Final Report

Aerial Survey Monitoring for Marine Mammals and Sea Turtles in the Hawaii Range Complex in Conjunction with Navy Training Events: Submarine Commanders Course 17–18 February 2015 & 2016

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Aerial photo of humpback whales (*Megaptera novaeangliae*) photographed north of Kauai. Photograph taken by Joseph Mobley under National Marine Fisheries Service permit no. 642-1536-03 issued to HDR.

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14. ABSTRACT

On 17–18 February in both 2015 and 2016, two days of aerial surveys (for a total of four days) were conducted on and around the Pacific Missile Range Facility (PMRF) for the purpose of detecting and observing marine mammals and sea turtles (MM/ST) that may be exposed to mid-frequency active sonar (MFAS) during the Submarine Commanders Course (SCC) training event. Most of the survey effort (74 percent) was spent flying elliptical orbits in advance of a United States Navy (Navy) warship participating in the SCC event. During the 30.6 hours of effort (with average Beaufort sea state [BSS] of 4.7), 96 sightings were recorded, representing six identified species. Nine of the sightings occurred while orbiting the ship consisting of five humpback whale (Megaptera novaeangliae) sightings (two of which behavioral data were collected), one unidentified small dolphin sighting and three unidentified sea turtle sightings. Sighting locations that occurred within 1 hour of MFAS transmissions were compared against ship locations at the time of transmission in order to estimate potential received levels (RLs) from MFAS exposure. A total of 49 sightings met this criterion, of which 33 also met higher confidence standards for the RL estimates and are reported here. The mean RLs for these 33 sightings ranged from 136.7 to 170.8 decibels referenced to 1 microPascal (dB re: 1µPa) root mean square. Despite estimated RLs reported here being higher than RLs found to elicit a behavioral avoidance response in beaked whales, no unusual behavior or signs of distress were observed during the four days of surveys. That being said, extended behavioral observations of a focal group were limited by the type of aircraft used, high BSS and limited number of sightings in close proximity to the ship.

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Acronyms and Abbreviations

BSS	Beaufort Sea State
dB re: 1µPa	decibels referenced to 1 microPascal
HRC	Hawaii Range Complex
HST	Hawaii Standard Time
km	kilometer(s)
MFAS	mid-frequency active sonar
MM/ST	marine mammals and sea turtles
NOAA	National Oceanic and Atmospheric Administration
PMRF	Pacific Missile Range Facility
RL	received level
SCC	Submarine Commanders Course
SD	standard deviation
SL	source level
SOW	Statement of Work
TL	transmission loss

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Section 1 Abstract

On 17–18 February in both 2015 and 2016, two days of aerial surveys (for a total of four days) were conducted on and around the Pacific Missile Range Facility (PMRF) for the purpose of detecting and observing marine mammals and sea turtles (MM/ST) that may be exposed to mid-frequency active sonar (MFAS) during the Submarine Commanders Course (SCC) training event. Most of the survey effort (74 percent) was spent flying elliptical orbits in advance of a United States Navy (Navy) warship participating in the SCC event. During the 30.6 hours of effort (with average Beaufort sea state [BSS] of 4.7), 96 sightings were recorded, representing six identified species. Nine of the sightings occurred while orbiting the ship consisting of five humpback whale (*Megaptera novaeangliae*) sightings (two of which behavioral data were collected), one unidentified small dolphin sighting and three unidentified sea turtle sightings. Sighting locations that occurred within 1 hour of MFAS transmissions were compared against ship locations at the time of transmission in order to estimate potential received levels (RLs) from MFAS exposure. A total of 49 sightings met this criterion, of which 33 also met higher confidence standards for the RL estimates and are reported here. The mean RLs for these 33 sightings ranged from 136.7 to 170.8 decibels referenced to 1 microPascal (dB re: 1µPa) root mean square. Despite estimated RLs reported here being higher than RLs found to elicit a behavioral avoidance response in beaked whales, no unusual behavior or signs of distress were observed during the four days of surveys. That being said, extended behavioral observations of a focal group were limited by the type of aircraft used, high BSS and limited number of sightings in close proximity to the ship.

Section 2 Introduction

In order to meet regulatory compliance for military training and testing under the Marine Mammal Protection Act and the Endangered Species Act, Navy is required to implement MM/ST monitoring. In support of these monitoring objectives, aerial surveys to monitor MM/ST were conducted in conjunction with the SCC naval training event. These two SCC events took place on 17–18 February of 2015 and 2016 within the Hawaii Range Complex (HRC) on the PMRF Barking Sands Tactical Underwater Range and Barking Sands Underwater Range Extension between Kauai and Niihau, Hawaii (**Figure 1**). The SCC generally occurs two times per year in the Pacific training areas and is designed to test prospective commanding and executive officers on all of the skills required for successful submarine command. SCC exercises involve surface ships, submarines, aircraft, and the use of MFAS.

These aerial surveys have been conducted since 2008 (Mobley & Smultea 2008) and are designed to address two of the five research questions identified in the U.S. Navy's *Hawaii Range Complex Monitoring Plan* (DoN 2008):

