APPENDIX B

(INCLUDED AS APPENDIX B WITHIN: FINAL 2013 COMPREHENSIVE EXERCISE AND MARINE SPECIES MONITORING REPORT FOR THE U.S. NAVY'S HAWAII RANGE COMPLEX)

June 11, 2013

Aerial Survey Monitoring for Marine Mammals and Sea Turtles in the Hawaii Range Complex in Conjunction with U.S. Navy Training Events

Summary of Focal Follow Analysis for 2008-2012 SCC Events: *Preliminary Report*

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Photo credit: Humpback whales (*Megaptera novaeangliae*) in waters off western Kauai. Taken by Joseph Mobley under NOAA Permit No. 14451.

Executive Summary

As part of the requirements of the annual Letter of Authorization issued by the National Marine Fisheries Service, the United States (U.S.) Navy is required to monitor impacts of its training on marine species protected by the Endangered Species Act of 1973 and Marine Mammal Protection Act of 1972. The *Hawaii Range Complex Monitoring Plan* (Department of the Navy [DoN] 2008) was developed to outline specific programs of monitoring potential impacts on marine mammals (MM) and sea turtles (ST) during training events in that region and was organized around specific research questions (see below).

For the Hawaii Range Complex (HRC), the biannual Submarine Commanders Course (SCC) training event was identified as the optimum event for aerial monitoring during actual anti-submarine warfare (ASW) training. For this event, the primary concern vis-à-vis protected species impacts is the use of mid-frequency active sonar (MFAS).

For an SCC training event, aerial monitoring has involved flying a twin-engine high-wing aircraft at 244 to 305 meters (m) (800 to 1,000 feet [ft]) in elliptical orbits in front of a guided missile destroyer (DDG) vessel involved in the ASW exercise. When MM/ST are sighted within approximately 5 kilometers (km) (2.7 nautical miles [nm]) of the ship, their initial locations are noted and the survey plane climbs to 457 m (1,500 ft), an altitude shown previously to reduce impacts of aircraft noise on humpback whale (*Megaptera novaeangliae*) behavior. This commences the focal follow protocol of focusing on the behavior of an individual or group of MM (Note: ST were not considered for focal follows). The focal-follow session is documented in each case using a high-definition, hand-held video camera with audio inputted from the intercom system of the plane. The goal is then to circle the focal group for as long as possible, documenting each behavior (e.g., blow, breach, fluke-up dive, etc.). Videos are later transcribed with time stamps for each event using a behavioral ethogram (**Appendix A**). Variables of interest are subsequently derived for subsequent analyses (e.g., respiration intervals, surface/dive durations and rates of travel, among others).

The purpose of this preliminary report is to describe the status of progress on data analysis and describe the relevant research questions that may be addressed. Of the five research questions identified in the U.S. Navy's *Hawaii Range Complex Monitoring Plan* (DoN 2008), two of them were judged to be addressable using the focal-follow approach:

1. *Question 1:* "Are marine mammals (and sea turtles) exposed to MFAS, especially at levels associated with adverse effects? If so, at what levels are they exposed?"
2. *Question 3:* "If marine mammals (and sea turtles) are exposed to MFAS, what are their behavioral responses to various received levels?"

During five SCC training events spanning the period from 19 August 2008 through 17 February 2012, 16 of 18 (89 percent) focal follows conducted involved humpback whales. The remaining two cases involved false killer whales and spinner dolphins (*Pseudorca crassidens* and *Stenella longirostris* respectively). Mean duration of all focal follow sessions was 15.0 minutes (min) (standard deviation [SD] = 13.5). The resultant videos were graded for quality according to predetermined criteria (**Table 1**). Ten of the 18 (56 percent) sessions were rated as "fair," "good," or "excellent" in quality, and five were rated as "good" or "excellent." Those rated as "good" or "excellent" were deemed to contain sufficient behavioral data to permit behavioral analysis. Mean duration was 24 min (SD = 18) for sessions rated good to excellent (range = 2 to 47 min). Video quality was judged to be more important for behavioral analysis, but is less important for calculating received levels (RLs) where all that is needed vis-à-vis the focal animals is their position.

For behavioral analyses, a key issue is that of statistical power. A sufficient sample size is needed to discern changes in such variables as respiration rate, dive/surface times and rates of travel. Proposed analytical approaches that will be assessed once additional MFAS sound and ship position data are obtained are:

1. Conduct preliminary power analyses on existing data to identify estimated minimum sample sizes needed to identify potential effects, and to identify the power of statistical tests.
2. Determine whether the ideal "A-B" analytical design can be applied to optimize statistical power. An A-B design is where a period of no exposure to MFAS is followed (or preceded) by a period of exposure. Such repeated measures designs are best suited for demonstrating behavioral change with minimum sample size.
3. Statistically compare the behavior of focal follows involving humpback whales described here with that of "typical" behavior in Hawaiian waters using unpublished University of Hawaii data. This may broaden the number of useful comparisons beyond those containing both baseline and exposure segments as required by the previous option.
4. Develop case studies for each focal follow. This would involve a detailed description of behavior relative to MFAS status. This approach can be implemented when sample sizes are too small to conduct valid statistics. It also provides additional insight into potential types of reactions (or lack thereof) that may occur.

Once the total number of sessions that involve actual MFAS exposures is ascertained (i.e., beyond 2011 and 2012 reported here), the feasibility of these approaches can be evaluated with one or more approaches performed as appropriate. In addition to quantitative comparisons, the qualitative descriptions, or case studies, of sessions involving the greatest richness of behavioral detail may prove informative as well.

To calculate RLs for MM/ST sightings exposed to MFAS, the following data were required: (a) onset and offset times of sonar transmissions; (b) source ship locations during transmissions; and (c) environmental data for sound velocity estimation (e.g., temperature, salinity). Ship position data have been received for the 2011 and 2012 SCC training events thus far. Positions of focal-follow sightings were determined by fitting polynomial regression lines to the paths of the orbiting survey plane. MFAS transmission times were determined using recordings from Pacific Missile Range Facility (PMRF) assets. Environmental data were obtained from archived electronic datasets obtained online.

Four of the five focal follows (80 percent; all involving humpback whales) conducted during 2011 and 2012, for which MFAS transmission times, ship and whale positions were available, were used to calculate RLs for exposed whales. The resultant calculations of RLs revealed estimates of maximum values ranging from 135 to 161 decibels referenced to one microPascal (dB re: 1 µPa) root mean square (rms).

Regarding possible behavioral analysis, since only one focal follow session recorded during 2011-2012 was of good or better quality, neither behavioral nor power analysis was feasible. As a result, the only available approach was that of case study. A case study of one particular focal session (16 February 2012), involving the juxtaposition of behavior with estimated RLs, is included in this report.

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Table of Contents

Appendices

Figures

Tables

List of Acronyms and Abbreviations

ASW	anti-submarine warfare
BARSTUR	Barking Sands Underwater Tactical Range
BSS	Beaufort sea state
BSURE	Barking Sands Underwater Range Expansion
COMPACFLT	Commander, U.S. Pacific Fleet
dB	decibel(s)
dB re: 1µPa	decibels referenced to one microPascal
DDG	guided missile destroyer
ft	foot/feet
GDEM-V	Generalized Digital Environmental Model
GPS	Global Positioning System
hr	hour(s)
HRC	Hawaii Range Complex
kHz	kilohertz
km	kilometer(s)
LF	low-frequency
m	meter(s)
MFAS	mid-frequency active sonar
min	minute(s)
MM	marine mammal(s)
nm	nautical mile(s)
NAVOCEANO	U.S. Naval Oceanographic Office
NOAA	National Oceanic and Atmospheric Administration
PMRF	Pacific Missile Range Facility
RL	received level
rms	root mean square
SCC	Submarine Commanders Course
SD	standard deviation
SPAWAR	Space and Naval Warfare Systems Center
ST	sea turtle(s)
U.S.	United States
WAAS	Wide Area Augmentation System

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Introduction

Aerial surveys to monitor for marine mammals (MM) and sea turtles (ST) were conducted in conjunction with six Commander, United States (U.S.) Pacific Fleet (COMPACFLT) training events in the Hawaii Range Complex (HRC) in the Main Hawaiian Islands from 19 August 2008 through 17 February 2012 (HDR 2012). This report focuses on "ship-follow" aerial surveys that occurred annually over 3-4 day periods in February (except for a summer event in 2008) during Submarine Commanders Course (SCC) training events. During an SCC training event, the aircraft flies elliptical orbits in advance of a guided missile destroyer (DDG) conducting anti-submarine warfare (ASW) exercises involving the transmission of mid-frequency active sonar (MFAS). Location and timing of MFAS transmissions were unknown to the observers during the field survey effort. The goal was to first identify whale or dolphin groups near (within 5 kilometers [km] [2.7 nautical miles (nm)]) of the DDG, then to perform focal follows to monitor MM behavior for any changes using prescribed observation methods.

