

Humpback Whale Tagging in Support of Marine Mammal Monitoring Across Multiple Navy Training Areas in the Pacific Ocean: Preliminary Summary of Field Tagging Effort in Hawaii in March 2018

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14. ABSTRACT In 2018, Oregon State University (OSU) conducted a tagging and tracking study on Eastern North Pacific humpback whales to determine their movement patterns, occurrence, and residence times within US Navy training and testing areas in Hawaii and elsewhere in the North Pacific. This report presents detailed results from the tagging, biopsy sampling, and photo-ID efforts conducted in Hawaii in 2018, as well as results from previous OSU studies of humpback whales in Hawaii from 1995 to 2015. Whale use of Navy training and testing areas as well as their use of NMFS-identified Biologically Important Areas (BIAs) in Hawaii and Alaska is also examined. Twenty-five humpback whales (20 dive monitoring [DM] tags, 5 Dive Duration Monitoring Plus [DUR+] tags) were tagged off Maui in March 2018. Argos locations were received from 22 of the 25 tags, with tracking periods ranging from 1.1 to 160.0 days (mean=25.8 d, SD=40.0 d, n=17) for DM tags, and 2.2 to 104.5 days (mean=33.5 d, SD=43.4 d, n=5) for DUR+ tags. A total of 77 humpback whales were tagged by OSU in Hawaii prior to 2018 (1995-2000, 2015). Of these, 61 were deployed off Maui (1997, 1998, 1999, 2000, 2015); 10 were deployed off Kauai (1995, 1996, 1997); and 6 were deployed off Hawaii (1996). Tracking data was obtained for 59 whales (the remaining tags provided no locations), with tracking durations ranging from 0.04 to 152.8 d. Data from this study demonstrated a mean residence time in Hawaii from tagging to departure (for whales with known departure date from the archipelago) was 11.9 d (range=1.1-42.8 d, SD=10.2 d, n=23), and was lower for females (mean=10.4 d, range=2.7-22.6 d, n=3) than for males (mean=16.2 d, range=3.3-42.8 d, n=7), lending support to earlier			

studies that found that there is a rapid turnover of individuals in this breeding area during the winter season, as well as differences between the sexes (although the sample size for females was quite small). Migratory destinations were tracked for 9 humpback whales tagged off Maui, supporting previous telemetry, genetic, and photo-ID studies, with 5 whales going to northern British Columbia and Southeast Alaska, and 4 going to the eastern Aleutian Islands. One of the latter 4 whales continued on to the Kamchatka Peninsula, while another traveled to the western end of the Aleutian Island chain off Kamchatka, then to the Bowers Basin in the southwestern Bering Sea, and ultimately north into the Gulf of Anadyr, Russia, just south of the Bering Strait.

A limited number of tagged whales spent time in the Navy training ranges off Hawaii, with Area W188A being the most heavily used (15% of tagged whales), followed by Area W188B (14% of tagged whales). Even fewer whales (7% of less) used the other ranges. A higher proportion of whales tagged off Kauai spent time in the Navy ranges compared to those tagged off Maui. No whales tagged off the island of Hawaii had locations in any of the Navy ranges. This is not surprising, with the ranges' close proximity to Kauai. The longest time spent within a Navy range (13.3 d), however, was from a whale tagged off Maui.

Tagged humpback whales spent time in all Hawaiian BIAs, with the vast majority of locations occurring in the Maui BIA, where maximum residency BIA was 30.2 d. This was not surprising, as most of the tag deployments took place within this BIA. Of the five humpback whales migrating to the northwestern coast of the US and Canada, only two were tracked within the Southeast Alaska BIA. However, their residency there was extensive (maximum of 70 d), and could have been longer had the tags continued to transmit. Humpback whale use of feeding area BIAs outside the Southeast Alaska BIA was minimal, due in part to the small number of whales tracked to these areas, but also for the whales' preference for the southern and western side of the Aleutian Island chain. An area of high use approximately 160 km south of Akutan Island and Unimak Pass by 2 humpback whales tagged 19 years apart highlights this area as important feeding habitat for some humpbacks. The north and west coasts of Haida Gwaii, British Columbia, were also shown to be high use areas.

