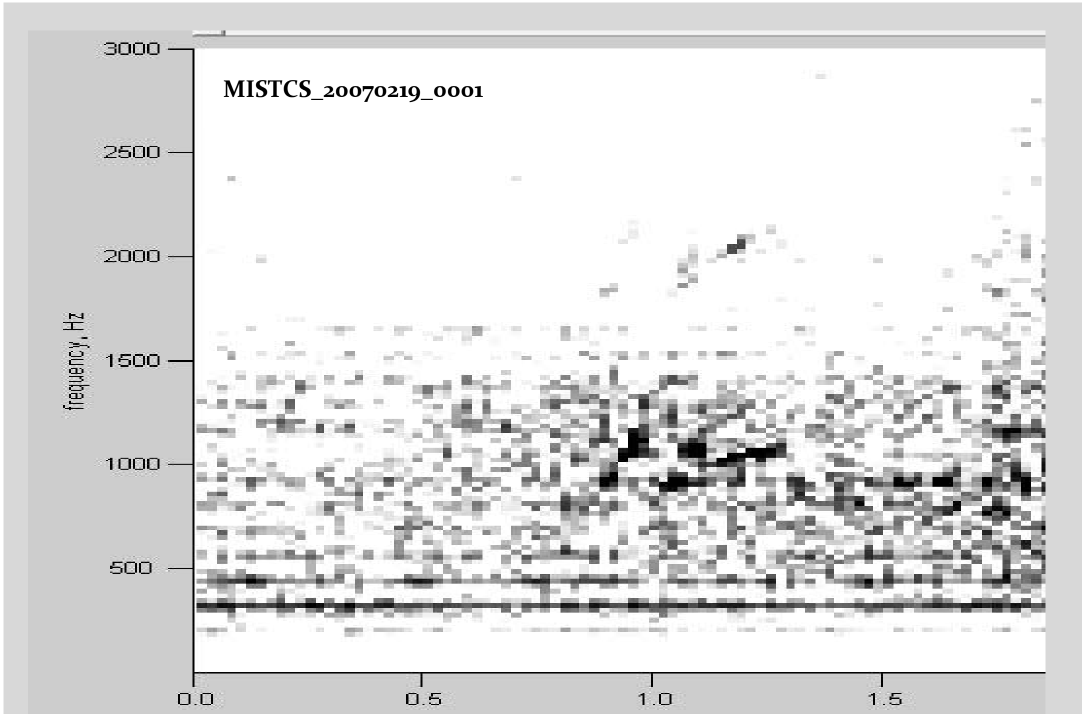


Figure 5-13. Example of Type 5A sei whale call spectrographic display showing frequency (Hz) along the y-axis and time (sec) along the x-axis with amplitude reflected as color intensity

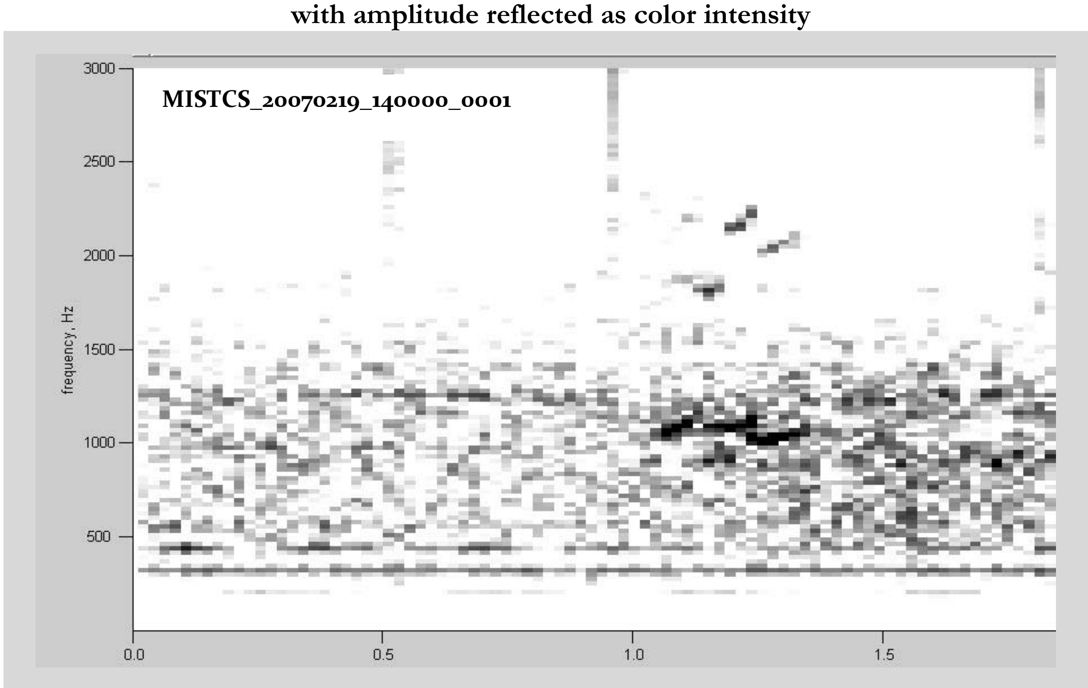


Figure 5-14. Example of Type 5A sei whale call spectrographic display showing frequency (Hz) along the y-axis and time (sec) along the x-axis with amplitude reflected as color intensity

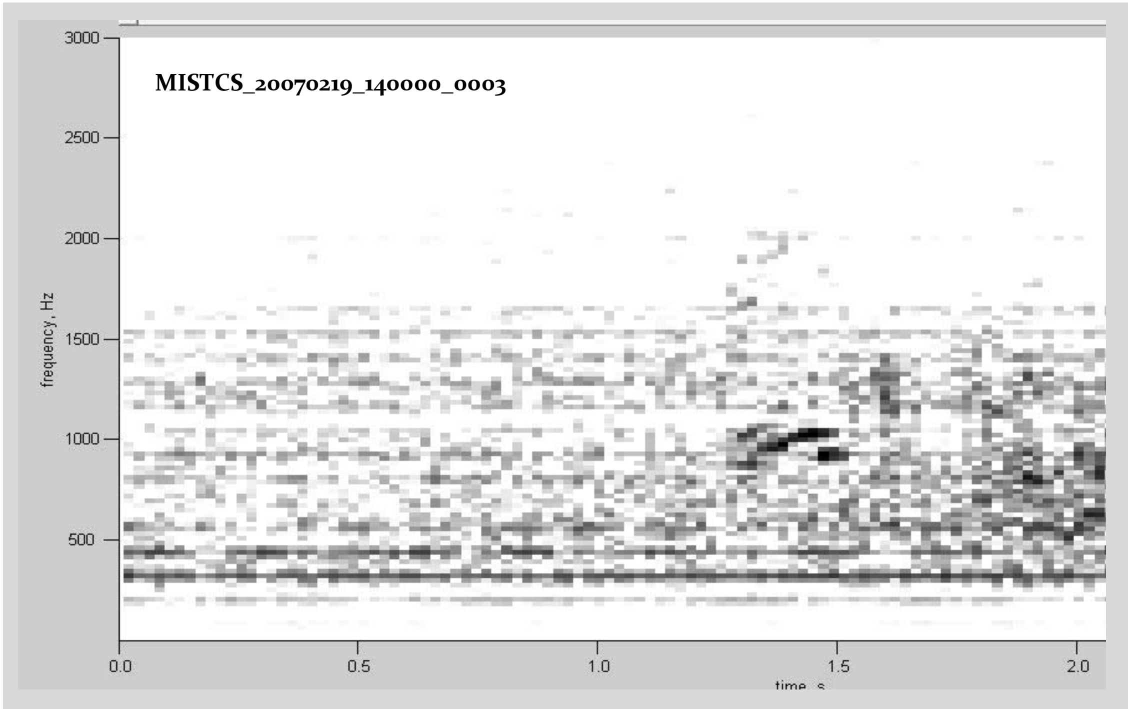


Figure 5-15. Example of Type 5A sei whale call spectrographic display showing frequency (Hz) along the y-axis and time (sec) along the x-axis with amplitude reflected as color intensity

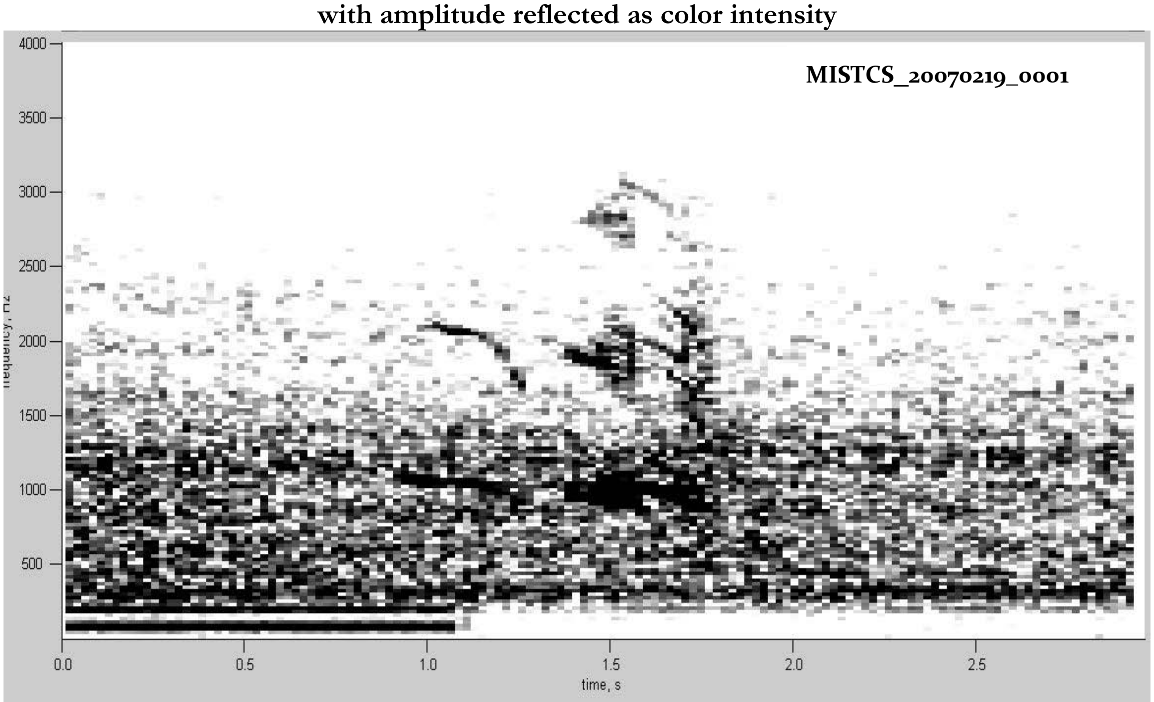


Figure 5-16. Example of Type 5B sei whale call spectrographic display showing frequency (Hz) along the y-axis and time (sec) along the x-axis with amplitude reflected as color intensity

