ODONTOCETE STUDIES ON THE PACIFIC MISSILE RANGE FACILITY IN JULY/AUGUST 2013: SATELLITE-TAGGING, PHOTO-IDENTIFICATION, AND PASSIVE ACOUSTIC MONITORING

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ABSTRACT

A joint project in July and August 2013 on and around the Pacific Missile Range Facility (PMRF) combined passive acoustic monitoring and boat-based field efforts. There were 671 kilometers (36.6 hours [hr]) of small-vessel survey effort over the course of the 8-day project, with 55.1 percent of time (20.2 hr) spent within the PMRF instrumented hydrophone range boundaries. A total of 33.0 hr of acoustic monitoring coincided with the small-vessel field effort. There were 18 sightings of four species of odontocetes, five of which were directed by acoustic detections from the Marine Mammal Monitoring on Navy Ranges (M3R) system. Bottlenose dolphins (*Tursiops truncatus*) were encountered on six occasions, spinner dolphins (*Stenella longirostris*) on three, rough-toothed dolphins (*Steno bredanensis*) on eight, and false killer whales (*Pseudorca crassidens*) once. Recordings on the M3R system were made for three of the four species (all but spinner dolphins) to improve species classification for future acoustic monitoring efforts. During the encounters 4,393 photos were taken for individual identification, two biopsy samples were obtained for genetic studies, and three depth-transmitting satellite tags were deployed on two species (one false killer whale, two rough-toothed dolphins). Data were obtained from the two tagged rough-toothed dolphins for 9.9 and 13.4 days. During this period they remained associated with Niʻihau, with each found inside PMRF range boundaries on 11 occasions, spending 34 percent and 46 percent of their time on PMRF, respectively. The tagged false killer whale was identified as part of the Northwestern Hawaiian Islands population, known from previous efforts to use the area around Kauaʻi. Data were obtained for 21.3 days; during this period the tagged individual was found inside PMRF boundaries on 17 occasions, spending 24 percent of its time on PMRF. Based on preliminary sound propagation analyses and the locations of animals tracked during this study, both of these populations are likely exposed to mid-frequency active sonar on PMRF, but appear to use the overall area in different ways. Thus, the likelihood of exposure to different sound levels also probably varies by species. Continued collection of movement and habitat use data from all species should allow for a better understanding of the use of the range as well as provide datasets that can be used to estimate received sound levels at animal locations and examine potential responses to exposure.

INTRODUCTION

The Marine Mammal Monitoring on Navy Ranges program (M3R) is a real-time passive acoustic monitoring (PAM) system that has been implemented at three major Navy undersea test and training ranges: the Atlantic Undersea Test and Evaluation Center (2002–present, see Morrissey et al. 2006), the Southern California Offshore Range (2006–present, see Falcone et al. 2009), and most recently at the Pacific Missile Range Facility (PMRF) between Kauaʻi and Niʻihau (2011–present). The purpose of this report is to present results of a joint project in July and August 2013 undertaken on and around the PMRF instrumented hydrophone range, involving a combination of M3R passive acoustic monitoring (PAM) and boat-based field efforts including photo-identification and satellite tagging. This work addresses a specific Navy monitoring question: what are the spatial movement and habitat use patterns (e.g., island-associated or open-ocean, restricted ranges vs. large ranges) of species that are exposed to mid-frequency active (MFA) sonar, and how do these patterns influence exposure and potential responses? Additional goals include providing visual species verification for M3R acoustic detections and obtaining cetacean movement and habitat use information on and around PMRF before, during, and after a Submarine Commanders Course (SCC) scheduled to be undertaken after the field efforts, using data obtained from satellite tags. In addition, Blainville's beaked whale detection archives are being collected and will be combined with previous archives to derive the spatial and temporal distribution of this species on PMRF as well as estimating abundance.

The M3R system consists of specialized signal-processing hardware and detection, classification, localization, and display software that provide a user-friendly interface for real-time PAM via 199 PMRF bottom-mounted hydrophones (Jarvis et al. 2014). Prior to 2013, the M3R system at PMRF was used on three occasions (**Table 1**) in collaboration with vessel-based field efforts. This combination approach provides visual species verifications for groups detected acoustically, as well as visual sightings of animals on the range that have not been acoustically detected, and increases the encounter rate for vessel-based efforts. Increased encounter rates results in greater opportunities for deploying satellite tags (see below) as well as photo-identifying individuals and collecting biopsy samples for genetic studies.

Boat-based field studies of odontocetes first began off Kaua'i and Ni'ihau in 2003 (Baird et al. 2003), as part of a long-term, multi-species assessment of odontocetes in the main Hawaiian Islands (Baird et al. 2013a). Studies using satellite tags to assess movements and behavior of individual toothed whales on and around the PMRF were first begun in June 2008 in association with the Rim-of-the-Pacific naval exercise (Baird et al. 2008a). During that effort three melon-headed whales (*Peponocephala electra*) and a short-finned pilot whale (*Globicephala macrorhynchus*) were tagged and tracked for periods ranging from 3.7 to 43.6 days (Baird et al. 2008a; Woodworth et al. 2011). Since 2008 and prior to July/August 2013, there have been five additional boat-based field projects off Kaua'i (four in conjunction with M3R monitoring) during which satellite tags were deployed. During all of these efforts, 25 satellite tags were deployed on five different species of odontocete cetaceans off the islands of Kaua'i and Ni'ihau (**Table 1**; Baird et al. 2011, 2012a, 2012b, 2013b, 2013c).

To put the results from the July/August 2013 field effort into context, we also include results from previous photo-identification and satellite tagging efforts on and around PMRF. This includes matching of photos of tagged individuals and companions to long-term photo-identification catalogs (Baird et al. 2008b, 2008c, 2009; Mahaffy 2012) to allow for the assessment of population identity and re-sighting history of tagged individuals, as well as presentation of location data from previously satellite-tagged individuals (Baird et al. 2013b, 2013c).

METHODS

PMRF Undersea Acoustic Range

The PMRF instrumented hydrophone range is configured with 219 bottom-mounted hydrophones, 199 which are available for PAM. They were installed in four phases, such that each system has different acoustic monitoring capabilities (**Table 2**). The four range systems are: the Shallow Water Training Range (SWTR), the Barking Sands Tactical Underwater Range (BARSTUR), the legacy Barking Sands Underwater Range Expansion (BSURE), and the refurbished BSURE (**Figure 1**). Each range consists of several offset bottom-mounted cables (strings), with multiple hydrophones spaced along each string to create hexagonal arrays.

M3R System

Passive acoustic data pass through the range's operational signal-processing system and the M3R system in parallel. In this way, marine mammal monitoring does not interfere with range use. Signals from all of the hydrophones are processed in parallel, providing marine mammal detection, classification, and localization results for the entire range in real time. These real-time results allow a PAM analyst to isolate animal vocalizations on the range, confirm species classification and choose optimal group localizations for attempting at-sea species verification. To date, classification is accomplished using real-time embedded software with manual review by an analyst. Classification may be to the species or guild level depending on the animal in question. Hydrophones are sampled at 96 kilohertz (kHz), providing an analysis bandwidth of 48 kHz. A Fast Fourier Transform (FFT)-based detector is implemented using an adaptive threshold (exponential average) in each bin of the FFT. If the bin energy is over the adaptive threshold, the bin(s) is set to a "one" and a detection report is generated. All detections are archived including the hard-limited (0/1) FFT output. Detections are classified first by type (whistle or click). Clicks are further categorized, based on the hard-limited FFT frequency content, into five descriptive categories: <1.5 kHz click, 1.5–18 kHz clicks (representative of sperm whales [*Physeter macrocephalus*]), 12–48 kHz click (representative of delphinid species), 24–48 kHz clicks (representative of beaked whales), and 45–48 kHz clicks. Additional Support Vector Machine-based classifiers are also being tested with a focus on Blainville's (*Mesoplodon densirostris*) and Cuvier's beaked whales (*Ziphius cavirostris*). The basic FFT-based detector adjusted for low frequency baleen whale calls runs in parallel. It provides an analysis bandwidth of 3 kHz and a frequency bin resolution of 1.46 kHz.

These broad automatic classifications are further refined using MMAMMAL real-time display software. MMAMMAL displays a color-coded map of the hydrophones indicating the level of detection activity for each hydrophone. The hydrophone color code indicates the number of standard deviations each hydrophone is above the mean detection rate of all the hydrophones. The PAM user can select hydrophones from the map based on detection activity and display a real-time, hard-limited FFT-based spectrogram. These spectrograms are used by trained PAM personnel to classify the whistles and clicks to species level when possible. Prior to this test, detection archives from previous PMRF species verification tests were reviewed to create a compilation of exemplar spectrograms for visually verified species including: rough-toothed dolphin (*Steno bredanensis*), spinner dolphin (*Stenella longirostris*), bottlenose dolphin (*Tursiops truncatus*), false killer whale (*Pseudorca crassidens*), short-finned pilot whale, killer whale (*Orcinus orca*), and Blainville's beaked whale. This compilation provided a reference set for PAM personnel to identify vocalizing species during the test. Unique frequency characteristics based on the MMAMMAL spectrograms were visually identified and noted to aid in providing initial discrimination between species (**Table 3**). However, due to the small visual verification sample size for most species and high overlap in signal characteristics between many odontocete species, these characteristics are far from exhaustive for feature characterization. Additional factors such as typical travel speed, habitat depth range, and dispersion of groups, based on field studies (e.g., Baird et al. 2013a), were used to help indicate potential species for prioritization of directing the small boat to groups when multiple groups were present in the area.

Supplementary to MMAMMAL, software Worldview also displays the hydrophone layout, color-coded for detection rate, with the addition of satellite imagery and digital bathymetry as a background. The Worldview display includes the positions of vocalizing animals derived from automated localization software and frequency segmentation-based whale type similar to MMAMMAL. However, additional information is provided with each position to help the PAM user determine the accuracy of the automated localization, including the number of neighboring localizations and number of 'same' localizations, where 'same' is defined as the same position localized by multiple detections. Typically, a higher quantity of same or neighboring localizations indicates a more accurate localization. Due to the localization methodology, a single-click position is more likely to be a false positive than a cluster of click positions each indicating several neighbors. Automated click localizations provide the PAM user a real-time range-wide map for odontocete distribution of click classification type (e.g., beaked whale, sperm whale, small odontocete). In the absence of automatically generated positions, a MMAMMAL tool for manually calculating positions using hand-selected whistles or clicks is available. When the same click or whistle is visually observed on three or more hydrophones, the user can mark the time-of-arrival on each. These times are then used in a localization algorithm to determine the animal's position. This tool was most often used on bottlenose dolphin (indicated *Tt*) whistles to give the at-sea team a localization (within approximately 100 meters [m]) of a vocalizing individual (hereafter termed a POSIT). Typically, when a group of animals is present, a cluster of POSITs based on multiple vocalizing animals will be plotted around the position of the group. With time, the movement of the group is evident by the track of any one individual within the group. The Worldview display also includes several standard geographic tools such as the ability to measure distance, add points to the map, and include ship navigation data when available.

