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 2019

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14. ABSTRACT
Between 11 and 25 March 2019, Oregon State University (OSU) conducted a field study involving satellite telemetry, genetics, and photo-identification (photo-ID) of humpback whales (Megaptera novaeangliae) in waters of Maui, Hawaii. This work is in support of marine species monitoring activities by the United States (US) Navy in its training and testing range complexes in the Pacific Ocean. Specifically, the study seeks to help delineate humpback whale Distinct Population Segments found off the US West Coast, as well as to describe their feeding-season home range, migration to the breeding areas, diving behavior, habitat use, and ecological characteristics. This Preliminary Summary provides an overview of field survey methodologies as well as initial summaries of the data collected through 1 July 2019. Twenty-five tags were deployed and Argos satellite locations were received from 24 of them. For the period covered by this report, tracking durations ranged from 0.1 to 81.3 days (mean = 21.4 days, standard deviation = 20.2 days), while minimum distance traveled averaged 1,978 km (standard deviation = 2,073 km, maximum = 8,062 km). Locations for humpback whales tagged off Maui ranged from the south coast of Maui to the southwest coast of Baranof Island in Southeast Alaska. While in Hawaiian waters, the majority of locations were in the Maui Nui region. Penguin Bank was another area heavily frequented by the tagged whales, while a few animals ranged into waters of the Papahanaumokuakea Marine National Monument, mostly near Middle Bank. Residence time in Hawaii ranged from 3.6 to 36.5 days. Of the twelve whales that began their northbound migration, three reached the high-latitude feeding area off British Columbia, Canada. Other possible destinations based on the trajectories of partial tracks included the northern Gulf of Alaska and the Aleutian Islands.

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Abstract

Between 11 and 25 March 2019, Oregon State University (OSU) conducted a field study involving satellite telemetry, genetics, and photo-identification (photo-ID) of humpback whales (*Megaptera novaeangliae*) in waters of Maui, Hawaii. This work is in support of marine species monitoring activities by the United States (US) Navy in its training and testing range complexes in the Pacific Ocean. Specifically, the study seeks to help delineate humpback whale Distinct Population Segments found off the US West Coast, as well as to describe their feeding-season home range, migration to the breeding areas, diving behavior, habitat use, and ecological characteristics. This Preliminary Summary provides an overview of field survey methodologies as well as initial summaries of the data collected through 1 July 2019. Twenty-five tags were deployed and Argos satellite locations were received from 24 of them. For the period covered by this report, tracking durations ranged from 0.1 to 81.3 days (mean = 21.4 days, standard deviation = 20.2 days), while minimum distance traveled averaged 1,978 km (standard deviation = 2,073 km, maximum = 8,062 km). Locations for humpback whales tagged off Maui ranged from the south coast of Maui to the southwest coast of Baranof Island in Southeast Alaska. While in Hawaiian waters, the majority of locations were in the Maui Nui region. Penguin Bank was another area heavily frequented by the tagged whales, while a few animals ranged into waters of the Papahanaumokuakea Marine National Monument, mostly near Middle Bank. Residence time in Hawaii ranged from 3.6 to 36.5 days. Of the twelve whales that began their northbound migration, three reached the high-latitude feeding area off British Columbia, Canada. Other possible destinations based on the trajectories of partial tracks included the northern Gulf of Alaska and the Aleutian Islands.

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 monitoring 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' Endangered Species Act[1] (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).

The available information indicates that three of these DPSs, Hawaii, Mexico, and Central America, are primarily found along the western coast of North America during the summer-fall feeding season. During this season, these DPSs occur in somewhat distinct feeding aggregations, with Hawaii animals

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

being found in southeastern Alaska and northern British Columbia; Mexico animals being found off northern Washington-southern British Columbia; and Central America animals being found off California and Oregon (Bettridge et al. 2015). However, some degree of mixing of DPSs occurs in the feeding areas, with Hawaii whales also being found throughout the Gulf of Alaska, the Aleutian Islands, and eastern Russia; and Mexico whales also being found off California and Oregon, as well as in the northern and western Gulf of Alaska and the Bering Sea (Bettridge et al. 2015). Finally, animals from the Western North Pacific DPS may also be present in small numbers in these areas (Bettridge et al. 2015). This mixing of DPSs in the feeding areas complicates unequivocal assignment of individuals to breeding stock for management purposes without further information. As a result, there is a need for data on occurrence and habitat use by these different DPSs in the feeding grounds, and their overlap with shipping traffic, fishing grounds, and areas of military operation, so that management agencies can prioritize actions to mitigate potential impacts from these activities.