Dives on the breeding grounds were generally shallow (<100 m), with occasional dives reaching 400 m. However, maximum dive depth was likely limited by bottom depth in many cases, and there were no discernable spatial patterns to dive behavior. Dive behavior during migration was generally similar to on the breeding grounds. However, for the first 7-14 d of migration whales consistently made deep (> 200 m), long-duration (>15 min) dives at night. The purpose of these dives is unclear, but may be related to acoustic orientation or magnetic navigation. Dives on the feeding grounds were very different between the two areas occupied (Haida Gwaii/Southeast Alaska versus eastern Aleutians/Kamchatka/Gulf of Anadyr). One whale (#5736, a male) showed a consistent diel trend in both dive duration and dive depth near the Aleutian Islands and in the western Bering Sea, while the whales near Haida Gwaii showed no temporal trends and made generally shallower dives.

Biopsy samples were collected from 23 of the 25 whales (3 female, 20 male) tagged in Hawaii in 2018. Mitochondrial DNA sequences of the samples resolved six haplotypes; all were previously described for North Pacific humpback whales. The DNA profiles of the 23 individuals were compared to the SPLASH reference database, and two matches (i.e., genotype recaptures) were detected, one to an individual sampled in Hawaii in 2004 and one to an individual sampled in northern British Columbia in 2005.

15. SUBJECT TERMS
Monitoring, marine mammals, baleen whales, tagging, biopsy, genetics, photo-identification, Hawaii Range Complex

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Introduction

The purpose of this Cooperative Ecosystem Studies Unit (CESU) agreement between the Department of the Navy (Navy) and Oregon State University (OSU) is to support marine mammal studies in compliance with the Letters of Authorization and Biological Opinions issued by the United States (US) National Marine Fisheries Service (NMFS) to the Navy for activities in all Pacific Ocean testing and training range complexes. With regard to humpback whales (*Megaptera novaeangliae*), in 2016 NMFS divided the global population into 14 Distinct Population Segments (DPSs) for purposes of listing under the United States' (US) Endangered Species Act¹ (ESA). Four DPSs were designated for the North Pacific based on the location of distinct breeding areas (Federal Register 2016a, b): "Western North Pacific", "Hawaii", "Mexico", and "Central America". The corresponding ESA status is "Endangered" for both the Western North Pacific (estimated at 1,066 animals; Wade 2017) and the Central America DPSs (estimated at 783 animals; Wade 2017), "Threatened" for the Mexico DPS (estimated at 2,806 animals; Wade 2017), and "Not Listed" for the Hawaii DPS (estimated at 11,571 animals; Wade 2017) (Federal Register 2016a, b).

OSU conducted early tagging efforts in the late 1990s in two breeding areas in the North Pacific, Hawaii and Mexico. These studies showed that humpback whales from Hawaii migrate north into the Gulf of Alaska, with some turning west towards Russia and others transiting east towards southeast Alaska (Mate et al. 2007). Tagging in the Revillagigedo Islands off Mexico showed that some of these whales may transit through US West Coast waters while *en route* to migratory destinations in British Columbia (Canada), while others travel through international waters heading toward the Gulf of Alaska and the Aleutian Islands (Lagerquist et al. 2008). These results indicate that North Pacific humpback whales from the Hawaii and Mexico DPSs spend time in Navy activity areas off California, the Pacific Northwest, and the Gulf of Alaska (including more local areas like Behm Canal in Southeast Alaska and the inland waters of Washington State), in addition to spending time in activity areas off Hawaii (for Hawaii DPS whales). However, it is unknown what portion of these DPSs is present in these locations relative to the other North Pacific DPSs, or the proportion of time they spend in them.