The Cornell Lab of Ornithology Raven signal analysis package is also available for real-time analysis. An M3R interface module has been added to the program that allows selection of individual or small numbers of hydrophones for examination. The software is used to analyze selected hydrophone signals when questions arise as to signal type and origin. This is particularly useful for verifying the presence of beaked whale vocalizations when questions arise. It has also proven useful for collecting time and frequency images and broadband cuts of selected signals.

Data post-processing is expedited by using the detection archives, which allow rapid evaluation of detections over long periods of time. Additionally, raw hydrophone data are recorded using the recently installed M3R disk recorder, allowing for detailed analysis of marine mammal and environmental signals. The disk recorder is capable of recording precisely time-aligned audio data from all 199 hydrophones.

Specific software tools have been developed for the automated isolation of Blainville's beaked whale click trains; then a second tool marks the position of individual foraging dives. These tools are being modified for PMRF. As the mean group size and detection statistics for Blainville's beaked whales on PMRF are determined, estimation of their density and distribution will be possible (Moretti et al. 2010).

Passive Acoustic Monitoring

PAM began at 0630 every morning and continued until the research vessel left the range, either to return directly to port or to survey in areas south of the range if weather conditions on the range were not suitable for small-boat operations or if the range was closed. At all times the PAM objective was to keep the scientists aboard the rigid-hulled inflatable boat (RHIB) informed of the species and distribution of vocalizing marine mammals that had been localized on the range, focusing in areas that were known to have suitable sea conditions for small-boat operations. A typical visual verification cycle initiates with a radio communication from the PAM operator to the vessel providing the species and locations (referenced by hydrophone for ease of communication) of all known groups vocalizing within a reasonable range of the RHIB. As an example, a communication would detail groups on the SWTR and BARSTUR ranges, but not the BSURE range if the RHIB was on the southern end of the SWTR area (see **Figure 1**). The decision of what group to pursue is left to the on-board scientists so that they can prioritize the combination of species preference, weather conditions, and time of day.

Once the group of interest is radioed back to the PAM team, this group is then followed closely using the M3R system by the PAM team and an attempt is made to provide an updated position. Most often the POSITs are generated automatically by M3R. PAM operators assess the POSIT and relay the coordinates via radio. Sometimes localization involved manually waiting for and selecting whistles to localize. This process is termed a "manual POSIT." A best effort is made to also communicate the confidence level of the POSIT (i.e., the number of solutions at the same location or in the nearby area). Human error can occur when calculating manual whistle localizations, but this is typically minimal with trained PAM personnel. Also, successive whistles are used to generate multiple solutions which provide an increased level of confidence. As the vessel approaches the group, additional position updates are communicated by the PAM team in real time until receiving confirmation that the on-the-water team had sighted the group. At this time, the PAM team remains on standby until receiving additional communication in order to not disrupt tagging and photo-identification activities onboard the RHIB. While standing by, the PAM team continues to assess the entire range in the context of providing information for the next cycle.

Detection archives are collected from all hydrophones for the entire period, 24 hours (hr) per day. These archives capture all detection reports, and automated localizations generated during the test.

FIELD METHODS

Tag types and programming

Ten satellite tags were available for deployment, including six location-dive tags (Wildlife Computers Mk10-A) and four location-only tags (Wildlife Computers SPOT5) in the LIMPET configuration. Each tag is attached with two titanium darts with backward facing petals, using either short (4.4-centimeter [cm]) or long (6.8-cm) darts (Andrews et al. 2008), depending on species (e.g., short darts for rough-toothed dolphins, long darts for false killer whales).

For each tag type (location-only or location-dive) there were different programming combinations depending on species. The combinations are based on the average number of respirations per hour from previous tagging studies, while taking into account the speed of surfacing and the likelihood of the tag remaining attached for longer than approximately 30 days, which varies by species. Location-dive tags programmed for false killer whales transmitted 15 hr/day with a maximum of 600 transmissions a day, giving an estimated battery life of approximately 29 days. Location-dive tags programmed for rough-toothed dolphins transmitted for 17 hr/day with a maximum of 800 transmissions per day, giving an estimated battery life of approximately 22 days. Location-dive tags were set to record a time series (recording depth once every 1.25 minutes for rough-toothed dolphins and once every 2.5 minutes for false killer whales), as well as dive statistics (start and end time, maximum depth, duration) for any dives greater than 30 m in depth, with depth readings of 3 m being used to determine the start and end of dives, thus dive durations are slightly negatively biased. Given typical odontocete descent and ascent rates of 1–2 m/second, dive durations recorded are likely only 3–6 seconds shorter than actual dive durations. Prior to the field effort, satellite pass predictions were carried out using the Argos web site to determine the best hours of the day for transmissions given satellite overpasses for the approximately 2-month period starting at the beginning of the deployment period.

A land-based Argos receiver station was set up on Mākaha Ridge, Kaua‘i, to try to increase the amount of dive and surfacing data obtained from the location-dive tags. This is a similar system to that used in February 2013 (see Baird et al. 2013c), however the system during this effort included three Telonics TGA-100 7-element antennas, each connected to a Telonics TSUR-400 uplink receiver, rather than a single antenna/receiver system. Each system was connected to a laptop with data recorded using Telonics Uplink Logger v. 1.00. The antennas were at a 456-m elevation, one oriented to the north, one oriented to the west, and one oriented to the southwest.

Vessel, time and area of operations

The vessel used was a 24-foot rigid-hulled Zodiac Hurricane, powered by twin Suzuki 140-horsepower outboard engines, and with a custom-built bow pulpit for tagging and biopsy operations. The vessel was launched each morning at sunrise, and operations continued in daylight hours as long as weather conditions were suitable. The launch site was the Kīkīaola small boat harbor, but alternative sites, including Port Allen and Nāwiliwili Harbor, were available if the prevailing weather conditions warranted. For calculating effort by depth and time within the PMRF instrumented hydrophone range boundaries, effort locations were recorded on the global positioning system unit at 5-minute intervals. When weather conditions permitted, the primary area of operations was the PMRF hydrophone range, with a focus on deep-water areas to increase the likelihood of encountering high-priority species. When positions from the M3R system were available, the RHIB operator would transit to specific locations in response to the positions and otherwise would survey areas for visual detection of groups. When conditions on PMRF were sub-optimal and there were better conditions elsewhere, or if the range was closed due to Navy activity the RHIB team worked in areas off the range. The RHIB team communicated each morning with the PMRF Range Control prior to entering the range and remained in regular contact with Range Control throughout the day as needed to determine range access limitations.

During encounters

Each group of odontocetes encountered was approached for positive species identification. Decisions on how long to stay with each group and what type of sampling (e.g., photographic, tagging, biopsy) was undertaken depended on a variety of factors, including current weather conditions and weather outlook, information on other potentially higher-priority species in the area (typically provided by M3R), and the relative encounter rates. Species encountered infrequently (false killer whales) were given higher priority than frequently encountered species (spinner, bottlenose, and rough-toothed dolphins). Extended work with frequently encountered species was typically only undertaken with groups that were suitable for tagging given behavior and sea conditions, and when no other higher-priority species were in areas suitable for working.

In general, species were photographed for species confirmation and individual identification. For each encounter we recorded information on start and end time and location of encounter, group size (minimum, best, and maximum estimates), sighting cue (e.g., acoustic detection from M3R, splash), start and end behavior and direction of travel, the group envelope (i.e., the spatial spread of the group in two dimensions), the estimated percentage of the group observed closely enough to determine the number of calves and neonates in the group, the number of individuals bowriding, and information necessary for permit requirements.

If conditions were suitable for tagging, for all infrequently encountered species, we attempted to deploy at least one satellite tag per group. For frequently encountered species, we attempted to deploy one tag per group, unless the group was unusually large (e.g., >50 individuals) and thus likely comprised more than one social group. When more than one tag deployment was attempted within a single group, the second individual to be tagged was not closely associated with the first.

After tagging, or if individuals appeared un-approachable for tagging, we sometimes attempted to collect biopsy samples, either to confirm sex of tagged animals or, for species that are known or thought to exhibit population structure within Hawaiian waters (e.g., false killer whales), to help interpret results of tagging and photo-identification. Biopsy samples were sent to the Southwest Fisheries Science Center for genetic analyses.

Data analyses

Five-minute effort locations were processed with ArcGIS to determine depth and whether locations were inside or outside the PMRF instrumented hydrophone range boundaries. Locations of tagged individuals were estimated by the Argos System using the least-squares methods and were assessed for plausibility using the Douglas Argos-filter v. 8.2 to remove unrealistic locations, following protocols previously used (Schorr et al. 2009; Baird et al. 2010, 2011). Resulting filtered location data were processed with ArcGIS to determine depth, distance from shore, and location relative to PMRF boundaries. From this, the proportion of time spent within PMRF boundaries, as well as the number of times an individual was found inside the range boundaries, were estimated for each individual. For estimating the proportion of time within the range boundaries, when consecutive locations spanned the boundary, the time spent inside the boundary was considered to start at the last location outside the boundary and end at the time of the last location inside the boundary. The number of times an individual was found inside the range boundaries was determined by examining consecutive locations for whether they were inside or outside of the range boundary.

When more than one tag was deployed on the same species, we assessed whether individuals were acting in concert during the period of overlap by measuring the straight-line distance (i.e., not taking into account potentially intervening land masses) between pairs of individuals when locations were obtained during a single satellite overpass (approximately 10 minutes). We used both the average distances between pairs of individuals and the maximum distance between pairs to assess whether individuals were acting independently, following protocols described by Schorr et al. (2009) and Baird et al. (2010).

Data obtained from the land-based Argos uplink receivers and from the Argos System were processed through the Wildlife Computers DAP Processor v. 3.0 to obtain diving and surfacing data from the location-dive tags. To visualize the depth time series in relation to bathymetry, a pseudotrack was developed. To generate this pseudotrack, both the time series and the Argos position data were imported into separate pages of an Excel spreadsheet. For each Argos position, the distance and bearing to the next Argos position were calculated using the GeoFunc Excel Geometry Add-in[1], and the average rate of travel to the next location was calculated by dividing the distance between the two points by the time elapsed between them. We then used the time stamp for each point in the depth time series to look up the latitude and longitude of the nearest preceding Argos position in time. A new offset location for each time series point was generated using the time difference, the average rate of travel, and the bearing between the preceding and following Argos locations. The spatially referenced depth time series points were then converted to a three-dimensional track and overlaid on bathymetric imagery using GPSVisualizer[2] to create a Google Earth kml layer.