The purpose of this preliminary report is to present preliminary findings and summarize the current status of analysis of focal-follow data collected during SCC training events from 2008 through 2012. Results focusing on the two *Hawaii Range Complex Monitoring Plan* (DoN 2008) research questions judged to be addressable using the focal-follow approach:

1. Question 1: "Are marine mammals (and sea turtles) exposed to MFAS, especially at levels associated with adverse effects? If so, at what levels are they exposed?"
2. Question 3: "If marine mammals (and sea turtles) are exposed to MFAS, what are their behavioral responses to various received levels?"

Methods

SCC training events occurred on the Pacific Missile Range Facility (PMRF) Barking Sands Tactical Underwater Range (BARSTUR) and Barking Sands Underwater Range Extension (BSURE) between Kauai and Niihau in the HRC (**Figure 1**). Monitoring surveys were conducted over waters with bottom depths to 6,000 meters (m) (19,680 feet [ft]). The majority of survey efforts were conducted northwest of Kauai and concentrated in the PMRF hydrophone range. Beaufort sea state (BSS) ranged from 0 to 7 for these surveys (**Table 1**).

Survey methods used here departed from those of traditional line transect surveys, in that elliptical orbits were flown in advance of the DDG throughout its movements, rather than following pre-determined line transects. Thus far, the HRC is the only range complex utilizing this monitoring approach. Aerial survey methodology is discussed in **Section 2.1**, while behavioral sampling is detailed in **Section 2.2**.

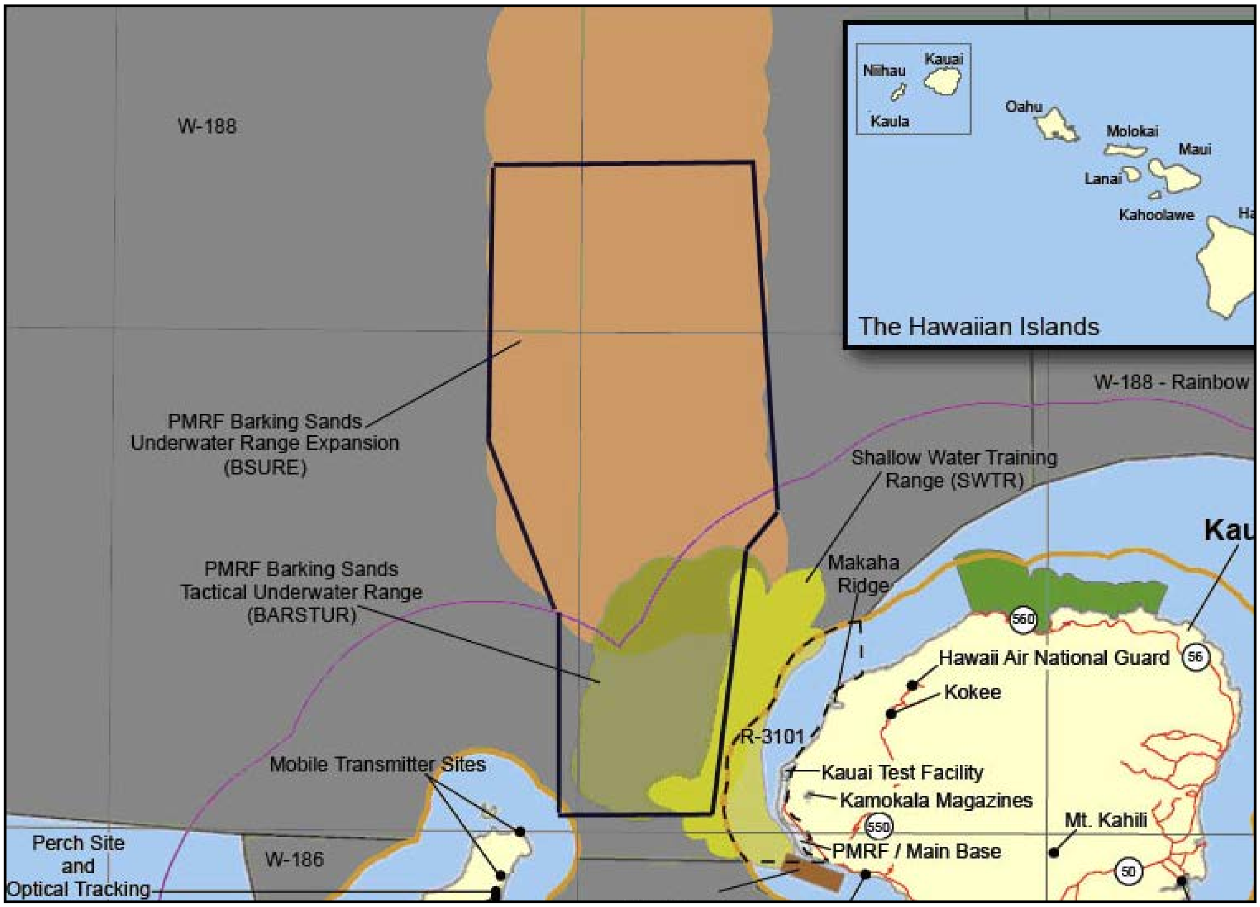

Figure 1. Location of the BSURE and BARSTUR ranges of the PMRF, including the area where SCC training events take place (black box).

Table 1. Summary of monitored SCC training events (2008-2012).

Survey Title	Source	Survey Month	Beaufort Sea State[1]		
			Mean	Max	Min
Monitoring during SCC 08	Smultea and Mobley 2009	Aug-08	4.9	7	0
Monitoring during SCC 09-1	Smultea et al. 2009	Feb-09	5.4	7	3
Monitoring during SCC	Mobley and Milette 2010	Feb-10	4.53	6	0
Monitoring during SCC 11-1 & USWEX	Mobley 2011	Feb-11	4.49	6	0
Monitoring during SCC 12	Mobley and Pacini 2012	Feb-12	4.54	6	0

Note: [1]Averaged from wheels up to wheels down for ship-follow days only;
Key: SCC = Submarine Commanders Course; USWEX = Undersea Warfare Exercise.

2.1 Aerial Monitoring

Overall, survey effort was typically divided into two parts (note: additional tasks [e.g., assisting tagging efforts, verifying passive acoustic detections, etc.] were sometimes added during different years):

1. Ship follows, during the SCC training event (3-4 days): This involved flying 4-6 km (2.2–3.2 nm) elliptical orbits in front of the DDG (**Figure 2**). The goal was to find target species in the vicinity of the DDG to observe and record their behavior using focal-follow methods (see **Section 2.2**).
2. Circumnavigation surveys, post-SCC training event (2 days): Following the SCC training event at varying intervals, the aircraft flew along the Kauai and Niihau coastlines looking for stranded or near-stranded MMs, as well as free-swimming MM/ST, along the shoreline.