Through the use of satellite telemetry, genetic analyses, and photo-identification (photo-ID), this CESU study seeks to provide greater detail on which humpback whale DPSs (as delineated under the ESA; Federal Register 2016a, b) use the Navy activity areas in the North Pacific Ocean. In spring 2018, OSU conducted new satellite tag deployments in Hawaii to track the migrations of humpback whales throughout the Pacific basin for multiple weeks to multiple months after deployment. This Preliminary Summary provides an overview of field survey methodologies for work conducted in Hawaii in March 2018 under this CESU agreement, including the type and number of tags deployed and initial summaries of the data collected through 17 June 2018.

¹ See: "Listing of Humpback Whale Under the ESA" <https://www.fisheries.noaa.gov/action/listing-humpback-whale-under-esa>

Study Goals

With this project, OSU seeks to track humpback whale movement between or through Pacific Navy range complexes and to collect photo-IDs and genetic samples (taken during tag placement) to help delineate the DPSs, as well as to describe their breeding-season home range, migration to the feeding areas, habitat use, and ecological characteristics. In addition, data from tagged whales will provide detail on dive duration, feeding activity, and behavioral characteristics over periods spanning multiple weeks to multiple months. Specifically, the type and number of tags deployed in Hawaii included:

- 5 Telonics RDW-665 Dive Duration Monitoring Plus (DUR+) satellite tags (equipped with accelerometers and lunge-detection software) to monitor dive duration and movement behavior.
- 20 Telonics RDW-665 Dive Monitoring (DM) satellite tags (equipped with depth sensors, accelerometers, and lunge-detection software) to monitor detailed diving (depth and duration) and movement behavior.

Additionally, through the collection of biopsy samples and genetic analyses of tagged whales, this study will provide:

- Sex determination
- Individual identification using mitochondrial haplotype sequencing and nuclear microsatellite loci, including matching with individually-identifying photographs and tissue samples from whales previously sampled
- Assignment of individuals to DPS using mitochondrial haplotype sequencing and nuclear microsatellite loci, with population structure analysis including comparison to existing published databases for humpback whales in the Pacific Ocean.

This Preliminary Summary reports on field efforts, tag deployments, and summaries of data collected from March through 17 June 2018.

Summary of Fieldwork

Hawaii Field Effort – Maui, 10-24 March 2018:

Participants: Ladd Irvine (chief scientist/tagging), Craig Hayslip (photography), Barbara Lagerquist (boat driver, data recorder), Martha Winsor (biopsy collection).

Twenty-five tags (5 DUR+ and 20 DM) were deployed off the leeward side of Maui from 12 to 21 March, using the 10 m R/V *Kohola*, chartered from the Hawaiian Islands Humpback Whale National Marine Sanctuary (HIHWNMS). Tags were deployed using an air powered applicator from a distance of 1.5-4 m. Biopsy samples were collected using a crossbow on the same surfacing as the tag was deployed.

The science team arrived on Maui in the evening of 10 March and moved into their accommodations in Maalaea Harbor. The next day was spent purchasing groceries and supplies, attending a vessel orientation for the Sanctuary research vessel, and readying the vessel for tagging. Prevailing winds were

high during much of the field effort. However, the island generated a large sheltered lee of calm water, which allowed tagging to occur during essentially all daylight hours. Intermittent rain caused a later departure on one day but otherwise the team was on the water by 07:00 h every day and back at the harbor slightly before sunset at 18:00 h. Whales were not abundant compared to other years and Sanctuary personnel thought the peak in whale abundance occurred approximately three weeks early this year. Competitive groups were observed in limited numbers and often were attended by whale-watching boats, making them unavailable for tagging. There was often a lull during the day where whales were difficult to find, although the timing of this varied from morning to afternoon. Many whales were encountered in pairs and were often making extended duration dives where they would hang motionless for 15-20+ minutes before surfacing. The team was often able to see the whales from the surface during these dives and remain above them to make an approach on their first surfacing. Mothers with calves were encountered less frequently and were more difficult to approach. Variations in the number of tags deployed each day were more related to the cooperativeness of the whales encountered rather than the number of whales encountered. Tag deployment locations and details are provided in Table 1. A complete cruise log of every day is provided in Appendix I.