Through the use of satellite telemetry, genetic analyses, and photo-identification (photo-ID), this study seeks to provide greater detail on which humpback whale DPSs use the Navy activity areas in the North Pacific Ocean. Previously, in 2017 and 2018 OSU conducted marine species monitoring on behalf of the Navy off the US West Coast and Hawaii under Cooperative Agreement N62473-17-2-0001. This Cooperative Agreement continues the Navy's monitoring requirement in these regions in 2018 and 2019. In spring 2019, 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 2019 under this Cooperative Agreement, including the type and number of tags deployed, along with information on location and date of deployments. Also provided are initial summaries of the data collected through 1 July 2019.

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, activity levels, and other behavioral characteristics over periods spanning multiple weeks to multiple months. Specifically, the type and number of tags deployed in Hawaii included:

- 25 Telonics RDW-665 Dive-Monitoring (DM) satellite tags (equipped with depth and accelerometer sensors and event-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 North Pacific Ocean.

This Preliminary Summary reports on field efforts, tag deployments, and summaries of data collected from March through 1 July 2019.

Summary of Fieldwork

Hawaii Field Effort – Maui, 11-25 March 2019:

Participants: Barb Lagerquist (chief scientist/boat driver/data recorder), Craig Hayslip (photography), Ken Serven (tagging), Renee Albertson (biopsy collection).

Twenty-five DM tags were deployed off the leeward side of Maui from 13 to 21 March, using the 11-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 (in 19 cases), or on subsequent surfacings (in two cases).

The science team arrived in Kahului, Maui, on the evening of 11 March and moved into their accommodations near Maalaea Harbor. The following day, 12 March, was spent grocery shopping and preparing equipment for tagging. The science team also participated in a safety orientation and set up tagging equipment on the research vessel. With the exception of 15 March, when the research vessel was unavailable (chartered by another program), every day up to and including 21 March was spent on the water, at which point all 25 tags had been deployed.

Tagging operations departed from Maalaea Harbor, where the research vessel was docked. Strong winds occurred on most days, but as the direction was primarily east or northeast, a workable area of sheltered water was found in the shadow of the West Maui Mountains. The research vessel was able to operate for approximately 10 hours every day, except for one, when strong northwesterly winds created unworkable conditions by early afternoon. Whales were numerous most days, although long dive times and evasive behavior made tagging difficult on some days. Mothers with calves were encountered less frequently and were more difficult to approach. The presence of other vessels (fishing, whale-watching) in close proximity was a frequent obstacle to tagging. Twenty-five whales were tagged and biopsies were collected from 21 of the tagged whales. One additional biopsy was collected from an untagged whale when the biopsy collector accidently deployed the biopsy dart on an unsuccessful tagging approach. 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 2019 (**Table 1**). Tracking periods ranged from 0.1 to 81.3 d (mean = 21.4 d, SD = 20.2 d, n = 24). Minimum distance traveled averaged 1,978 km (SD = 2,073 km, maximum = 8,062 km, n = 24; **Table 1**). Biopsy samples and fluke photographs were obtained from 21 tagged whales (not necessarily the same 21 whales; see Table 1). Whales will hereafter be referred to by their tag number.

Locations for humpback whales tagged off Maui ranged over 35 degrees of latitude, from the south coast of Maui (20.5°N) to the southwest coast of Baranof Island in Southeast Alaska (56.3°N; **Figure 1**). While in Hawaiian waters, the majority of locations were in the Maui Nui region (inner waters between Maui, Molokai, Lanai, and Kahoolawe; **Figure 2**). Penguin Bank was another area heavily frequented by the tagged whales, with 16 humpbacks spending time there. Four whales had locations within the Papahanaumokuakea Marine National Monument (PMNM), with the majority of these located at the eastern edge of the monument near Middle Bank (approximately 125 km northwest of Niihau (**Figure 2**).

Twelve humpback whales began their northbound migration during their tracking periods (the remaining 12 tags did not transmit long enough to show migration), and three of these whales reached a high-latitude feeding area before their tags stopped transmitting (**Figures 3 and 4**). 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 Molokai (five whales), the north coast of Oahu (five whales), and Middle Bank at the eastern edge of PMNM (two whales). Departure dates, defined as the dates on which whales crossed a 50-km buffer zone around the main Hawaiian Islands (see Mate et al. 2019 for details), ranged from 22 March to 23 April. Residency within the 50-km buffer zone, or the time from tag deployment to migration departure, ranged from 3.6 to 36.5 d (mean = 12.9 d, SD = 9.1 d, n = 12; **Table 1**).

