

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 Washington in September-October 2019

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Abstract

Between 16 September and 7 October 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 the Strait of Juan de Fuca, Washington. 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 18 November 2019. Twenty-four tags were deployed and Argos satellite locations were received from 22 of them. For the period covered by this report, tracking durations ranged from 4.2 to 59.3 days (mean = 35.6 days, standard deviation = 15.9 days), while minimum distance traveled ranged from 171 to 3,186 km (mean = 1,669 km, standard deviation = 925.3 km). Locations for humpback whales tagged off Washington ranged from the northwest corner of Vancouver Island, British Columbia, Canada, to Seaside, Oregon. The densest area of locations occurred over Swiftsure Bank, approximately 16 km northwest of Cape Flattery, while a smaller cluster of locations occurred approximately 45 to 65 km offshore of Grays Harbor, southern Washington. One whale tagged in 2019 had been previously tagged by OSU in Washington in 2018, providing a unique opportunity to compare movements between years for the same individual. Killer whales (*Orcinus orca*) were observed and photographed opportunistically on two occasions in 2019. Information is also presented for seven encounters with killer whales made during the 2018 field effort. Of the estimated 91 individual killer whales encountered, 45 were matched to the J, K, and L pods of the Southern Resident killer whale population.

Between 16 September and 7 October 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 the Strait of Juan de Fuca, Washington. 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 18 November 2019. Twenty-four tags were deployed and Argos satellite locations were received from 22 of them. For the period covered by this report, tracking durations ranged from 4.2 to 59.3 days (mean = 35.6 days, standard deviation = 15.9 days), while minimum distance traveled ranged from 171 to 3,186 km (mean = 1,669 km, standard deviation = 925.3 km). Locations for humpback whales tagged off Washington ranged from the northwest corner of Vancouver Island, British Columbia, Canada, to Seaside, Oregon. The densest area of locations occurred over Swiftsure Bank, approximately 16 km northwest of Cape Flattery, while a smaller cluster of locations occurred approximately 45 to 65 km offshore of Grays Harbor, southern Washington. One whale tagged in 2019 had been previously tagged by OSU in Washington in 2018, providing a unique opportunity to compare movements between years for the same individual. Killer whales (*Orcinus orca*) were observed and photographed opportunistically on two occasions in 2019. Information is also presented for seven encounters with killer whales made

during the 2018 field effort. Of the estimated 91 individual killer whales encountered, 45 were matched to the J, K, and L pods of the Southern Resident killer whale population.

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 training and testing 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 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).

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 being found in southeastern Alaska and northern British Columbia; Mexico animals being found off 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, eastern Russia, and Washington-southern British Columbia; 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, NMFS 2016a, b). 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.

Since 2017, OSU has been conducting marine species monitoring on behalf of the Navy off the US West Coast and Hawaii under Cooperative Agreements N62473-17-2-0001 and N62473-19-2-0002. The study seeks to provide greater detail on which humpback whale DPSs use the Navy activity areas in the North Pacific Ocean through the use of satellite telemetry, genetic analyses, and photo-identification (photo-ID) (Mate et al. 2019a, b). This Preliminary Summary provides an overview of field survey methodologies

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

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for work conducted in Washington in September and October 2019, 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 18 November 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 biopsy samples (taken during tag placement) to help delineate the DPSs, as well as to describe their feeding-season home range, migration to the breeding areas, habitat use, and ecological characteristics.

Besides tracking feeding-area movements and long-distance migrations, tag data will also provide detail on dive duration, activity levels, and other behavioral characteristics over periods spanning multiple weeks to multiple months. The type and number of tags deployed in Washington in 2019 included:

- 24 Telonics RDW-665 Dive-Monitoring (DM) satellite tags (equipped with depth sensors, accelerometers, and event-detection software) to monitor detailed diving behavior and activity levels.

Additionally, through the collection of biopsy samples for genetic analyses, 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.

Finally, through the collection of identification photographs and matching to existing photo-ID databases, we will be able to extend the information available for each individual, including sighting history and potentially DPS assignment.