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?"*

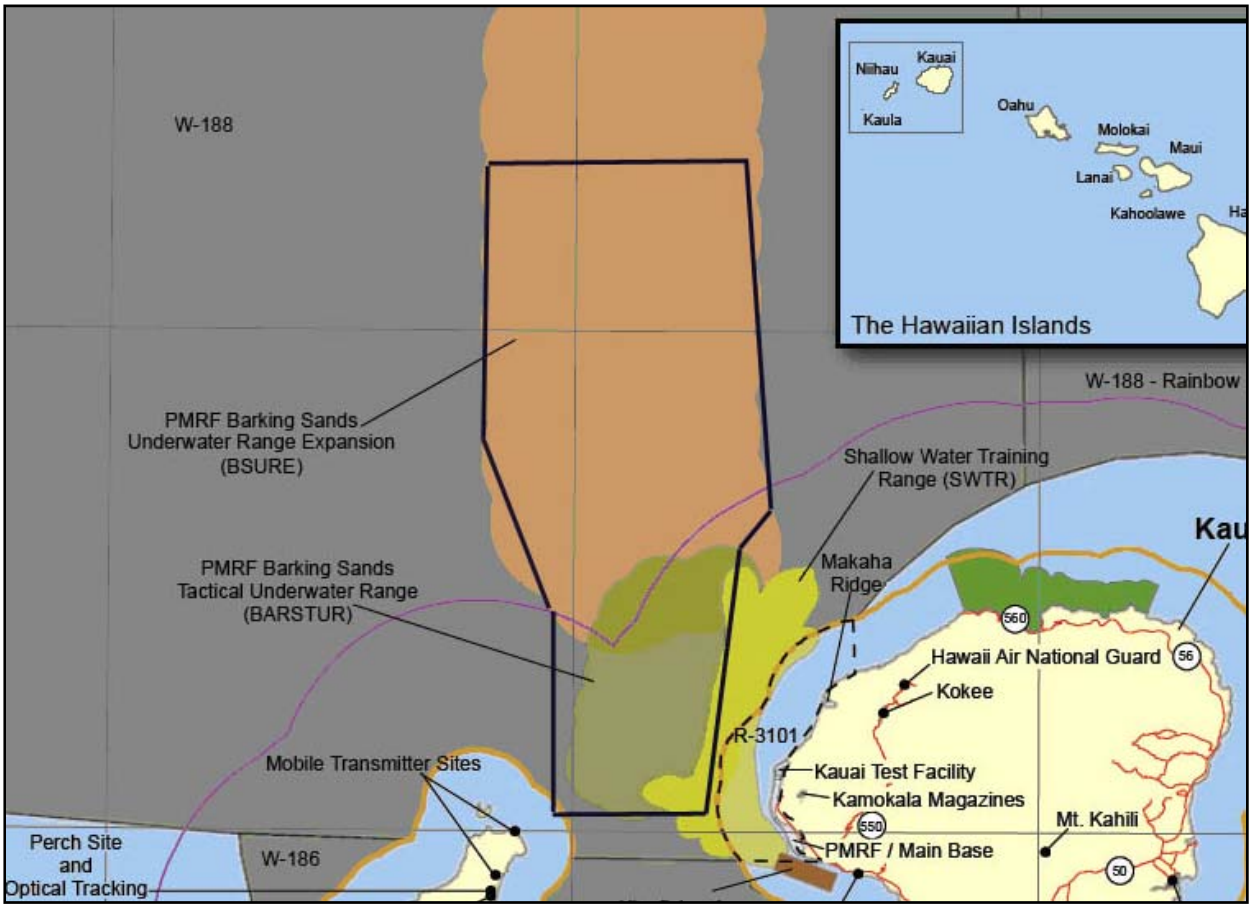

Figure 1. Location of the aerial survey monitoring area (black box = area for ship follows) in and near the U.S. Navy PMRF west and northwest of Kauai, Hawaii.

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

The survey methods and sampling design were approved in advance by the Navy and outlined in the Statement of Work (SOW) issued by the Navy Contracting Officer Representative, and followed previously established protocol (Mobley et al. 2015, Mobley and Pacini 2013; Mobley and Milette 2010; Smultea et al. 2009a,b).

Prior to each training event, the chief scientist and primary pilot attended planning sessions known as 'pre-sails' with the Navy Technical Representative and other U.S. Navy staff at Pearl Harbor to coordinate survey efforts in conjunction with the SCC February 2015 and February 2016 training events. Per the SOW, the goal of the aerial survey was to identify MM/ST in the vicinity of the ship and then to perform focal follows using accepted observation methods (Altmann 1974) to monitor their behavior. Further analysis would examine the exposure levels of MM/ST sightings to MFAS emissions by comparing the timing and positions of sightings and MFAS events. These analyses were conducted by personnel authorized to handle sensitive data.

Section 3 Methods

Effort

Monitoring effort followed protocols implemented in previous SCC training events (Mobley et al. 2015, Mobley and Pacini 2013, Mobley 2011, Mobley and Milette 2010). The approach involved flying elliptical-shaped patterns in front of a ship conducting ASW training where MFAS may be used. The ellipticals extended from the front of the ship (approximately 200 meters) out to approximately 2,500 meters over a width of 5 km. Survey effort was conducted from a fixed-wing Aero Commander 500 and summarized in **Table 1**.

Table 1. Summary of effort type, time on effort, and sea state by date.

Date	Total Survey Hours*	Hours on Effort	Hours with ship	Mean BSS While with the ship
17 Feb 2015	7.4	7.3	5.2	3.1
18 Feb 2015	8.3	8.1	6.7#	3.9
17 Feb 2016	7.5	7.4	5.5	6.2
18 Feb 2016	7.5	7.4	5.2	6.6
Total	**30.6**	**30.3**	**22.5**	**4.6**

* Computed wheels up to wheels down
#Time was split between two different ships

Unless otherwise directed by flight controllers or for safety reasons, the pilot tried to maintain a consistent aircraft ground speed of approximately 185 km/hour (100 knots) and an altitude of approximately 305 meters. Observations from the monitoring aircraft involved five personnel: the pilot and copilot, two primary observers surveying the left and right sides of the plane, and a data recorder. The survey crew and pilot were not informed as to the status of MFAS transmissions, which minimized the potential for observational bias.

The data recorder was responsible for collecting survey, environmental, and sighting information. Data were collected on a tablet computer using customized Filemaker Go software (version 13.0.9, Filemaker Inc., Santa Clara, CA). Survey data included the start and end of flights (“wheels up” and “wheels down”), when systematic surveying began and ended (“on effort” and “off effort”), and when the plane was transiting or orbiting the ship (“with ship” and “not with ship”). Environmental data consisted of the BSS, percentage of the visual arena impacted by glare (“glare”), and an estimate of the distance that a group of 20 dolphins could be detected by the observer (“visibility”) for each observer. These data were recorded at the start of the effort and whenever environmental conditions changed for either observer. The position of the aircraft was recorded automatically via a Garmin GPS receiver every 5 seconds.

When MM/ST were detected, the primary observer obtained a vertical angle to the sighting using hand-held Suunto® clinometer, once the sighting was abeam of the aircraft (90 degrees to the trackline). The vertical angle is used to estimate a geographic position of the sighting based on the plane’s position and elevation. The species and number of individuals in the group were also recorded. If additional data were required for the sighting, the plane orbited the sighting to

allow the observer to obtain additional data and photos. Photographs were taken opportunistically to assist in species identification using a Canon 5D digital camera with a Canon image-stabilized 100–400-millimeter telephoto lens.

Focal Follows

Sightings made in close proximity of the ship were selected for a focal follow. During a focal follow, with permission from PMRF air traffic control (Range Control), the aircraft ascended to 457 meters, an altitude shown to minimize reactivity to fixed-wing aircraft (Smultea et al. 1995), and the sighting was orbited for as long as possible. A high-definition Canon Vixia HF10 camcorder with 12-power optical zoom was used to video-record focal-follow behavioral data. The intercom system of the aircraft was connected to the audio input port of the digital camcorder so that all observers' comments about behavioral observations could be recorded with a minimum of ambient noise. Time stamps on the Canon camcorder were synchronized with those from the Garmin GPS receiver. The resultant digital audio/video file and digital photos will be made available to the U.S. Navy for subsequent behavioral analysis.

The position of vocalizing cetaceans that are of high priority to the Navy (e.g., beaked whales) were on occasion texted to the survey plane by personnel acoustically monitoring cetaceans on the PMRF using the Navy's fixed bottom-mounted hydrophone array (Barking Sands Underwater Range Expansion). Discretion was made by the aerial team based on the planes proximity to these locations and authorization from Range Control on whether or not to dedicate some observation effort in those areas.

Received Levels

To estimate the RL that an animal, or group of animals, is exposed to requires knowing: 1) the location of the animal(s), 2) the location of the surface ship when it transmitted MFAS, 3) and the source level (SL) of the MFAS transmission. Given this information, the estimated RL is calculated as the SL minus the transmission loss (TL). Multiple MFAS surface ships participated in both the February 2015 and 2016 SCC training events. Source levels were assumed to be 235 dB re: 1µPa root mean square as provided for the AN/SQS-53C sonar (with center frequencies of 2.6 and 3.3 kilohertz) based on the published specifications associated with the 2000 Bahamas stranding event (DoN 2013).