Seven humpback whales followed a northeasterly trajectory toward British Columbia after departing the Hawaiian Islands, with four of them departing from Molokai, two departing from Oahu, and one departing from Middle Bank (**Figure 3**). Two of these whales traveled to Haida Gwaii, reaching the islands on 5 May (whale #843, 29 d after departing the Hawaii buffer zone near Oahu) and on 27 May (whale #847, 34 d after departing from Middle Bank). Whale #843 arrived at the west coast of Graham Island (northernmost Haida Gwaii island) and spent 18 d along the west and northwest coast of the island before being last located on the north coast of the island on 23 May (**Figure 4**). Whale #847 arrived at the southwest coast of Moresby Island (southernmost Haida Gwaii island), spending 5 d on the west coast of Haida Gwaii before traveling north to the southwest coast of Baranof Island in southeastern Alaska (**Figure 4**). Whale #847 was tracked for 5 d in this location before its tag stopped transmitting on 7 June. A third whale (#1390) traveled to within approximately 100 km west of the northern tip of Vancouver Island before its tag stopped transmitting on 1 May (30 d after departing the Hawaii buffer zone near Molokai). The remaining four whales with a northeasterly trajectory were not tracked to a feeding area, and only partial migratory information is available for them. The approximate distances these whales traveled upon leaving the 50-km Hawaii buffer zone ranged from 655 to 3,205 km, over periods of time ranging from 6 to 29 d (**Figure 3**).

Three whales departed from Hawaii on a north-northeasterly trajectory, with possible destinations in the northern Gulf of Alaska (**Figure 3**). One of these whales (#1387) departed from Oahu and was tracked for 6 d and approximately 610 km after leaving the 50-km Hawaii buffer zone. Another whale (#2083) departed from Molokai and was tracked for 12 d and approximately 1,760 km. The third whale (#5648) departed from Middle Bank and was tracked for 24 d and approximately 2,615 km.

The last two of the migrating whales departed from Oahu and followed a north-northwesterly heading, with possible destinations in the Aleutian Islands (**Figure 3**). Whale #4176 was tracked for 5 d and approximately 880 km after leaving the 50-km Hawaii buffer zone, and whale #5655 was tracked for 8 d and approximately 1,185 km after leaving the buffer.

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 potential matches to feeding and breeding areas, throughout the North Pacific Basin, and particularly within Navy ranges.
- 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/HIHWNMS/PMNM 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/HIHWNMS/PMNM for each track, using the least-squares cross-validation bandwidth selection method.
- Dive activity/behaviors in Hawaii waters, during migration, and in foraging areas, using the sensor data from the DM tags.
- Ecological/oceanographic characteristics of the areas visited by the tagged whales to increase our understanding of habitat preferences.

References

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Table 1. Deployment and performance data for 25 satellite-monitored radio tags (Telonics Dive-Monitoring tags) deployed on humpback whales off Maui, Hawaii, in March 2019. Genetic analysis of biopsy samples is ongoing so no sex information is listed. Hawaiian Island (HI) residency is the number of days from tagging to departure from a 50-km buffer zone around the main Hawaiian Islands. Inferred migratory destination, arrival date, and migration duration for incomplete tracks are based on the track trajectory and presented in italics.