Summary of fieldwork in Washington, 16 September to 7 October 2019

Participants: Ladd Irvine (chief scientist/tagging), Craig Hayslip (photography), Tomas Follett (boat driver, data recorder), Daniel Palacios (biopsy collection from 16–29 September), Ken Serven (biopsy collection from 29 September – 4 October), and Barbara Lagerquist (biopsy collection from 4–7 October).

The science team arrived in Neah Bay, Washington, the evening of 16 September and prepared for tagging. Tagging operations took place in the western Strait of Juan de Fuca and nearby offshore waters, departing out of Neah Bay harbor. The Strait of Juan de Fuca is bisected along its long axis by the US-Canada international boundary (i.e., the Exclusive Economic Zone, EEZ; Figure 1), and care was taken to

only operate in US waters at all times. Details of tag deployment and collection of biopsies and photo-IDs are provided in Table 1. A complete summary of daily activities is provided in Appendix I.

Weather was generally either very good (clear, winds < 10 knots) or very bad (winds 15-25 knots and/or rain) in equal measure (see Tables A1 and A2 in Appendix II for daily weather conditions during the 2019 field effort, as well as Figure A1 for historical wind speeds for the area), such that the team was able to get on the water for 10 of the 21 days in the field. Tagging took place from a 6.7-m rigid-hulled inflatable boat (RHIB) during the first three days on the water (18 to 20 September), after which the RHIB experienced a mechanical problem and was returned to Newport, Oregon, for repair. The RHIB repair (21-23 September) fortunately coincided with a period of bad weather (maximum winds 12-18 knots, maximum waves 1.7-3.2 m; see Appendix II) in which boat operations would have been canceled anyway. Tagging resumed on 24 September, and after 30 September tagging was conducted from a 7.0-m RHIB. The science team traveled home to Oregon on 7 October.

Whales were most often observed near Swiftsure Bank, typically in large numbers (> 50). Swiftsure Bank is an area of shallow water (approximately 45 m depth) centered at approximately 48.543°N and 124.992°W (per NOAA nautical chart 18460, Strait of Juan de Fuca Entrance), with a large portion of it in Canadian waters (Figures 1 and 2). Whales often occurred very close to, or in Canadian waters, where the team was not permitted to tag. Surface feeding was observed on two days, one of which involved a behavior that was not observed in 2018 (our first year of tagging in this area). During this behavior, whales would pull their flukes out of the water, rapidly move them back and forth, and then lunge through the area where the flukes had been moving.

Fifteen tags were deployed in the first three days on the water (18 to 20 September) and nine were deployed during four days between 24 September and 6 October. Biopsy samples were collected from 18 of 24 tagged whales and an additional nine biopsy samples were collected from untagged whales. Tags were deployed using an air-powered applicator from a distance of 2-4 m. Biopsy samples were collected using a crossbow, on the same surfacing as the tag was deployed (in 17 cases), or on a subsequent surfacing in one case, from a distance of 3 m.

At least four whales were observed with marks that suggested they had been tagged in a previous year. Based on photo-ID analysis back at the lab, all four whales were positively identified as having been tagged by OSU in the area during 2018. One of these whales was re-tagged during our tagging efforts in 2019 (tag # 4177 in 2018 and # 5743 in 2019). Fluke identification (ID) photographs were collected for 18 tagged whales and four biopsied-only whales. Resight assessment of all ID photos taken during the 2019 tagging effort is underway, which may reveal more matches with previously tagged whales.

Killer whales were observed opportunistically on two occasions during our tagging operations in 2019, but were not approached. On 30 September a minimum of seven killer whales (including two adult males, two juveniles, no calves) were seen, while on 6 October two to three individuals were sighted. Killer whales were not approached closer than 50 yards (i.e., "taken") due to the limited number of authorized takes in our NMFS Scientific Research permit (50 killer whale takes annually).