RL estimates were limited to those animals sighted within 1 hour before or after MFAS transmissions. Animal locations were based on the location recorded when observers on the plane initially sighted the animal(s). Location of the closest MFAS ship to a particular sighting was obtained from PMRF data products provided following the training event. Environmental data were derived from the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information, formerly the National Oceanographic Data Center. The sound speeds were calculated from the NOAA World Ocean Atlas 2009 seasonal 1-degree temperature and salinity datasets (Locarnini et al. 2010; Antonov et al. 2010). Bathymetry data came from the NOAA Coastal Relief model (3 arc-second resolution). TL was calculated using the propagation model Peregrine (Ocean Acoustical Services and Instrumentation Systems, Inc., Lexington, MA). The TL was estimated by averaging over 40 frequencies in the MFAS band to reduce single-frequency destructive interference effects which can result in

unrealistically high TLs. In an effort to gain insight into the variability of the estimated RLs, the TL was estimated at 1,000 distances over the nominal ship-to-animal distance plus or minus 10 percent to represent animal location uncertainty from both sighting accuracy and potential animal movement. The animals were modeled near the sea surface (where sighted) rather than over a range of possible depths.

Communications

Communications were possible between the survey aircraft and marine mammal observers aboard the ship using aviation-band VHF radios broadcasting on 123.45 megahertz. This system was more reliable whenever the aircraft was within about 10 km of the ship. Communications at greater distances were carried with Range Control, who also directed us to the ship when approaching PMRF. A standard operating procedure was established prior to the event which was to be followed in the event that communications were lost (**Appendix B**).

Safety on the PMRF is paramount. Safety briefings were held at the PMRF on 5 February 2015 and 8 February 2016. Rules were established to ensure the safe operation of civilian aircraft in the context of a U.S. Navy training event with active military aircraft in the vicinity (**Appendix B**).

Section 4 Results and Discussion

Effort

A total of 30.3 hours of “on effort” surveying was completed over 8 surveys and 4 days (**Table 1**). During these surveys, the aircraft accompanied the ship for 22.5 hours (74 percent) of the total survey time. The remaining 26 percent involved transiting to and from the location of the ship to start or end the day or for refueling between surveys.

Only 28 percent of survey effort was in favorable sea state conditions (i.e., BSS 3 or less), but 66 percent of sightings occurred in BSS ≤ 3 (**Figure 2**). Conditions were much more favorable in 2015 with 51% (7.9 hours) of survey effort in BSS ≤ 3 compared with 4% (0.1 hours) in 2016.

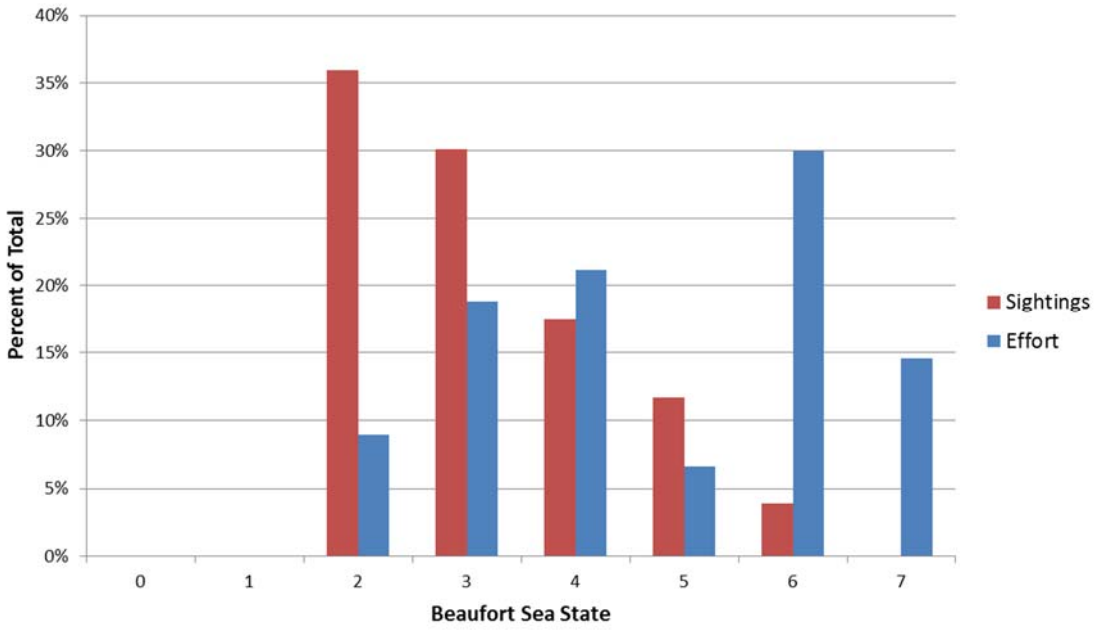

Figure 2. Percentage of sightings and effort by BSS (all survey days combined).

Sightings

There were 96 sightings made during the four days of surveys (**Tables 2-3, Figures 3 and 4, Appendix A**). These included two whale carcasses, initially sighted by Cascadia Research Collective (Robin Baird, pers. comm.) the day prior, who provided the aerial survey team with the sighting locations. Based on the size of the severely decomposed carcasses, it was determined that both of these were unidentified large whales (**Figures 5 and 6**) but species confirmation could not be made due to their advanced state of decay. Assuming these two carcasses were the same as those reported the day prior, one carcass would have drifted 22.7 km over 18.8 hours for a drift rate of 3.0 kilometers per hour, while the second, much larger carcass was estimated to have drifted 12.1 km over 19.6 hours for a drift rate of 1.75 km per hour. The carcasses drifted in a direction of 56 degrees and 34 degrees respectively, relative to true north.

The majority (79 percent) of the 94 living sightings were humpback whales (N=74).; Sixty-four (86 percent) of the humpback whale sightings were in waters shallower than 183 meters (100 fathoms), known to be preferred habitat of humpbacks in Hawaii based on past survey results (Mobley et al. 1999; Mobley 2004). These inshore sightings of humpback whales occurred during transits to and from the ship.

When all living humpback whale sighting data are converted to sighting rates, the result is 0.013 humpback whale sightings/km of effort (effort distance was calculated as time [hours] × 185 km/hour mean speed). Humpback whale sighting rates in 2015 were 0.029 sightings per hour (mean BSS 3.3) compared to 0.005 humpback whale sightings per hour (mean BSS 5.8) in 2016, which could be explained by the improved sighting conditions in 2015. However, in 2013, when sighting conditions were similar to 2016 (mean BSS 6.0), the humpback whale sighting rate of 0.011 (Mobley and Pacini 2013) was still twice that of 2016, suggesting fewer humpback

whales may have been present. This phenomenon of fewer humpback whales observed in 2016 was anecdotally reported by whale watchers and researchers throughout the Main Hawaiian Islands. One study using long-term passive acoustic monitoring reported that the number of singing humpback males (a proxy of overall whale density) was significantly lower in 2016 off West Maui compared with 2015 (Kügler el al. 2016), adding support what was being observed.

Table 2. Summary of sightings by species.