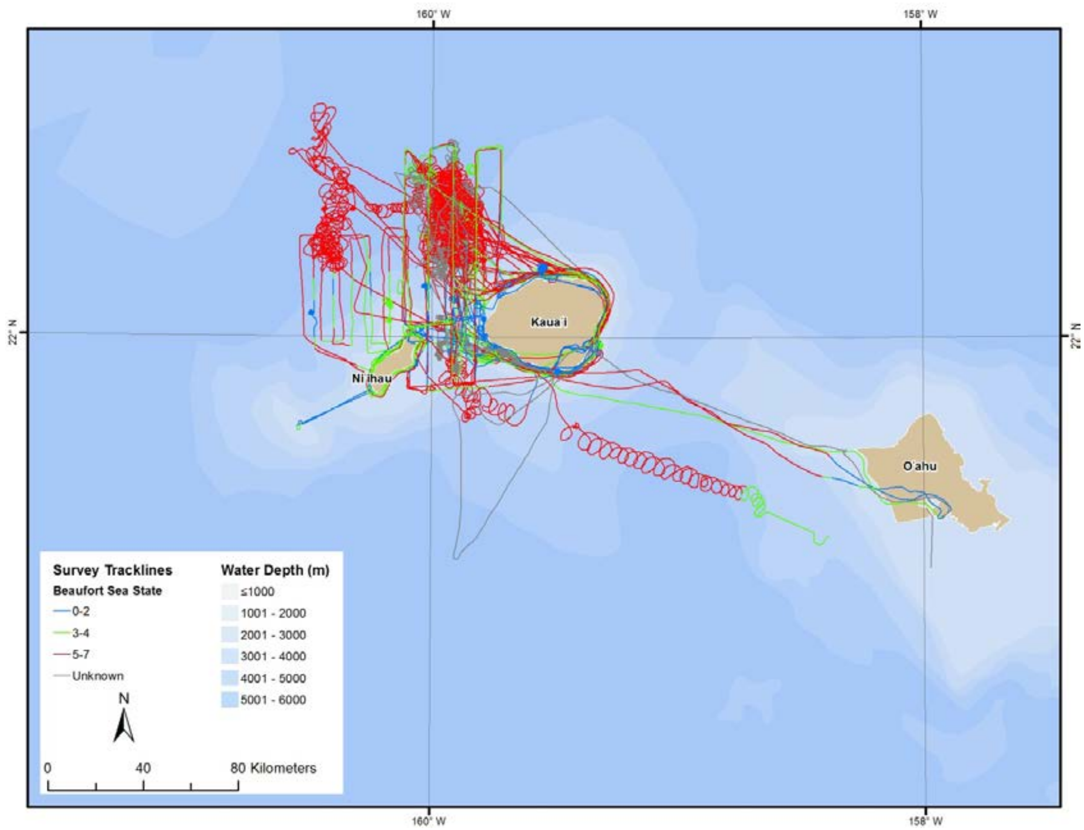

Figure 2. Combined vessel and aerial monitoring survey effort during SCC training events (2008-2012).

Surveys were conducted from a twin-engine high-wing aircraft (Partenavia P68 Observer or Aero Commander) during ship follows and from the same fixed-wing aircraft or a helicopter (e.g., Robinson R44) during shoreline surveys conducted at varying intervals following the event. All aircraft flew at 100 knots (185 km/hr) groundspeed and an altitude of approximately 244 to 305 m (800 to 1,000 ft) (unless the pilot was directed to fly at alternate altitudes by flight controllers for safety reasons; this occurred 1-5 times per flight day). Observations from the monitoring aircraft involved four or five personnel including a pilot, a co-pilot (2010–2012), two observers, and a data recorder/videographer. The survey crew and pilot(s) were not informed as to the status of MFAS transmissions, which minimized the potential for observational bias.

When MM/ST were first detected, the vertical angle to the sighting when abeam at 90 degrees to the trackline was recorded using hand-held Suunto clinometers (this was later converted to perpendicular distance from the aircraft). Animals were then typically followed by orbiting to identify species and, in the case of MMs, to characterize behavior and direction of travel. Photographs were taken opportunistically by the data recorder to assist in species identification using a Canon 5D digital camera with a Canon 100- to 400-millimeter telephoto lens with image stabilizer. BSS was recorded at the start of effort and when conditions changed (note: glare was not recorded during ship-follows since circling the DDG meant that glare changed too frequently to be recordable). Positional data via a Wide Area Augmentation System (WAAS)-enabled Global Positioning System (GPS) were automatically recorded every 3 seconds and manually when sightings occurred.

2.2 Behavioral Sampling

When sightings were observed close to the DDG (i.e., within 5 km or 2.7 nm) and were judged to be suitable (i.e., could be reliably tracked), focal follows were performed using standard behavioral sampling methodology (Altmann 1974; Mann 1999). The aircraft immediately ascended to 457 m (1,500 ft), an altitude shown to minimize reactivity of some baleen whale species to circling fixed-wing aircraft (Richardson et al. 1985a,b, 1986, 1995; Smultea et al. 1995; Würsig et al. 1985, 1989). The sighting was then orbited and behavior was documented with video for as long as possible. A high-definition Canon Vixia HF10 camcorder with 12-power optical zoom and built-in image stabilization was used to video focal follows. The intercom system of the aircraft inputted to the audio port of the digital camcorder so that all behavioral observations could be recorded with minimal ambient noise. Time stamps on the Canon camcorder were synchronized with those from the Garmin GPS receiver before each daily flight. Animals were followed for as long as successive surfacings were visible. Focal sessions were terminated when animals were not resighted for 10 minutes (min), whereupon the survey aircraft returned to its station circling in front of the DDG.

Digital videos of focal follows were transcribed and rated for quality based on predetermined criteria (**Table 1**). Only those rated "good" or "excellent" were considered eligible for behavioral analysis. Humpback whales were chosen as the primary species for behavioral analysis since only one focal follow was recorded for each of the other two species (spinner dolphins and false killer whales) (Table 3).,

2.3 Received Levels

Thus far, the combination of recordings of MFAS from PMRF hydrophones plus ship positions has only been made available for 2011 and 2012. Based on the MFAS transmission data, it was determined that four of the six focal follows (67 percent) conducted during 2011-2012 involved exposures to MFAS. Received levels (RLs) were estimated only for these four focal follows for the sake of this preliminary report. Calculating the RLs of MFAS requires knowing the focal group's and the ship's positions, times of transmissions, the source level of the signal, as well as environmental parameters (e.g., temperature and salinity) affecting sound velocity. DDG positions were provided from PMRF data products provided in support of the SCC event (**Appendix B**). For the positions of MM focal groups, initial positions were obtained using sighting angles as described previously. Once the plane commenced orbiting, however, angles could not be obtained unless the aircraft was leveled. Thus, positions were estimated by computing the centroid of the aircraft orbits by extracting GPS positions every 3 min (the approximate time to complete one orbit). The statistical approach of weighted moving averages with a polynomial fit was then used to estimate the position of the focal group. The resultant line (**Figure 3 a-c**) provides the best estimate of the focal group's position at any given time.