Preliminary Results

Twenty-four DM tags were deployed on humpback whales out of Neah Bay, Washington, between 18 September and 6 October 2019. Argos satellite locations were received from 22 tags (Table 1); two tags did not transmit at all (one of which was struck by the biopsy dart during deployment and possibly damaged). Tracking details are presented from the time of tagging to the cutoff date for this Preliminary Summary of 18 November. Tracking periods ranged from 4.2 to 59.3 days [d] (mean = 35.6 d, standard deviation [SD] = 15.9 d, n = 22). Minimum distance traveled ranged from 171 to 3,186 kilometers [km], (mean = 1,669 km, SD = 925.3 km, n = 22).

Locations for humpback whales tagged off Washington ranged from the northwest corner of Vancouver Island, British Columbia, Canada, to Seaside, Oregon (Figure 1). The vast majority of locations occurred between Clallam Bay, 30 km east of Neah Bay, and approximately 100 km west-southwest of Cape Flattery. A smaller cluster of locations occurred approximately 45 to 65 km offshore of Grays Harbor, southern Washington. The densest area of locations occurred over Swiftsure Bank, approximately 16 km northwest of Cape Flattery (Figure 1).

The whale with tag # 5743 in 2019 was the same whale that was tagged by OSU with tag # 4177 in Washington in 2018, where it was photo-ID'd and genetically identified as a male from a biopsy sample (Mate et al. 2019b). This re-tagging event provided a unique opportunity to compare movements between years for the same individual. In 2018, this whale (hereafter referred to as whale # 4177/5743) was tagged in Swiftsure Bank on 3 August, where it spent 2 d before heading approximately 70 km southwest to the shelf edge between Juan de Fuca and Nitinat Canyons (Figure 2). The whale remained in the area for 3 d before heading approximately 110 km northwest to Clayoquot Canyon, where it spent another 6 d until its tag's stopped transmitting. This tag was an Advanced Dive Behavior (ADB) tag that we were unable to recover (presumably it came off the whale still attached to its housing and sank to the seafloor, where it either failed to release or became lodged on the seafloor after release; see Mate et al. 2019b). In 2019, whale # 4177/5743 was tagged on 20 September, within 10 km of where it was tagged the previous year (Figure 2). After spending a couple of days in the tagging area, the whale traveled to the shelf edge between Juan de Fuca and Nitinat Canyons, as in 2018, where it remained for the next 20 d until its tag stopped transmitting (Figure 2). Despite a difference of 48 d in tagging date between the two years, the similarities in areas visited by this whale demonstrate the persistent foraging locations of Swiftsure Bank and the offshore canyons to the northwest corner of the Olympic Peninsula for this animal.

Killer whale photo-ID

In addition to the two killer whale encounters during fieldwork in 2019 (an estimated 10 animals), we include here information from seven sightings made in 2018 in Washington (an estimated 81 animals) under this Cooperative Agreement. A total of 1,042 killer whale photographs were obtained from seven of these sightings (Table 2). No identifying photographs were taken during two sightings (of three whales each; see Table 2). All photos were sent to Brad Hanson and Candice Emmons at NMFS's Northwest Fisheries Science Center for matching with existing killer whale identification catalogs. Forty-five matches were found, with all animals identified as Southern Resident killer whales (including

multiple sightings of some individuals; Table 2). Of these, 12 whales were from J pod, five from K pod, and 28 from L pod. Groups consisted of individuals from J and L pods together (three sightings), K and L pods together (one sighting), or unmixed groups of J, K, and L pods (three sightings each; Table 2). A map showing the location of all nine killer whale sightings made in 2018 and 2019 is presented in Figure 3.

Planned analyses

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

- Genetic sex determination and population identity, as it relates to the recently designated DPSs.
- 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 interpolated locations at regular intervals.
- Kernel density home ranges and core areas of use for each track, using the least-squares cross-validation bandwidth selection method.
- Diving patterns and foraging behaviors, 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 requirements.

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Table 1. Deployment and performance data for 24 satellite-monitored radio tags (Telonics DM tags) deployed on humpback whales off Washington in September and October 2019. Genetic analysis of biopsy samples is ongoing so no sex information is listed. Deployment dates are represented as UTC dates.