Species	Groups	Individuals	Average Group Size
Humpback Whale *(Megaptera novaeangliae)*	74	114	1.6
Unidentified Cheloniidae (sea turtle)	12	12	1.0
Bottlenose Dolphin (*Tursiops truncatus*)	2	8	6.0
Spinner Dolphin (*Stenella longirostris*)	2	53	26.5
Unidentified Small Cetacean	2	7	3.5
Short-finned Pilot Whale (*Globicephala macrorhynchus*)	1	8	8.0
Hawaiian Monk Seal *(Neomonachus schauinslandi)*	1	1	1.0
Unidentified Large Dead Whale	1	1	1.0
Unidentified Large Dead Whale Fragments	1	-	-
Total	**96**	**204**	**48.6**

Table 3. Total survey effort and sightings while orbiting and transiting to and from the ship. All times are Hawaii Standard Time (HST).

Date	Time Wheels Up (HST)	Time Wheels Down (HST)	Hours On Effort	Hours Not with Ship	Hours with Ship	Numbers of Sightings with Ship	Numbers of Sightings Away from Ship	BSS	Humpback Whale Sightings Per km of Effort
2/17/15	9:10	13:24	4.2	1.2	3.1	3	24	2.9	0.026
2/17/15	15:00	18:07	3.1	1.0	2.1	1	9	3.0	0.016
2/18/15	7:38	12:46	5.0	1.0	4.1	2	23	3.5	0.021
2/18/15	14:25	17:34	3.1	0.5	2.6	3	18	3.9	0.031
2/17/16	8:37	12:36	4.0	1.0	3.0	0	2	5.3	0.003
2/17/16	14:04	17:33	3.5	1.0	2.5	0	0	6.3	0.000
2/18/16	7:06	11:10	4.0	0.8	3.3	0	6	6.3	0.007
2/18/16	12:30	15:56	3.4	1.4	2.0	0	5	5.4	0.002
		Totals	**30.3**	**7.8**	**22.5**	**9**	**87**	**4.3**	**0.013**

*Survey plane noted as “with ship” during elliptical orbits around ship. Sightings were noted as “with ship” if initially recorded during orbits; otherwise noted as “away from ship.”

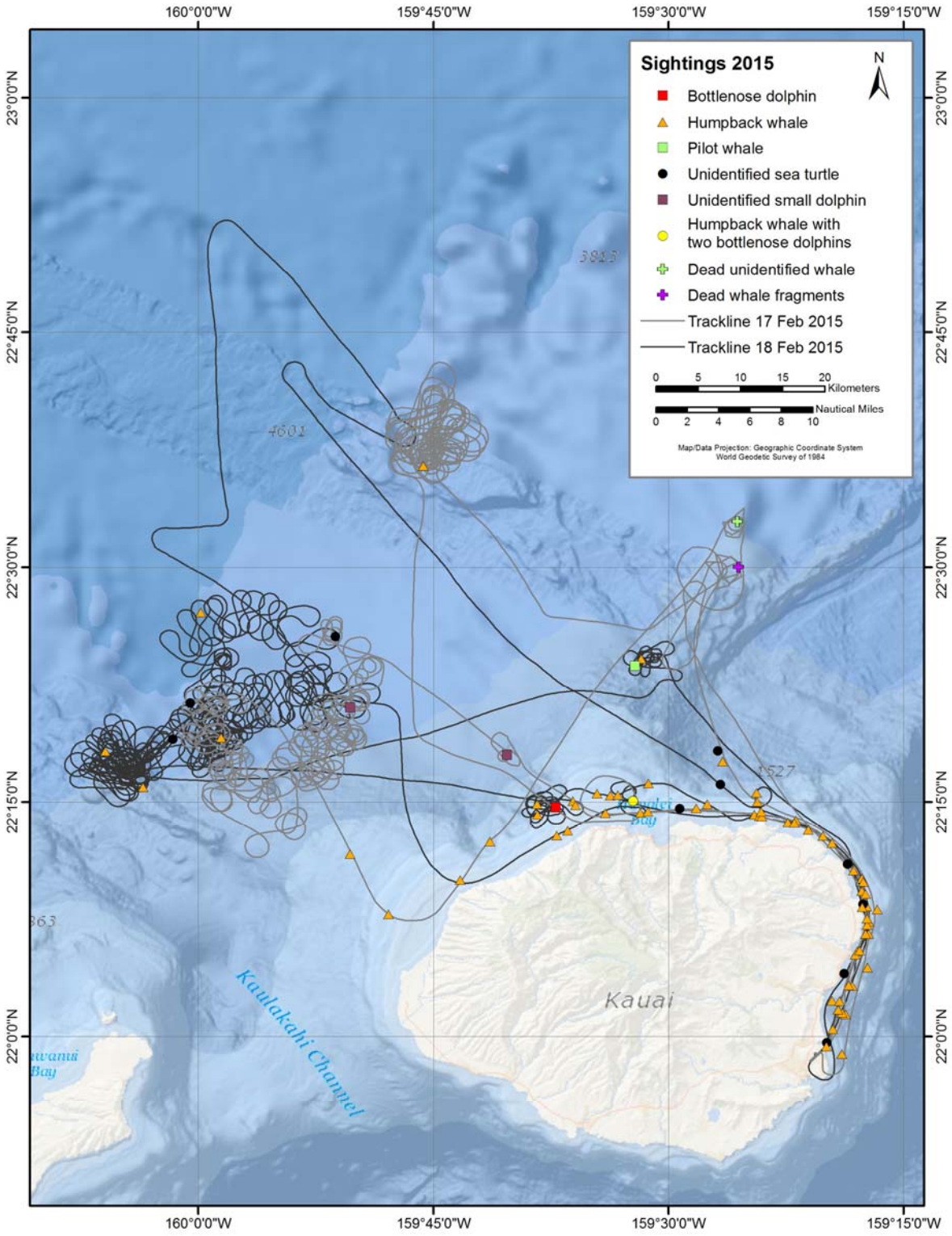

Figure 3. Effort and sighting locations during days involving ship follows with the ship (17–18 February 2015).