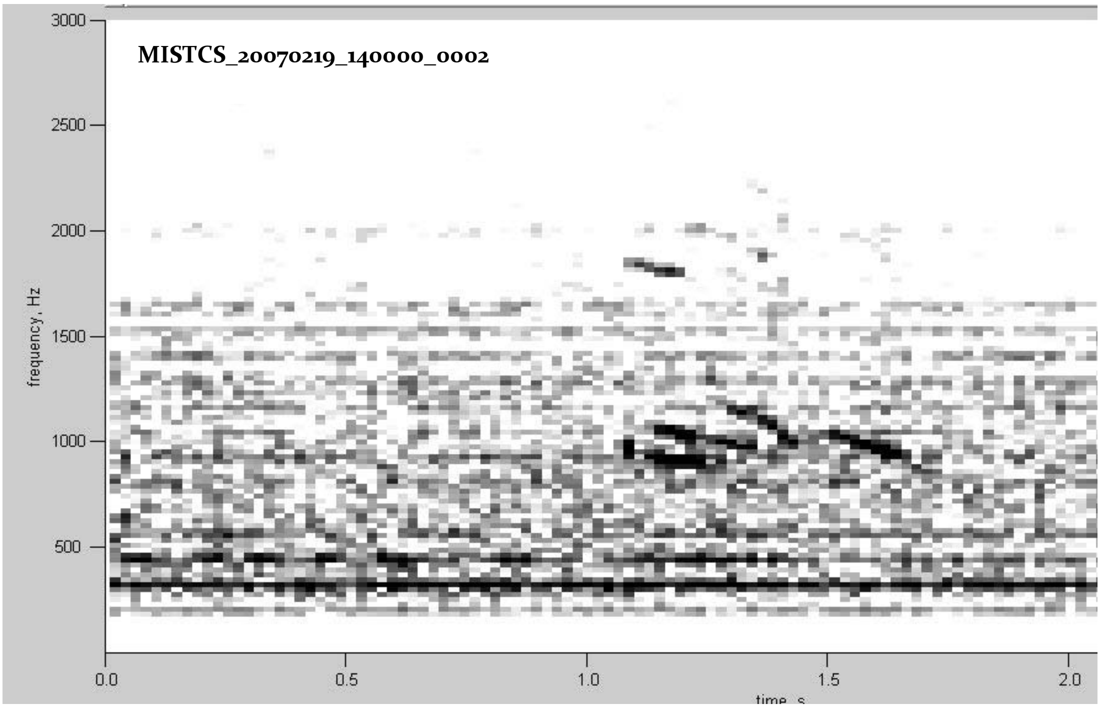


Figure 5-17. Example of Type 5B sei whale call spectrographic display showing frequency (Hz) along the y-axis and time (sec) along the x-axis with amplitude reflected as color intensity

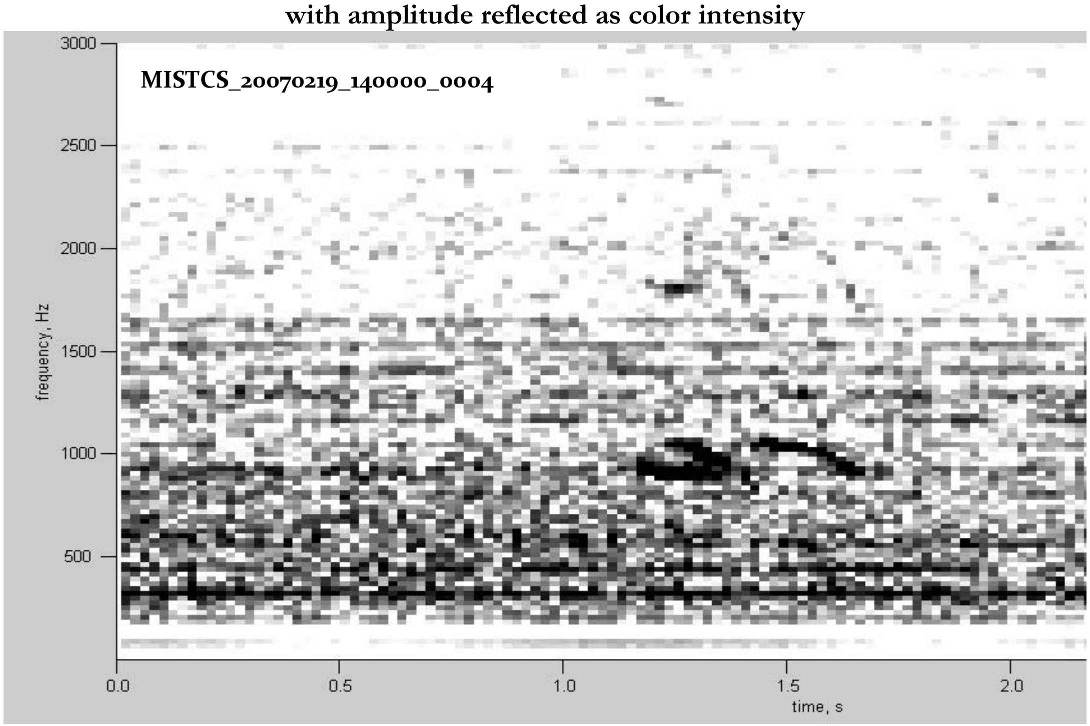


Figure 5-18. Example of Type 5B sei whale call spectrographic display showing frequency (Hz) along the y-axis and time (sec) along the x-axis with amplitude reflected as color intensity

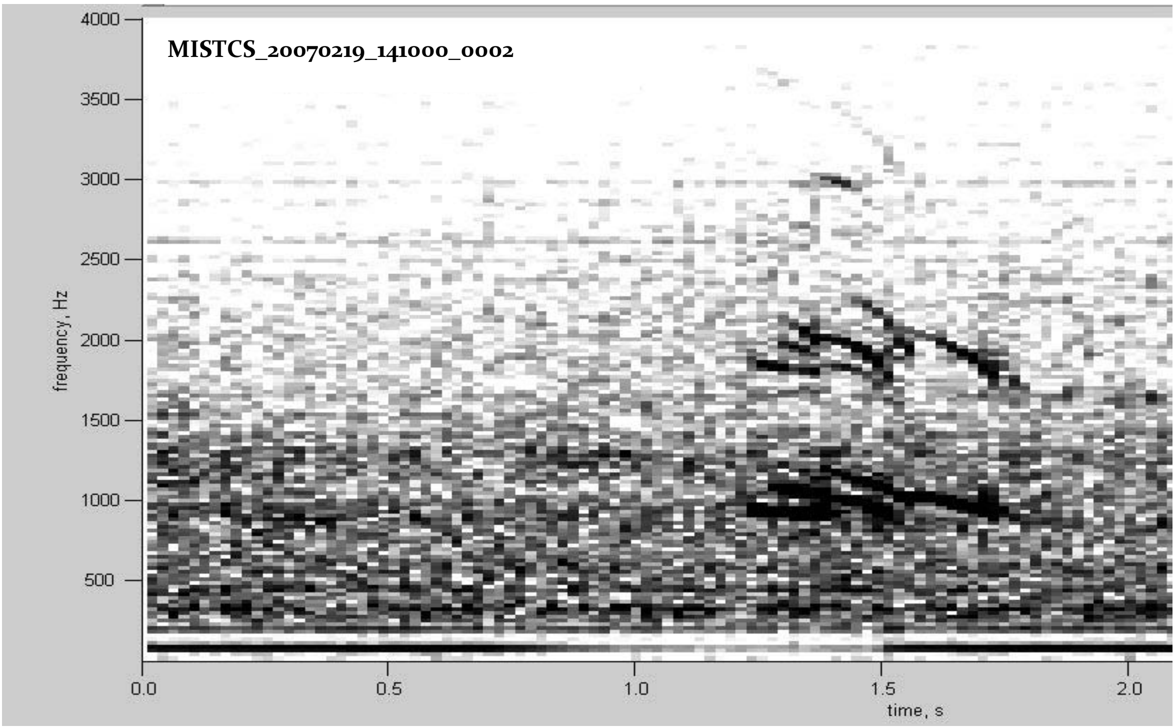


Figure 5-19. Example of Type 5B sei whale call spectrographic display showing frequency (Hz) along the y-axis and time (sec) along the x-axis with amplitude reflected as color intensity