Figure 3a) 18 February 2011

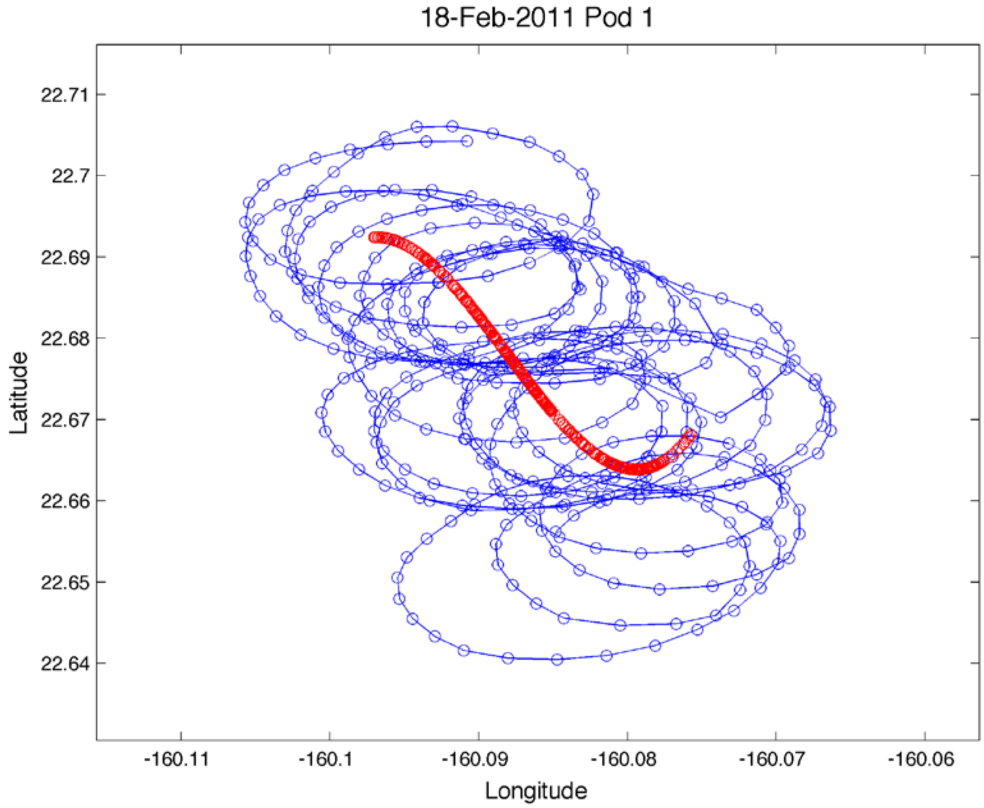

Figure 3b) 16 February 2012, Pod 1

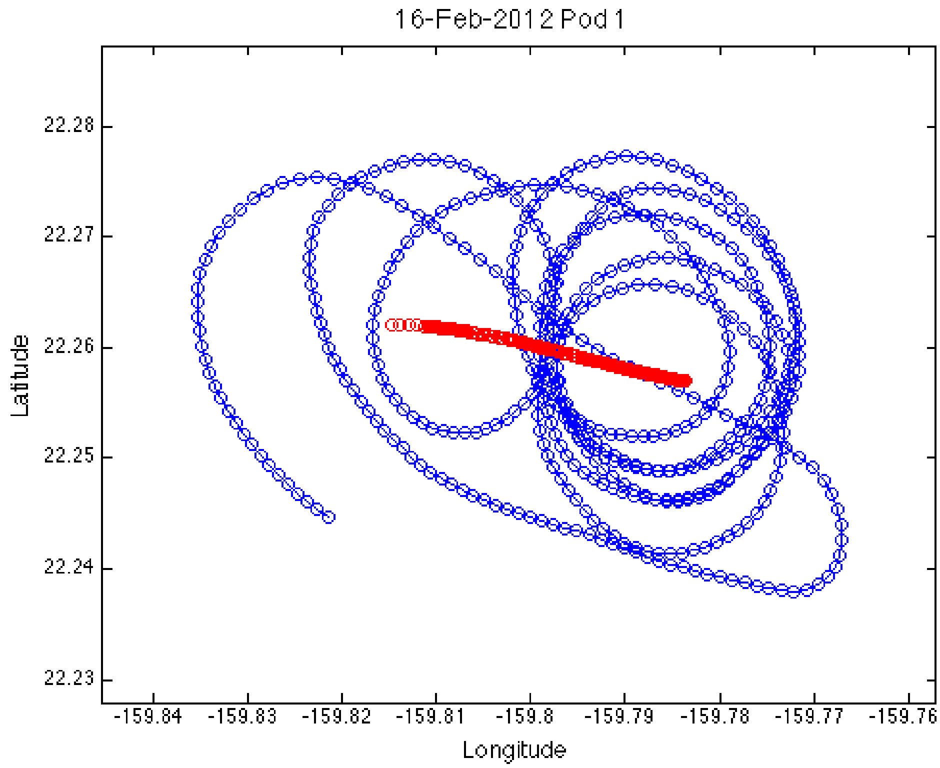

Figure 3c) 17 February 2012

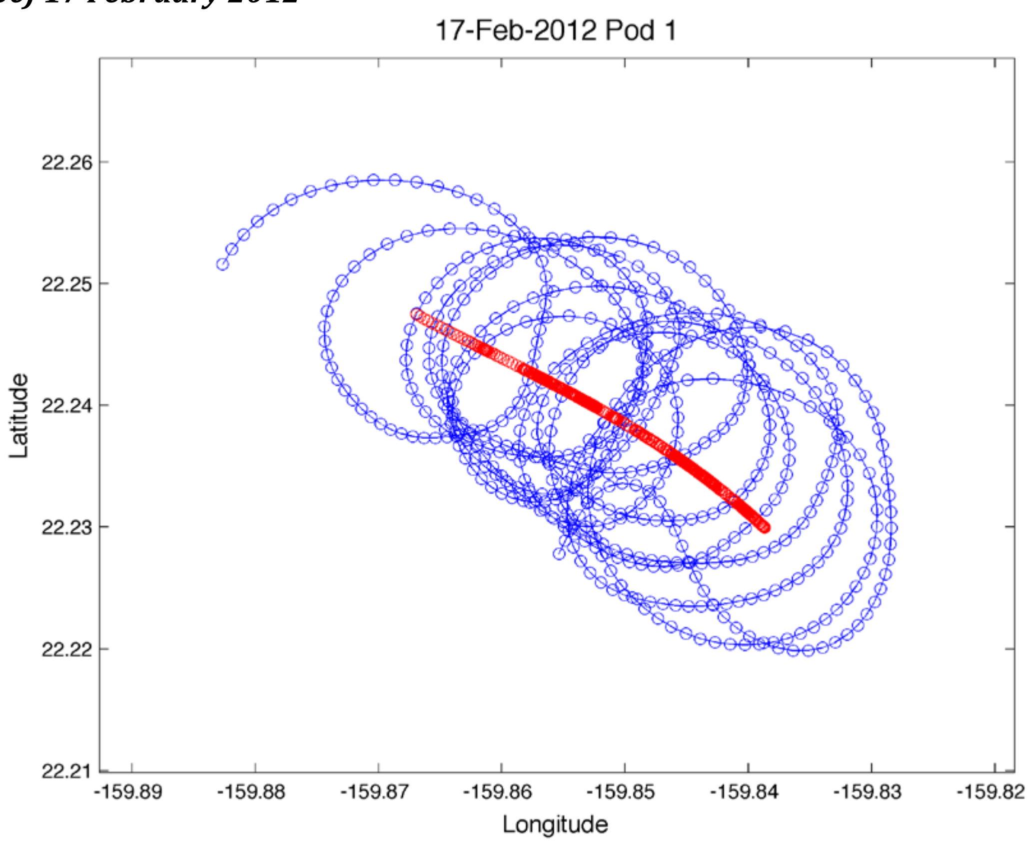

Figure 3 a-c. Estimated positions of humpback whale groups during selected focal-follow sessions (i.e., focal follows for which ship location and sound transmission times were available): a) #13 (18 February 2011); b) #15 (16 February 2012, Pod 1); and c) #17 (18 February 2012) showing position of plane (blue circles) and fitted polynomial lines (red).

The ship's sonar source level was assumed to be 235 decibels referenced to 1 microPascal (dB re: 1µPa) root mean square (rms) as published for the AN/SQS-53C sonar (with center frequencies of 2.6 and 3.3 kilohertz [kHz]) in conjunction with the 2000 Bahamas stranding event (Evans and England 2001). Sound velocities were obtained from the Generalized Digital Environmental Model (GDEM-V, Version 2.5, NAVOCEANO 2000). Bathymetry was extracted from the ETOPO2 dataset (NOAA 2006). This dataset includes the Digital Bathymetric Data Base 5-min from the U.S. Naval Oceanographic Office (NAVOCEANO). To calculate surface loss, the Beckmann-Spizzichino surface loss function was used (Hodges 2011). The wind speed input to this function was derived from the BSS descriptions from the observers during each focal follow. The transmission loss due to ocean bottom characteristics in the present study was determined by empirical analysis of minke whale (*Balaenoptera acutorostrata*) recordings, at a frequency near that of the active sonar sources as recorded by Steve Martin of Space and Naval Warfare Systems Center (SPAWAR), San Diego. Steve Martin reported that a 7 decibel (dB) loss per bounce was the best estimate. Therefore, Curve 1 from the high-frequency bottom loss model from the Oceanographic and Atmospheric Master Library of the NAVOCEANO was selected for the bottom loss function. The BELLHOP propagation model (Porter 2005) was used to calculate transmission loss.

Position data for the DDG were obtained from PMRF data products. A single, MFAS-transmitting ship position (latitude/longitude) was provided for each focal follow. If there was more than one MFAS transmission (i.e., more than a 1-2 second "ping"), the closest position was specified. Therefore, in all cases, the ship was modeled to open in range relative to the whale's position (i.e., increasing distance from initial position). In one case for the focal follows discussed here, the whale was sighted off the starboard beam of the MFAS-transmitting vessel. In this case, a nominal beam pattern was specified. For the three remaining cases, the relative position of the MM put it in or near the baffles (i.e., area directly behind the ship). For these cases, an omnidirectional source was assumed.

The focal-group position was modeled to vary between 5 and 20 m (16 and 66 ft) of depth during simulations (i.e., models). Simulations were run for 10 min, to allow some variability in the results to reflect the uncertainty in absolute positions and depths of the whales. For this reason, median RL estimates are reported. However, if there was only a single MFAS transmission from the ship, simulation duration was reduced to 1 min.