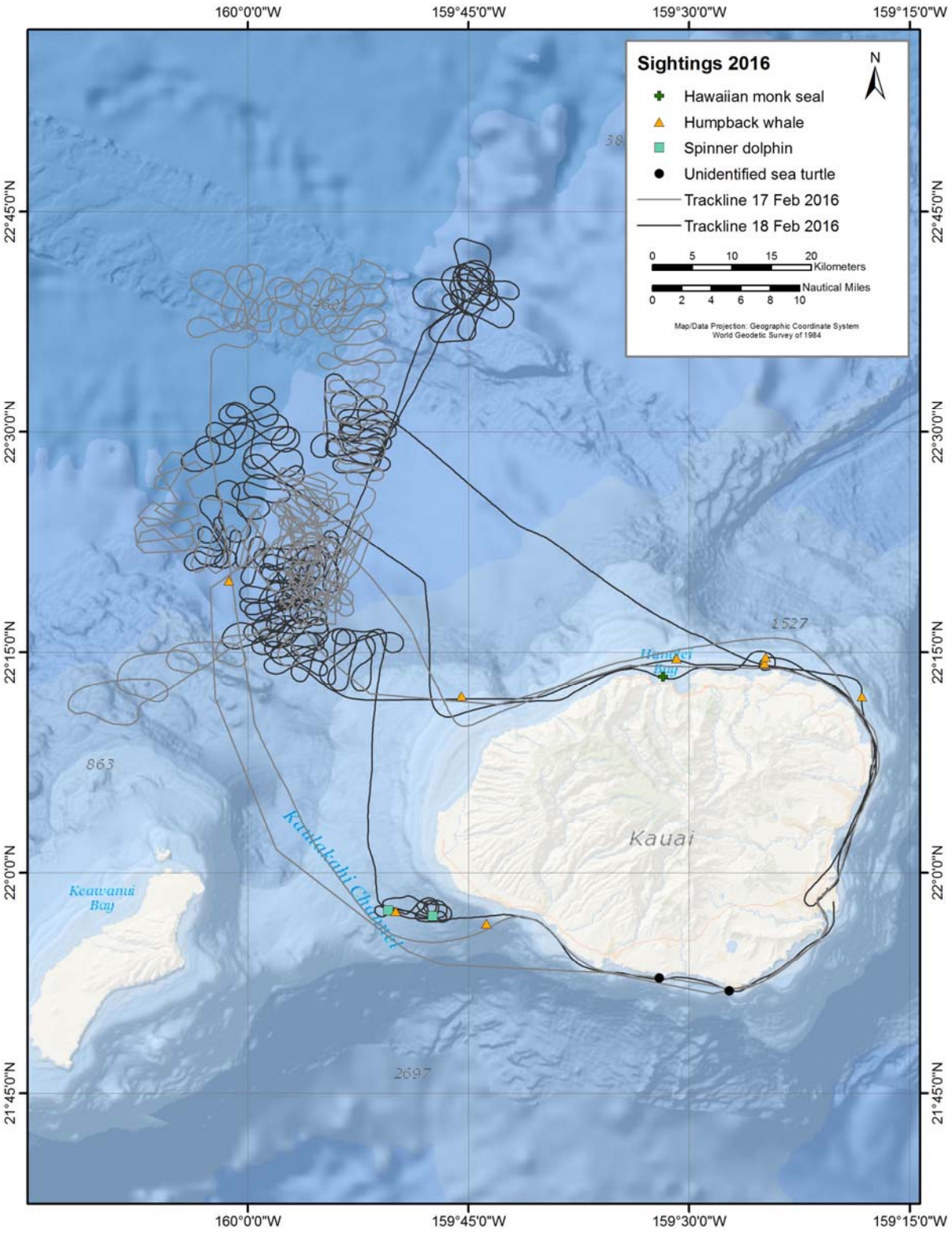

Figure 4. Effort and sighting locations during days involving ship follows with the ship (17–18 February 2016).

Figure 5. Aerial photograph of the first, large unidentified whale carcass observed on 17 February 2015. Photograph taken by Marc Cotter.

Figure 6. Aerial photograph of the second, large unidentified whale carcass observed on 17 February 2015. Photograph taken by Marc Cotter.

Images of both carcasses (**Table 2**) were sent to a necropsy specialist (Dr. Kristi West, Hawaii Pacific University) who concluded that both had likely been dead for more than one month, thereby placing the time of death well in advance of the SCC training event.

For the remaining 94 sightings of living MM/STs no instances of unusual behavior or signs of distress (e.g., near strandings, defensive or evasive behaviors) were observed during the four days of surveys. This does not mean that no adverse effects occurred, merely that none were detected.

Focal Follows

Most sightings during the two-day SCC event each year occurred during transits between Lihue, Kauai, and the ship's position **(Figures 3 and 4)**. However, nine sightings, including five sightings of humpback whales, occurred while orbiting the ship during 2015 (**Table 3)**. No sightings were observed near the ship during 2016; sighting totals were much lower everywhere, likely due primarily to high sea state. Two of the humpback whale sightings were the targets of focal-follow sessions with video-recording (**Table 4**); the first was a pair of whales and the second was a solitary individual.

Table 4. Summary of Focal Follows (17 & 18 February 2015).

Date	Time Sighted (HST)	Species	No. Individuals	Video? (Y/N)	Comments:
02/17/2015	15:39:13	Humpback Whale	2	Y	2-minute video; whales occasionally visible
02/18/2015	11:17:26	Humpback Whale	1	Y	11-minute video; whales occasionally visible

The combined duration of the two video-recorded sessions was 13 minutes—2 and 11 minutes, respectively (**Table 4**). During much of this time, however, the whales were not in view due to the orientation of the plane and subsequent obscuring by the engine mount, glare, or the whales traveling underwater. Since the video quality was poor, the recordings obtained in these cases were not useful for the ongoing analysis of video-recorded focal follows.

Estimated Received Levels

A total of 49 animal sightings occurred within 1 hour of MFAS transmissions; however, 16 of those sightings had inconclusive estimated RLs (e.g., multimodal estimated RLs, difference between minimum and maximum estimated RLs well over 20 dB re: 1µPa, RLs standard deviations over 4.0 dB). The other 33 RL estimates were judged to be reliable with means ranging from 136.71 to 170.8 dB re: 1µPa (**Table 5**). The method utilized was different from previous methods (Baird et al. 2014) in the following areas: 1) multiple frequencies around the center frequency of transmissions were utilized in the modeling to reduce the artificial low values resulting from destructive interferences associated with single frequency model estimated; 2) estimates were only calculated near the surface (10m depth, +/- 5m); 3) a single estimated RL is provided for each aerial sighting for the closest (in time) MFAS transmitting

ship; and 4) the uncertainty in range data was not available, so an simplified estimate of +/-10% of the distance from the ship to the estimated animal position was utilized to provide some statistical representation of the modeled estimated RL.

This approach and its assumptions produce the following caveats:

1. Sonar was modeled as omnidirectional for security concerns. However, the angle of the animal relative to the ships' bow was determined in four 90 degree sectors centered on: the bow, the port and starboard beams and the stern. Thus, one could reduce the estimated RLs for animals exposed in the stern sector given the shadowing effect of the ships' hull to the aft of the ship.

2. RL estimates did not account for any animals' movement (i.e. stationary animal) relative to the ship MFAS transmission which could have occurred from one hour before to one hour after an MFAS transmission. Actual RL may vary depending on how much the animal may have moved during the time period prior to and after MFAS transmission.

3. The actual location of marine mammals also depends upon the accuracy of the aerial sightings (which is unknown). Here a ±10 percent of total distance was used to represent distance uncertainties and may not reflect actual errors of the sighting position estimation methodology.

4. The historical sound velocity profile mismatch with actual conditions at the time of the training event can cause relatively large differences in the estimated RLs (e.g. strength of the near surface ducting and upper layer after duct and estimates at longer distances.

These estimates include the two focal follow sightings (designated with focal case numbers in **Table 5**). The first focal case involved a pair of humpback whales, estimated to be exposed to RLs of 156.7 dB re:1µPa root mean square from a distance of 10.4 km. The second focal case involved a single humpback whale, estimated to be exposed to 159.5 dB re:1µPa root mean square from a distance of 17.2 km. MFAS transmission occurred 26.8 and 56.9 minutes respectively after the initial sighting occurred.