Tag #	Deployment Date	Date of Last Location	Biopsy Collected	Fluke Photo Collected	Sex	# Days Tracked	# Filtered Locations	Total Distance (km)
833	18-Sep-2019	8-Oct-2019	Yes	Yes	Unknown	19.9	180	873
4173	19-Sep-2019	20-Oct-2019	Yes	Yes	Unknown	30.9	224	1,478
5670	19-Sep-2019	10-Nov-2019	Yes	No	Unknown	51.2	295	3,186
5678	19-Sep-2019	18-Nov-2019**	Yes	Yes	Unknown	59.3	446	3,181
5679	19-Sep-2019	29-Sep-2019	Yes	Yes	Unknown	9.9	91	515
5701*	19-Sep-2019	-	Yes	No	Unknown	-	-	-
5742	19-Sep-2019	18-Nov-2019**	Yes	No	Unknown	59.1	408	1,786
5743***	20-Sep-2019	15-Oct-2019	No	Yes	Unknown	24.0	208	1,054
5803	20-Sep-2019	2-Nov-2019	No	Yes	Unknown	42.1	246	2,210
5826	20-Sep-2019	6-Nov-2019	Yes	Yes	Unknown	46.7	298	2,943
5840	21-Sep-2019	18-Nov-2019**	Yes	Yes	Unknown	58.0	288	3,098
5921	24-Sep-2019	18-Nov-2019**	Yes	No	Unknown	54.3	318	3,002
10820	24-Sep-2019	21-Oct-2019	Yes	No	Unknown	26.8	236	1,472
10823	24-Sep-2019	4-Nov-2019	Yes	Yes	Unknown	40.8	233	1,286
10826	24-Sep-2019	29-Sep-2019	Yes	Yes	Unknown	4.2	44	171
10827	30-Sep-2019	26-Oct-2019	Yes	Yes	Unknown	25.4	238	1,147
10830	30-Sep-2019	14-Nov-2019	No	Yes	Unknown	44.8	319	2,385
10833	5-Oct-2019	14-Nov-2019	No	Yes	Unknown	40.0	299	1,417
10838	5-Oct-2019	30-Oct-2019	Yes	Yes	Unknown	24.4	129	903
10840	5-Oct-2019	1-Nov-2019	No	Yes	Unknown	26.2	244	896
10842	5-Oct-2019	24-Oct-2019	Yes	No	Unknown	18.7	181	861
23031	5-Oct-2019	18-Nov-2019**	Yes	Yes	Unknown	43.3	379	1,550
23038	7-Oct-2019	14-Nov-2019	Yes	Yes	Unknown	32.2	195	1,306
23043*	7-Oct-2019	-	No	Yes	Unknown	-	-	-
Mean						35.6	250	1,669
Median						36.1	241	1,445

*No locations were received for tag #s 5701 and 23043, so these tags were not included in summary calculations.

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**These tags were still transmitting as of 18 November 2019, the cutoff date for this Preliminary Summary.

***The animal with DM tag # 5743 in 2019 was previously tagged during the 2018 field effort with ADB tag # 4177 (as well as biopsy sampled and photo-ID'd)

Table 2. Summary of killer whale sightings during humpback whale tagging efforts off Washington in 2018 and 2019, including photo-ID matches to Southern Resident killer whales (in the photo-ID catalog of Brad Hanson and Candice Emmons, NMFS/Northwest Fisheries Science Center).

Sighting #	Date and Time (PDT) of Sighting	Estimated Group Size	Photo Matches		
			J Pod	K Pod	L Pod
1	3-Aug-2018, 10:35	4	2	0	2
2	3-Aug-2018, 16:38	50	3	0	18
3	6-Aug-2018, 10:45	7	3	0	3
4	8-Aug-2018, 10:05	10	0	3	0
5	8-Aug-2018, 11:24	1	0	0	1
6	15-Aug-2018, 10:04	6	4	0	0
7	17-Aug-2018, 10:03	3	No useful photos		
8	30-Sep-2019, 17:51	7	0	2	4
9	6-Oct-2019, 18:30	3	No photos taken		
Total		91	12	5	28