RESULTS

From 26 July to 02 August 2013 there were 671.5 kilometers (km) (36.6 hr) of small-vessel field effort, with the boat on the water 7 of the 8 days (**Table 4**). There was no effort on 30 July due to Tropical Storm Flossie, and closure or restrictions on PMRF limited access on 4 of the remaining 7 days. Over the 36.6 hr of survey effort, 55.1 percent of the time (20.2 hr) was spent within the PMRF instrumented hydrophone range boundaries (**Figure 1**), and 89.5 percent of effort (49.3 hr) was in depths less than 1,000 m (**Figure 2**). Forecast winds during the 8-day period included 2 days of 15-knot winds, 5 days of 25-knot winds, and 1 day of gale force winds, with winds either from the east or northeast, limiting field operations most days to relatively shallow waters west of Kaua‘i and on some days primarily to areas south of PMRF (**Figure 1**). Acoustic monitoring with the M3R system was undertaken prior to the RHIB entering the PMRF range each day and concluded after the RHIB left the range, for a total of 33 hr of acoustic monitoring (**Table 5**).

Overall there were 18 sightings of four species of odontocetes, nine of which were on PMRF (**Table 6**). Bottlenose dolphins were encountered on six occasions, spinner dolphins on three, rough-toothed dolphins on eight, and false killer whales once. Five of the nine encounters were directed by acoustic detections from the M3R system. Confidence of acoustic detections on the range by species is given in **Table 7**. **Table 7** includes only real-time acoustic observations logged in notes and cannot be interpreted for species presence/absence. Because the PAM team was often viewing only the BARSTUR/SWTR area where the RHIB was located, there could be days where, as an example, sperm whales were present on BSURE but were not noted.

Recordings on the M3R system to improve species classification for future acoustic monitoring efforts were made for three of the four species of odontocetes encountered (all but

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[1] www.afsc.noaa.gov/nmml/software/excelgeo.php
[2] www.GPSVisualizer.com

spinner dolphins). During the encounters 4,393 photos were taken for individual identification, two biopsy samples were obtained for genetic studies (sent to the Southwest Fisheries Science Center), and three satellite tags were deployed on two species (**Table 8**). Spinner dolphins were encountered on three occasions, once on PMRF and twice off the range. Identification photos were obtained from all three encounters for contribution to a photo-identification catalog held at the Pacific Islands Fisheries Science Center, but no attempts were made to satellite tag these photographed individuals due to the small size of their dorsal fins.

False killer whales

False killer whales were encountered on a single occasion, with the group initially detected by M3R and the research vessel vectored to the group. We were able to obtain identification photos of seven individuals, although only five of the seven were classified as distinctive. We also obtained one biopsy sample, and deployed one location-dive satellite tag. Genetic analysis of the biopsy sample indicated the individual had haplotype 1 (K. Martien, pers. comm.; see Martien et al. 2014). Identification photos were compared to our long-term photo-identification catalog (Baird et al. 2008b) that includes individuals from the main Hawaiian Islands insular, northwestern Hawaiian Islands (see Baird et al. 2013d), and Hawaiʻi pelagic stocks. Four of the five distinctive individuals had been previously documented, three of them in June 2012 off Kauaʻi during a previous field effort (including one that had been satellite tagged during that effort, HIPc520; see Baird et al. 2013b). One of these three, and the fourth re-sighted individual, had also been photo-identified off Oʻahu in an encounter by the Wild Dolphin Foundation in April 2013. The individual that was satellite tagged HIPc523 in our catalog was previously documented both in June 2012 off Kauaʻi and in April 2013 off Oʻahu (**Table 9**). A social network of photo-identified false killer whales including the June 2012 and July 2013 Kauaʻi groups and the April 2013 Oʻahu group is shown in **Figure 3**, as well as individuals documented off Nīhoa in 2010 and associated individuals. None of the individuals documented associated with the main Hawaiian Islands insular population, despite relatively large sample sizes of identifications within each encounter. Combined with the genetic results, these indicate the individuals are part of the Northwestern Hawaiian Islands population (see also Baird 2009; Baird et al. 2013b, 2013d).

Location data were obtained from the satellite tag over a 21-day span. During that period, the tagged individual remained associated with Kauaʻi and Niʻihau, circumnavigating both islands (**Figure 4**). There were 17 different periods of time when the tagged individual was located inside PMRF boundaries, with 24 percent of the total time (approximately 121 hours) inside the range boundary (**Table 10**). Location data are now available for six false killer whales from the northwestern Hawaiian Islands population, four of which were satellite tagged off Kauaʻi (Figure 4).

Dive and surfacing data were obtained from the tag during the first 13.7 days, with data covering 9.4 days during that period (i.e., there were gaps in the dive/surfacing data totaling 4.3 of the 13.7 days). Although 53.4 hours of dive data were obtained from the Mākaha Ridge receiving station, dive data obtained overlapped with those obtained through Argos. The median straight-line distance from the Mākaha Ridge station to the tagged whale was 29.6 km. One hundred and fourteen dives were documented, with median and maximum depths of 137.5 and 927.5 m, and median and maximum durations of 3.91 and 15.23 minutes. Median depth of locations of the tagged individual was 710 m, suggesting that at least some of the deepest dives were likely to, or close to, the bottom (see **Figure 5**).

Bottlenose dolphins

Bottlenose dolphins were sighted on six occasions and good quality photographs of distinctive individuals were obtained from five of the six encounters. Sixteen identifications (i.e., not excluding re-sightings) of distinctive individuals with good or excellent quality photos were obtained and compared to the long-term photo-identification catalog (Baird et al. 2009). From these 16 identifications, 14 individuals were identified. Of the 14 individuals, 13 had been previously documented, all off Kauaʻi and/or Niʻihau, with seven of the 13 being identified in years prior to 2013. Individuals from each of the five encounters had been previously documented, and all linked by association in a single social network (not shown), indicating that all five groups were from the island-associated population.

Rough-toothed dolphins

Rough-toothed dolphins were encountered on eight occasions, with four of the eight sightings outside of PMRF boundaries and a fifth sighting in an area with hydrophones that are not being used for PAM (**Table 2**). Two individuals were tagged with location-dive satellite tags, in separate encounters two days apart, with both tag deployments on individuals in groups encountered off the range (**Table 8**). One of the two individuals (SbTag009, catalog ID HISb0424) had been previously photo-identified off the island of Kauaʻi in November 2005 (**Table 9**); a social network analysis indicates that this individual is linked by association with the main social cluster of rough-toothed dolphins off Kauaʻi and Niʻihau (**Figure 6**). The second tagged individual (SbTag010, catalog ID HISb0939) had not been previously sighted, nor had either of the other two individuals photo-identified in the group (**Figure 6**), so it was not possible to say, based on association patterns from photo-identification, whether this individual was part of the resident population.

Location data were obtained for 9.9 (SbTag009) and 13.4 days (SbTag010), and dive data were obtained for 8.5 and 7.5 days, respectively. From the land-based receiving station, 29.4 and 34.0 hours of dive data were obtained, however data from SbTag009 overlapped with data obtained from Argos, and only 1.4 hours of non-overlapping dive data were obtained from SbTag010. The median straight-line distances from the Mākaha Ridge receiving station to the tagged individuals were 31.4 and 26.7 km, respectively. An analysis of distance between locations of the two individuals obtained during the same satellite overpasses showed that those distances varied widely (**Figure 7**). There were two occasions when the two individuals were within 1 km of each other, although they remained separated by an average of 11.2 km (maximum of 37.5 km) over the entire period of overlap. Thus the movement and dive data from the two individuals are considered to be independent. During the period of tag attachment the two individuals remained either in the channel between Kauaʻi and Niʻihau or generally associated with the island of Niʻihau (**Figure 8**). There were 11 different periods for each individual where the individuals were inside the PMRF boundary, with 34.0 percent (approximately 81 hours) and 46.7 percent (approximately 150 hours) of their time spent inside the range boundary (**Table 10**).

Dive data indicated that rough-toothed dolphins were relatively shallow divers (maximum depths of 287.5 and 227.5 m for SbTag009 and SbTag010, respectively; **Table 11**).

Given that the median depths of locations for the two tagged individuals were 1,215 and 1,047 m (**Table 10**), respectively, all dives were likely to mid-water (see **Figure 9**).

DISCUSSION AND CONCLUSION

Access restrictions on PMRF and weather conditions limited our ability to utilize the M3R system to increase encounter rates and for visual verifications of acoustic detections on 5 of the 8 field days during this field effort. Given the low densities of most species of odontocetes around the main Hawaiian Islands (Baird et al. 2013a), the amount of field effort, particularly in deep waters (**Figures 1 and 2**), was not enough to have a high likelihood of encountering many of the high priority deep-water species, such as Cuvier's or Blainville's beaked whales, sperm whales, or melon-headed whales. That said, for three different species of odontocetes, one of which has only been rarely encountered in previous field efforts, considerable progress was made towards addressing our primary monitoring question: what are the spatial movement patterns and habitat use (e.g., island-associated or open-ocean, restricted ranges vs. large ranges) of species that are exposed to MFA sonar, and how do these patterns influence exposure and potential responses?

The most valuable data from this field effort came from the encounter with false killer whales, cued in by an acoustic detection from the M3R system. Location data from the tagged false killer whale showed a very different pattern in spatial use than had been previously documented for the false killer whales from the northwestern Hawaiian Islands population. Prior to this effort, false killer whales from this population had been tagged on two different occasions, off Nīhoa in 2010 (Baird et al. 2013d), and off Kauaʻi in June 2012 (Baird et al. 2013c). The two previous tagging occasions were of individuals from at least two different social groups (**Figure 3**), although movement patterns were generally similar, with broad-scale movements from Kauaʻi/Nīhoa to Gardner Pinnacles (Baird et al. 2013b, 2013d; see **Figure 4**). The individual tagged in July 2013 was from the same social group as at least two of the individuals tagged in July 2012 (**Figure 3**), yet remained associated with the Kauaʻi and Niʻihau area for the entire 21 days post-tagging (**Figure 4**). The tagged individual remained associated with the island before, during and after the SCC held in August 2013, and passed through the PMRF range twice during the SCC.