Results and Discussion

Eighteen focal follows were conducted during five SCC training events from 2008 to 2012 (**Table 2**) for a total of 4.5 hr of video recording (**Table 3**). Seventeen of the 18 (94 percent) focal follows occurred during February SCC training events (4 of the 5 aerial-monitored SCC events occurred in February). Sixteen of the 18 (89 percent) sessions involved humpback whales (*Megaptera novaeangliae*); the remaining two were of spinner dolphins (*Stenella longirostris*) and false killer whales (*Pseudorca crassidens*). Humpback whales are primarily seen November through April in the HRC, when the species seasonally uses Hawaiian waters as a major overwintering and breeding ground (Mobley 2004). Spinner dolphins were the subjects of the only focal follow that occurred during August 2008. Humpback whale focal groups primarily consisted of one to two individuals (**Table 4**), which is representative of typical group sizes for the species in Hawaiian waters (Mobley et al. 1999).

BSS conditions were generally good during the 2008-2012 focal follows, considering the exposure of the offshore study area to prevailing trade winds. A BSS of 4 or less was recorded during 63 percent of total focal-follow time (**Figure 4**). Ten of the 18 (56 percent) focal follows were judged in quality to be "fair" or better ($\bar{X}$ = 22 min; SD = 14.5; range: 2-47 min) and four focal follows (25 percent—including one rated "fair" to "good") as "good" or "excellent" (**Figure 5**) ($\bar{X}$ = 24 min; SD = 18; range: 2-47 min).

BSS and resultant video quality are important for behavioral analyses, where resolving visual detail is important. It is less important when calculating RLs since for the latter, all one needs to know with regards to the focal animals is their position. RLs were estimated for 4 of the 18 (22 percent) focal follows, for which MFAS transmission times and positions of marine mammals and ships were available (see "*Research Question 1*" below). These videos were recorded during BSS 3-6 and were rated as "poor" to "good."

Table 2. Criteria used for judging video quality for focal follows.

Video Quality	Utility Definitions
Poor	Behavior and audio indiscernible. For example, animal never seen in video or behavior cannot be determined because animal too far away, video shaky/out of focus/moving too much, BSS too rough (i.e., cannot determine dispersal distance between individuals, blows and (for whales), individual surface-active behaviors, and/or orientation of animal), and/or audio cannot be understood due to interference/static noise or was not recorded.
Fair	Some behavior and most audio discernible. For example, animal seen in video and behavior, orientation, and dispersal can be determined but in view on video for only a short period of time (<30 seconds per video clip). Most audio can be understood.
Good	Most behavior and audio discernible. Most periods animal at or near surface are captured on video and most audio is understandable. Animal seen in video for a longer length of time (e.g., >30 seconds per video clip) and can determine behavior. Nearly all individual behavioral events, blows (for whales), behavior state, orientation, and dispersal distances can be determined via combined video and/or audio.
Excellent	Behavior easily discernible all times animal in view below/above surface and audio discernible (e.g., animal[s] seen throughout entire video when visible at or below the water surface and all audio can be understood). All behavioral events and blows (for whales), behavior state, heading, and dispersal distance can be determined. Video footage is relatively steady and focused. Usually occurs when BSS is less than 3.

Table 3. Summary of focal follows recorded during SCC events in the HRC off Kauai 2008-2012.

Date	Session#	Species	Group Size (Best Estimate)	BSS[1] During Focal Follow	Session Duration (min)	Video Quality[2]
08/19/2008	1	Spinner dolphin (*Stenella longirostris*)	80	5	5.3	Fair
02/16/2009	2	Humpback whale (*Megaptera novaeangliae*)	1	5	2	Poor
02/17/2009	3	Humpback whale	2	3	10.5	Poor
02/18/2009	4	Humpback whale	1-2	3	23.3	Fair-Good
02/19/2009	5	Humpback whale	1	6	2	Poor
	6	Humpback whale	1	6	3.5	Poor
	7	Humpback whale	2	6	5.5	Poor
02/16/2010	8	Humpback whale	1	5	6.3	Poor
	9	Humpback whale	2	4	7.5	Fair

Date	Session#	Species	Group Size (Best Estimate)	BSS[1] During Focal Follow	Session Duration (min)	Video Quality[2]
02/18/2010	10	Humpback whale	8	4	12	Excellen t
02/19/2010	11	Humpback whale	3	4	47	Good
02/20/2010	12	False killer whale (*Pseudorca crassidens*)	12	4	2	Good
02/18/2011	13[4]	Humpback whale	2	3-4	37.3	Fair
02/15/2012	14	Humpback whale	2	2	18.5	Fair
02/16/2012	15[4]	Humpback whale	2	6	35	Good
	16[4]	Humpback whale	1	6	9.5	Poor[3]
02/17/2012	17[4]	Humpback whale	3	6	30.5	Fair
	18	Humpback whale	2	6	13	Poor

Notes: [1] Beaufort sea state; [2] Descriptions are found in **Table 2**; [3]Focal follow attempted, but group not resighted;
[4]Received levels estimated for these groups.

Table 4. Summary of focal groups (2008-2012): Species and group composition.

Species	No. Groups	Group Size (Best Estimate)	No. Calves
Humpback whale (*Megaptera novaeangliae*)	6*	1	0
	8	2	0
	1	3	0
	1	8	0
Spinner dolphin (*Stenella longirostris*)	1	80	0
False killer whale (*Pseudorca crassidens*)	1	12	0

Note: *includes one that became a dyad.

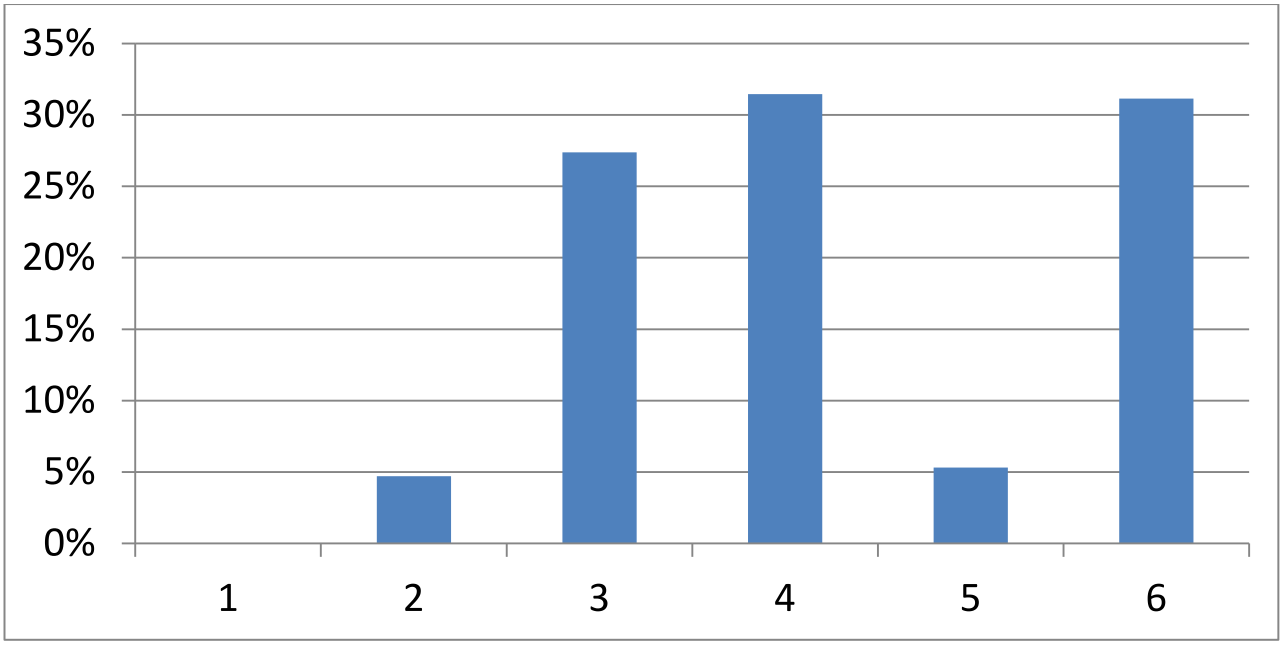

Figure 4. BSS during 18 focal follows for SCC training events in the HRC from 2008 to 2012.