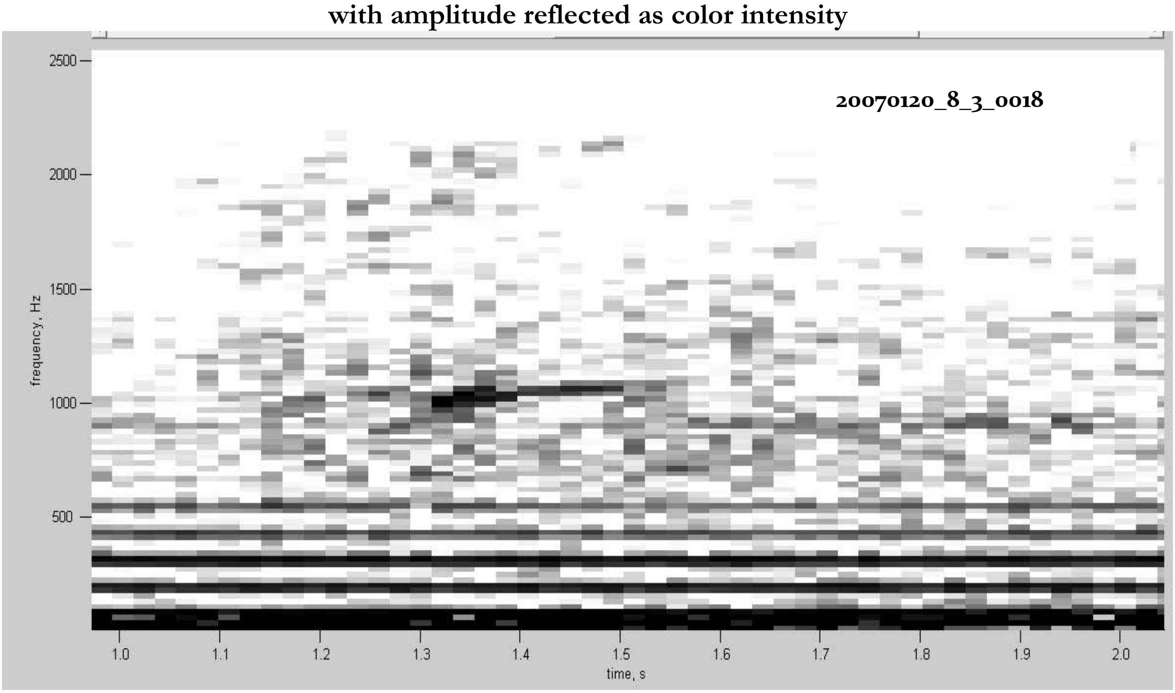


Figure 5-20. Example of Type 6 sei whale call spectrographic display showing frequency (Hz) along the y-axis and time (sec) along the x-axis with amplitude reflected as color intensity

5.7 Literature Cited

Barlow, J. 2003. *Cetacean abundance in Hawaiian waters during summer/fall 2002*. Southwest Fisheries Science Center Administrative Report LJ-03-13. National Marine Fisheries Service, La Jolla, CA..

Baumgartner, M.F. and D.M. Fratantoni. 2008. Diel periodicity in both sei whale vocalization rates and the vertical migration of their copepod prey observed from ocean gliders. *Limnology and Oceanography* 53(5, Part 2):2197-2209.

Baumgartner, M.F. S.M. Van Parijs, F.W. Wenzel, C.J. Tremblay, H.C. Esch, and A.M. Warde. 2008. Low frequency vocalizations attributed to sei whales (*Balaenoptera borealis*). *Journal of the Acoustical Society of America* 124(2):1339-1349.

DoN (Department of the Navy). 2005. *Marine resources assessment for the Marianas Operating Area*. Pacific Division, Naval Facilities Engineering Command, Pearl Harbor, Hawaii. Contract number N62470-02-D-9997, CTO 0027. Prepared by Geo-Marine, Inc., Plano, Texas.

DoN (Department of the Navy). 2007. *Marine mammal and sea turtle survey and density estimates for Guam and the Commonwealth of The Northern Mariana Islands*. Final report contract No. N68711-02-D-8043. Prepared for U.S. Navy, Pacific Fleet, Naval Facilities Engineering Command, Pacific, Honolulu, Hawaii.

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

Gedamke, J. and S.M. Robinson. 2010. Acoustic survey for marine mammal occurrence and distribution off East Antarctica (30º-80ºE) in January-February 2006. *Deep Sea Research Part II: Topical Studies in Oceanography* 57 (9-10):968-981.

Horwood, J. 1987. *The sei whale: Population biology, ecology, and management*. Croom Helm Ltd., London, England.

Knowlton, A., C.W. Clark, and S. Kraus. 1991. Sounds recorded in the presence of sei whale, *Balaenoptera borealis. Journal of the Acoustical Society of America* 89(4B):1968.

McDonald, M., J.A. Hildebrand, S.M. Wiggins, D. Thiele, and D. Glascow. 2005. Sei whale sounds recorded in the Antarctic. *Journal of the Acoustical Society of America*. 118(6):3941.

Mellinger, D.K., and J.W. Bradbury. 2007. Acoustic measurement of marine mammal sounds in noisy environments. In: *Proceedings of the Second International Conference on Underwater Acoustics Measurements: Technologies and Results, Heraklion, Greece, 25-29 June 2007.*

National Marine Fisheries Service (NMFS). 2011. *Final Recovery Plan for the Sei Whale (*Balaenoptera borealis*)*. National Marine Fisheries Service, Office of Protected Resources, Silver Spring, MD.

Newhall, A.E., L. Ying-Tsong, J.F. Lynch, and M.F. Baumgartner. 2009. Sei whale localization and vocalization frequency sweep rate estimation during the New Jersey Shallow Water 2006 experiment. *Journal of the Acoustical Society of America* 125(4, Part 2):2738.

Rankin, S. and J. Barlow. 2007. Vocalizations of the sei whale *Balaenoptera borealis* off the Hawaiian Islands. *Bioacoustics*. 16:137-145.

Smultea, M.A., T.A. Jefferson, and A.M. Ziodis. 2010. Rare sightings of a Bryde's whale (*Balaenoptera edeni*) and sei whales (*B. borealis*) (Cetacea: Balaenopteridae) northeast of O'ahu, Hawai'i. *Pacific Science* 64(3):449-457.

Thompson, T. J., H.E. Winn, and P.J. Perkins. 1979. Mysticete sounds. Pages 403-431 in H.E. Winn and B.L. Olla, eds. *Behavior of marine animals: Current perspectives in research. Volume 3: Cetaceans*. Plenum Press, New York.

Tillman, M. F. 1977. Estimates of population size for the North Pacific sei whale. Reports of the International Whaling Commission, Special Issue 1:98-106.

Wada, S., M. Oishi and T.K. Yamada. 2003. A newly discovered species of living baleen whale. *Nature* 426:278-281.

Appendix E –
FY13-15 Marine Species Monitoring Plan

Prepared for the National Marine Fisheries Service
Office of Protected Resources
Prepared by U.S. Pacific Fleet Environmental Readiness Office

Mariana Islands Range Complex Marine Species Monitoring Plan FY13-2015

This Monitoring Plan is submitted to NMFS in support of the Taking and Importing Marine Mammals; U.S. Navy Training in the Mariana Islands Range Complex

AND

Programmatic Biological Opinion on the U.S. Navy's Training in the Mariana Islands Range Complex

LIST OF ACRONYMNS

AMR	Adaptive Management Review
CFR	Code of Federal Regulations
CNO	Chief of Naval Operations
DoD	Department of Defense
EIS	Environmental Impact Statement
OEIS	Overseas Environmental Impact Statement
DON	Department of the Navy
ESA	Endangered Species Act
FY	fiscal year
GPS	global positioning system
HQ	headquarters
HRC	Hawaii Range Complex
ICMP	Integrated Comprehensive Monitoring Program
ITA	Incidental Take Authorization
LOA	Letter of Authorization
MIRC	Mariana Islands Range Complex
MMO	marine mammal observer
MMPA	Marine Mammal Protection Act
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
nmi	Nautical miles
NOAA	National Oceanographic and Atmospheric Administration
ONR	Office of Naval Research
PAM	passive acoustic monitoring
PIFSC	Pacific Islands Fisheries Science Center
R&D	Research and Development
SAG	Science Advisory Group

EXECUTIVE SUMMARY

The U. S. Navy (Navy) has developed this Mariana Islands Range Complex (MIRC) Monitoring Plan to provide marine mammal and sea turtle monitoring as required under the Marine Mammal Protection Act (MMPA) of 1972 and the Endangered Species Act (ESA) of 1973. In order to issue an Incidental Take Authorization (ITA) for an activity, Section 101(a)(5)(a) of the MMPA states that National Marine Fisheries Service (NMFS) must set forth "requirements pertaining to the monitoring and reporting of such taking." The MMPA implementing regulations in 50 CFR Section 216.104 (a)(13) note that requests for Letters of Authorization (LOAs) must include the suggested means of accomplishing the necessary monitoring and reporting that will result in increased knowledge of the species and of the level of taking or effects to populations of marine mammals that are expected to be present.

Navy marine species monitoring conducted in the MIRC from FY10 to FY12 has utilized a combination of visual line-transect surveys, non-random/non-systematic visual surveys, and passive acoustics. Through the process of adaptive management, input was solicited from an independent scientific advisory group. In order to meet the top level goals established by the Navy and NMFS and through the lessons learned from past monitoring, the Navy is recommending revisions to the monitoring plan for FY13 and FY14. The monitoring plan includes visual survey from either a vessel or shore-based station, maintenance of autonomous passive acoustic monitoring devices in FY13 and FY14 and subsequent analysis, use of a dipping hydrophone during vessel surveys, support for collection of biopsy samples (including preliminary analysis and archiving) per year, support for satellite tagging including purchase of tags and analysis of data per year, mark-recapture abundance estimates, and either line transect diving sea turtle surveys per year or turtle tagging.

1. INTRODUCTION

The Mariana Islands Range Complex (MIRC) is located in the western North Pacific Ocean and encompasses an area of approximately 500,000 nm2. The range complex surrounds the Mariana Island Archipelago which includes the Commonwealth of the Northern Mariana Islands and the Territory of Guam (see Figure 1). Very little is known about the marine mammal and sea turtle species in the MIRC (Ligon et al., 2011).

Because the islands are a geographically isolated archipelago, it is hypothesized that the assemblage of marine mammals and sea turtles would bear some ecological resemblance to the isolated Hawaiian Islands archipelago. The expected similarities between the archipelagos, in terms of the cetacean assemblage, include low density and high diversity, but could also include island-associated odontocetes, overlapping ranges of oceanic, offshore, and island-associated odontocete populations, resident offshore species, and seasonally present baleen whales.