While no tags were deployed on bottlenose dolphins, all five groups that had individuals photo-identified had matches back to our catalog from the island of Kauaʻi, providing further evidence of a resident population (see also Baird et al. 2009; Martien et al. 2011; Baird et al. 2013b, 2013c). Data obtained from the two satellite-tagged rough-toothed dolphins also provided additional support for a resident island-associated population off Kauaʻi and Niʻihau, with individuals regularly using the PMRF range and spending a considerable portion of their time there (34 percent and 46.7 percent; **Table 10**). Location data are now available for 10 rough-toothed dolphins satellite-tagged off Kauaʻi, with all individuals generally remaining associated with Kauaʻi and Niʻihau (**Figure 8**; see also Baird et al. 2013b), with a concentration of locations in the channel between the islands. Combined with previous tag deployments on this species (Baird et al. 2013b, 2013c), data suggest that over periods of up to 3 weeks rough-toothed dolphins around Kauaʻi and Niʻihau remain broadly associated with the island slope (**Figure 8**).

We also obtained 226 hr of dive data from the tagged false killer whale and a combined 385 hr of dive data from the two tagged rough-toothed dolphins (**Table 11, Figures 5, 8**); little is known of the diving behavior of either species in Hawaiian waters or elsewhere in the Pacific and these datasets represent a substantial increase in sample size available for future detailed analyses of diving behavior. While a combined 118 hours of dive data was obtained for the three species from the land-based receiver stations, this largely overlapped with data obtained directly though Argos, thus there was a relatively small contribution from the land-based stations in comparison to data obtained from tagged animals in February 2013 (Baird et al. 2013c). While the exact reasons for this remain unclear, the much greater average distances from the tagged animals to the receiver stations during the current efforts in comparison to bottlenose dolphins tagged in February 2013 likely influence the amount of dive data obtained during this effort.

Preliminary acoustic propagation analyses of sonar use on PMRF during SCCs suggest that MFA sonar on PMRF is generally audible to cetaceans throughout PMRF (S.W. Martin, SPAWAR Systems Center Pacific, personal communication). Thus, based on locations of the tagged false killer whale, individuals from the northwestern Hawaiian Islands false killer whale population are likely to be exposed to MFA sonar on PMRF. However, given the known movement patterns of individuals from this population from previous tagging, such exposure is likely infrequent. While individuals from the main Hawaiian Islands insular population have not been photographically documented at PMRF, satellite tagged individuals from that population have been documented moving through the range (Baird et al. 2012), and thus may also occasionally be exposed to MFA sonar. At least one of the two satellite tagged rough-toothed dolphins appear to be from an island-associated population (**Figure 6**). Movements from both tagged animals overlapped substantially with PMRF (**Figures 7 and 8**). Data from all 10 animals satellite tagged off Kaua‘i since July 2011 demonstrate widespread movements around Kaua‘i and Ni‘ihau with high density of locations within the channel between the two islands. Given the considerable overlap between the channel and PMRF, exposure to MFA sonar is likely more common for this population.

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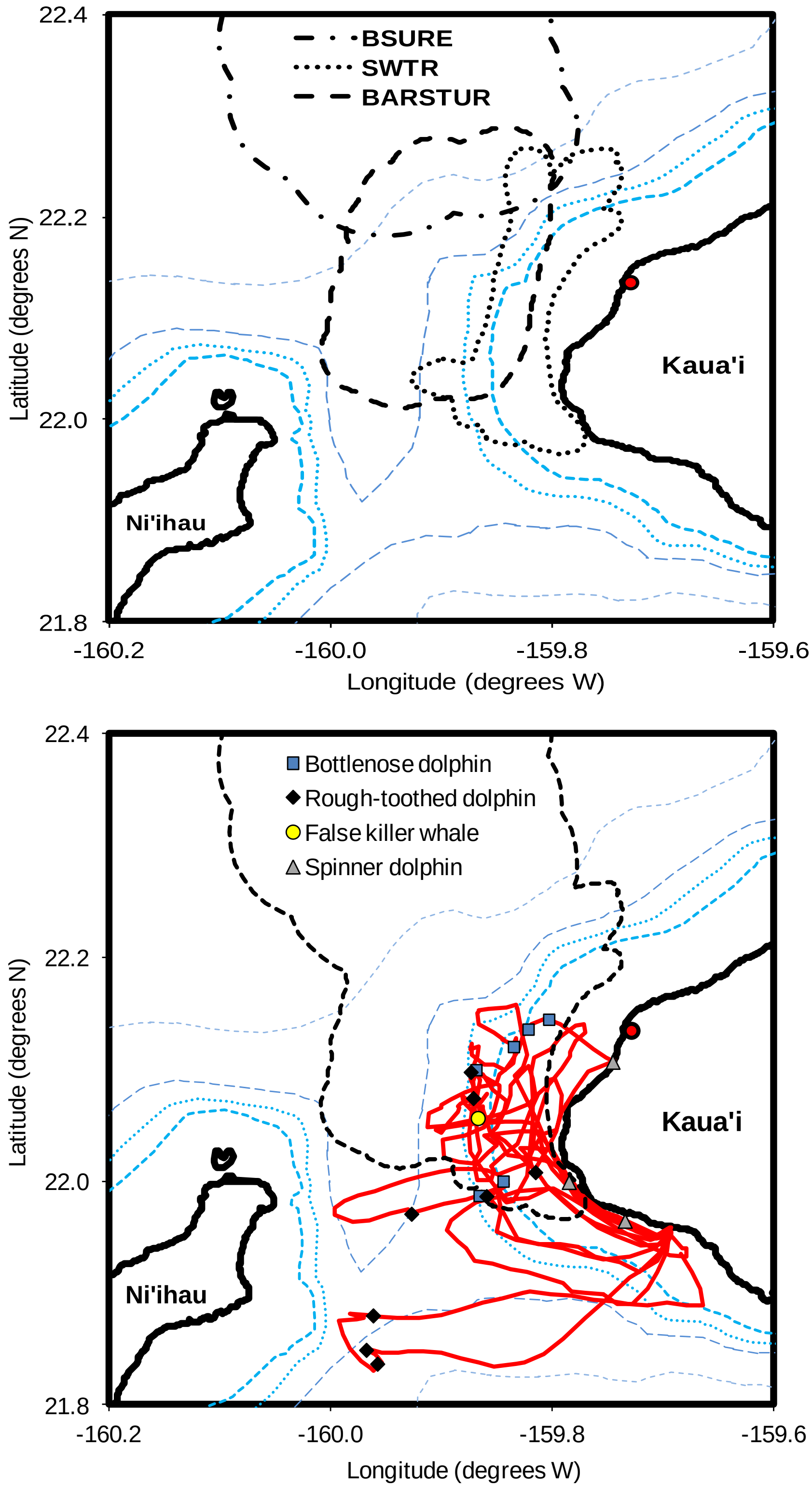


Figure 1. Map showing boundaries of instrumented hydrophone ranges (top, see Table 2) as well as tracklines of small-vessel field effort in July/August 2013 with sightings indicated and overall PMRF range boundary shown (bottom). The land-based receiver station on Mākaha Ridge is indicated by a red circle. The 100-m, 500-m, 1,000-m and 2,000-m depth contours are shown.

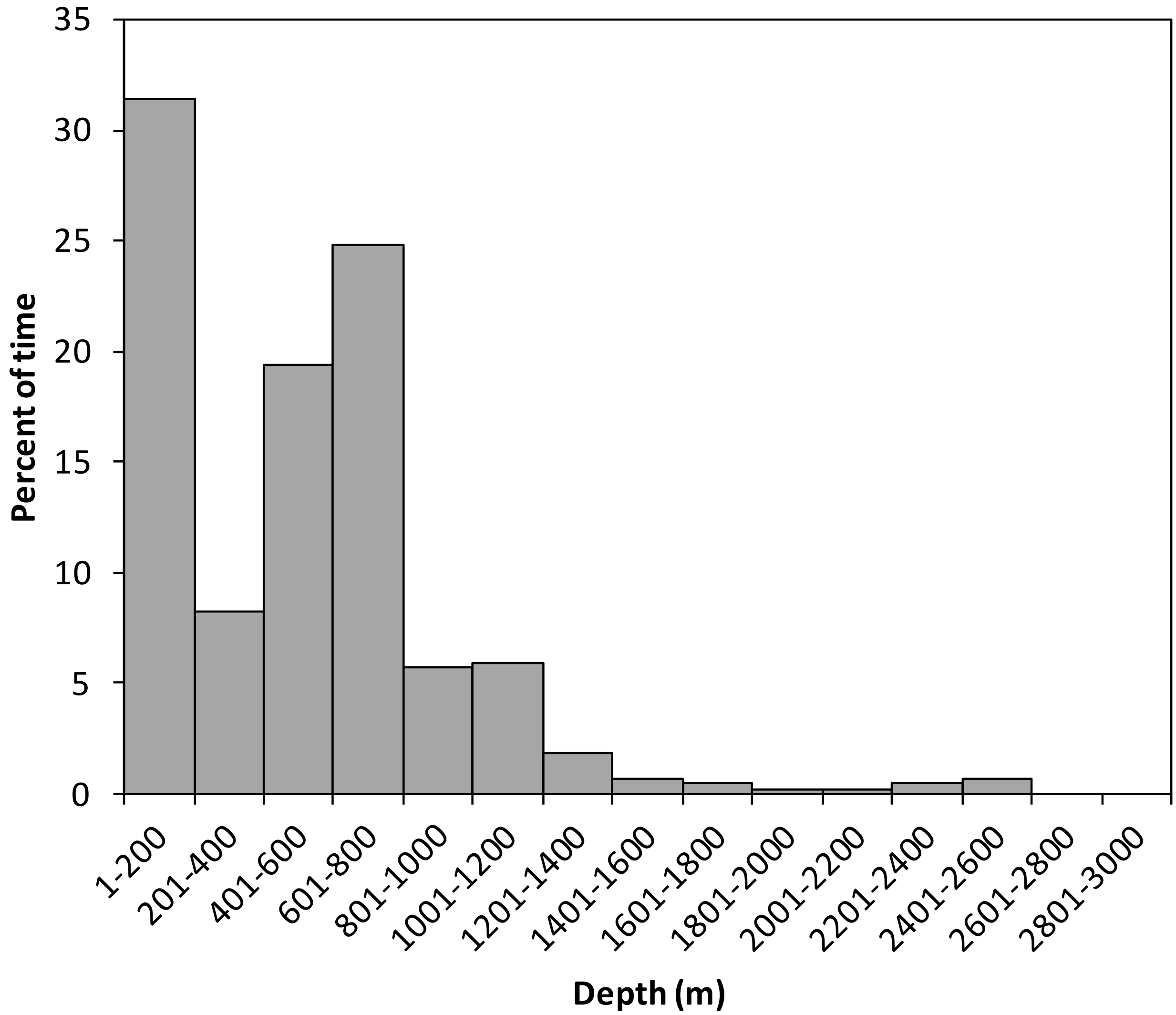


Figure 2. Depth distribution of small-vessel effort during July/August 2013 field effort.