PTT	Deployment Date	Date of Last Location	Biopsy/Fluke Photo Collected	Days Tracked	Filtered Locations	Total Distance (km)	HI Departure	HI Residency (d)	Feeding Area Arrival	Migration Duration (d)	Migratory Destination
825	14-Mar-19	-	Yes/Yes	-	-	-	-	-	-	-	-
827	14-Mar-19	8-Apr-19	Yes/Yes	24.5	114	1,404	-	-	-	-	-
830	14-Mar-19	4-Apr-19	Yes/Yes	20.8	88	1,186	-	-	-	-	-
831	16-Mar-19	2-Apr-19	Yes/Yes	17.0	116	916	-	-	-	-	-
834	16-Mar-19	2-Apr-19	No/Yes	16.5	129	1,105	-	-	-	-	-
835	16-Mar-19	6-Apr-19	Yes/Yes	20.4	120	1,946	27-Mar-19	10.9	-	-	-
836	16-Mar-19	5-Apr-19	No/Yes	19.9	128	2,388	24-Mar-19	7.1	-	-	-
838	**16-Mar-19**	**30-Mar-19**	**Yes/No**	**13.4**	**71**	**604**	**-**	**-**	**-**	**-**	**-**
839	16-Mar-19	17-Mar-19	Yes/Yes	0.3	4	49	-	-	-	-	-
840	17-Mar-19	17-Mar-19	Yes/No	0.1	1	18	-	-	-	-	-
843	17-Mar-19	23-May-19	Yes/No	67.8	368	6,046	5-Apr-19	19.9	5-May-19	29.1	Haida Gwaii
845	17-Mar-19	18-Mar-19	Yes/Yes	0.6	7	39	-	-	-	-	-
847	17-Mar-19	7-Jun-19	Yes/Yes	81.3	567	8,062	23-Apr-19	36.5	27-May-19	34.3	Haida Gwaii
848	19-Mar-19	21-Mar-19	Yes/No	2.7	14	123	-	-	-	-	-
1385	19-Mar-19	21-Apr-19	Yes/Yes	33.0	252	3,822	22-Mar-19	3.6	-	-	-
1386	19-Mar-19	1-Apr-19	Yes/Yes	13.0	70	1,122	26-Mar-19	7.2	-	-	-
1387	19-Mar-19	2-Apr-19	Yes/Yes	13.8	87	1,258	27-Mar-19	8.1	-	-	-
1389	19-Mar-19	14-Apr-19	No/Yes	25.4	179	1,612	-	-	-	-	-
1390	19-Mar-19	1-May-19	No/Yes	42.1	343	4,956	31-Mar-19	11.5	*1-May-19*	*30.6*	*Vancouver Island*
2082	20-Mar-19	20-Mar-19	Yes/Yes	0.2	3	14	-	-	-	-	-
2083	**20-Mar-19**	**21-Apr-19**	**Yes/Yes**	**31.4**	**244**	**3,223**	**9-Apr-19**	**19.1**	**-**	**-**	**-**
4175	21-Mar-19	21-Mar-19	Yes/Yes	0.3	2	11	-	-	-	-	-
4176	21-Mar-19	12-Apr-19	Yes/Yes	22.8	151	2,074	7-Apr-19	17.4	-	-	-
5648	21-Mar-19	21-Apr-19	Yes/Yes	30.7	185	3,614	29-Mar-19	7.1	-	-	-

5655	22-Mar-19	5-Apr-19	Yes/Yes	14.7	83	1,878	28-Mar-19	6.9	-	-	-
Mean				**21.4**	**139**	**1,978**		**12.9**			
Median				**18.5**	**115**	**1,331**		**9.1**			