Evidence for low marine mammal density is suggested by low sighting rates from a Navy study (Fulling et al., 2011) and small boat surveys during 2010 and 2011 off Guam and Saipan (HDR, 2011; Hill et al., 2011; Ligon et al., 2011). Evidence for high diversity and similar species assemblages comes from sighting/acoustic records: Twelve species were sighted during the Navy-sponsored, large-vessel Mariana Islands Sea Turtle and Cetacean Survey (MISTCS) (DoN, 2007), and ten species were sighted during the collaborative Pacific Island Fisheries Science Center (PIFSC)/Navy large vessel cruises during 2010 (Oleson and Hill, 2010). Several additional species not detected visually were detected by passive acoustic methods in both studies. Patterns of species' presence and density may be similar to Hawaii.

The above mentioned studies represent nearly the entirety of the scientific corpus on this topic; therefore fundamental issues of occurrence and distribution of species have yet to be fully described, and such knowledge is a prerequisite to deeper conclusions through the monitoring program regarding the potential impacts of Navy training.

Monitoring in the Mariana Islands presents special challenges. Past experience has proved that windward sides of islands and offshore areas are difficult to access in small vessels (HDR, 2011; Hill et al., 2011; Ligon et al., 2011). Winter conditions consistently impair field efforts. For these reasons, sighting opportunities of baleen whales are infrequent. Alternative means of collecting data that complement visual surveys are recommended as ways to achieve data collection goals.

There are four levels that guide implementation of the Adaptive Management Review (section 2.3) process for monitoring in the MIRC:

1) The Navy's Integrated Comprehensive Monitoring Program (ICMP) provides the overarching structure for the monitoring program. The ICMP is a planning tool, developed through coordination with the National Marine Fisheries Service (NMFS), which establishes top-level goals for Navy marine species monitoring pursuant to the Endangered Species and the Marine Mammal Protection Act.

2) The Scientific Advisory Group (SAG) Report is the product of an independent scientific advisory panel which convened to critically evaluate Navy marine species monitoring plans and propose recommendations for the refinement of the monitoring and mitigation program. Establishing the SAG was an outgrowth of the adaptive management process.

The SAG made conceptual and programmatic recommendations which address ICMP goals but are more specific to range complex level monitoring plans.

3) Communication with researchers: The Navy also solicited additional input on local monitoring questions and priorities from researchers at universities, science centers, and private institutions who have worked in MIRC or the Hawaiian Islands. The contributors had expertise across disciplines, species, and techniques and had publications relevant to Navy marine species monitoring in the MIRC or the Hawaiian Islands.

4) Previous surveys: Current scientific and monitoring knowledge gained through previous efforts in the study area.

These four items are described in more detail below.

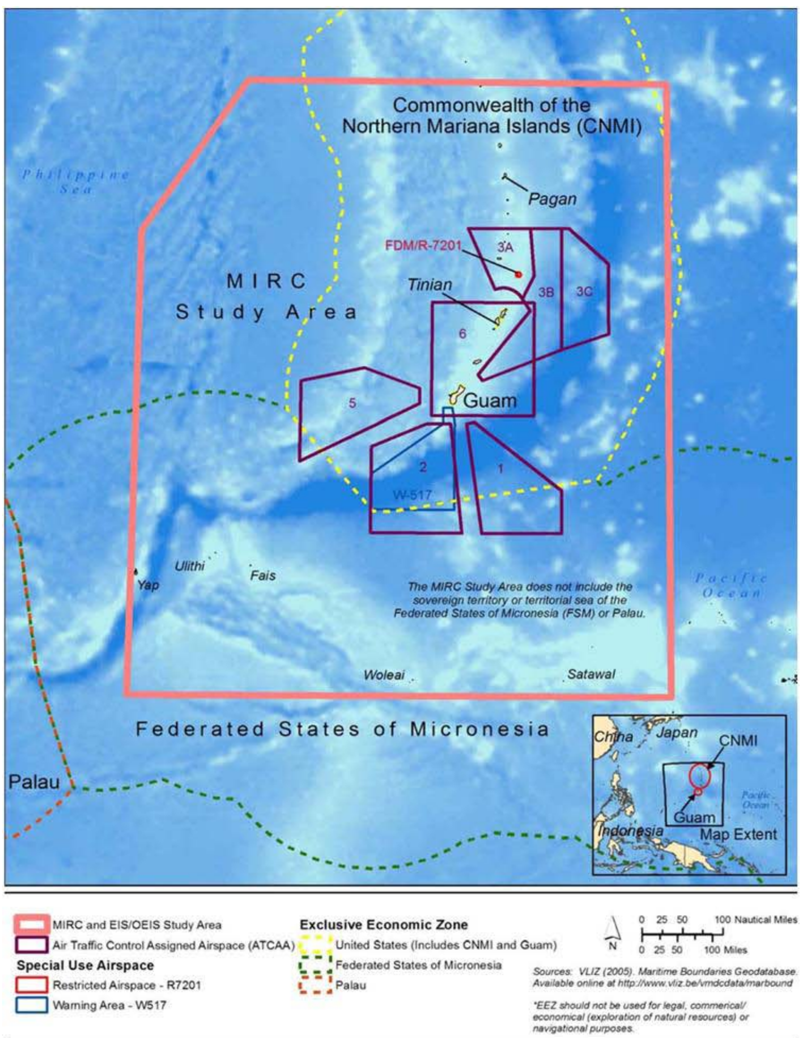


Figure 1. MIRC Study Area

1.1 INTEGRATED COMPREHENSIVE MONITORING PROGRAM (ICMP)

The ICMP provides the overarching framework for coordination of the Navy's monitoring program. It is intended for use as a planning tool to focus Navy monitoring priorities pursuant to Endangered Species Act (ESA) and Marine Mammal Protection Act (MMPA) requirements. It is also an adaptive management tool to analyze and refine monitoring and mitigation techniques over time. The ICMP was developed in direct response to Navy range permitting requirements established in the various MMPA Final Rules, ESA Consultations, Biological Opinions, and applicable regulations. As a framework document, the ICMP applies by regulation to those activities on ranges and operating areas for which the Navy sought and received incidental take authorizations. The ICMP is an "umbrella" document over specific monitoring plans that have been or are being developed for the Navy's range complexes and operating areas, depicted in Figure 2. Additional ranges or study areas may be added to the ICMP consistent with future Navy range permitting requirements.

The MMPA Final Rules provides that the primary objectives of the ICMP are to:

- Monitor and assess the effects of Navy activities on protected marine species;
- Ensure that data collected at multiple locations is collected in a manner that allows comparison between and among different geographic locations;
- Assess the efficacy and practicality of the monitoring and mitigation techniques;
- Add to the overall knowledge base of protected marine species and the effects of Navy activities on these species.

The ICMP meets these requirements and objectives by:

- Identifying top-level goals for the monitoring program, as well as guidelines for use in prioritizing monitoring projects and related Research & Development;
- Defining standard procedures for the compilation and management of data from range/project-specific monitoring plans;
- Establishing an adaptive management process that includes annual reviews with NMFS;
- Making provisions to review relevant monitoring-related research and, where appropriate, incorporate findings as updates to the range/project-specific monitoring plans and mitigation measures through adaptive management; and
- Providing an unclassified recordkeeping system that will allow interested parties to see how each Range Complex is contributing to ongoing monitoring.

The ICMP is evaluated annually through the adaptive management process (Section 2.3) to assess progress, provide a matrix of goals for the following year, and make recommendations for refinement and analysis of the monitoring and mitigation techniques. This process includes conducting an Adaptive Management Review (AMR) at which Navy and NMFS will jointly consider the prior year goals, monitoring results, and related science advances to determine if modifications are needed to more effectively address monitoring program goals.

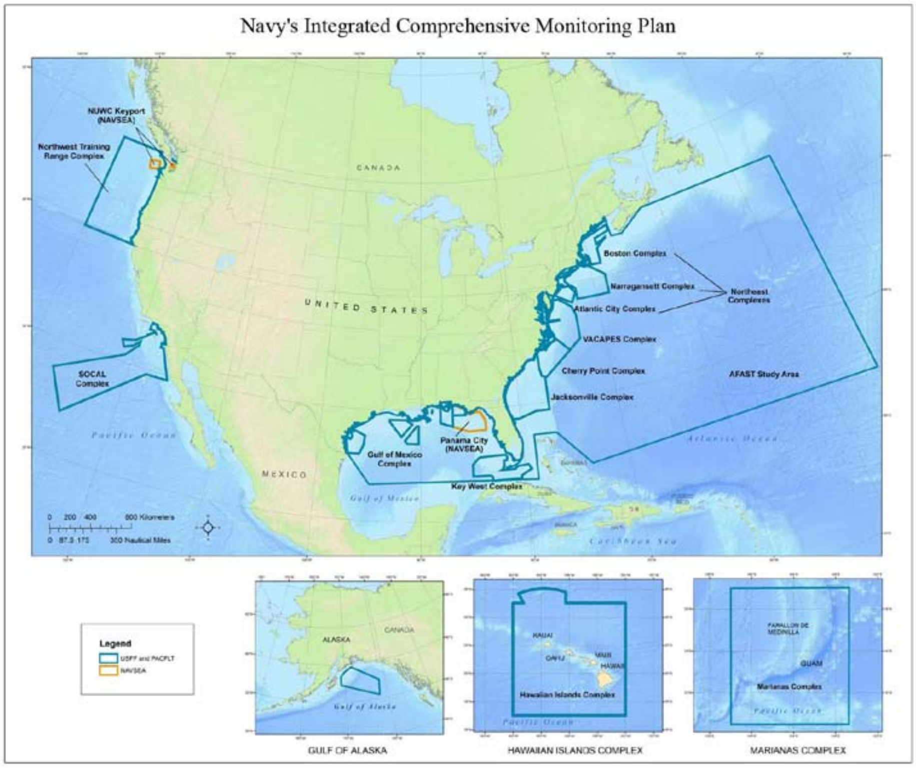


Figure 2. Navy Range Complexes and Study Areas included under the ICMP

1.2 THE SCIENTIFIC ADVISORY GROUP REPORT

The SAG Report laid out range-specific recommendations that follow a framework of knowledge which considers the occurrence of marine mammals, exposure to Navy training, potential response to those activities, and potential consequences of the interactions. The range specific recommendations for MIRC were:

> *"The Mariana Islands Range Complex is located in the western Pacific, encompassing a large (500,000 nm2) region where little effort has been conducted on the study of marine mammals. Because so little is known about species occurrence in this area, the priority for this region should be on establishing occurrence. Passive acoustic monitoring is highly recommended for use in this region, in combination with recordings from small boats to obtain species-specific vocalizations. Other appropriate methods to collect occurrence data in this region include small boat surveys, biopsy sampling, satellite tagging and photo-identification (photo-ID). Photo-ID mark-recapture studies represent the best opportunity for evaluating the abundance of small populations, as opposed to standard line-transect methods. Photo-ID is also a useful mechanism for fostering and enabling local research capabilities. There will be a high return for monitoring in the Mariana Islands, because even basic information will greatly expand what is known for this region. In addition, the medium-to-high level of naval activity in the region also increases its importance for monitoring effort."*

An assessment was also made for the comparing the range complexes. MIRC was rated high in the need for basic occurrence information and medium in the suggested level of monitoring effort, relative to SOCAL and AFAST (high) and HRC (medium/high). For a summary of programmatic changes recommend by the SAG, please see the Final Scientific Advisory Group for Navy Marine Species Monitoring Workshop Report and Recommendations which can be found online at http://www.nmfs.noaa.gov/pr/pdfs/permits/navy_species_monitoring.pdf.

1.3 RECOMMENDATIONS FROM REGIONAL RESEARCHERS

Researchers with experience working in MIRC and similar environments were asked to submit their recommendations for future marine species monitoring given lessons learned from the previous surveys (listed below in Section 1.4). This input varied from broad conceptual questions to the challenges and logistics of working in the Marianas. To summarize, the unique recommendations which added to the existing recommendations of the SAG report included a focus on collection of visually validated acoustic recordings, investigation into local areas of high density, aerial line-transect surveys conducted in the summer, a Lookout Effectiveness embarkation during a naval exercise in MIRC and surveying during seasons of the best weather.

1.4 PREVIOUS SURVEYS

Prior to 2007 there was little information available on the abundance and density of marine mammals and sea turtles in the MIRC Study Area. Most information on the occurrence of marine mammals came from short surveys (several days) and opportunistic sightings (NMFS Platform of Opportunity, oceanographic cruises or strandings). Eldredge (1991) compiled the first list of published and unpublished records for the greater Micronesia area, reporting 19 marine mammal species. Some of these species accounts were based on unsubstantiated reports and may not reflect true species distribution in the region. Eldredge (2003) refined this list specifically for 13 cetacean species thought to occur around Guam. The following surveys were funded by the U.S. Pacific Fleet (unless noted) in support of marine species monitoring in the MIRC.

2007 Aerial Survey - An aerial monitoring survey was conducted after the Valiant Shield training exercise in July 2007. The survey covered 2,352 km of linear effort, with transect grids distributed randomly throughout an 163,300 km2 area. A total of 8 sightings were recorded during the five-day period including seven cetacean (Bryde's whale, pygmy or dwarf sperm whale, Cuvier's beaked whale, pantropical spotted dolphin, and rough-toothed dolphin) and one unidentified turtle species (Mobley, 2007).

2007 MISTCS - The first comprehensive survey of the area, MISTCS, was conducted from January to April 2007 (DoN, 2007; Fulling et al., 2011;). The visual survey was conducted using the systematic line-transect survey protocol developed by the NMFS Southwest Fisheries Science Center (Barlow, 2006; Barlow and Forney, 2007; Ferguson and Barlow, 2001; 2003). Acoustic detection methods were made using two towed arrays and sonobuoys; these methods supplemented the visual detections. There were 148 sightings of 12 marine mammal species (sperm whale, sei whale, Bryde's whale, false killer whale, short-finned pilot whale, melon-headed whale, pygmy killer whale, pantropical spotted dolphin, striped dolphin, bottlenose dolphin, spinner dolphin, rough-toothed dolphin), and one sightings of a hawksbill turtle. The full report is provided at http://www.nmfs.noaa.gov/pr/permits/incidental.htm#applications under the section title 2008 Mariana Island Range Complex, as well as at http://www.nmfs.noaa.gov/pr/pdfs/permits/mirc_mistcs_report.pdf.

Navy / NMFS collaborative survey - January to May 2010, NMFS, PIFSC was partially supported by the U.S. Pacific Fleet to conduct visual surveys from both small boats and a large research vessel

(Oleson and Hill, 2010) (available as "Appendix A" within the 2010 MIRC monitoring report: http://www.nmfs.noaa.gov/pr/pdfs/permits/navy_mirc_monitoring2011.pdf). Sea turtle effort was not part of the protocols. The report consisted of four separate field efforts tasks:

Task 1 (OES 10-01): A large vessel line transect survey was conducted on the high seas between Honolulu and Guam during January and February 2010 for 16 days covering 1,285 nmi of trackline over 146 on-effort hours, and had 25 sightings, 6 species (sperm whale, sei whale, false killer whale, melon-headed whale, striped dolphin, and Mesoplodon spp.), 626 photographs, and 1 biopsy. There was also an acoustic component consisting of: a) a towed array that made over 100 detections, mostly of sperm and minke whales; and b) 37 sonobuoy drops that detected humpback, sperm, minke, fin, and sei whales, and possible delphinid clicks and whistles

Task 2 (OES 10-03): an opportunistic line transect survey was conducted during transit legs of a large vessel oceanography cruise off Micronesia and CNMI during March and April 2010 covering 792 nmi of trackline over 172 on-effort hours, and had 9 sightings of 3 species (Risso's dolphin, short-finned pilot whale, striped dolphin). Photography and biopsy sampling were not part of the study protocol. Conductivity/temperature/depth sampling was also conducted.

Task 3 (OES 10-04): a large vessel line transect survey was conducted on the high seas between Honolulu and Guam including a circuit around Wake Island during April and May2010 covering 1,285 nmi of trackline over 171 on-effort hours, and had 21 sightings, 7 species (sperm whale, sei whale, short-finned pilot whale, melon-headed whale, false killer whale, pantropical spotted dolphin, and spinner dolphin), 1,243 photographs, and 0 successful biopsies. There was also an acoustic component consisting of: a) 150 hours of towed array recordings that detected pilot whales, melon-headed whales, and false killer whales, with 6 detections being matched with concurrent sightings from the visual team; and b) 37 sonobuoy deployments that detected delphinid whistles, sperm whales, minke whales, and sei whales.

Task 4: small boat cetacean surveys were conducted off Guam, Tinian, and Saipan during February and March 2010, and is summarized separately below (Ligon et al., 2011)

Small Boat Cetacean Surveys - February to March 2010 - From February 9 to March 3, 2010, small small-boat nonrandom opportunistic surveys were conducted off the islands of Guam, Tinian, and Saipan (Ligon et al., 2011). The surveys covered 700 nmi of trackline over 98 on-effort hours. The Guam portion of the effort yielded 11 sightings with 3 species (sperm whale, spinner dolphin, pantropical spotted dolphin), 2,769 photographs, and 8 biopsy samples. The Tinian-Saipan portion yielded 7 sightings of 2 species (sperm whale, spinner dolphin), and 4 biopsies. Sea turtle effort was not part of the study protocol.

MISTCS acoustic analysis - In 2011, additional analyses of the MISTCS acoustic array data were conducted (Norris et al., 2012). The results included improved estimates of the density and distribution of minke and sperm whales in MIRC. An attempt was made to compare a small sample of humpback whale song from MIRC to Hawaiian humpback whale song. The results were inconclusive. Odontocete whistles were classified into acoustic groups. Finally, sei whale vocalizations were described and qualitatively compared with sei whale vocalizations from other locations in the Pacific.

Small Boat cetacean surveys - February to March 2011 – From February 17 to March 3, 2011, was a small-boat non-random opportunistic survey was conducted off the island of Guam (HDR, 2011). The surveys covered 553 nmi of trackline over 71 on-effort hours, and resulted in 6 sightings of green sea turtles, 9 sightings of 3 cetaceans species (primarily spinner dolphin with the exception of one mixed-species group of short-finned pilot whales and bottlenose dolphins), and 1,830 photographs. Biopsy sampling was not part of the study protocol.

Small-boat cetacean surveys - August to September 2011 – small boat surveys were conducted off Guam, Saipan, and Rota (Hill et al., 2011). The surveys covered 1691 nmi of trackline over 205 on-effort hours, and there were 38 sightings of cetaceans of 6 species (short-finned pilot whale, dwarf sperm whale, pygmy killer whale, bottlenose dolphin, pantropical spotted dolphin, spinner dolphin). 89 biopsy samples were collected and 10,782 photographs were taken. Sea turtle effort was not part of the study protocol.

2. MARIANA ISLANDS RANGE COMPLEX MONITORING PLAN

2.1 MONITORING PLAN OBJECTIVES

The overall objective of this monitoring plan is to further our understanding of the occurrence of marine mammals and sea turtles which may be exposed to mid-frequency active sonar and explosives in the MIRC, as a prerequisite to better understanding the impacts of Navy training. This will be achieved by addressing the monitoring questions listed in Table 1.

The data resulting from the MISTCS survey (Fulling et al., 2011; Norris et al., 2012; Thorson et al., 2007) provides the first step in elucidating the large-scale distribution patterns and density estimates of marine mammals in the entirety of the MIRC. However, many potentially sensitive species such as beaked whales may be island-associated with limited ranges (as some populations in the Hawaiian archipelago) and thus may have an additional risk factor for anthropogenic disturbance; such cryptic species (e.g., beaked whales, minke whales) are less likely to be fully characterized during the course of a single or small number of field efforts, and may require specifically tailored and dedicated techniques to improve the description of their occurrence and distribution.