Preliminary Results

Argos satellite locations were received from all but one of the 25 tags deployed on humpback whales in 2018 (Table 1). One other tag provided two locations, but neither one passed our location filtering criteria, so this tag is also not included in summary statistics. Tracking periods and minimum distances traveled by each whale are calculated from deployment through 17 June 2018. Tracking periods for DUR+ tags ranged from 2.2 to 90.2 days (d) (mean = 30.6 d, standard deviation [SD] = 37.6 d, n = 5). Tracking periods for DM tags ranged from 0.1 to 91.2 d (mean = 20.6 d, SD = 26.7 d, n = 18). Minimum distance traveled averaged 1,807 km (SD = 3,070 km, maximum = 7,274 km) for DUR+ tags, and 1,649 km (SD = 2,712 km, maximum = 9,032 km) for DM tags (Table 1).

Locations for humpback whales tagged off Maui ranged over 35 degrees of latitude, from the south coast of Maui to Prince of Wales Island in Southeast Alaska (55 degrees north; Figure 1a). While in Hawaiian waters, the majority of locations were in the inner waters of the "four-island region" of Maui, Molokai, Lanai, and Kahoolawe (Figure 1b). Penguin Bank was another area heavily frequented by the tagged whales, with nine humpbacks spending time there. Eight whales also spent time off the north coast of Maui, but with an obvious avoidance of the nearshore waters off Kahului Harbor.

Seven humpback whales began their northbound migration, and four of these whales reached a high-latitude feeding area during their tracking periods (Figures 1c and 1d). There was a tendency for whales to travel north and northwest through the Hawaiian Island chain after leaving Maui, with migratory departures beginning off the north coast of Oahu (four whales), the north coast of Niihau (one whale), the north coast of Molokai (one whale), and the north coast of Maui (one whale). Departure dates ranged from 17 March to 11 April. The time from tag deployment to migration departure ranged from 3 to 23 d.

Two humpback whales departing from Oahu (Tag #10833 and #843) traveled northwest on a trajectory toward the Aleutian Islands. These tags stopped transmitting approximately 2,200 and 2,400 km northwest of Oahu, 25 and 40 d after departure, respectively. Tag #5736, also departing from Oahu, maintained a more northerly trajectory initially, before heading slightly northwest, arriving to an area approximately 200 km south of Unimak Pass on 28 April (28 d after departure). This latter whale stayed in this area for 20 d, after which it headed west along the southern edge of the Aleutian Island chain for 21 d. Tag #5736 traveled as far west as 161.6°E, approximately 200 km west of the Kamchatka Peninsula, and then headed northeast into the Bering Sea, where it was still being tracked on 17 June, when we began preparation of this Preliminary Summary (Figure 1c).

The tracks of four other migrating whales followed a northeasterly trajectory toward northern British Columbia (Figure 1d). Three whales traveled to Haida Gwaii, reaching the islands on 16 April (Tag #4172, 30 d after leaving Molokai) and 9 May (Tag #5784, 46 d after leaving Maui; Tag #5800, 36 d after leaving Niihau). Both whales #4172 and #5800 traveled to the southwest side of Moresby Island (the south island), reaching points within 5 km of one another at the end of their migration, albeit more than 3 weeks apart. Whale #4172 spent two weeks traveling along the west and north coast of Haida Gwaii before heading south (along the west coast) to Queen Charlotte Sound, where it remained for 5 d until its tag stopped transmitting (on 6 May). Whale #5800 spent 8 d traveling up the west coast of Haida Gwaii to Prince of Wales Island in Southeast Alaska before its tag stopped transmitting on 17 May. Whale #5784 migrated to the northwest coast of Moresby Island, and spent the remainder of its tracking period off the west and north coast of Graham (North) Island. It was still being tracked there on 17 June, the cutoff date for this Preliminary Summary. The fourth whale with a northeast migratory trajectory (Tag #5641) was tracked approximately 630 km northeast of its departure point on Oahu before its tag stopped transmitting, on 2 April (4 d after departure).