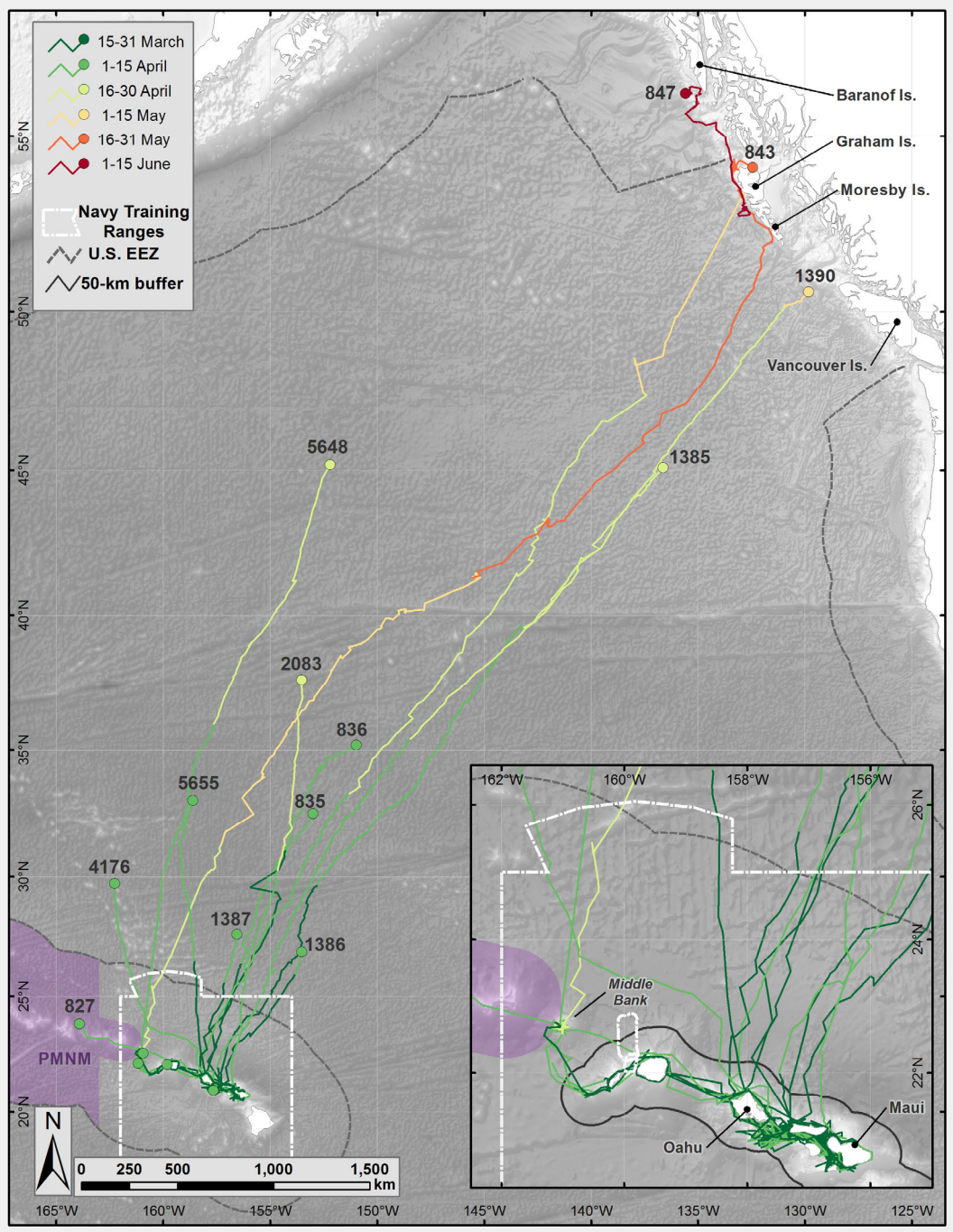

Figure 1. Satellite-monitored tracks of humpback whales tagged off Maui, Hawaii, in March 2019. The main figure shows the full extent of tracks, while the inset highlights tracks within Hawaii and the beginning of migration. Individual US Navy training ranges BSURE and BARSTUR are shown in the inset, while only the overall boundary of training ranges is shown in the main figure. The 50-km buffer zone around the main Hawaiian Islands is only shown in the inset. The eastern portion of the Papahanaumokuakea Marine National Monument (PMNM) is shown in purple.