Table 1. Monitoring questions for the MIRC

Question #	Monitoring questions
1	What species of beaked whales and other odontocetes occur around Guam and Saipan?
2	Are there locations of greater relative cetacean and/or sea turtle abundance around Guam and Saipan?
3	What is the baseline abundance and population structure of odontocetes which may be exposed to sonar and/or explosives in the near shore areas of Guam, Saipan, Tinian, and Rota?
4	What is the seasonal occurrence of baleen whales around Guam, Saipan, Tinian, and Rota?
5	What is the occurrence and habitat use of sea turtles in areas where the Navy conducts underwater detonations?

Beyond the recommendations of the SAG report, beaked whales continue to be a priority to the Navy because of the conclusion that MFAS was likely a causal factor in mass stranding of Cuvier's beaked whales in the Bahamas in 2000 (Evans and England, 2001). Correlations between strandings and naval exercises employing sonar have also occurred in the Mediterranean and Caribbean seas, but no such correlations have been described in Japan, MIRC, or Southern California (Filadelfo et al., 2009). An unusual event of melon headed whales entering Hanalei Bay, Kauai and remaining for 24 hours during the Navy exercise RIMPAC (Southall et al., 2006) elevates this species in the priority list for monitoring, although the cause of the event has also been postulated to be related to lunar prey cycles due to the observation of a simultaneous and similar event involving the same species in Rota (Mobley et al., 2007). These priorities do not preclude the monitoring of other species of cetaceans in MIRC, as sighting frequencies are low and relatively little is known across all species, although the justification of such priorities can provide a role in influencing types of monitoring effort, for example to focus visual survey techniques to be facilitated toward the study of odontocetes. Based on the absence of even a single baleen whale sighting detected by a cumulative total of 56 days of survey by small boat platforms (HDR, 2011; Hill et al., 2011; Ligon et al., 2011) as compared to their successful detection by methods such as large vessel (DoN, 2007; Oleson and Hill, 2010;) and aerial platforms (Mobley, 2007), baleen whales are likely not to be encountered within the areas amenable to small boat platforms, especially in prevailing conditions of the winter season. The optimal alternative to small-boat methods, as well as other more resource-intensive methods (e.g., large vessel, aerial) would be to detect baleen whales by passive acoustic methods, a prospect facilitated by the relatively larger propagation distances of their vocalizations.

The presence of two mine neutralization areas off the coast of Guam, and in relatively deep water, elevates this region for focused monitoring effort with respect to impacts of underwater explosives, especially in light of a sperm whale sighting in the near shore area ~1 nmi from shore at Orote Point on Guam (Ligon et al., 2011) (Figure 3).

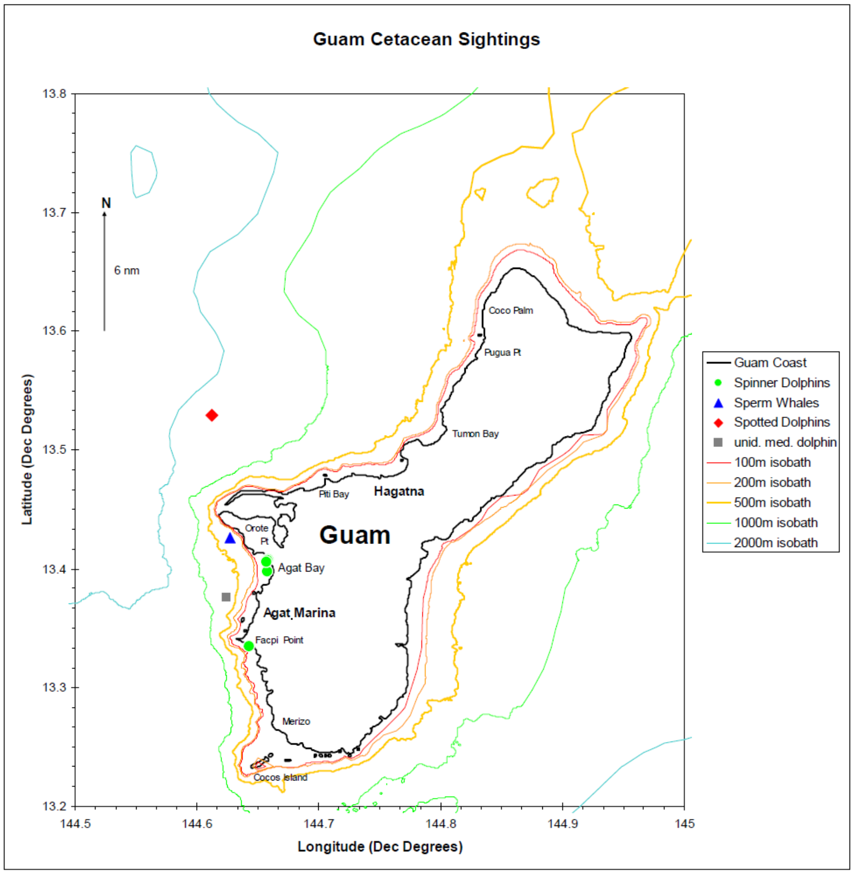


Figure 3. Guam cetacean sightings during the February-March 2010 small boat survey (Ligon et al., 2011).

Based on the recommendations of the SAG report, the Navy is prioritizing the monitoring of marine mammals and sea turtles through small boat visual surveys which include biopsy sampling, photo-ID mark recapture abundance estimates, satellite tagging, and the collection of visually-verified representative acoustic samples with a dipping hydrophone. Because of the current lack of knowledge, each successful satellite tag will generate new information on species' habitat use and distribution. Mark-recapture analysis and biopsy sampling will provide some of the first estimates of resident population sizes and structure. Visually-verified hydrophone recordings will provide the necessary basis for interpreting passive acoustic recordings, such as classifying detections to species, as well as developing resource-effective automated techniques for detection and classification.

Small-vessel visual surveys will address the spatial component of marine mammal occurrence near Guam and Saipan, but may also include Tinian and Rota, and may also include alternate methods given availability of resources. The Navy will maintain passive acoustic monitoring devices along with analysis of the acoustic data in the MIRC in order to address the temporal component of occurrence in the MIRC; given the experience learned through previous years of monitoring, it has been determined that further refining and applying acoustic analysis methods is equally important as collecting more data sets; therefore relatively more effort will be expended towards analysis tasks across fewer devices than in previous years. Because the presence of baleen whales can be addressed more efficiently through the use of passive acoustics, visual efforts will be focused more on odontocetes (which are more difficult to monitor and identify to species through passive acoustics alone) and will result in a greater return on monitoring investment. Sea turtles will be addressed separately from cetaceans.

While this plan is written for a three year period, it should be noted that projects which address questions 2, 3, and 5 are part of a multi-year goal. Addressing seasonal abundance of baleen whales (question 4) has the potential to be answered within a shorter time frame and at least partially through the analysis of an existing data set.

2.1.1 Shore survey pilot study. Challenging weather and sea states restrict the areas that can be safely surveyed with a small vessel to a greater degree than in the Hawaiian Islands, particularly in the winter months when the sea states are consistently high, as experienced in the previous surveys in the region (see Section 1.4). This limitation reduces the amount of information known about marine mammal distributions on the windward side of Guam and CNMI. Pilot studies of a shore-based survey for marine mammals utilizing theodolite-based fixes is an option to collect better data in areas that are covered by small vessel surveys infrequently. MIRC is the only location that the SAG recommended shore-based surveys could be used, but the method was given the relative priority of "low." The monitoring plan does not propose to use this method everywhere, but as a supplemental means to know more about marine mammals in areas that cannot predictably be surveyed by small vessel.

The theodolite is a surveying instrument that can measure horizontal and vertical angles to sightings, allowing the positioning sightings upon latitude-longitude coordinates (Lerczak and Hobbs, 1998). The technique was first used for marine mammals by Payne in the 1970s for large whales and further developed by Wursig for dolphins (Würsig and Würsig, 1979). Most commonly this shore based survey technique has been used to track animal movements and habitat preferences, for example for bottlenose dolphins (Würsig and Würsig, 1979), dusky dolphins (Cipriano, 1992; Würsig et al., 1991; Yin, 1999), and humpback whales (Frankel et al., 1995; Helweg, 1989; Helweg and Herman, 1994). The technique has also been utilized to examine the reactions of marine mammals to anthropogenic stimuli, for example gray whales (Clark et al., 1983; Malme et al., 1984) and humpback whales (Frankel and Clark, 2002; Mithriel and Würsig, 2011; Smultea, 1994). It has also been utilized for multiple-species reaction studies (Tyack, 1993).

Shore stations typically are outfitted with an electronic theodolite interfaced with a laptop computer for real-time acquisition of sighting fixes (e.g., see http://www.tamug.edu/mmbeg/pythagoras.htm), as well as other visual observers using either handheld or mounted binoculars. Typically only a single species might be expected to be able to be sighted from a shore station. However, in several of the above cases where the shore station was at an ideally high elevation immediately adjacent to deep water, multiple species were sighted, for example off the Big Island of Hawaii, Argentina, and New Zealand. Similarly, a complement of multiple species including humpback whales, dugongs, humpback dolphins, bottlenose dolphins, and killer whales were sighted utilizing a shore station in Australia (Smultea, pers. comm.). Shelden and Rugh (2010) completed a formal survey for cetacean occurrence of all species using a shore station off the coast of central California.

The Mariana Islands are ideal locations for use of shore surveys because they are limestone karst islands with steep cliffs close to shore and deep water adjacent to the near shore environment. The MIRC study area has multiple areas of high elevation adjacent to deep waters, where species such as sperm whales have been sighted ~ 1 nm from shore (Ligon et al., 2011). Data generated by a shore-based survey will be particularly relevant in this location because this study area also is among the most poorly characterized with respect to marine mammals among all U. S. Navy range complexes such that enhancing knowledge about basic occurrence and distribution is currently one of the initial goals of the monitoring program. Prevailing weather has constrained small-boat surveys on the majority of days to very nearshore waters, and especially in winter almost exclusively to the leeward sides of the islands, especially in winter (HDR, 2011; Ligon et al., 2011)—any shore-based data from windward sides would generate almost entirely new and complementary sets of data on distribution and occurrence.