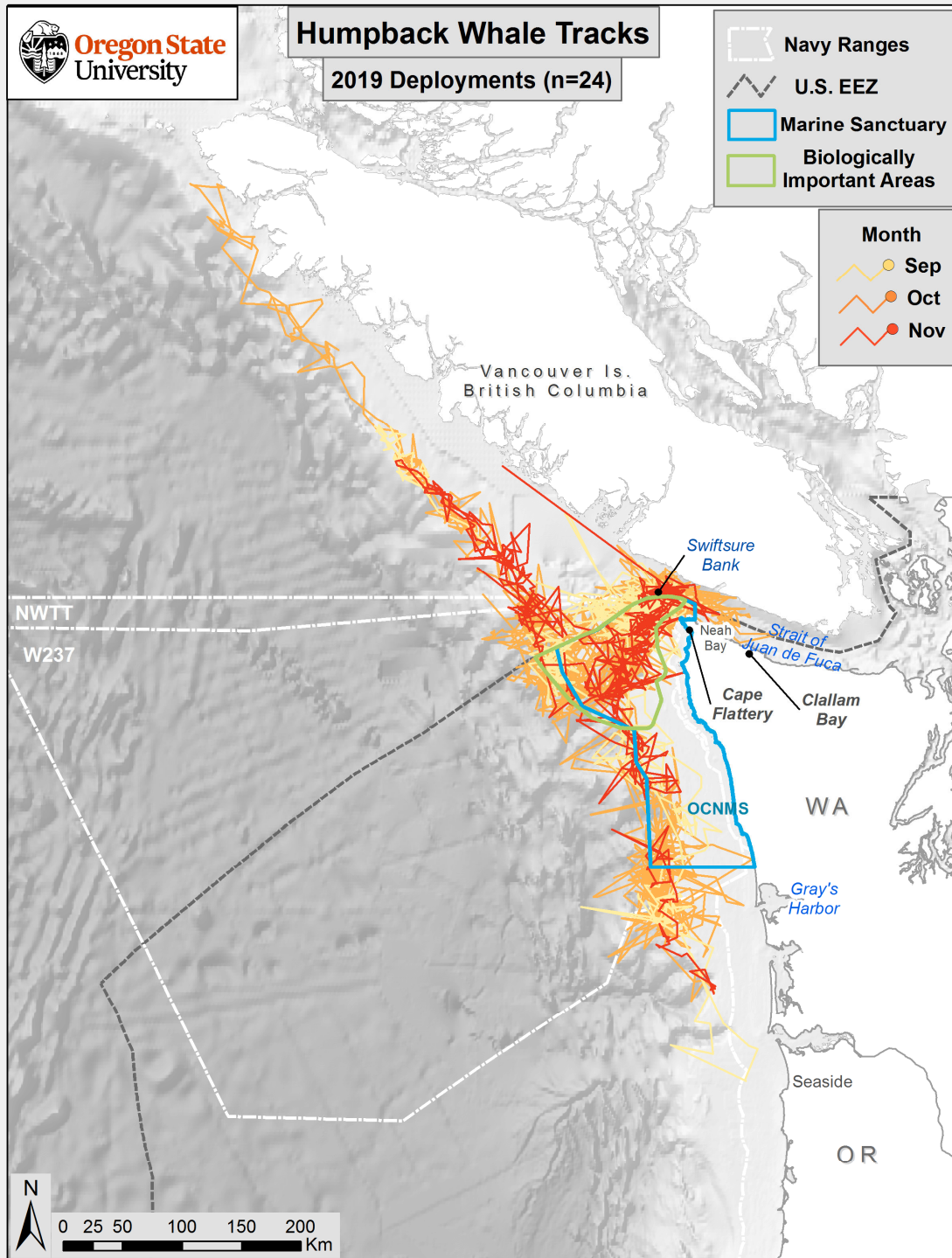


Figure 1. Satellite-monitored tracks of humpback whales tagged off Washington in September and October 2019. Circles indicate each track's last location and circle color corresponds to a month, as shown in the legend. The Olympic Coast National Marine Sanctuary (OCNMS) is indicated by the hatched polygon in blue, and the northern Washington BIA by the hatched polygon in yellow.