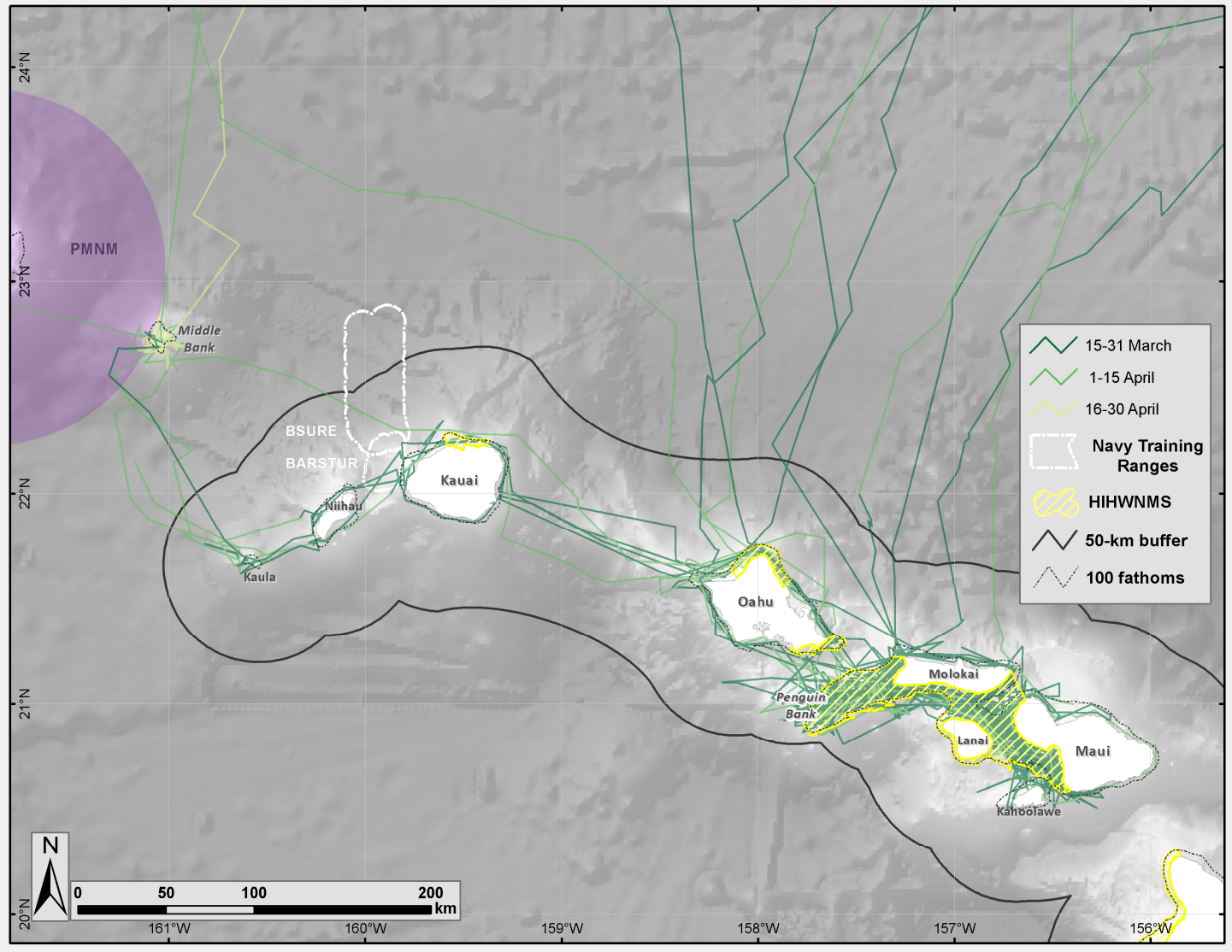

Figure 2. Satellite-monitored tracks in the Hawaiian Archipelago for humpback whales tagged off Maui, Hawaii, in March 2019. The eastern portion of the Papahanaumokuakea Marine National Monument (PMNM) is shown in purple.