Planned Analyses

The following analyses are ongoing and their results will be presented in the Final Report:

- Genetic sex determination and population identity, as it relates to the recently designated DPS.
- Matching of identification photographs of tagged whales to existing photo-ID databases to extend the information available for each tagged individual, including DPS assignment if available.
- Assessment of the number of satellite locations occurring inside versus outside Navy activity areas and Biologically Important Areas (BIAs) for each whale track, with the percentage of locations inside reported as a proportion of the total number of locations obtained for each whale.
- Residence time within Navy activity areas and BIAs for each whale track estimated from filtered Argos locations.
- Kernel home ranges and core areas of utilization within the Hawaii winter breeding area and also for feeding areas (for those whales that make it to such areas), including the degree to which whales used Navy activity areas and BIAs for each track, using the least-squares cross-validation bandwidth selection method.

- Diving patterns and speeds whales used in Hawaii waters, during migration, and in foraging areas, including activity/behaviors in relation to Navy activity areas and BIAs, using the sensor data from the DM and DUR tags.
- Ecological/oceanographic characteristics of the areas visited by the tagged whales to increase our understanding of habitat preferences.

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Table 1. Deployment and performance data for 25 satellite-monitored radio tags deployed on humpback whales off Maui, Hawaii, in March 2018. Genetic analysis of biopsy samples is ongoing so no sex information is listed. Two tags (Tags #5736 and #5784) were still transmitting at the time of report preparation, on 17 June 2018.

PTT	Sex	Lab ID	Deployed	Tag type	Biopsy	ID Photo Collected ^s	# Days Tracked	# Filtered Locations	Total Distance (km)
832*	Unknown	Mno18HI_832	14-Mar-18	DM	Yes	No	0.9	0	0
836	Unknown	Mno18HI_836	12-Mar-18	DM	Yes	Yes	13.0	78	751
839	Unknown	Mno18HI_839	13-Mar-18	DM	Yes	Yes	15.3	97	647
843	Unknown	-	15-Mar-18	DM	No	No	63.0	143	3,294
849	Unknown	Mno18HI_849	13-Mar-18	DM	Yes	No	11.4	18	276
4172	Unknown	Mno18HI_4172	14-Mar-18	DM	Yes	No	53.7	385	6,296
5641	Unknown	Mno18HI_5641	16-Mar-18	DM	Yes	No	17.2	82	1,019
5655	Unknown	Mno18HI_5655	17-Mar-18	DM	Yes	Yes	4.3	20	144
5685	Unknown	Mno18HI_5685	17-Mar-18	DM	Yes	Yes	4.7	22	264
5701*	Unknown	Mno18HI_5701	18-Mar-18	DM	Yes	No	0	0	0
5736**	Unknown	Mno18HI_5736	18-Mar-18	DM	Yes	Yes	91.2	624	9,032
5742	Unknown	Mno18HI_5742	18-Mar-18	DM	Yes	Yes	4.5	20	204
5743	Unknown	Mno18HI_5743	18-Mar-18	DM	Yes	Yes	2.5	7	61
5746	Unknown	Mno18HI_5746	18-Mar-18	DM	Yes	Yes	8.0	49	429
5800	Unknown	Mno18HI_5800	19-Mar-18	DM	Yes	Yes	58.2	214	6,259
5843	Unknown	Mno18HI_5843	20-Mar-18	DM	Yes	No	0.1	2	13
5878	Unknown	Mno18HI_5878	20-Mar-18	DM	Yes	Yes	1.1	8	117
5938	Unknown	Mno18HI_5938	20-Mar-18	DM	Yes	Yes	11.1	58	438
10827	Unknown	Mno18HI_10827	20-Mar-18	DM	Yes	Yes	7.3	38	266
10829	Unknown	Mno18HI_10829	21-Mar-18	DM	Yes	Yes	4.0	25	169
Mean							20.6	105	1,649
Median							9.5	44	352
4177	Unknown	Mno18HI_4177	15-Mar-18	DUR+	Yes	No	2.2	11	126
5644	Unknown	Mno18HI_5644	17-Mar-18	DUR+	Yes	No	11.1	53	576
5784**	Unknown	Mno18HI_5784	19-Mar-18	DUR+	Yes	No	90.2	612	7,274