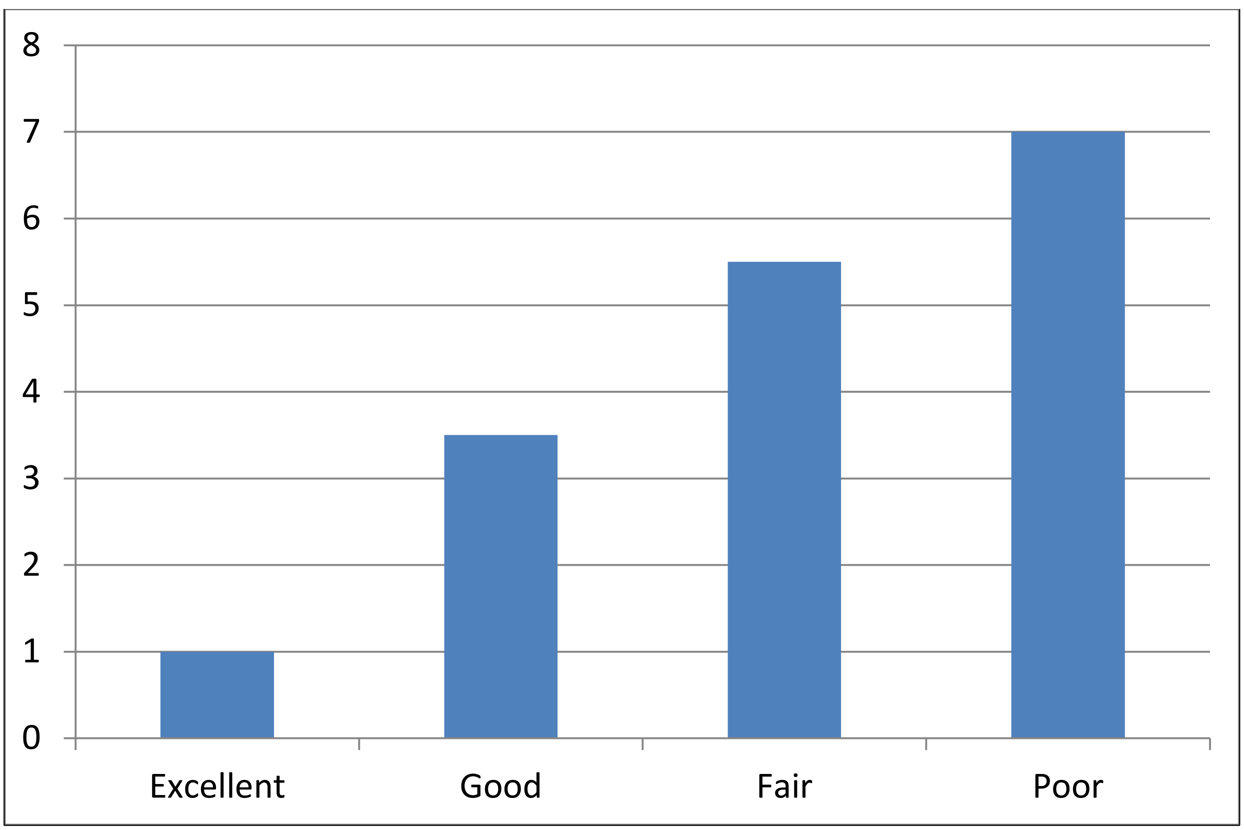

Figure 5. Video quality for 18 focal follows during five SCC events in the HRC from 2008 to 2012. Criteria for the video quality categories are presented in Table 1.

The remaining discussion focuses on the status of results most relevant to the focal-follow approach with respect to the two research questions of the *Hawaii Range Complex Monitoring Plan* (DoN 2008):

Research Question #1: "Are marine mammals (and sea turtles) exposed to MFAS…and if so, at what levels?"

Based on ship position and MFAS transmission time data obtained for the 2011 and 2012 SCC training events, four focal follows involving seven humpback whales (Session # 13, 15, 16, and 17) overlapped with MFAS transmissions, enabling calculation of RLs (**Table 5**). Estimated maximum RLs at focal group locations ranged from 135 to 161 dB re: 1 µPa. Two sessions (13 and 17) involved exposure to a single MFAS transmission and two (Nos. 15 and 16) involved exposure to multiple sonar transmissions. Focal whale positions were estimated using polynomial functions fitted to the path of the orbiting survey plane, as described previously. An exception was Session # 16, where the whales involved were not resighted. In the latter case, the initial sighting data (GPS location plus sighting angle) were used to estimate the pod's position.

Table 5. Summary of RL calculation results for the four focal-follow events for humpback whales conducted during MFAS transmissions during 2011-2012.

Date	Session#	Median RL[1] (dB re: 1 µPa)[2]	Maximum RL (dB re: 1 µPa)	Median Absolute Deviation	Comments
02/18/2011	13	134	137	2.4	1 MFAS[3] "ping" transmission
02/16/2012	15	142.5	148	2.5	Multiple MFAS transmissions
02/16/2012	16	117.5	135	7.0	Group position estimated from initial sighting; multiple MFAS transmissions
02/17/2012	17	156	161	2.7	1 MFAS "ping" transmission

Notes: [1]RL = received level; [2](dB re: 1 µPa) = decibels referenced to one microPascal; [3]MFAS = mid-frequency active sonar.

In a somewhat parallel effort related to this research question, Martin and Manzano-Roth (2012) estimated RLs for 16 cetacean sightings recorded during the February 2011 SCC training event: 12 sightings of confirmed humpback whales and 4 sightings of unidentified cetacean species. These included 10 sightings made by observers aboard U.S. Navy ships plus six sightings made during aerial surveys (note: the 10 sightings made from U.S. Navy ships were all unique groups except for one group that was listed twice to document MFAS exposure from two different ships). Of the six aerial sightings, two were sighted within 5 km (2.7 nm) of the DDG and focal follows were attempted; however, the animals were not resighted after the initial sighting was made; therefore they do not correspond to the focal follow reported in **Table 3** (Session # 13). The remaining four aerial sightings occurred during transits to and from the DDG and Lihue Airport (on the southeast coast of Kauai) at distances considerably greater than the 5-km (2.7 nm) distance used for the ship follow protocol. RLs of 136 dB to 196.9 dB re: 1µPa were estimated for the 16 sightings. While the PMRF data may provide accurate ship position data, the authors noted that one major concern was that the acoustic data were not as accurate; specifically, "the recorded acoustic data are utilized to determine when MFAS transmissions occurred, as this level of detail is not present in the standard PMRF data products for the training event" (Martin and Manzano-Roth 2012). Therefore, recordings of MFAS transmissions from the PMRF hydrophone range would be important for any future estimation of RL.

Little is known about the effects of MFAS sound on baleen whales. Most of what is known about the effects of noise on whales has focused on low-frequency (LF) sound (e.g., Croll et al., 2001; Frankel & Clark, 2000).

Thus far, clear demonstrations of temporary or permanent threshold shifts at particular RLs have only been documented for captive toothed whales where laboratory experiments are possible. For example, Mooney et al. (2009) demonstrated temporary threshold shift using playbacks of recorded-MFAS signals with captive bottlenose dolphins (*Tursiops truncatus*) at RLs of 214 dB re: 1µPa. However, efforts to derive estimates of RLs required to induce similar hearing threshold shifts among baleen whales would have to overcome methodological challenges of achieving experimental control with free-swimming animals or would require a captive animal(s).

In summary, based on these results, marine mammals were exposed to MFAS in the instances described here at estimated RLs ranging from 135–161 dB re: 1 µPa. The biological significance of this, however, with respect to hearing threshold shifts and other potential impacts, cannot be determined as yet based on available evidence.

Research Question #3: "If marine mammals (and sea turtles) are exposed to MFAS, what are their behavioral responses to various received levels?"

The videos from all 18 focal follows were examined and transcribed using methods described previously (Smultea and Bacon 2011), based on a behavioral ethogram (**Appendix A**). Of the 10 videos rated as "fair" to "excellent," eight (80 percent) involved humpback whales and provided the majority of annotations in the transcribed behavior dataset. The resulting dataset will become the focus of future analyses involving the calculation of derived variables such as rate of travel, direction of travel (relative to DDG), behavior state transition, and respiration rate, surface and dive durations, as possible. The latter parameters have been indicative of the responses of Hawaiian humpback whales to LF sound (Frankel and Clark 1998, 2000) and vessel presence (Bauer and Herman 1986). Four possible analytical approaches are proposed:

1. Conduct preliminary power analyses on existing data to identify estimated minimum samples sizes needed to identify potential effects, and to identify the power of statistical tests.
2. Determine whether the ideal "A-B" analytical design can be applied to optimize statistical power. An A-B design is where a period of no exposure to MFAS is followed (or preceded) by a period of exposure. Such repeated measures designs are best suited for demonstrating behavioral change with minimum sample size (Kerlinger and Lee 2000). This approach was used successfully by Tyack et al. (2011) using playbacks of simulated MFAS in the Bahamas. They showed that individual beaked whales changed their vocal behavior and showed evidence of avoidance at received levels below 142 dB re: 1 µPa. As of the completion of this preliminary report, it is not known how many of the recorded focal follows meet this A-B pattern.