Table 5. Summary of Estimated RLs (dB re: 1µPa) for Sightings Exposed to MFAS[1]

Date	Time (HST)	Species	Focal Case #	Time difference[2] mm:ss	distance (km)[3]	Estimated Received Level	
						Mean	SD
2/17/2015	9:19:12	Humpback Whale		58:13	58.4	139.6	1.75
2/17/2015	9:21:14	Humpback Whale		56:11	49.0	142.8	0.94
2/17/2015	9:21:35	Unid. Turtle		55:50	48.2	143.1	0.93
2/17/2015	9:52:21	Humpback Whale		25:04	29.7	140.0	0.70
2/17/2015	9:55:51	Humpback Whale		21:34	30.2	149.9	0.60
2/17/2015	9:57:24	Humpback Whale		20:01	22.0	153.3	0.69
2/17/2015	10:12:04	Unid. Turtle		05:09	2.1	166.7	0.56
2/17/2015	12:08:01	Humpback Whale		27:46	32.5	151.1	1.11
2/17/2015	12:34:51	Unid. Small Dolphin		16:47	1.6	170.8	0.71
2/17/2015	12:55:14	Unid. Turtle		27:04	8.2	162.4	0.44
2/17/2015	13:05:31	Unid. Small Dolphin		32:42	16.5	158.1	0.74
2/17/2015	13:11:09	Humpback Whale		33:26	25.4	153.0	0.78
2/17/2015	13:11:53	Humpback Whale		22:24	29.0	154.6	3.19
2/17/2015	13:12:47	Humpback Whale		38:54	31.0	150.9	2.65
2/17/2015	13:17:21	Humpback Whale		29:27	50.5	143.3	3.69
2/17/2015	15:09:03	Humpback Whale		59:37	53.6	142.5	2.19
2/17/2015	15:39:13	Humpback Whale	1	26:49	17.2	156.7	0.89
2/18/2015	7:47:17	Humpback Whale		27:03	44.2	140.4	0.92
2/18/2015	7:47:31	Humpback Whale		29:16	43.8	140.6	0.91
2/18/2015	7:49:44	Unid. Turtle		00:00	39.7	142.1	0.93
2/18/2015	9:49:31	Humpback Whale		27:10	17.5	165.1	0.39
2/18/2015	11:17:26	Humpback Whale	2	56:54	10.4	159.5	0.14
2/18/2015	14:38:21	Humpback Whale		55:05	49.7	141.6	1.41
2/18/2015	14:40:10	Humpback Whale		54:16	43.1	144.4	1.07
2/18/2015	14:40:59	Humpback Whale		21:07	39.9	145.6	1.35
2/18/2015	16:28:45	Humpback Whale		31:37	10.9	152.6	0.36
2/18/2015	16:39:15	Unid. Turtle		43:42	7.4	153.5	0.16
2/18/2015	16:48:52	Humpback Whale		16:04	15.4	152.3	0.26
2/18/2015	17:16:30	Humpback Whale		24:17	45.2	145.2	1.00
2/18/2015	17:17:37	Pilot Whale		27:46	42.1	145.5	0.96
2/18/2016	15:23:16	Spinner Dolphin		00:01	39.3	138.8	1.39
2/18/2016	15:24:35	Spinner Dolphin		01:18	41.5	136.7	1.41
2/18/2016	15:26:31	Humpback Whale		01:56	39.4	138.4	1.39

[1] Table includes a subset (N=33) of total N=49 estimates with greater levels of precision

[2] Difference between initial sighting time and time of beginning of MFAS transmission

[3] Distance between sighting and transmitting ship positions

When all 33 sightings are considered, the distances from the ship ranged from 1.6 to 58.4 km with RLs ranging from 136.7 to 170.8 dB re:1µPa (**Table 5**). These RLs are generally higher than those reported by other comparable studies involving exposures to actual MFAS transmissions. Baird et al. (2014) reported RLs of 130–144, 149–168, and 141–162 dB re: 1µPa for satellite-tagged cetaceans, including two rough-toothed dolphins (*Steno bredanensis*), a bottlenose dolphin (*Tursiops truncatus*), and a short-finned pilot whale (*Globicephala macrorhynchus*), respectively. Tyack et al. (2011) used existing U.S. Navy assets on the Atlantic Undersea Test & Evaluation Center range in the Bahamas to track echolocating Blainville's beaked whales (*Mesoplodon densirostris*) during a U.S. Navy training event involving AN/SQS-56 and AN/SQS-53C sonars, and estimated RLs ranging from 101 to 157 dB re: 1 µPa at distances of 2.2–28.9 km away from transmitting ships.

Section 5 Overall Conclusions

The following summarizes findings with respect to each of the two research questions.

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?"*

Sighting position data from these surveys were compared against ship position data and MFAS transmission times to permit the calculation of estimated RLs for 49 sightings that were observed within 1 hour of MFAS transmissions. Estimated mean RLs reported here for a subset of those with higher levels of confidence where the estimated RLs have unimodal distributions with standard deviations under 4.0 dB. A total of 33 estimated RLs are reported here (Table 5) which ranged from 136.7 to 170.8 dB (SD=1.11). Twenty of these sightings included cetaceans subject to estimated RLs greater than 140 dB, a level that caused disruption of beaked whale foraging behavior, including avoidance by moving away from the source when exposed to controlled and uncontrolled sonar, although sample sizes were small (Tyack et al. 2011). At the same time, 28 of these sightings included cetaceans subject to estimated RLs less than 169 dB, an MFAS exposure level that did not result in any broad-scale movement away from the sound source or other obvious avoidance behavior detectable from a tagged bottlenose dolphin (Baird et al. 2014) and two short-finned pilot whales (Baird et al. 2017). Recent work with blue whales suggested potential effects of MFAS exposure at received levels ranging from approximately 130-165 dB (Goldbogen et al. 2013). Determining received levels of exposed animals is an important step in ascertaining possible effects of MFAS transmissions. Using the ship-follow method described here permits the detection of marine mammal exposures at higher levels than those described previously using different monitoring approaches (Tyack et al. 2011; Baird et al. 2014).

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

This question is the more challenging of the two. As summarized in an earlier report on the focal-follow results (Mobley et al. 2013), analysis of the video data has been hampered by low image quality and short periods of usable footage. The Aerocommander aircraft used in these surveys was not designed for visual reconnaissance; specifically its large engine housings tend to occlude the top half of the observer's window, and even more as the plane orbits. This

resulted in only brief periods where the focal animals were visible through the observer's window, which made it difficult to resight the focal animals when their previous positions came back into view. Most of the quantitative analyses described in Mobley et al. (2013) require continuous observation for long periods of time (>20 minutes). As a result, obtaining metrics such as respiration rate, dive/surface intervals and aerial behavior rates are not possible. Only gross behavioral characteristics, such as inter-individual distance and changes in pod size are available from the brief observations of behavior available from the video images captured here.

As was the case with the 2013 SCC surveys, Range Control interventions were reduced to near zero during the present event. As a result, there was virtually no disruption of the marine mammal monitoring effort. This fact underscores the importance of maintaining continuous and reliable communications with Range Control during the event as well as during the pre-event briefing, and having standard operating procedures in the form of PMRF INSTRUCTION 3125.1 in place for operating our civilian aircraft on PMRF.