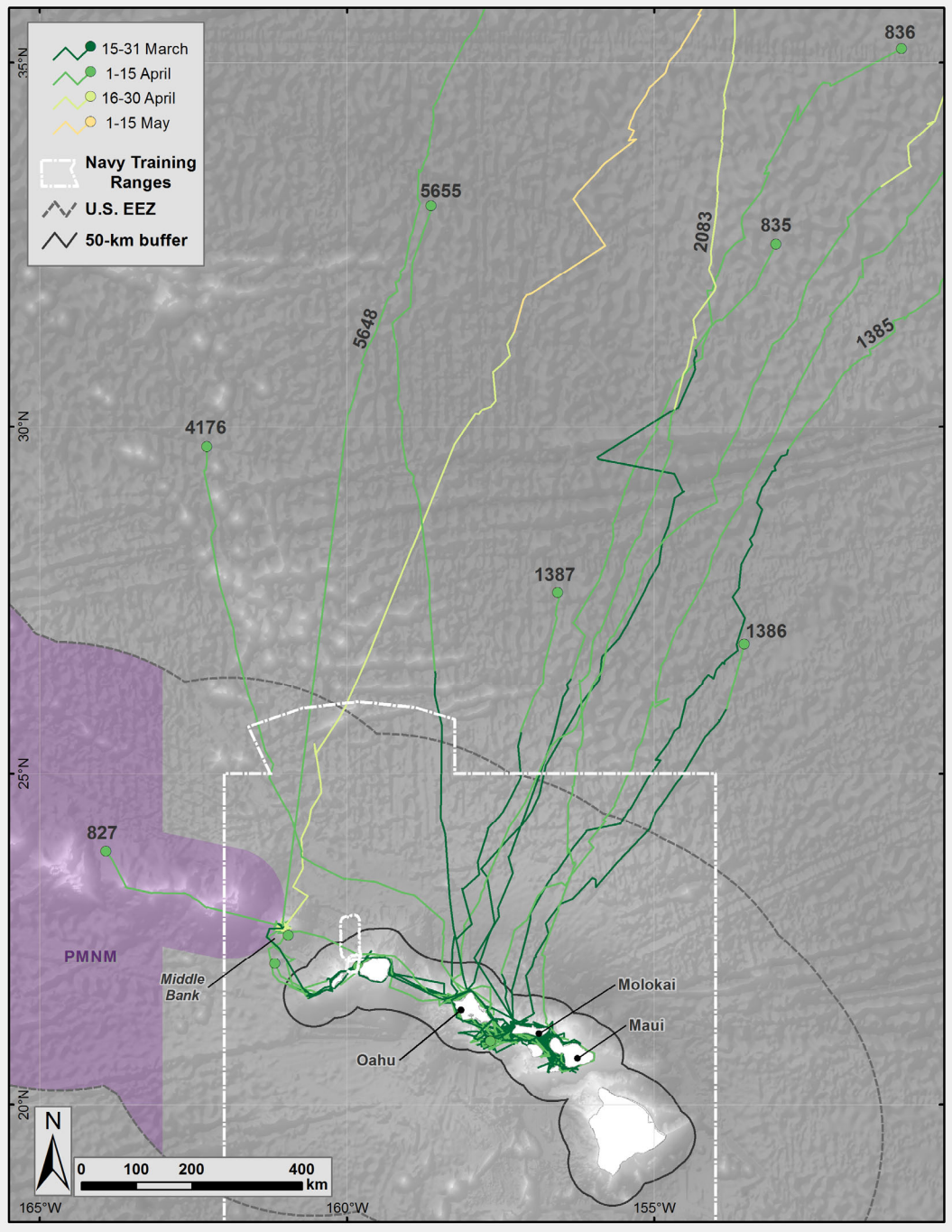

Figure 3. Satellite-monitored tracks of humpback whales tagged off Maui, Hawaii, in March 2019, highlighting partial migration routes for nine whales.