5826	Unknown	Mno18HI_5826	19-Mar-18	DUR+	Yes	Yes	4.2	23	200
10833	Unknown	-	21-Mar-18	DUR+	No	Yes	45.4	51	860
Mean							30.6	150	1,807
Median							11.1	51	576

*No locations were received (or passed filtering criteria) for Tag #s 832 and 5701, so these tags were not included in summary calculations

**Tag #s 5736 and 5784 were still transmitting as of 17 June 2018

[§]This column refers to tail fluke IDs, which were obtained only from whales that showed their flukes. Dorsal fin IDs were obtained from all tagged whales.

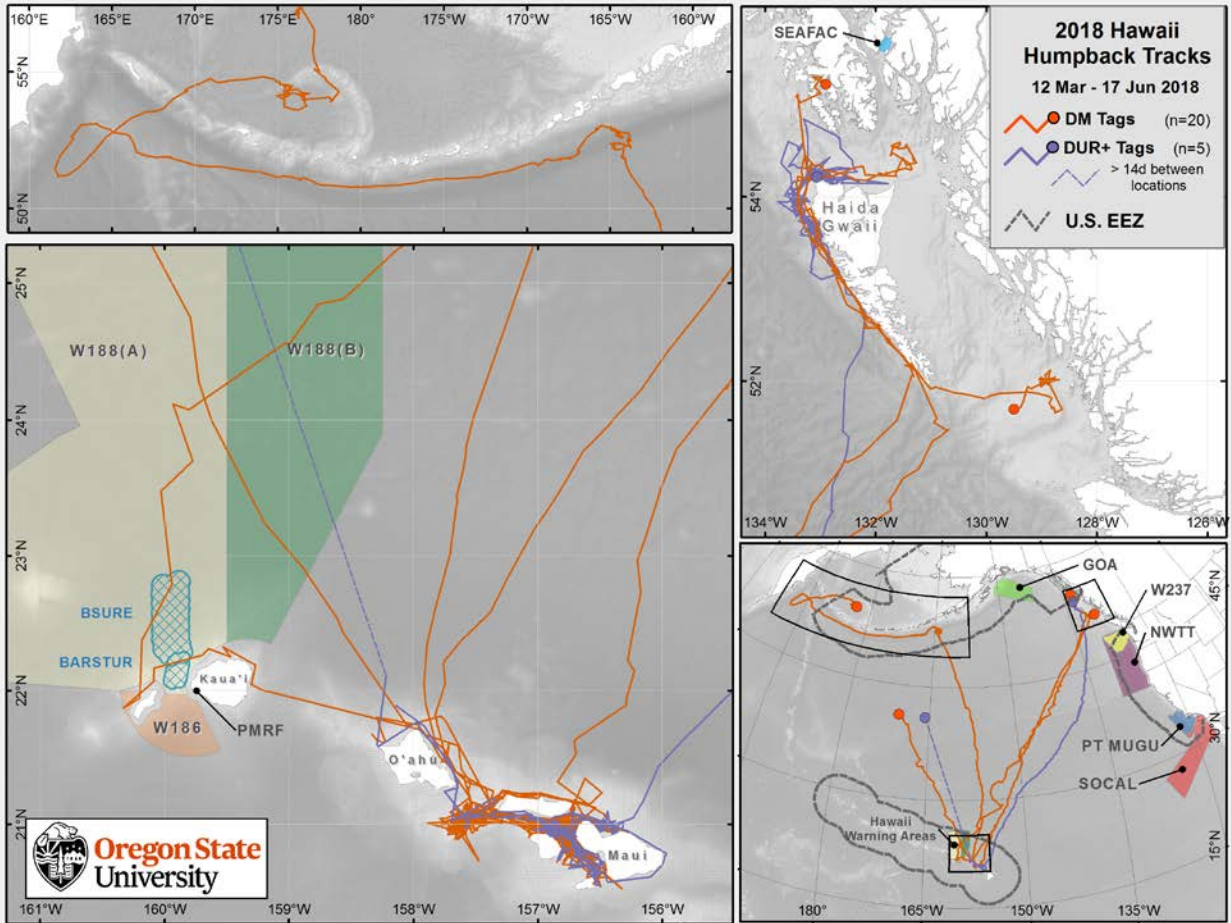


Figure 1. Satellite-monitored radio tracks of humpback whales tagged off Maui, Hawaii, in March 2018. Two tags were still transmitting at the time of report preparation on 17 June 2018. Figure panels are cited in the text as: 1a) bottom right; 1b) bottom left; 1c) top left; and 1d) top right.

Appendix I

Hawaii 2018 Cruise Log

March 10: Land in Maui at 16:30. Get rental car and move into accommodations

March 11: Swap airport rental car for a minivan in town (cheaper that way), then grocery shopping at Costco. 1 pm met Sara Thompson (Vessel Operations Coordinator), Ed Lyman (Large Whale Entanglement Response Coordinator, Hawaiian Islands Humpback Whale National Marine Sanctuary), and Ted (alternate captain for the Sanctuary boat) for a vessel introduction and prep work. Then more grocery shopping and back to the condo to prepare for tagging.

March 12: Met at the boat at 06:30 on the water by 07:00 after a safety briefing. Worked whales all day. Confined to a lee by high winds but it was a large lee. Also had intermittent light rain. Returned to Maalaea at 18:00. Deployed one tag.

March 13: Met at the boat at 09:00 due to rain in the forecast. Rain never materialized. Ed Lyman went out with us. Worked whales all day and returned to Maalaea at 18:00. Deployed three tags, one on a mother/calf.

March 14: Met at the boat at 06:30 and were on the water by 07:00. Navy contract officer Jessica Chen joined us as a recorder and observer. Worked whales all day. Deployed one tag. VERY few whales around in the afternoon. Returned to the dock at 17:30