A pilot study for a general cetacean survey utilizing a shore station is justified by: a) the available and ideal options for locations to establish an effective shore station, b) the emphasis and relative data-deficiency with regard to questions of occurrence and distribution in this range complex, and c) the use of a shore station a complementary technique to boat-based methods, given their relative expense and geographic limitations. Because Yin et al. (2005) noted that in the case of short and intermediate distances, measurements of animal locations using handheld reticled binoculars with a compass may be comparable with those made by theodolite, final determination of equipment to be utilized will depend upon evaluation of the shore station site conditions such as accessibility. If the pilot study is successful in gathering species-specific data on cetacean occurrence, the study may be extended across multiple monitoring years as well as other potential shore station sites identified in the study area.

One of the recommendations of the SAG was to develop local marine mammal expertise in the Mariana Islands. A shore-based study provides an opportunity to involve local interested parties in marine mammal monitoring. Students from University of Guam, officials with Federal or local agencies, or members of the local fishing community could be included in setting up stations, taking data, and analyzing the results.

2.2 MONITORING PLAN IMPLEMENTATION

The MIRC presents a challenging environment for monitoring. The area is well-known for its year round high sea states and frequent unpredictable typhoons. It is also less commercially developed than other range complexes, limiting access to, and increasing expenses for large research vessels and non-military aircraft appropriate for offshore field surveys. There is a lack of local expertise on marine mammals. To the extent practicable, the Navy plans to coordinate with NMFS and local researchers to maximize resources, expertise, equipment, and to extract maximum benefit from the effort expended (e.g., mark recapture abundance estimates can be used for Environmental Impact Statement (EIS) and Navy MMPA take estimates).

The methods recommended in Table 2 reflect the monitoring objectives and questions stated in Section 2.1. Specifically, these methods are expected to address the monitoring questions in the following manner:

Question 1: What species of beaked whales and other odontocetes occur around Guam and Saipan?

- Shore-based and continuation of vessel-based visual surveys will provide visual confirmation of species presence. Vessel surveys will provide opportunities to obtain recordings of visually verified species, and biopsy samples to confirm species identity and gain information on demographics and stock structure.

- Analysis from ongoing PAM deployments will complement the other acoustic data sets to provide acoustic information on acoustically identifiable presence of species in all seasons across almost two years.
- In addition to analysis of Navy-deployed data sets, if additional existing acoustic data sets can be acquired that might further Navy goals, we will consider analysis of those data.

Question 2: Are there locations of greater cetacean and/or sea turtle concentration around Guam and Saipan?

- Continuation of non-random, non-systematic small vessel surveys and passive acoustic monitoring will be used to address this question. The visual survey will be based on the study of Hawaiian Island odontocetes as a model. Weather conditions can greatly affect the productivity of visual surveys (Ligon et al., 2011), therefore the survey days can occur at any time of year. In order to capitalize on the data collection opportunity using the small boat platform, the visual survey will focus on satellite tagging, photo-identification, biopsy, and collection of representative acoustic samples using a dipping hydrophone
- Habitat use patterns can be addressed through satellite tagging to examine spatial movements and dive patterns. Photo-identification and mark-recapture methodologies can be used to examine residency and movement of individuals and groups. Biopsy samples will complement photo-identification methods in identifying sub-groups of species.
- Shore-based visual surveys can establish use patterns in particular areas. Comparison of use patterns between areas can establish the degree of presence of species of marine mammals and sea turtles.
- Comparison of rates of vocalizations among PAM recordings can provide some relative assessment of cetacean activity near PAM deployment sites.

Question 3. What is the baseline abundance and population structure of odontocetes, which may be exposed to sonar and/or explosives in the near shore areas of Guam, Saipan, Tinian, and Rota?

- The two primary methods used for the estimation of the abundance of marine mammals (which do not haul out or pass through migration corridors) are distance sampling and mark-recapture (Buckland et al., 2001; Evans and Hammond, 2004), Mark-recapture methods have advantages over line transect in cases where pragmatic considerations prohibit an effective line transect survey, such as in the current case where Beaufort sea states would require a large and expensive vessel for off-shore sections of a survey. Mark-recapture is thus better suited for smaller populations of local distribution (especially where a large proportion of the total population may be identified) while line-transect for populations dispersed over wide areas, especially those that are infrequently encountered (Buckland and York, 2009; Cañadas et al., 2006). Individually-identifying photographs obtained on visual surveys will be provided to PISFC for archiving and mark-recapture analysis.
- Baseline population abundance estimates will be obtained through mark-recapture techniques based on species-appropriate identification photos such as dorsal fins, flanks, or flukes. To date, photographs have been taken on five separate surveys. Photos taken on the 2007 aerial survey during Valiant Shield would not support individual identification. Photographs taken during MISTCS in 2007, the Navy/PIFSC 2010 small boat visual survey, the 2010 Navy/PIFSC large boat visual survey, and the 2011 Navy/PIFSC small boat visual

survey are currently held at PIFSC. The Navy will continue to support collection of photographs which can be used for mark-recapture abundance analysis throughout the monitoring period.

- In addition to population size, understanding population structure is an important component of natural resource management (Wade and Angliss, 1997), because it identifies management units of particular concern. The Navy will accomplish this through biopsy sampling to investigate genetic differentiation between local populations and photo-identification to investigate residency patterns and movements. The Navy will support biopsies through the purchase of biopsy supplies and equipment to support at least 50 biopsy attempts per year (number of biopsies collected is not guaranteed). Additionally the biopsy samples will be preserved and shipped to the appropriate location for a preliminary processing of samples which includes extraction of DNA, sexing, and storage. No analysis is anticipated until approximately 2015 or until the collection reaches greater maturity.
- The temporal component of baseline abundance will be addressed through analyzing PAM recordings to establish of seasonal presence of vocalizing or clicking animals over multi-year monitoring periods as well as diel behavioral patterns. Density estimation may be possible for species for which both reliable techniques and recordings exist.

Question 4. What is the seasonal occurrence of baleen whales around Guam, Saipan, Tinian and Rota?

- PAM data from current and future PAM deployments shall be analyzed to determine if there is a seasonal occurrence of blue whales, fin whales, sei whales, Bryde's whales, humpback whales, and minke whales.
- Any incidental sightings of baleen whales that have: a) successful biopsy sampling can confirm species-identity in the case of questionable visual identifications (e.g., sei, Bryde's, and Omura's whale), and b) successful satellite tagging will generate new information on distribution and movement patterns.

Question 5. What is the occurrence and/or habitat use of sea turtles in areas that the Navy conducts underwater detonations?

- Dive surveys, similar to those successfully established the density of sea turtles in Pearl Harbor, Hawaii and Apra Harbor, Guam will be conducted at the areas in which underwater detonations occur in order to provide an initial estimate of sea turtle presence. The established standardized protocol is designed to enable density estimation.

or

- Turtle tagging of either in-water or on-shore sea turtles near areas where underwater detonations occur in order to establish habitat use patterns.

Table 2. Summary of monitoring methods and level of effort, FY10-FY15

	FY10	ADAPTIVE MANAGEMENT REVIEW (AMR)	FY11	A M R	FY12	A M R	FY13	A M R	FY14	A M R	FY15
Passive Acoustic Monitoring			Deploy four passive acoustic monitoring devices around the Mariana Islands that are capable of gathering data throughout the year. Analyze existing acoustic data set which was collected during Navy's 2007 MISTCS survey.		Deploy four passive acoustic monitoring devices around the Mariana Islands that are capable of gathering data throughout the year. Analyze data from 4 PAM devices deployed in FY12		- Deploy PAM devices in the Mariana Islands that are capable of gathering data throughout the year. - Opportunistically collect acoustic recordings with a dipping hydrophone during visual survey effort. - Analyze data from PAM devices		- Deploy PAM devices in the Mariana Islands that are capable of gathering data throughout the year. - Opportunistically collect acoustic recordings with a dipping hydrophone during visual survey effort. - Analyze data from PAM devices		Opportunistically collect acoustic recordings with a dipping hydrophone during visual survey effort.
Visual Surveys	- Small boat surveys around Guam, Tinian and Saipan. - Visual observations using marine species observers aboard NMFS/PIFSC oceanographic survey in the Region, as well as during transits between Hawaii and Guam.		Conduct summer and winter visual surveys using a small boat and/or airplane around Guam, Tinian, Rota and Saipan in cooperation with NMFS and/or DAWR. Visual surveys would integrate methods such as photo ID that provide data that can be used for distribution and abundance. 45 days total.		Conduct summer and winter visual surveys using a small boat and/or airplane around Guam, Tinian, Rota and Saipan in cooperation with NMFS and/or DAWR. Visual surveys would integrate methods such as photo ID that provide data that can be used for distribution and abundance. 45 days total.		Conduct non-random, non-systematic visual survey or shore based surveys at any time of the year.		Conduct non-random, non-systematic visual survey or shore-based surveys at any time of the year.		Conduct non–random, non-systematic visual survey or shore-based surveys at any time of the year.
Biopsy							Purchase biopsy supplies to support biopsy attempts. Archive (preserve, extract DNA, sex) biopsy samples.		Purchase biopsy supplies to support biopsy attempts. Archive (preserve, extract DNA, sex) biopsy samples.		Purchase biopsy supplies to support biopsy attempts. Archive (preserve, extract DNA, sex) biopsy samples.
Satellite tagging							- Purchase satellite tags to support tagging attempts during visual surveys. - Analyze data from satellite tags.		- Purchase satellite tags to support tagging attempts during visual surveys. - Analyze data from satellite tags.		- Purchase satellite tags to support tagging attempts during visual surveys. - Analyze data from satellite tags.
Photo-ID and mark-recapture abundance estimates											Mark-recapture abundance estimate analysis for species with the highest likelihood of generating a statistically significant result.
Sea turtle distribution and density							Either line transect diving surveys or sea turtle tags along with analysis		Either line transect diving surveys or sea turtle tags along with analysis		Either line transect diving surveys or sea turtle tags along with analysis

2.3 ADAPTIVE MANAGEMENT

Background

Adaptive management is an iterative process of optimal decision making in the face of uncertainty, with an aim to reduce uncertainty over time via system monitoring. Within the natural resource management community, adaptive management involves ongoing, real-time learning and knowledge creation, both in a substantive sense and in terms of the adaptive process itself. Adaptive management focuses on learning and adapting, through partnerships of managers, scientists, and other stakeholders who learn together how to create and maintain sustainable ecosystems (Williams et al., 2007). Adaptive management helps science managers maintain flexibility in their decisions, knowing that uncertainties exist. It will improve understanding of ecological systems in order to achieve management objectives and is about taking action to improve progress towards desired outcomes (Williams et al., 2007). Further discussion of adaptive management in the natural resource community is available from the U.S. Department of Interior's Adaptive Management Guidelines: http://www.doi.gov/initiatives/AdaptiveManagement/index.html.