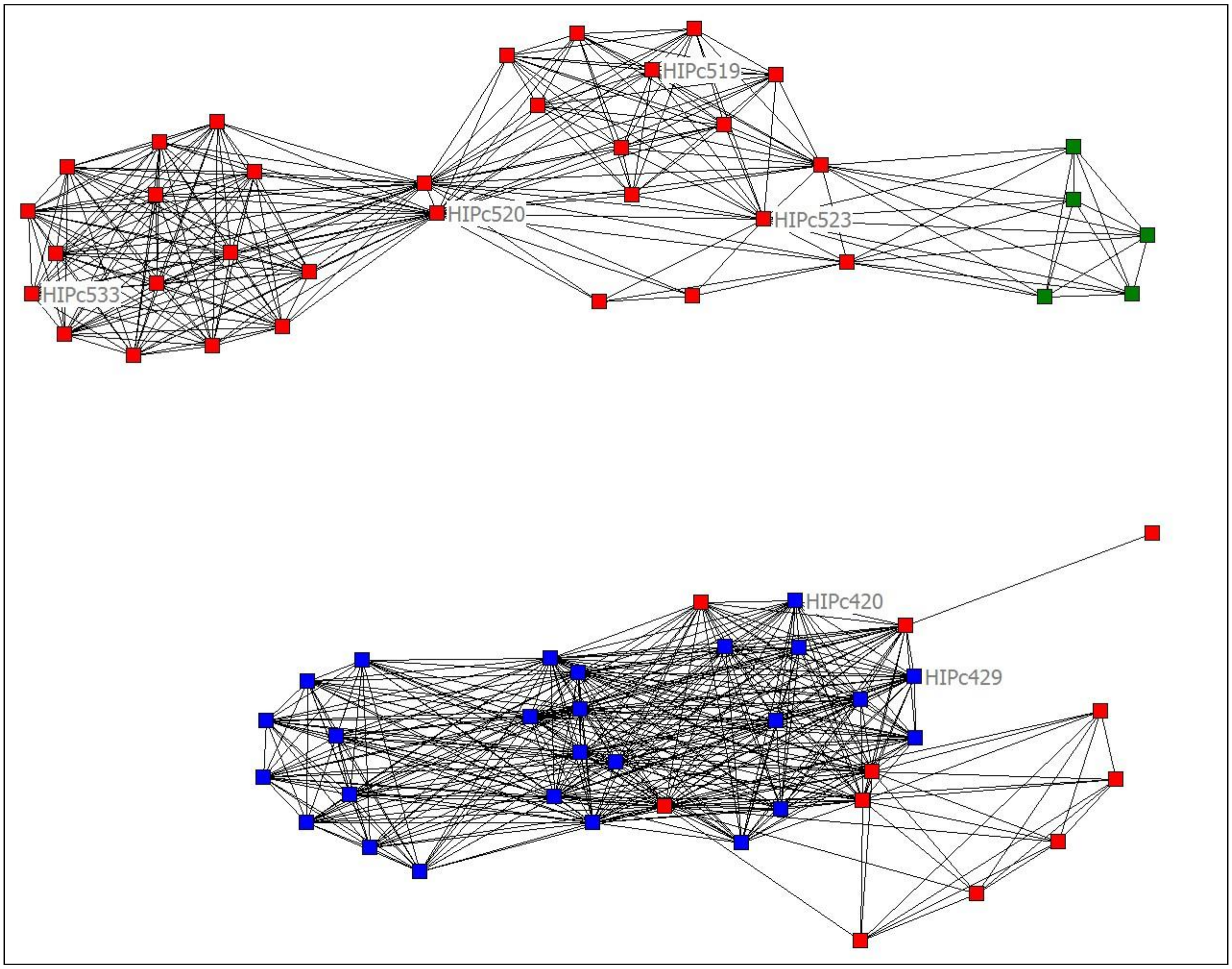


Figure 3. Social network of photo-identified false killer whales from the Northwestern Hawaiian Islands population, including slightly distinctive, distinctive and very distinctive individuals with fair or better quality photos (see Baird et al. 2008b). Each individual is represented by a square with lines joining individuals seen together. Area where individuals were first documented indicated by symbol color: red – Kauaʻi and/or Niʻihau; green – Oʻahu; blue – Nīhoa. Satellite-tagged individuals indicated by CRC photo-identification catalog identifier. HIPc523 was satellite tagged 26 July 2013, while HIPc519, HIPc520 and HIPc533 were tagged off Kauaʻi in June 2012 (see Baird et al. 2013b). Individuals HIPc420 and HIPc429 were satellite tagged off Nīhoa in 2010 (see Baird et al. 2013d).

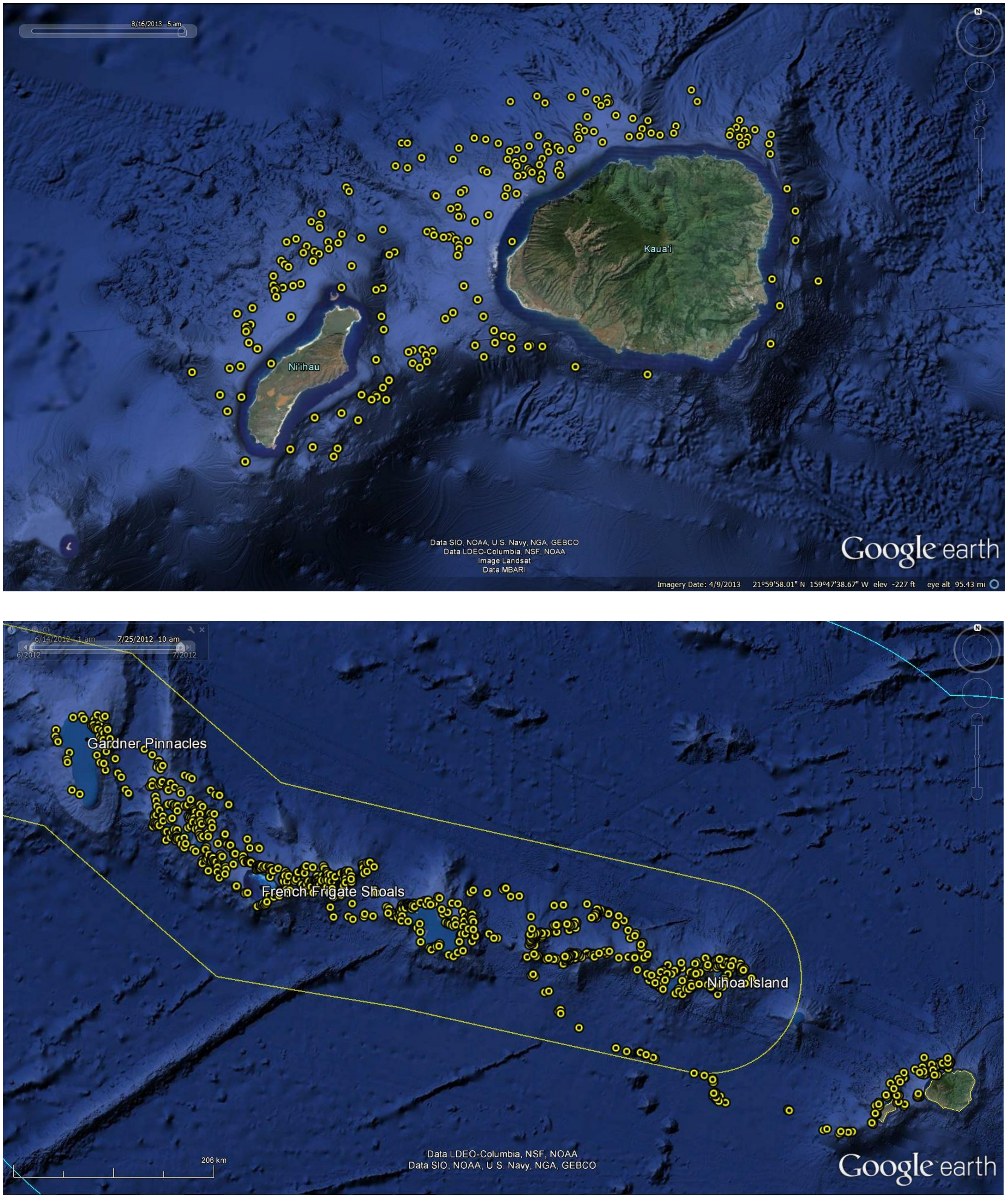


Figure 4. Top. Locations from false killer whale HIPc523 satellite-tagged 26 July 2013, over a 21-day period. Bottom. Locations from false killer whale satellite HIPc519 tagged off Kaua‘i 6 June 2012, over a 42-day period (from Baird et al. 2013b). Only the first three days of the track of HIPc519 were around Kaua‘i or Ni‘ihau.