March 15: Met at the boat at 06:30 and were on the water by 07:00. Jessica Chen joined us again. Worked until 10:00 when an entangled whale was reported. Returned to Maalaea to take on crew for a disentanglement. After reviewing video and photographs it was determined that no disentanglement effort would be made so we returned to tagging at 12:30. Worked the rest of the day and returned to the dock at 18:00. Three whales were tagged.

March 16: Boat was previously booked by another party for this day so it was a day off.

March 17: Met at the boat at 06:30 and were on the water by 07:00. Worked all day in good weather. Tagged three whales in the morning, then whales seemed more scarce in the afternoon. Returned to Maalaea at 18:00 with three whales tagged.

March 18: Met at the boat at 06:30 and were on the water by 07:00. Worked all day in good weather. Deployed six tags on whales. Did not seem to be any more whales around than other days, but the whales seemed more approachable. Returned to Maalaea at 18:00.

March 19: Met at the boat at 06:30 and were on the water by 07:00. Marc Lammers (Sanctuary's Research Coordinator) joined us. Worked all day in good weather. Deployed four tags. Two tags were deployed in the same competitive group where one tagged whale appeared to be the female. That same whale also had a very large, floppy dorsal fin, making us think it could possibly be a hybrid. Returned to Maalaea at 18:30.

March 20: Met at the boat at 06:30 and were on the water by 07:00. Worked all day in good weather. Deployed two tags early in the day, then had difficulty locating and/or approaching additional whales for the rest of the day. Returned to Maalaea at 18:00.

March 21: Met at the boat at 06:30 and were on the water by 07:00. Weather was very windy, creating a relatively small lee with workable ocean conditions. Deployed the last two tags on both whales of a pair. Did not get a biopsy from the last tagged whale, so made subsequent approaches for a biopsy attempt but were unsuccessful and eventually returned to Maalaea at 15:00.

March 22 – 23: Time off/de-mobilization/packing

March 24: Return to Oregon.