Section 6 Acknowledgements

We are grateful to U.S. Navy personnel from Commander, U.S. Pacific Fleet Environmental (N465) and Naval Facilities Engineering Command Pacific EV24 and PMRF control for their support, coordination, and facilitation in the implementation of these surveys. Many thanks to our observers Marc Cotter and Daniel Webster and to our pilots Steve Malin and Wade Yoshiyama. All observations were made in accordance with National Oceanic and Atmospheric Administration permit no. 642-1536-03 issued to HDR.

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A

Summary of Sightings

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Appendix A: Summary of Sightings with Positions

Date	Time (HST)	Species*	Number of Individuals	Latitude (N)		Longitude (W)	
				(degrees)	(minutes)	(degrees)	(minutes)
02/17/2015	9:12:59	MN	2	22	2.295	159	19.539
02/17/2015	9:15:39	MN	1	22	7.330	159	17.190
02/17/2015	9:16:05	MN	2	22	8.140	159	16.657
02/17/2015	9:19:12	MN	1	22	13.844	159	21.862
02/17/2015	9:21:14	MN	1	22	17.592	159	26.515
02/17/2015	9:21:35	UT	1	22	18.268	159	26.841
02/17/2015	9:35:39	UWD	1	22	30.028	159	25.514
02/17/2015	9:36:48	UWD	5	22	32.932	159	25.576
02/17/2015	9:52:21	MN	4	22	12.478	159	41.368
02/17/2015	9:53:26	MN	1	22	10.007	159	43.268
02/17/2015	9:55:51	MN	2	22	7.809	159	47.854
02/17/2015	9:57:24	MN	1	22	11.676	159	50.298
02/17/2015	10:12:04	UT	1	22	21.328	160	0.512
02/17/2015	12:34:51	USD	5	22	21.043	159	50.303
02/17/2015	12:55:14	UT	1	22	25.598	159	51.260
02/17/2015	13:05:31	USD	2	22	18.015	159	40.300
02/17/2015	13:11:09	MN	3	22	15.056	159	36.079
02/17/2015	13:11:53	MN	2	22	14.296	159	34.022
02/17/2015	13:12:47	MN	2	22	14.332	159	31.763
02/17/2015	13:12:58	MN	3	22	14.388	159	31.286
02/17/2015	13:15:33	MN	2	22	14.210	159	24.490
02/17/2015	13:15:43	MN	2	22	14.110	159	24.158
02/17/2015	13:17:21	MN	1	22	12.819	159	20.120
02/17/2015	13:17:38	MN	2	22	12.376	159	19.539
02/17/2015	13:20:15	MN	1	22	7.147	159	17.303
02/17/2015	13:21:05	MN	1	22	5.468	159	17.935
02/17/2015	13:23:12	MN	1	22	1.427	159	18.683
02/17/2015	15:01:22	MN	2	21	58.884	159	18.909
02/17/2015	15:03:59	MN	2	22	4.397	159	17.285
02/17/2015	15:08:27	MN	2	22	13.700	159	22.360
02/17/2015	15:08:56	MN	1	22	14.073	159	24.024
02/17/2015	15:09:03	MN	2	22	14.396	159	24.068
02/17/2015	15:10:29	MN	1	22	14.613	159	28.207
02/17/2015	15:10:49	UT	1	22	14.584	159	29.272
02/17/2015	15:13:16	MN	2	22	14.798	159	35.915
02/17/2015	15:39:13	MN	2	22	36.469	159	45.636
02/17/2015	18:02:28	MN	1	22	8.318	159	17.333

Date	Time (HST)	Species*	Number of Individuals	Latitude (N)		Longitude (W)	
				(degrees)	(minutes)	(degrees)	(minutes)
02/18/2015	7:40:31	MN	1	22	1.522	159	18.893
02/18/2015	7:41:24	MN	2	22	3.213	159	18.244
02/18/2015	7:42:14	MN	1	22	5.251	159	18.045
02/18/2015	7:42:48	MN	2	22	6.560	159	17.205
02/18/2015	7:44:14	MN	1	22	10.116	159	17.642
02/18/2015	7:45:51	MN	1	22	13.216	159	21.052
02/18/2015	7:47:17	MN	2	22	15.009	159	24.308
02/18/2015	7:47:31	MN	2	22	15.608	159	24.359
02/18/2015	7:49:44	UT	1	22	16.115	159	26.663
02/18/2015	9:49:31	MN		22	19.116	159	58.539
02/18/2015	11:17:26	MN	1	22	15.961	160	3.533
02/18/2015	12:13:08	TT	6	22	14.669	159	37.183
02/18/2015	12:14:41	MN	1	22	14.862	159	38.366
02/18/2015	12:17:26	MN	1	22	14.192	159	38.342
02/18/2015	12:33:02	MN	2	22	15.539	159	34.546
02/18/2015	12:33:24	MN	1	22	15.438	159	33.692
02/18/2015	12:33:56	MNTT	2	22	15.061	159	32.255
02/18/2015	12:38:04	MN	5	22	13.680	159	21.961
02/18/2015	12:39:51	UT	1	22	11.031	159	18.556
02/18/2015	12:40:07	MN	1	22	10.608	159	18.179
02/18/2015	12:40:47	MN	2	22	9.320	159	17.646
02/18/2015	12:41:14	CM	1	22	8.476	159	17.557
02/18/2015	12:44:38	MN	1	22	1.712	159	19.146
02/18/2015	12:45:46	UT	1	21	59.613	159	19.885
02/18/2015	14:30:42	UT	1	22	4.015	159	18.760
02/18/2015	14:32:03	MN	1	22	6.580	159	17.399
02/18/2015	14:33:12	MN	1	22	9.128	159	17.391
02/18/2015	14:33:34	MN	1	22	9.891	159	17.552
02/18/2015	14:38:21	MN	1	22	14.874	159	27.510
02/18/2015	14:40:10	MN	1	22	16.194	159	31.268
02/18/2015	14:40:59	MN	1	22	15.443	159	33.219
02/18/2015	14:47:17	MN	1	22	13.156	159	36.430
02/18/2015	14:47:40	MN	1	22	12.848	159	37.107
02/18/2015	16:28:45	MN	2	22	27.123	159	59.833
02/18/2015	16:39:15	UT	1	22	19.009	160	1.631
02/18/2015	16:48:52	MN	1	22	18.245	160	5.939
02/18/2015	17:16:30	MN	1	22	24.176	159	31.721
02/18/2015	17:17:37	GM	8	22	23.706	159	32.129
02/18/2015	17:29:25	MN	2	22	8.273	159	17.607