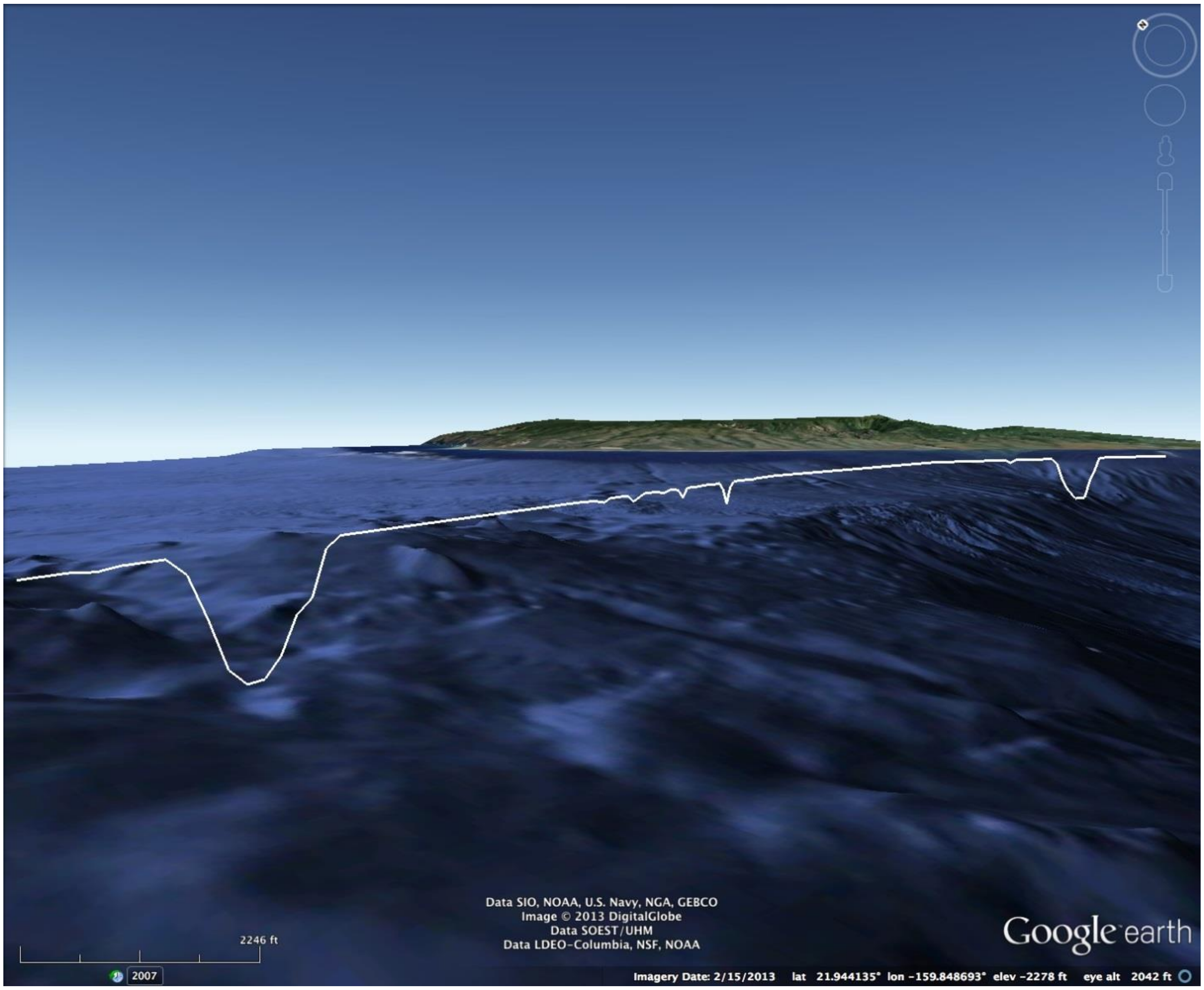


Figure 5. An example of dive and location data from false killer whale HIPc523 over a 3.8-hr period starting on 31 July 2013 at 05:00 hr (HST), as it transits from east (right side) to west. The two deep dives shown were to approximately 927 m (right) and 751 m (left). This representation uses time-series data with depth recorded every 2.5 minutes.

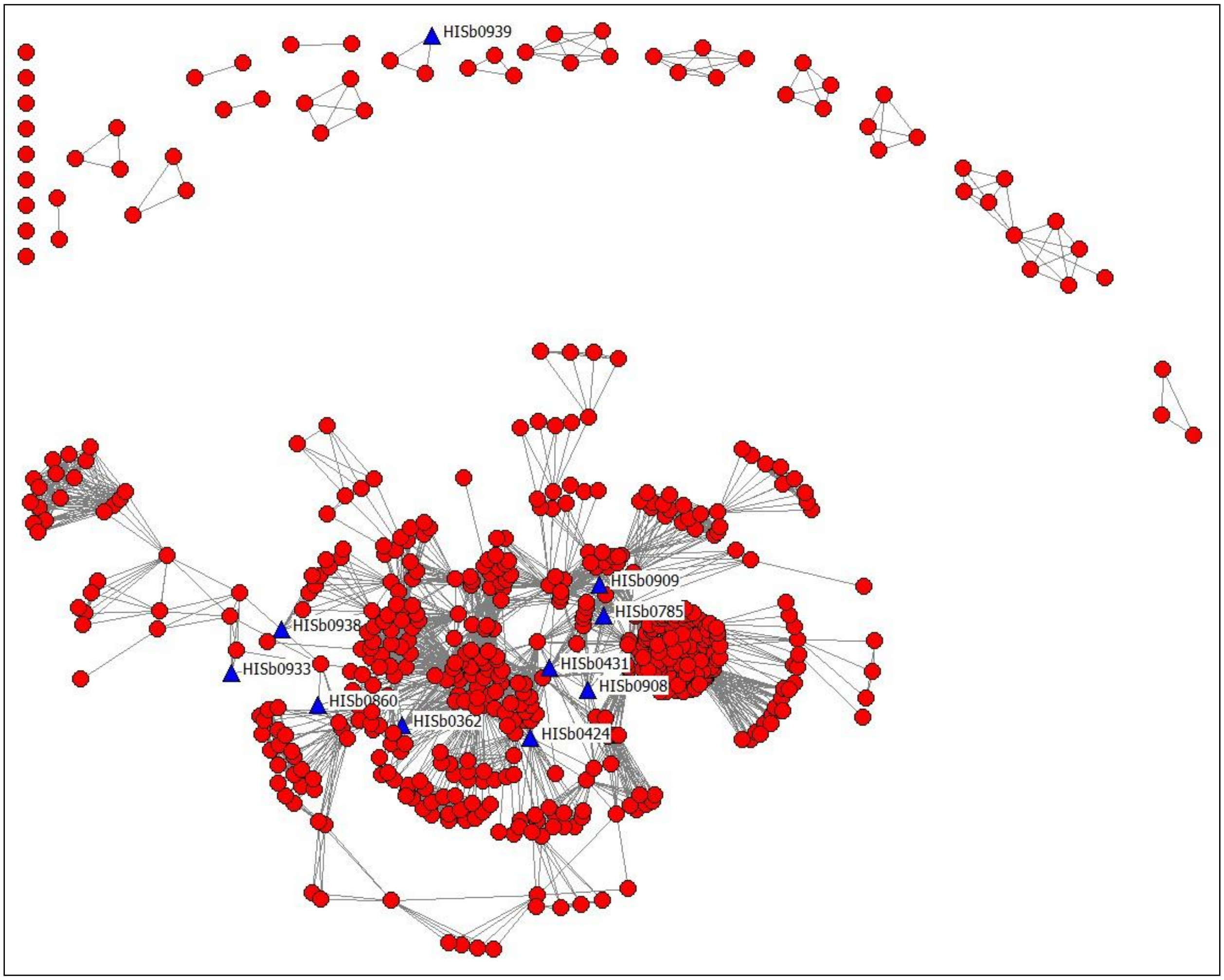


Figure 6. Social network of rough-toothed dolphins photo-identified off Kaua'i and Ni'ihau from 2003-2013, with tagged individuals noted by symbol type (triangles) and with ID labels. This includes all individuals categorized as slightly distinctive, distinctive, or very distinctive, with fair, good, or excellent quality photographs (see Baird et al. 2008c), with a total of 560 individuals shown (the main cluster contains 496 individuals). Individuals HISb0424 and HISb0939 were tagged in July/August 2013.

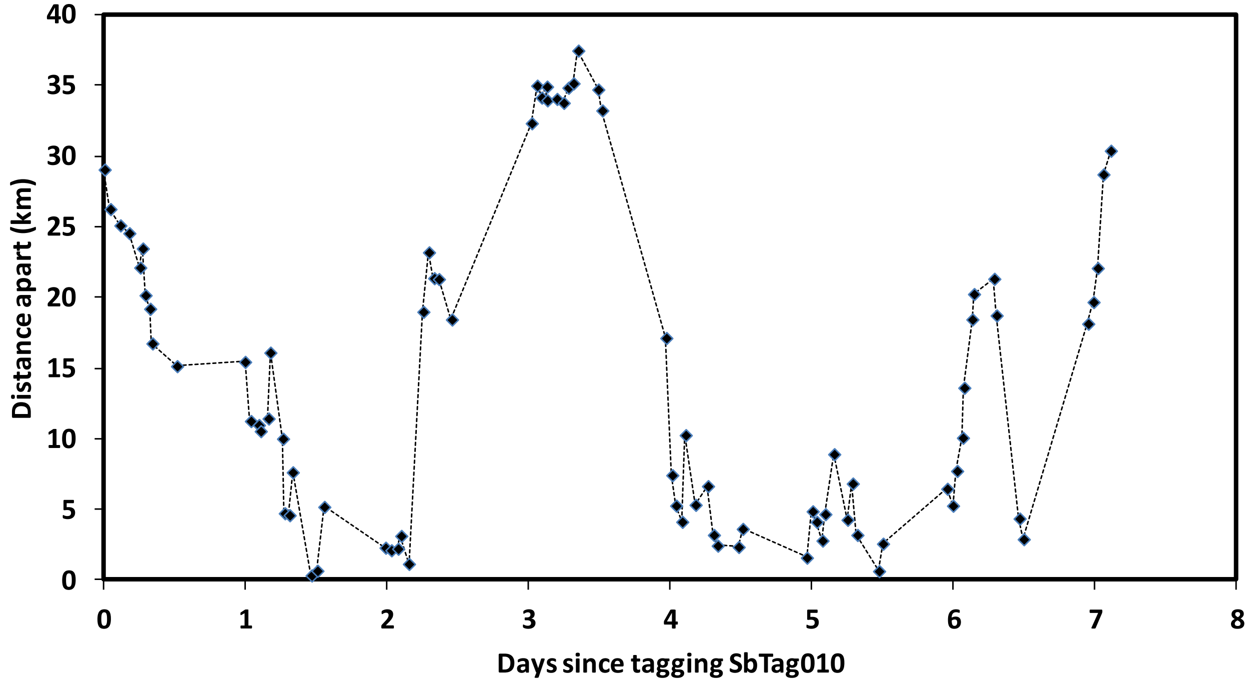
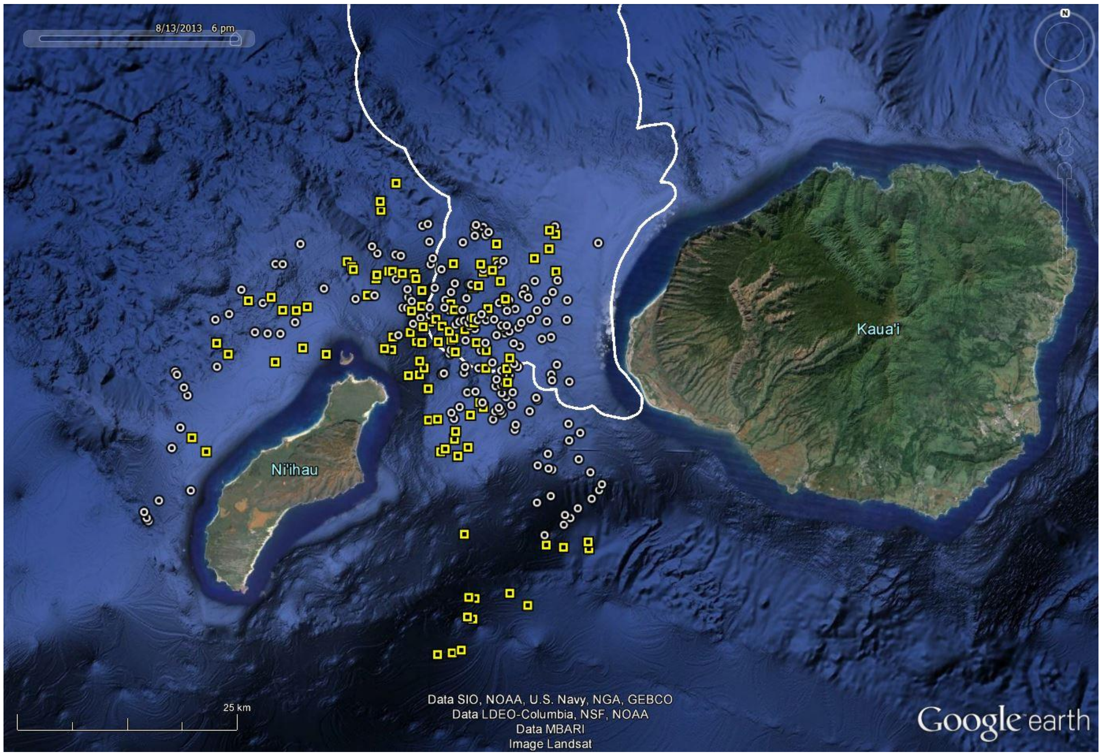


Figure 7. Distance between two tagged rough-toothed dolphins over the period of tag overlap. When SbTag010 was tagged on 1 August 2013, SbTag009 was approximately 29 km away. During the seven days of tag overlap the two individuals remained an average of 11.2 km apart (maximum = 37.5 km), although did approach within less than 1 km on two occasions.