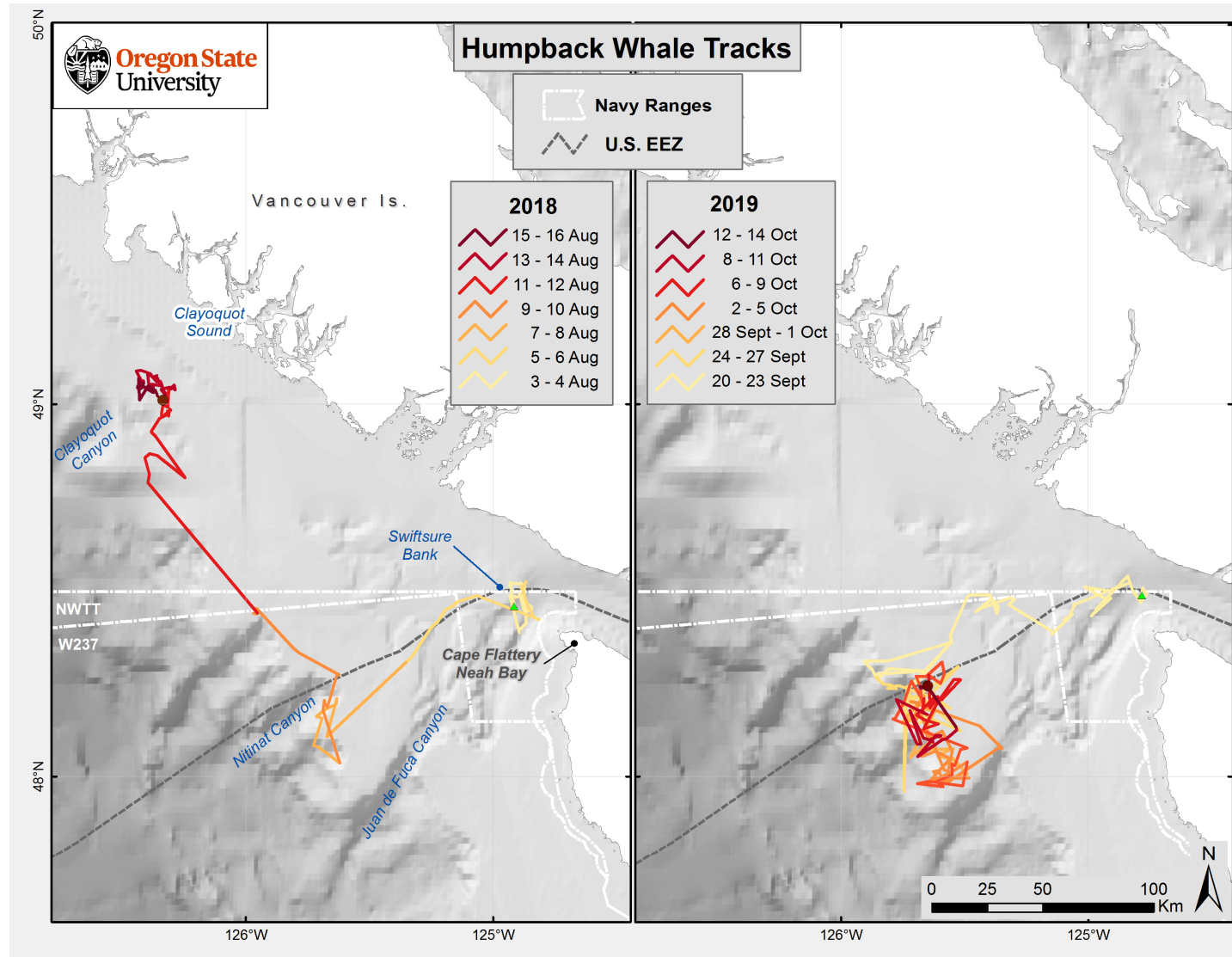


Figure 2. Satellite-monitored tracks of a humpback whale tagged off Washington in August 2018 (ADB tag # 4177, genetically identified as a male; left) and again in September 2019 (DM tag # 5743; right). The green triangles represent the tagging location and circles indicate each track's last location. Track segments of the same color correspond to the time periods shown in the legend.