Implementation

There are annual reporting requirements contained in NMFS' MMPA Letter of Authorization for the MIRC EIS/Overseas Environmental Impact Statement (OEIS). Following the Navy's Annual Report to NMFS, the Navy and NMFS meet to review the past year's results. The goal of this consultation and collaboration is to determine if these research elements and associated results continue to meet the overall objectives of the Plan specific to the MIRC. For instance, if one particular research element does not provide direct or indirect support to one of the objectives listed above, then resources for future instances of that element have be redirected to other research elements that do provide more support.

Proper application of the adaptive management concept allows adjustments to be made to the MIRC Monitoring Plan that will enhance overall scientific conclusions, lead to better statistical approaches, integrate new technologies in marine mammal monitoring and detection, and provide a stronger foundation upon which to base mitigation and policy decisions. In addition, as part of the annual review, a more complete cost-benefit analysis can be presented based on actual monitoring cost by research element within MIRC.

Through the process of adaptive management, the Navy is proposing to implement systematic improvements to the MIRC marine species monitoring in order to increase the likelihood of achieving top-level goals established by NMFS and the Navy. As described above, top-level monitoring goals are described in an ICMP that guides the Navy's monitoring effort. The process of using a SAG, described in section 1.2 is part of the adaptive management process. Incremental changes are implemented in this monitoring plan based on the SAG recommendations and are summarized below.

Table 3. Implemented changes in the monitoring plan based on SAG recommendations through the adaptive management process

Recommendation	Implementation
Conceptual shift to the proposed framework of occurrence, exposure, response, and consequence	Development of monitoring question(s) which address basic occurrence of marine species which may be exposed to SONAR and explosives in MIRC.
Increased transparency of MIRC monitoring plan implementation	Submission of MIRC related monitoring plan, literature, and reports to a website accessible to scientists and the public.
Shift of focus from groups of animals to individuals and population structure	Include satellite tagging, biopsy, and photo-ID data collection and analysis
Collection of visually validated acoustic samples for use in developing classifiers and detectors.	Opportunistic use of a dipping hydrophone during visual surveys for collection of representative samples.
Scheduling flexibility due to weather	Visual surveys can be done at any time of year and using shore-based methodologies that can be implemented even when sea conditions prevent vessel surveys.
Potential for shore-based surveys data collection	Pilot study on shore based surveys
Develop local expertise	Attempt to involve local parties in shore-based survey data collection

LITERATURE CITED

Barlow J. (2006) Cetacean abundance in Hawaiian waters estimated from a summer/fall survey in 2002. Marine Mammal Science 22:446-464.

Barlow J., Forney K.A. (2007) Abundance and population density of cetaceans in the California Current ecosystem. Fishery Bulletin 105:509-526.

Buckland S.T., York A.E. (2009) Abundance estimation, in: W. F. Perrin, et al. (Eds.), Encyclopedia of Marine Mammals, Academic Press, Amsterdam. pp. 1-6.

Buckland S.T., Anderson D.R., Burnham K.P., Laake J.L., Borchers D.L., Thomas L. (2001) Introduction to Distance Sampling: Estimating Abundance of Biological Populations Oxford University Press, Oxford, U.K.

Cañadas A., De Stephanis R., Perez S., S G., P V., S H.P. (2006) Methods for estimating cetacean abundance: model-based line transect and mark-recapture compared, Meeting of the IWC Scientific Committee, St. Kitts and Nevis, West Indies. pp. 7 pp.

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

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

DoN (2007) Marine Mammal and Sea Turtle Survey and Density Estimates for Guam and the Commonwealth of the Northern Mariana Islands. Authors: Thorson P., Fulling G., Norris T., Hall C., Sawyer K. Prepared by Man-Tech SRS Technologies and Geo-Marine for the Department of the Navy, US Pacific Fleet, Pearl Harbor, Hawaii.

Eldredge L.G. (1991) Annotated checklist of the marine mammals of Micronesia. Micronesica 24:217-230.

Eldredge L.G. (2003) The marine reptiles and mammals of Guam. Micronesica 35-36:653-660.

Evans L.G., England G. (2001) Joint Interim Report Bahamas Marine Mammal Stranding Event of 15-16 March 2000, Department of the Navy, Washington, D.C.

Evans P.G.H., Hammond P.S. (2004) Monitoring cetaceans in European waters. Mammal Review 34:131-156.

Ferguson M.C., Barlow J. (2001) Spatial distribution and density of cetaceans in the eastern Pacific Ocean based on summer/fall research vessel surveys in 1986-96. pp. 61.

Ferguson M.C., Barlow J. (2003) Addendum: Spatial distribution and density of cetaceans in the eastern tropical Pacific Ocean based on summer/fall research vessel surveys in 1986-96, NOAA Administrative Report, NOAA Fisheries, Southwest Fisheries Science Center, La Jolla, California. pp. 99 p.

Filadelfo R., Mintz J., Michlovich E., D'Amico A., Tyack P.L., Ketten D.R. (2009) Correlating military sonar use with beaked whale mass strandings: What do the historical data show? Aquatic Mammals 35:435-444. DOI: DOI 10.1578/AM.35.4.2009.435.

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

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

Fulling G.L., Thorson P.H., Rivers J. (2011) Distribution and Abundance Estimates for Cetaceans in the Waters off Guam and the Commonwealth of the Northern Mariana Islands. Pacific Science 65:321-343. DOI: 10.2984/65.3.321.

HDR. (2011) Guam Marine Species Monitoring Survey: Vessel based monitoring Surveys Winter 2011, Prepared for the Department of the Navy, US Pacific Fleet, Pearl Harbor, Hawaii. pp. 19 pp.

Helweg D.A. (1989) The Daily and Seasonal Patterns of Behavior and Abundance of Humpback Whales (Megaptera novaeangliae) in Hawaiian Waters, University of Hawaii, Honolulu, Hawaii.

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

Hill M.C., Ligon A.D., Deakos M.H., U A.C., Norris E., Oleson E. (2011) Cetacean Surveys of Guam and CNMI Waters: August - September, 2011, National Marine Fisheries Service, Pacific Islands Fisheries Science Center, Honolulu, Hawaii.

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

Ligon A.D., Deakos M.H., U A.C. (2011) Small Boat Ceteacean Surveys Off Guam and Saipan, Marianas Islands, February - March 2010, National Marine Fisheries Service, Pacific Islands Fisheries Science Center, Honolulu, Hawaii.

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

Mithriel M., Würsig B. (2011) Humpback whales (Megaptera novaeangliae) wintering off Puerto Rico, Poster presented at the 19th Biennial Conference on the Biology of Marine Mammals, November 27-December 2, 2011, Tampa, Florida.

Mobley J.R. (2007) Marine Mammal Monitoring Surveys in Support of "Valiant Shield" Training Exercises (Aug. 13-17, 2007), Department of the Navy, US Pacific Fleet, Pearl Harbor, Hawaii.

Mobley J.R., Jr., Martin S., Fromm D.M., Nachtigall P.E. (2007) Lunar influences as a possible cause for simultaneous aggregations of melon-headed whales in Halalei Bay, Kauai and Sasanhaya Bay, Rota., 17th Biennial Conference on the Biology of Marine Mammals, Cape Town, South Africa.

Norris T.F., Oswald J., Yack T., Ferguson E., Hom-Weaver C., Dunleavy K., Coates S., Dominello T. (2012) An Analysis of Acoustic Data from the Mariana Islands Sea Turtle and Cetacean Survey (MISTCS), Department of the Navy, US Pacific Fleet, Pearl Harbor, Hawaii. pp. 104 pp.

Oleson E.M., Hill M.C. (2010) 2010 Report to PACFLT: Report of Cetacean Surveys in Guam, CNMI, and the High-seas, Final report submitted by NOAA-NMFS-Pacific Islands Fisheries Science Center to Commander, U.S. Pacific Fleet. pp. 23 pp.

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

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

Southall B., Braun R., Gulland F.M.D., Heard A.D., Baird R.W., Wilkin S.M., Rowles T.K. (2006) Hawaiian Melon-headed Whale (Peponacephala electra) Mass Stranding Event of July 3-4, 2004, NOAA Technical Memorandum NMFS-OPR-31, NOAA Fisheries, Southwest Fisheries Science Center. pp. 73 pp.

Tyack P.L. (1993) Reactions of bottlenose dolphins, Tursiops truncatus, and migrating gray whales, Eschrichtius robustus, to experimental playback of low-frequency man-made noise. Journal of the Acoustical Society of America 94:1830.

Wade P.R., Angliss R.P. (1997) Report of the GAMMS Workshop, April 3-5, 1996, Seattle, Washington.

Williams B.K., Szaro R.C., Shapiro C.D. (2007) Adaptive Management: The U.S. Department of the Interior Technical Guide, Adaptive Management Working Group, U.S. Department of the Interior, Washington, D.C.

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

Würsig B., Cipriano F., Würsig M. (1991) Dolphin movement patterns: information from radio and theodolite tracking studies, in: K. Pryor and K. S. Norris (Eds.), Dolphin Societies: Discoveries and Puzzles, University of California Press, Berkeley, California. pp. 79-112.

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

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