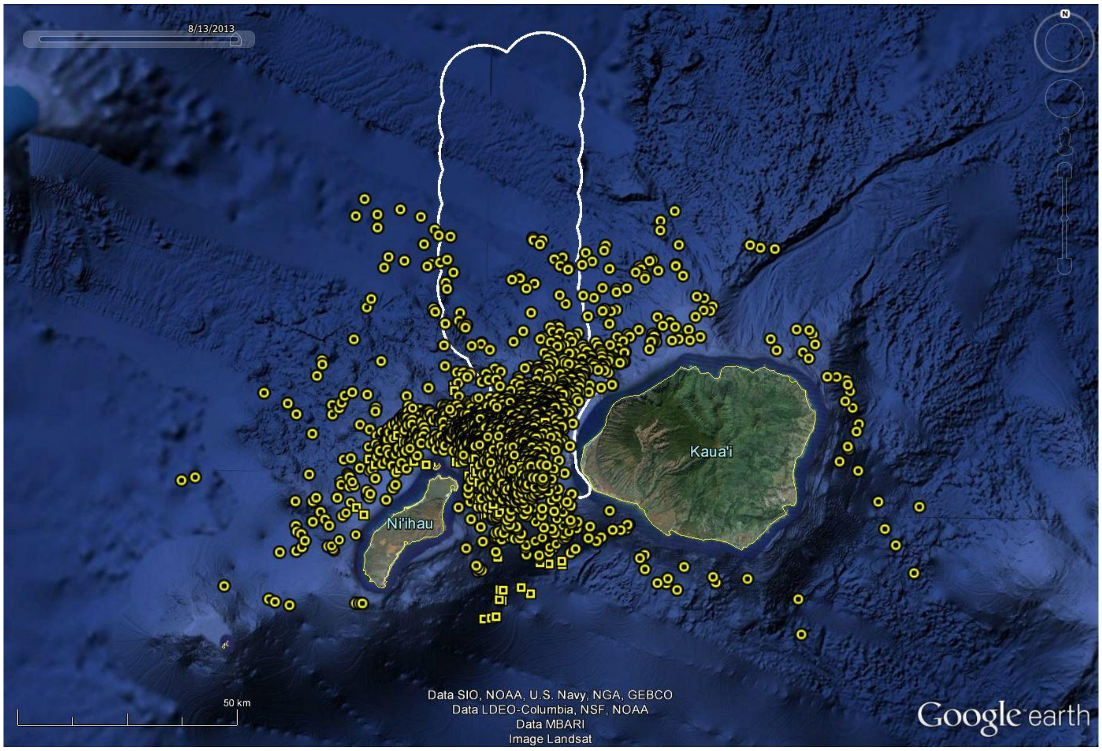


Figure 8. Top. Locations of rough-toothed dolphins satellite tagged in July 2013 (yellow squares SbTag009; white circles SbTag010). Bottom. Locations of 10 satellite-tagged rough-toothed dolphins, including individuals tagged in July/August 2011 (3 individuals), January 2012 (1 individual), June/July 2012 (3 individuals) February 2013 (1 individual), and July 2013 (2 individuals). The boundary of the Pacific Missile Range is shown in a solid white line.

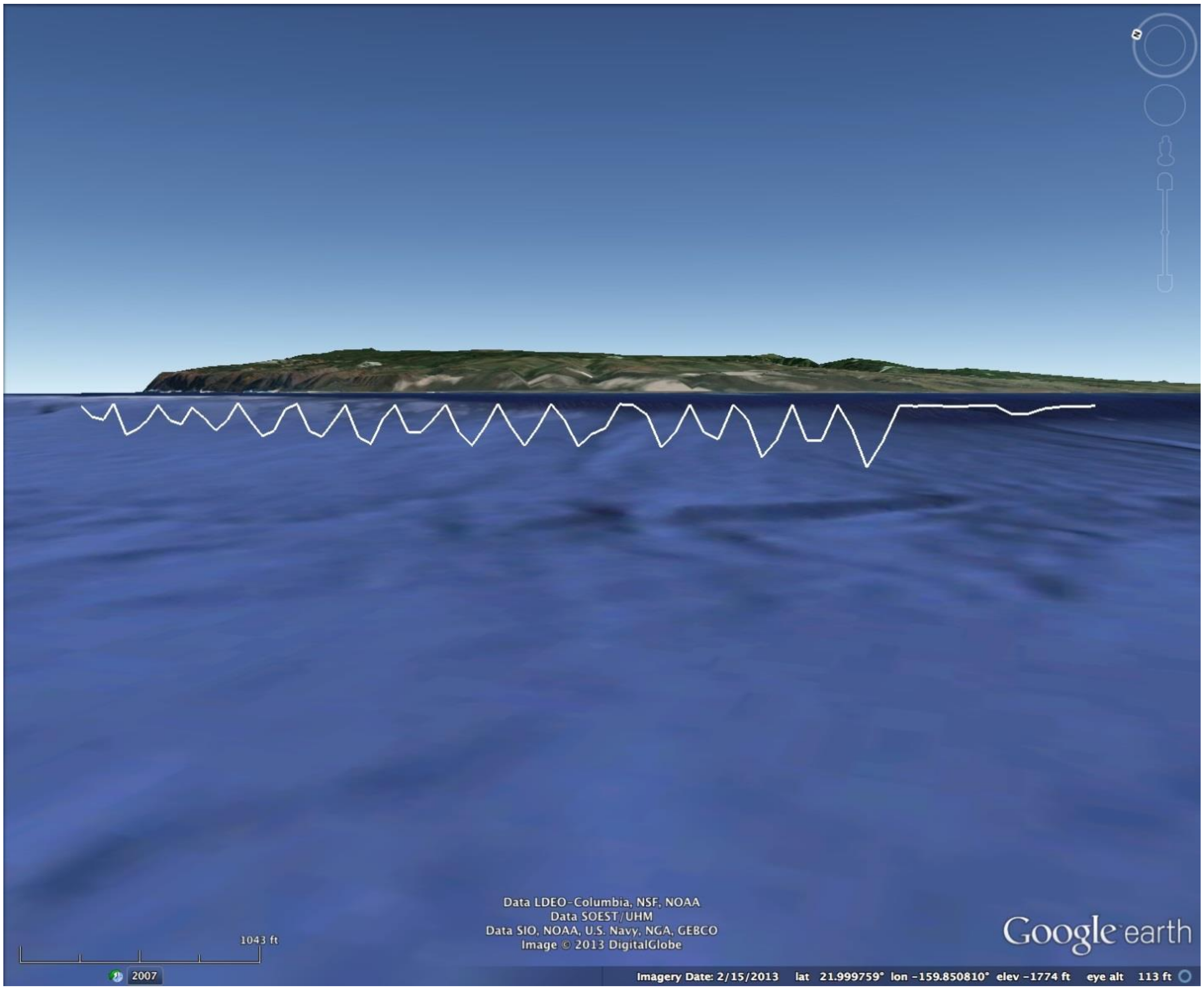


Figure 9. An example of dive and location data from rough-toothed dolphin HISb0939 over a 1-hr and 35 minute period starting on 9 August 2013 at 19:25 hr (HST), as it transits from south (right side) to north in the channel between Kaua‘i and Ni‘ihau. The deepest dive shown (right) was to approximately 140 m, where the bottom depth was greater than 400 m. This representation uses time-series data with depth recorded every 1.25 minutes.

Table 1. Details of previous field efforts off Kaua'i involving satellite tagging or M3R passive acoustic monitoring.

Dates	Hours Effort	Odontocete Species Seen[1]	Species Tagged (number tagged)	Odontocete Species Detected on M3R
25-30 Jun 2008	53.8	*Pe, Sb, Gm, Sl*	*Gm* (1), *Pe* (3)	N/A
16-20 Feb 2011	33.9	*Tt, Sb, Gm, Sl*	*Gm* (3)	N/A
20 Jul-8 Aug 2011	118.8	*Tt, Sb, Sl, Sa, Oo*	*Tt* (1), *Sb* (3)	*Tt, Sb, Sl*
10-19 Jan 2012	42.2	*Tt, Sb, Gm, Sl, Md*	*Sb* (1), *Gm* (2)	*Tt, Sb, Gm, Sl, Md*
12 Jun-2 Jul 2012	115.7	*Tt, Sb, Gm, Sl, Sa, Pc*	*Tt* (2), *Sb* (3), *Pc* (3)	*Tt, Sb, Gm, Pc*
2-9 Feb 2013	55.9	*Tt, Sb, Sl, Gm*	*Tt* (3), *Sb* (1), *Gm* (2)[2]	*Tt, Sb, Sl, Md, Pm*
Total	420.3		*Gm* (8)[2], *Pe* (3), *Tt* (6), *Sb* (8), *Pc* (3)	

[1]Species codes: *Tt = Tursiops truncatus, Sb = Steno bredanensis, Gm = Globicephala macrorhynchus, Pe = Peponocephala electra, Sl = Stenella longirostris, Sa = Stenella attenuata, Oo = Orcinus orca, Pc = Pseudorca crassidens, Pm = Physeter macrocephalus, Md = Mesoplodon densirostris*.
[2]One tag did not transmit, thus data available from seven pilot whale tags deployed off Kaua'i.
M3R = Marine Mammal Monitoring on Navy Ranges

Table 2. PMRF undersea range characteristics.