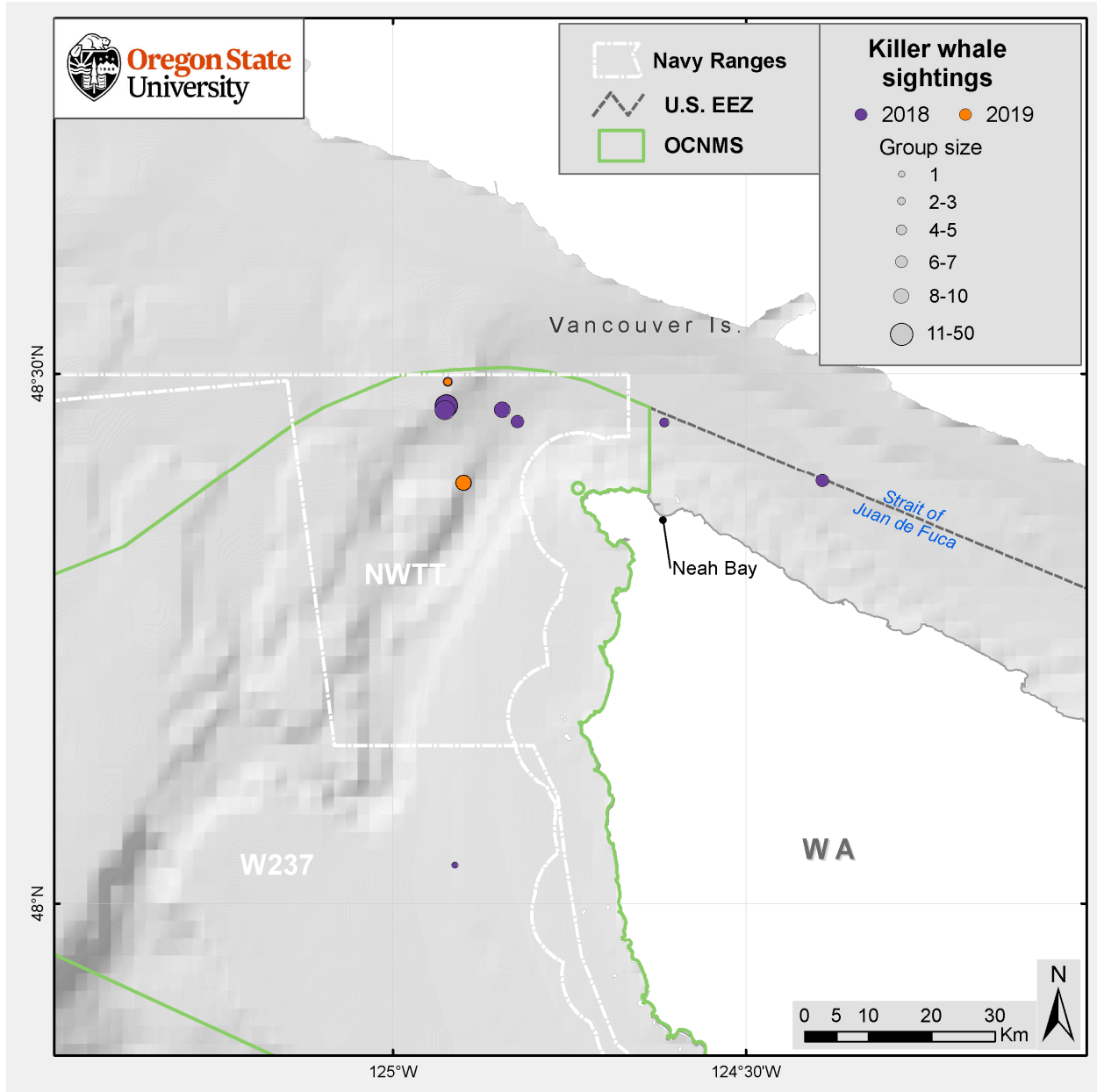


Figure 3. Locations of killer whale sightings during humpback whale field efforts off Washington in 2018 and 2019 (purple and orange circles, respectively). Circle size is scaled to group size, as reported in more detail in Table 2.