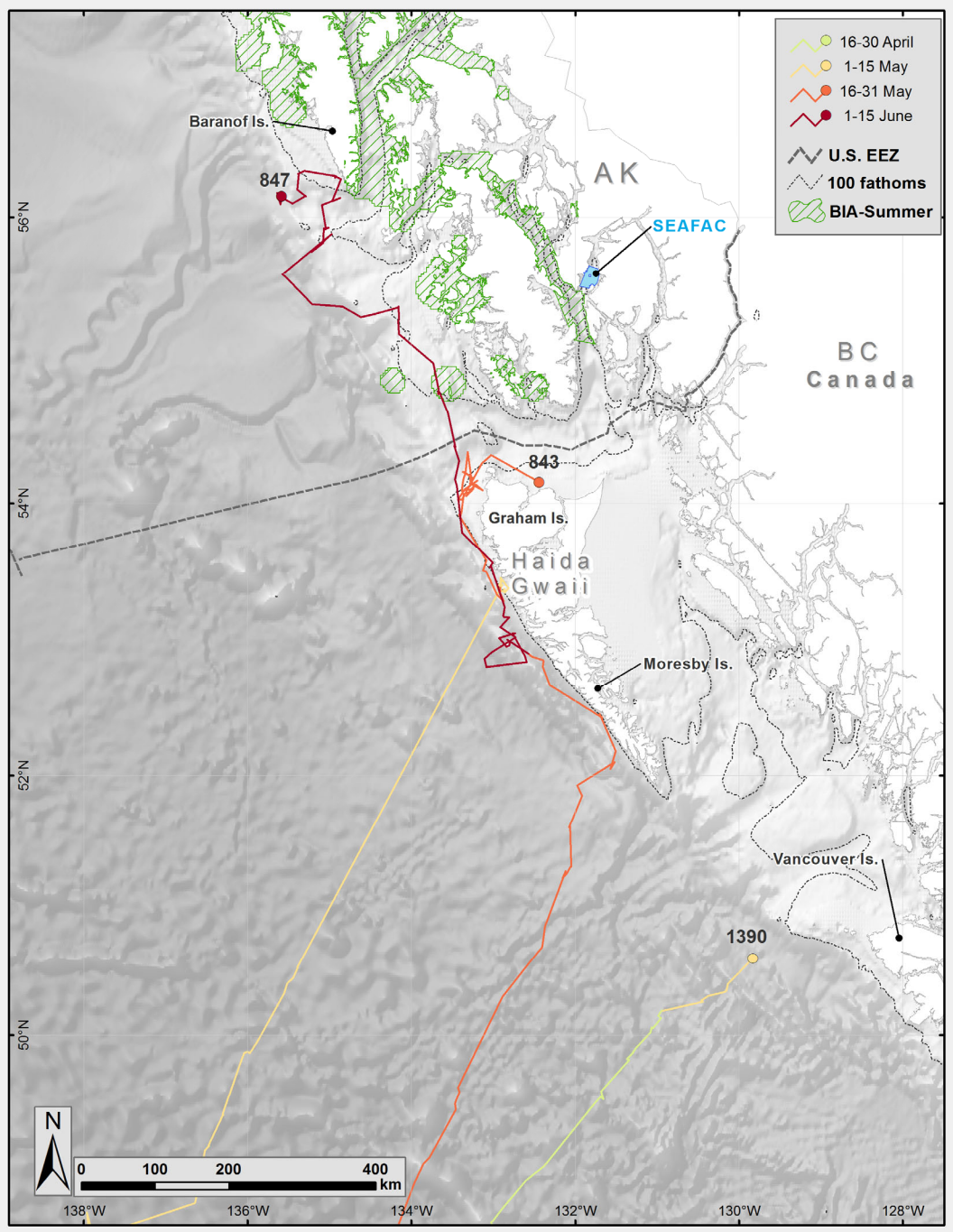

Figure 4. Satellite-monitored tracks of three humpback whales tagged off Maui, Hawaii, in March 2019 that were tracked to feeding areas in British Columbia and southeastern Alaska.

Appendix I

Hawaii 2019 Cruise Log

3/11/19 – Fly to Maui. Arrived at ~8:45 pm and traveled to condo.

3/12/19 – Spent the day grocery shopping, getting equipment ready, and loading gear on the R/V *Kohola*. We also had our safety orientation on the *Kohola*.

3/13/19 – Departed from Maalaea Harbor at 7:49 am and worked in lee of the West Maui mountains. Saw 20-25 whales, but they were not on the surface much and had long downtimes. We saw a mother with a neonate calf (folded dorsal fin) and didn't attempt to tag the mother. We also saw a mother/calf pair in which the mother had a big propeller scar (not recent) on her back. We deployed one DM tag on one adult in a triad. Returned to Maalaea Harbor at 5:17 pm.

3/14/19 – Departed from Maalaea Harbor at 6:58 am and worked in great weather conditions all day. Approached 40 whales, with similar dive times as the previous day. Whales were similarly hard to keep track of. We deployed two DM tags, both on escorts in M/C/E groups. Returned to Maalaea Harbor at 4:50 pm.

3/15/19 – Sanctuary vessel not available. Day off.

3/16/19 – Departed from Maalaea Harbor at 6:55 am and worked in great weather conditions all day. Approached 45 whales, including one competitive group of 14 whales. We deployed 8 DM tags. Returned to Maalaea Harbor at 5:01 pm.

3/17/19 – Departed from Maalaea Harbor at 6:55 am and worked in light winds early in the morning. Approached 22 whales and deployed 2 DM tags. High NNW winds picked up mid-morning, wrapping around both sides of Maui and made waters unworkable by the early afternoon. Returned to Maalaea Harbor at 1:52 pm.

3/18/19 – Departed from Maalaea Harbor at 6:53 am and worked in good weather conditions all day, with NE winds creating unworkable conditions in Maalaea Bay and north of Lahaina. For much of the day whales were either evasive or boats were in the vicinity. Two DM tags were deployed in the last hour of the day. Returned to Maalaea Harbor at 5:13 pm.

3/19/19 – Departed from Maalaea Harbor at 6:54 am. The weather was good in the morning, but winds picked up from the west and a short, steep southeasterly swell picked up in the afternoon. Five DM tags were deployed. The *Kohola* experienced problems with the starboard engine. It kept shutting off. Captain Sara Thompson hooked it up to a diagnostic computer but couldn't determine the problem. It

has had its thermostat removed because it was overheating. It may have been running too rich and fouling the spark plugs when at idle for too long. Barb Lagerquist began shutting it down at low rpms or idle and only using it when needed. Returned to Maalaea Harbor at 4:49 pm.

3/20/19 – Departed from Maalaea Harbor at 6:55 am. The weather was calm in the morning and afternoon, with a 12-15 knot SE breeze in mid-day. Three DM tags were deployed. Returned to Maalaea Harbor at 5:07 pm.

3/21/19 – Departed from Maalaea Harbor at 6:51 am and worked in the lee of the West Maui mountains. We approached 29 whales and deployed two DM tags. Returned to Maalaea Harbor at 4:54 pm. Unpacked all of our equipment from the *Kohola*, as this was our last day on the water.

3/22 to 3/24/19 - Time off/de-mobilization/packing.

3/25/19 - Return to Oregon.