Range Area Name	Depth Range (m)	Hydrophone Numbers (string names)	Hydrophone Bandwidth
BARSTUR	~1,000-2,000m	2-42 (1-5) 1,10,21,24,37,41	8-40 kHz 50 Hz-40 kHz
BSURE Legacy	~2,000-4,000m	43-60 (A,B)	50 Hz-18 kHz
SWTR	~100-1,000m	61-158 (C-H)	5-40 kHz
BSURE Refurbish	~2,000-4,000m	179-219 (I-L)	50 Hz-45 kHz

kHz = kilohertz; m = meters; ~ = approximately

Table 3. Observations of acoustic features used for species identification and differentiation from passive acoustic monitoring during previous M3R field efforts.

Species[1]	# Visual Verifications	Whistle Features	Click Features	Distinctive Spectrogram Features	Acoustically Similar Species
Sb	26	8-12 kHz, short sweeps centered at ~10 kHz	12-44 kHz with most energy 16-44 kHz	Short narrowband whistles centered at 10 kHz, lots of 12-44 kHz clicks	*Pc* (whistles)
Sl	5	8-16 kHz, highly variable	8-48 kHz, distinct presence of 40-48 kHz click energy, single animal similar to *Zc*	HF click energy from 40-48 kHz. Loses LF click energy first. Long ICI for single species.	*Md*, *Zc* (clicks) *Tt* (whistles)
Tt	13	primarily 8-24 kHz, highly variable, lots of loopy curves	16-48 kHz, short ICI	Density of clicks and whistles. Very wideband, long duration loopy whistles.	
Gm	2	Combination of short 6-10 kHz upsweeps with long 10-24 kHz upsweeps	12-44 kHz, repetitive, slowly changing ICI	Very wide band but short duration whistles. Often single up or down sweeps.	Tt
Pc	3	5-8 kHz upsweeps, loopy whistles 8-12 kHz	8-48 kHz, most energy 8-32 kHz, continual presence of energy to 8 kHz	Click energy at 8 kHz, extending upwards to 32-40 kHz.	*Sb* (whistles), need to pay close attention to clicks to differentiate
Md	1	n/a	24-48 kHz, 0.33 s ICI	Consistent ICI and click frequency content.	

[1]See footnote to Table 1.

ICI = inter-click interval kHz = kilohertz; n/a = not applicable; ~ = approximately

Table 4. July/August 2013 small-boat effort summary.

Date	Total km	Total Hours on Effort	Number of Sightings Total	Number Detected Acoustically by M3R	Depart Time HST	Return Time HST	Total km Beaufort 1	Total km Beaufort 2	Total km Beaufort 3	Total km Beaufort 4	Total km Beaufort 5
26 Jul 2013	97.6	5.8	5	1	6:02	11:46	6.3	56.6	34.7	0	0
27 Jul 2013	102.0	5.5	4	2	5:55	11:21	0	53.4	48.6	0	0
28 Jul 2013	119.7	6.4	1	1	5:49	12:15	0	89.3	25.4	5.0	0
29 Jul 2013	91.1	4.8	3	N/A	6:06	10:49	9.7	33.1	48.3	0	0
30 Jul 2013	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
31 Jul 2013	105.1	5.6	4	1	5:55	11:27	0	53.7	36.1	11.3	0.3
01 Aug 2013	97.6	5.1	1	N/A	6:05	11:10	0	64.8	21.9	8.6	0.1
02 Aug 2013	58.4	3.4	0	N/A	6:03	9:22	0	18.4	31.1	8.9	0
Total	671.5	36.6	18	5			16.0	369.3	246.1	33.8	0.4

HST = Hawai‘i Standard Time; km = kilometers; M3R = Marine Mammal Monitoring on Navy Ranges; N/A = not applicable; # = number

Table 5. July/August 2013 M3R effort summary.

Date	Range Availability for Small Boat Operations		PAM Effort (HST)		Recordings
	Area	Time	Start	Stop	
26 Jul 2013	Unlimited	Unlimited	6:30	11:20	Yes
27 Jul 2013	Unlimited	Unlimited	6:30	10:40	Yes
28 Jul 2013	Unlimited	Unlimited	6:15	11:56	Yes
29 Jul 2013	Closed	Closed	6:15	9:00	No
30 Jul 2013	Tropical storm Flossie				N/A
31 Jul 2013	BARSTUR closed	Closed	6:15	11:20	No
1 Aug 2013	BARSTUR closed	Closed	6:15	12:00	Yes
2 Aug 2013	Closed	Closed	6:15	11:00	No

BARSTUR = Barking Sands Tactical Underwater Range; HST = Hawai‘i Standard Time; N/A = not applicable

Table 6. Odontocete sightings on or around PMRF 26 July – 02 August 2013, with and without concurrent acoustic detections.

Date	Time (HST) of Visual Sighting	Species[1]	Group Size	Satellite Tag	Distance from PAM to visual ID position (km)	PAM Position		Visual ID Position	
						Latitude °N	Longitude °W	Latitude °N	Longitude °W
26 Jul 2013	7:16	*Pc*[2]	12	Yes	2.10	22.0526	159.8845	22.05658	159.86713
26 Jul 2013	9:19	*Tt*	3	No	ND	N/A	N/A	22.13605	159.82166
26 Jul 2013	9:44	*Tt*	2	No	ND	N/A	N/A	22.14486	159.80301
26 Jul 2013	10:19	*Sl*	90	No	Off range	N/A	N/A	22.10687	159.74536
26 Jul 2013	11:29	*Sl*	26	No	Off range	N/A	N/A	21.96469	159.73434
27 Jul 2013	7:33	*Sb*[2]	4	No	0.48	22.0966	159.8690	22.09778	159.87350
27 Jul 2013	8:05	*Sb*	2	No	0.64	22.0711	159.8656	22.07442	159.87132
27 Jul 2013	9:29	*Tt*[2]	2	No	0.25	22.0956	159.8684	22.09976	159.86876
27 Jul 2013	10:39	*Sl*	55	No	Off range	N/A	N/A	21.99937	159.78490
28 Jul 2013	7:45	*Tt*	12	No	1.25	22.1266	159.8447	22.12045	159.83485
29 Jul 2013	7:30	*Sb*	20	Yes	Off range	N/A	N/A	21.84923	159.96797
29 Jul 2013	8:02	*Sb*	16	No	Off range	N/A	N/A	21.83685	159.95795
29 Jul 2013	9:02	*Sb*	1	No	Off range	N/A	N/A	21.88002	159.96178
31 Jul 2013	6:45	*Sb*	2	No	Off range	N/A	N/A	21.98669	159.85937
31 Jul 2013	7:05	*Tt*[2]	12	No	1.25	22.1266	159.8447	21.98724	159.86583
31 Jul 2013	7:23	*Sb*	4	Yes	Off range	N/A	N/A	21.97093	159.92718
31 Jul 2013	10:08	*Sb*[2]	20	No	2.44	22.0127	159.8154	22.00813	159.81513
01 Aug 2013	6:58	*Tt*	16	No	Off range	N/A	N/A	22.00014	159.84423

[1]See footnote to Table 1; [2]sighting resulted from being directed to location of PAM detection

HST = Hawai‘i Standard Time; ID = identification; km = kilometer; N/A = not applicable; ND = in the range but Not Detected by PAM; PAM = passive acoustic monitoring; °N = degrees North; °W = degrees West

Table 7. PAM observations from the M3R system with species classification confidence indicated as High, Medium or Low.

Species[1]	26 July	27 July	28 July	29 July	30 July	31 July	01 Aug	02 Aug
Gm	-	-	Low	-	-	-	-	-
Md	High	High	High	-	-	Low	High	High
Pc	High	-	-	-	-	-	High	-
Pm	Low	Low	High	-	-	-	-	-
Sb	Medium	Medium	High	-	-	High	High	High
Sl	-	Low	-	-	-	-	-	-
Tt	Low	Low	Medium	-	-	Low	-	-
Zc	-	-	High	-	-	-	-	-

[1]See footnote to Table 1. *Zc* = *Ziphius cavirostris*

Table 8. Details on satellite tags deployed during 26 July – 02 August 2013 field effort.

Species[1]	Tag ID	Individual ID	Date Tagged	Sighting #	Duration of Signal Contact (days)	Lat (°N)	Long (°W)	Tag Type	Sex
Pc	PcTag037	HIPc523	26 Jul 2013	1	21.13	22.07	159.87	Mk10-A	Male
Sb	SbTag009	HISb0424	29 Jul 2013	1	9.92	21.85	159.96	Mk10-A	Unknown
Sb	SbTag010	HISb0939	31 Jul 2013	3	13.41	21.97	159.93	Mk10-A	Unknown

[1]See footnote to Table 1.

°N = degrees North; °W = degrees West; # = number

Table 9. Details on previous sighting history of individuals satellite tagged in July 2013.

Individual ID	Date First Seen	# Times Seen Previously	# Years Seen Previously	Islands Seen Previously
HIPc523	30 Apr 2013	2	1	O‘ahu
HISb0424	4 Nov 2005	1	1	Kaua‘i
HISb0939	31 Jul 2013	0	0	N/A

ID = identification; # = number

Table 10. Information from GIS analysis of satellite tag location data from July/August 2013 field effort.

Individual ID	# Locations	# Periods Inside PMRF Boundaries	% Time Inside PMRF Boundaries	Total Minimum Distance Moved (km)	Median / Maximum Distance from Deployment Location (km)	Median / Maximum Depth (m)	Median / Maximum Distance from Shore (km)
HIPc523	213	17	24.0	2,352.5	27.0/66.6	710/3161	8.7/28.8
HISb0424	124	11	34.0	623.3	25.5/57.6	1,215/4,089	11.5/27.9
HISb0939	179	11	46.7	770.9	12.8/41.5	1,047/2,067	12.3/20.4

ID = identification; km = kilometers; m = meters; # = number; % = percent

Table 11. Dive data information from satellite tags deployed during July/August 2013 field effort.

Individual ID	# Hours Data ARGOS Only	# Hours Data Combined ARGOS/ Land Receiver	# Dives ≥ 30 m	Median Dive Depth (m) for Dives ≥ 30 m	Maximum Dive Depth (m)	Median Dive Duration[1] (min)	Maximum Dive Duration[1] (min)
HIPc523	226.6	226.6	114	137.5	927.5	3.92	15.23
HISb0424	205.0	205.0	309	51.5	287.5	2.57	6.33
HISb0939	179.0	180.4	186	60.4	227.5	3.10	5.87

[1]Duration of dives underestimated as time spent in top 3 m not included. Typical rates of ascent/descent are in the 1-2 m/second range, so durations likely only underestimated by 3-6 seconds.

m = meters; min = minutes; # = number; ≥ = greater than or equal to