3. Statistically compare the behavior of focal whales described here with that of "typical" behavior in Hawaiian waters using archived data obtained during shore-based observations in 1983-1991 (Bauer, Frankel, Mobley, and Herman, 1983-1991, Kewalo Basin Marine Mammal Laboratory, and University of Hawaii data). This may broaden the number of useful comparisons beyond the A-B approach required by the previous option. Comparisons with the shore station data will be conducted when the total numbers of focal follows involving MFAS exposure are known (i.e., other than for 2011 and 2012), so that any differences in variables such as rate of travel, respiration rate, etc., become more interpretable.
4. Develop case studies for each focal follow. This would involve a detailed description of behavior relative to MFAS status (i.e., whether transmitting or not). This approach can be implemented when sample sizes are too small to conduct valid statistical tests. It also provides additional insight into potential types of reactions (or lack thereof) that may occur (see *Case Study* section below).

The challenge for these four options is the relatively small numbers of focal follows involved (n = 10 "fair" to "excellent" quality) and their relatively short durations (mean session length of 22 min [SD = 14.5] for "fair" to "excellent" quality). Thus, statistical test power may be insufficient to demonstrate statistically significant changes in behavior. Using case studies from focal-follow sessions with greater richness of detail could prove informative (see an example below). If obvious responses to MFAS occur, they may be evident using this qualitative approach, even if the quantitative results are not statistically significant due to small sample sizes.

Whereas the statistical analytical approach (e.g., A-B design) offers a macro view of potential responses to MFAS transmissions, the following case study approach offers a micro view that can help to identify the link between changes in the environment and corresponding changes in behavior. An example of the power of the case study approach can be seen in the description below that offers an expanded account of focal follow # 15 (Pod 1 seen on 16 February 2012).

Case Study (Focal-follow session # 15: 16 February, 2012 – Pod 1)

This focal follow was chosen as the subject of a case study for two reasons: a) based on PMRF hydrophone range monitoring data (S. Martin, SPAWAR, personal communication) in conjunction with DDG and whale locations, Pod 1 was exposed to 23 MFAS transmissions during a 20-min period largely overlapping with the 28-min period from first to last sighting; and b) Pod 1 spent the majority of time (approximately 60 percent) visible at the surface. Due to the whales' predominant surface travel, the decision was made to calculate RLs with whale positions modeled at 2, 4, 6, 8, and 10-m depth. The median RL values are shown in **Figure 6**.

Pod 1 of 16 February 2012, was first sighted at 8:39:33 based on the observation of a breaching adult humpback whale. At this time, the pod was at a distance of approximately 10.8 km (5.8 nm) from the DDG (extrapolated from position-time data). During the time of observation (i.e., from first to last sighting), both the DDG and Pod 1 were on closely corresponding northwest headings of 320 and 345 degrees true, respectively. This heading was maintained throughout the observation period. Due to the fact that the DDG was traveling faster than the pod, the distance between the two increased, with the DDG remaining ahead of Pod 1 throughout the period.

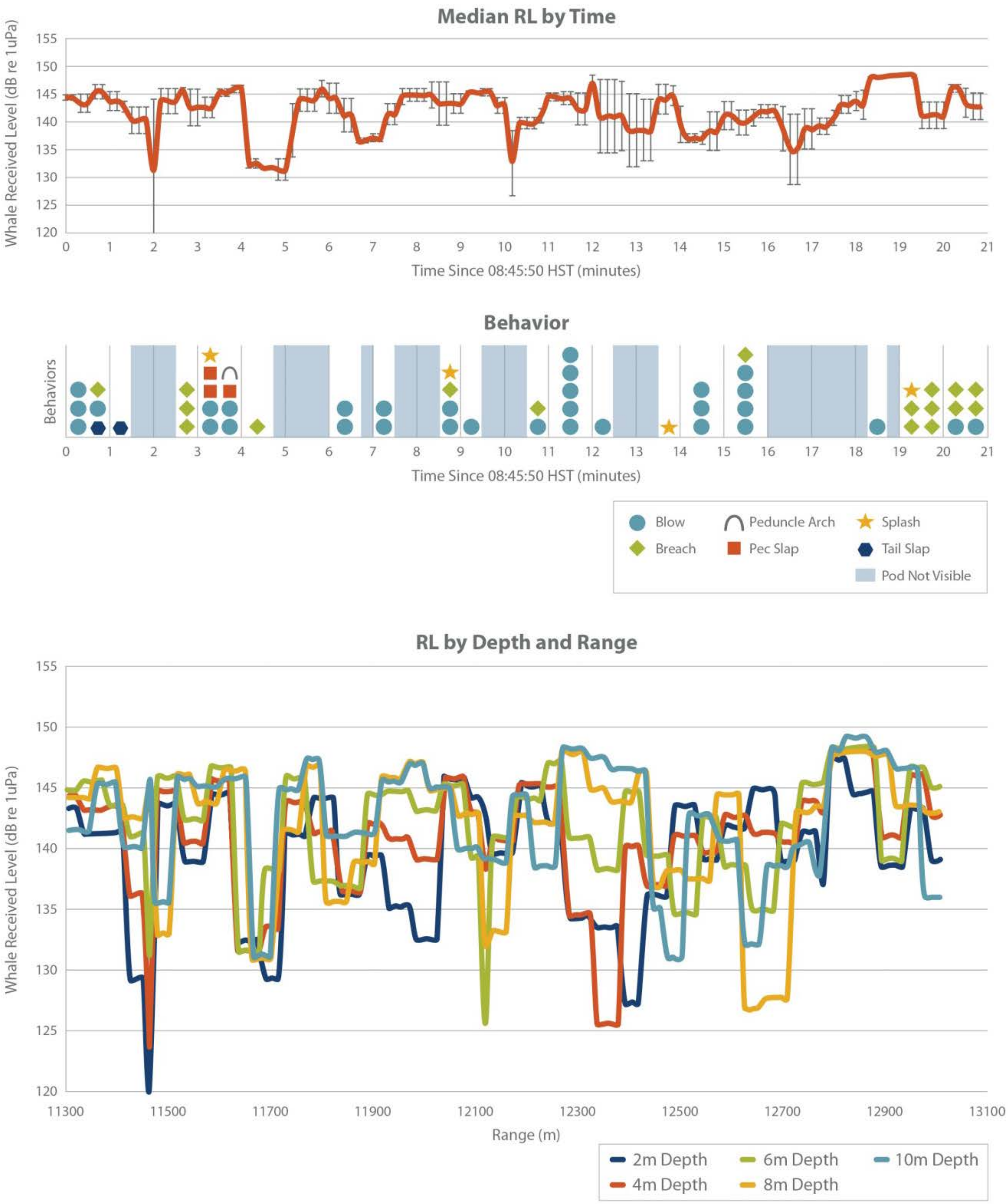

Figure 6. Whale behaviors (middle) correlated with MFAS RLs by time (top) and range from source (bottom).

Video recording commenced at 8:44:44 and an unidentified splash, presumably made by Pod 1, was recorded at 8:45:50. By this time, the pod composition was confirmed as two adult humpbacks. At 9:02:44, another whale was sighted "in the distance" and at 9:03:14, a whale was seen beneath the plane (not Pod 1), while the distant whale was sighted a second time. This is important contextual information since it implies that the behavior of Pod 1 may have been influenced by either the presence of the DDG, MFAS transmissions, or the presence of other whales in the vicinity.

During the 21-min period from first to last video-recorded behavior, Pod 1 produced a regularly-spaced series of behaviors including 32 blows, 17 breaches, three pectoral flipper slaps, two tail slaps, and a peduncle arch (**Figure 6**; see **Appendix A** for description of behaviors). There were several additional splashes without confirmed behaviors. During this time, the range of the pod from the DDG increased from approximately 11.3 to 13 km (6.1 to 7 nm), while estimated RLs decreased only slightly from a median estimate of 144.3 to 142.7 dB re: 1µPa. The low rate of transmission loss was due to the modeled presence of surface ducts in the upper 10 m (33 ft) of the water column.