Date	Time (HST)	Species*	Number of Individuals	Latitude (N)		Longitude (W)	
				(degrees)	(minutes)	(degrees)	(minutes)
02/18/2015	17:29:45	MN	1	22	7.564	159	17.295
02/18/2015	17:30:40	MN	1	22	5.499	159	17.773
02/18/2015	17:31:37	MN	3	22	3.264	159	18.472
02/18/2015	17:32:08	MN	3	22	2.252	159	19.061
02/18/2015	17:33:02	MN	1	22	0.471	159	19.498
02/18/2015	17:33:47	MN	2	21	59.371	159	19.904
02/17/2016	12:08:01	MN	1	22	19.866	160	1.258
02/17/2016	12:22:57	MN	2	21	56.522	159	43.767
02/18/2016	7:13:43	MN	2	22	11.985	159	18.222
02/18/2016	7:18:23	MN	2	22	14.598	159	30.837
02/18/2016	7:23:25	MN	1	22	12.014	159	45.453
02/18/2016	11:00:10	MN	1	22	14.267	159	24.842
02/18/2016	12:41:19	MN	1	22	14.680	159	24.766
02/18/2016	12:45:39	NS#	1	22	13.349	159	31.763
02/18/2016	15:23:16	SL	40	21	57.436	159	50.431
02/18/2016	15:24:35	SL	13	21	57.053	159	47.429
02/18/2016	15:26:31	MN	1	21	57.367	159	49.941
02/18/2016	15:48:08	UT	1	21	52.833	159	32.029
02/18/2016	15:50:41	UT	1	21	51.949	159	27.264

#On the beach

*Species Code	Species (Latin name)
MN	humpback whale (*Megaptera novaeangliae*)
MNTT	humpback whale (*Megaptera novaeangliae*) and bottlenose dolphin (*Tursiops truncatus*)
GM	short-finned pilot whale (*Globicephala macrorhynchus*)
NS	Hawaiian monk seal (*Neomonachus schauinslandi*)
SL	spinner dolphin (*Stenella longirostris*)
TT	bottlenose dolphin (*Tursiops truncatus*)
USD	unidentified small dolphin
UT	unidentified sea turtle
UWD	unidentified large whale, dead

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B

Mitigation Flight Guidelines

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Appendix B: Mitigation Flight Guidelines

DEPARTMENT OF THE NAVY
PACIFIC MISSILE RANGE FACILITY
P.O. BOX 128
KEKAHA, HAWAII 96752-0128

IN REPLY REFER TO:
PMRFINST 3125.1
N3R/:RC:src
13 FEB 2012

PACMISRANFAC INSTRUCTION 3125.1

From: Commanding Officer, Pacific Missile Range Facility

Subj: MARINE MAMMAL MITIGATION FLIGHT GUIDELINES

Ref: (a) Meeting at PMRF with COMPACFLT Environmental Personnel on 27Jul11

1. Purpose. In accordance with (IAW) reference (a), this instruction is to establish procedures for operational execution and contract oversight for Marine Mammal Mitigation (M3) Flights during fleet exercises.

2. Background. As part of the Navy's permit to train with Medium Frequency Active Sonar (MFAS), marine mammal monitoring is required. This involves 120-160 hours of visual surveys by boat or air. Fleet exercises, such as the Submarine Commander Course (SCC), provide optimal opportunity to accomplish these requirements due mainly to the size and scope of their operations. In an effort to accomplish the M3 goals and ensure safe operation of all craft involved, procedures need to be put in place for civilian observer aircraft.

3. Operational Execution.

a. Aircraft check in points – remain at 2000 feet (ft) or above until cleared by air operations then descend to 800-1000ft as agreed to by Commander, Destroyer Squadron Three One (COMDESRON THREE ONE) and Pacific Missile Range Facility (PMRF) Range Safety.

(1) Northern approach – Makaha Ridge

(2) Southern approach – South Kauai Vortec

b. Check in procedures – aircraft should state the following information upon check in with PMRF Air Operations.

(1) Working call sign

(2) Mission (to include time on range)

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(3) Mode 3

(4) Number of souls on board

(5) Fuel state (meaning hours left on station)

c. Aircraft safe holding area/lost communications procedure – it is a requirement that aircraft have one (1) working radio at all times. Loss of radio communication will require aircraft to depart operating area.

(1) Aircraft must have at least one (1) working radio and be in communication with Range Operations at all times. Radio checks will be conducted if no communication from either the aircraft or Range Air Operations has been received on the quarter hour. If unable to establish radio communications, aircraft will be required to exit operation area, return to base, and call Range Control via land line to report loss of communications.

(2) Safe holding area is 10-15 miles on 360 radial at 2000 ft, weather permitting. In the event of bad weather they will depart the range and return to base. PMRF is a VFR (visual flight rules) range.

(3) Should communications fail, aircraft must attempt to contact Range Facility Control (RFCO) on VHF 125.2 first then the tower on VHF 126.2. If unable, return to base of origination, call Range Operations on a land line explaining loss of communication.

(4) Declared emergency

(a) Squawk 7700 for one (1) minute

(b) Call tower on VHF 125.2

(c) Send out International Air Distress on VHF 121.5

(d) Proceed to PMRF for emergency landing.

(e) All other emergencies, communicate intentions to PMRF if possible

d. Class D Airspace – aircraft is not permitted to enter any Class D airspace unless cleared to enter by Air Operations Control coordinated with PMRF tower.

e. PMRF Operation areas

(1) Area of exercise (SCC operations or other scheduled exercises) is instrumented range within W-188.

(2) Minimum three (3) mile standoff of Niihau island.

(3) Unless in pursuit of mammals, the marine mammal observer aircraft is to remain off the bow of their assigned observer ship. When conducting observations of mammal groups, aircraft will inform PMRF Air Operation Control of sighting and remain with mammal group until observations are completed. Then return to station, which in most cases transects ahead (bow) of assigned ship.

(4) Observer aircraft are prohibited from entering pre-determined ships radii other than assigned unit unless cleared by air operations.

(5) Prior to the execution of any air launches, ships will be required to call in flight quarters. Flight quarter status changes of the assigned M3 surface vessel will be communicated to the M3 aircraft.

(6) Maintain 800 ft hard deck to allow U.S. Navy participating aircraft to maintain an airspace plan to work 500ft and below and 1500ft and above. Working altitude should be 800-1000 ft once cleared by assigned range air controller.

f. Operating around ships

(1) Safety briefs will define safe operating procedures and reference this instruction while also including special instances to include live fire events, Electromagnetic Interference (EMI), Hazards of Electromagnetic Radiation to Person (HERP), and Hazards of Electromagnetic Radiation to Ordnance (HERO) concerns.

(2) Marine Mammal Mitigation team to provide CONOPS of daily activities

(3) Aircraft will communicate clearly and regularly throughout their time on range, particularly when changing their course or altitude. They will inform range control when mammals are observed, when observations have ended, and when they are going to return to assigned ship.

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g. Pre-Flight Procedures for M3 aircraft

(1) Contact range on land line for following information

(a) Daily flight plan will include confirming relevant radio channel frequencies

(b) Situation report (SITREP) from PMRF

(c) Confirm contact phone numbers for all crew on board, PMRF, RFCO and Operations Conductor

(2) Provide PMRF with operational frequencies between aircraft and Marine Mammal Observer onboard ship.

h. Operational instructions between both ships and aircraft and aircraft to aircraft will be addressed at the mandatory safety briefs.

(1) Follow PMRF Air Operation procedures as required for safe operation and mission success.

(2) Operating areas – stay in W-188 unless cleared

4. Conclusion. Safety is of utmost importance and flight check in procedures will be strictly enforced. Failure to comply with range instructions will result in immediate expulsion from range area and termination of Marine Mammal Mitigation participation in fleet exercises.

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List 1