Analysis of this case study reveals several noteworthy findings. First, Pod 1 persisted in its northwest heading moving towards the retreating DDG despite exposure to repeated MFAS transmissions throughout the period of observation (i.e., from first to last sighting). Past research on responses of baleen whales to LF sound showed avoidance in the form of course changes to be a fairly typical response (e.g., Richardson et al. 1985a, 1985b; Richardson et al. 1995), as well as changes in dive patterns and surface time (Frankel and Clark, 1998, 2000; Tyack et al. 2011). Regarding the latter point, Pod 1 remained visible at the surface throughout most of the 21-min focal follow (middle section, **Figure 6**). This is particularly remarkable given the presence of surface ducting that produced greater noise levels at the water's surface. In light of this, Pod 1 could have theoretically reduced exposure to higher-amplitude MFAS by simply traveling deeper underwater. Finally, the rate of behavior production remained relatively consistent throughout the observation period, with behaviors that are typically seen in the context of the social interactions during the winter breeding season. As noted above, it cannot be easily ascertained whether the behaviors observed were in response to the DDG, the MFAS transmissions or the presence of other whales nearby.

With this type of detailed case study approach, one is able to juxtapose changes in the acoustic environment (e.g., variations in RLs) with possible changes in the focal animals' behavior. Though one cannot necessarily draw generalizable conclusions from single cases, if other cases show similar responses with changes in acoustic levels, it begins to provide supportive evidence regarding the effects of MFAS on the species in question.

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APPENDIX A

Focal Animal Behavioral Ethogram[1]

BEHAVIOR STATE (≥50% of group's activity--note once per minute; also note if unknown when animals not in view during that minute)	**CODE**	**DEFINITION (e.g., per *Encyclopedia of Marine Mammals**)**
Rest/Slow Travel	RE	≥50% of group exhibiting little or no forward movement (<1 km/hr) remaining at the surface in the same location or drifting/traveling slowly with no wake.
Travel	TR	≥50% of group swimming with an obvious consistent orientation (directional) and speed, no surface activity. Medium travel = 1-3 km/hr wake no white water; Fast travel = >3 km/hr with white water.
Mill	MI	≥50% of group swimming with no obvious consistent orientation (non-directional) characterized by asynchronous headings, circling, changes in speed, and no surface activity. Can include feeding.
Surface-Active Mill	SM	While milling, occurrence of aerial behavior that creates a conspicuous splash (includes all head, tail, pectoral fin, and leaping behavior events—see individual behavior events below). Can include feeding.
Surface-Active Travel	ST	While traveling, occurrence of aerial behavior that creates a conspicuous splash (includes all head, tail, pectoral fin, and leaping behavior events—see individual behavior events below).
Probable Foraging*	PF	Apparent searching for prey; the process of finding, catching, and eating food.
Unknown	UN	Not able to determine behavior state (e.g., animals out of sight, too far to determine, on a dive, etc.).
Other	OT	Describe in notes.
Individual Behavior Event		
Logging	LG	Lying at the surface with body exposed with no directed forward movement.
Breach*	BR	A behavior in which a marine mammal leaps out of the water.
Porpoise*	PO	The behavior of marine mammals leaping at least partially clear of the water surface during rapid swimming.
Sternride	SR	The action or behavior pattern of riding on the pressure wave at the stern or abreast of a ship.
Spin	SP	Leap clear of water and spin (dolphins only).
Bowride*	BO	The action or behavior pattern of riding on the pressure wave in front of the bow of a ship or abreast of a ship.
Head Slap/Lunge	HS	Leap out of water w/ forward thrust or side at >40º and slap ventral surface on water creating large splash.

BEHAVIOR STATE (≥50% of group's activity--note once per minute; also note if unknown when animals not in view during that minute)	CODE	DEFINITION (e.g., per *Encyclopedia of Marine Mammals**)
Foraging	FO	Seen chasing fish or prey and/or zig-zag pursuit swimming.
Sprint	ST	Brief increase in speed often associated with foraging/feeding.
Social	SO	Two or more animals in physical contact.
Roll Over	RO	Animal completely rolling over.
Zig-Zag	ZZ	Swimming in a zig-zag pattern.
Tail Slap*	TS	A behavior in which a marine mammal slams its flukes down on the water, usually repeatedly.
Individual Behavior Event (continued)		
Pectoral Fin Slap	PS	Slap water surface with pectoral fin - ventral or dorsal up.
Inverted Swim	IS	Animal swimming with ventral side up, dorsal side down – inverted.
Unknown	UN	
Other Behavior	OB	Behavior not listed above: describe in notes.
Missed Behavior	OMB	Did not see/missed a behavior.
Whales Only		
Blow*	BL	Visible respiration (i.e., cloud of vapor and sea water mixed with air that is exhaled by cetaceans).
No Blow Rise	NB	Surface with no visible blow/respiration.
Missed Blow	MB	A blow/surfacing is suspected to have been missed/not seen.
First Blow	FB	First blow of surface sequence (where surface sequence consists of closely spaced blows usually followed by a dive).
Peduncle Arch	PA	Arching of peduncle (posterior portion of the body bearing the tail or flukes) without lifting tail/flukes.
Fluke Up	FU	Arching of back followed by lifting tail flukes into air (fluke facing up) usually before an extended dive.
Fluke Down	FD	Arching of back followed by lifting tail flukes into air (fluke facing down) usually before an extended dive.
Unidentified Large Splash	US	Large splash associated with an unidentified/unseen behavior.
Vertical	VU	Vertical in water with head up.
Vertical Down	VD	Vertical in water with head down.

Notes:

* Perrin, W.F., B. Würsig, and J.G.M. Thewissen, eds. 2009. *Encyclopedia of Marine Mammals. Second Edition*. Academic Press, San Diego, California.

[1] Taken from: Smultea, M.A., and C.E. Bacon. 2012. *A Comprehensive Report of Aerial Marine Mammal Monitoring in the Southern California Range Complex: 2008-2012*. Prepared for Commander, U.S. Pacific Fleet, Pearl Harbor, Hawaii. Submitted to Naval Facilities Engineering Command Southwest (NAVFAC SW), EV5 Environmental, San Diego, California 92132 under Contract No. N62470-10-D-3011 issued to HDR, Inc., San Diego, California.

APPENDIX B

Summary of 6 September 2012 Conference Call with U.S. Navy and HDR Representatives Regarding Data Needed for Acoustical Analysis

Report by Adam Frankel, Marine Acoustics, Inc. (from email sent: 7 September 2012):

Present: Sean Hanser CIV NAVFAC Pacific, EV; Joseph Mobley HDR; Julie Rivers CIV COMPACFLT, N01CE1JR; Adam Frankel MAI; Steve Martin CIV SPAWARSYSCEN-PACIFIC, 71510; Roy Sokolowski CIV COMPACFLT, N01CE1RS; Morgan Richie CIV NAVFAC Pacific, EV; Kristen Ampela HDR

From the discussion, there appear to be at least four potential data sources.

1. The most basic is SPORTS, which is the sonar reporting system. This is the hourly ship position data, and time sonar is on and off, and that is about it. This is likely the only data available for 2008-2009.
2. The second source is "PMRF range data," which has the ship positions every second, but no acoustic data. According to my notes, Range data is available for 2010 and 2011. They may be able to get it for 2012. Certainly this data can be used to determine ship heading.
3. The third source is the "acoustic data," which I take to be a literal acoustic recording from some sensor (PMRF phones?). This acoustic record can be scanned to determine the exact time of a sonar transmission. According to my notes, they have acoustic data from 2011-2012.
4. The 4th potential source is the ATAS data. However, there was much doubt as to whether this data was collected. I am not familiar with the ATAS data system and cannot comment on that.

Someone is going to query NAVOCEANO about XBTs that were dropped within one day of each focal follow. These data would provide much more accurate sound velocity profiles to improve the fidelity of the propagation modeling. If these data cannot be obtained, we can always use the Navy historical database.

Finally we are going to use the Beaufort sea state observations from the video transcription as our metric of wind speed. The wind speed value is input into the propagation model to describe sea surface roughness, which in turn is used to calculate the surface loss portion of the propagation model.

What seems to be unavailable is a record of the sonar operation mode, steer angle, source level and beam pattern. It is still possible to make good estimates of what was likely being done. Perhaps a more accurate would be to say that the RL would have been X dB under mode #1, and Y dB under mode #2.

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