Appendix I: Summary of daily activities during Washington 2019 fieldwork

Daily log

- 9/16 Travel from Newport, OR, to Neah Bay, WA. Departed Newport at 10:00 and arrived in Neah Bay at 20:45. Stopped at Costco in Warrenton to get lunch supplies. The right rear trailer bearing was hot when we stopped for lunch, but we added grease and it cooled down.
- 9/17 Rain all day. Took care of some additional grocery shopping, got the boat ready for tagging and other miscellaneous activities.
- 9/18 Departed Neah Bay at 8:40. Worked our way west along the shipping lanes to Swiftsure Bank, south ~10 miles, and back to Swiftsure. Observed one medium-sized group (~ 20 whales) and one large group (~100 whales), both of which were in Canadian waters. The larger group was only about 500 m across the border. Otherwise we mostly encountered solitary whales with the exception of one mother/calf pair and an additional pair of adults. One whale tagged and biopsied. Returned to Neah Bay at 19:00.
- 9/19 Departed Neah Bay at 8:00. Ran toward Swiftsure Bank and encountered numerous scattered groups of whales. Worked the area all day until it started raining in the afternoon. Eventually it was raining hard enough to make tagging difficult. We deployed the tag in the applicator and decided it was too wet to try getting another ready. Six whales were tagged and biopsies were collected from each tagged whale plus an additional whale that was too small to tag. Returned to Neah Bay at 17:00.
- 9/20 Departed Neah Bay at 8:30 and worked the same area as the last two days. Most whales were back on the Canadian side of the border, but we found scattered groups of three to six whales. Worked all day, tagging four whales and collecting biopsies from two of them. On the way in, the boat started making grinding and clunking noises suggesting there was a problem with the outdrive. We returned to Neah Bay at 19:00 and pulled the boat out of the water in order to transport it back to Newport for repairs.
- 9/21 Traveled to Newport with the boat, arriving at 16:00. Met our boat engineer, Ken Serven, and he got to work on it with the expectation it would be finished by the end of the following day. Rest of the team had a down day in Neah Bay.
- 9/22 Day off while RHIB was getting repaired.
- 9/23 Boat repairs were completed, so traveled from Newport to Neah Bay with the boat for tagging on 9/24.
- 9/24 Departed Neah Bay at 08:15 and worked generally the same area as the last days on the water. Found a large group of surface-feeding whales but they were difficult to tag as they were not on the surface long, were constantly changing direction, and there were so many it was a constant

challenge to not run over other whales during an approach. The surface feeding dissipated around 13:00, after which whales became fairly scarce. We found two groups of five to eight whales but unfortunately they traveled into Canadian waters, so we had to abandon them. We tagged a total of four whales and collected biopsies from all of them, then returned to Neah Bay at 18:15.

- 9/25 Departed Neah Bay at 08:00 and travelled to the same area as previous days near Swiftsure Bank. Few whales were around and the ones we found were surfacing infrequently and moving long distances. Found about 20 whales about five miles to the west in the afternoon and worked with them the rest of the day. The whales were surface feeding, moving erratically, and often making 180 degree turns in an area as small as the length of their bodies. Many whales were also engaged in possible prey-aggregation behavior in which they would rapidly move their flukes back and forth multiple times in a vertical position at the surface of the water, then turn and lunge through this same area. We generally didn't approach whales engaged in this behavior. No whales tagged but six biopsies were collected during the last hour of the day. Returned to Neah Bay at 18:40.
- 9/26 High winds all day. No tagging.
- 9/27 High winds all day. No tagging.
- 9/28 High winds all day. No tagging.
- 9/29 High winds all day. No tagging. Ken Serven arrived with the new RHIB boat and swapped places with Daniel Palacios. We spent some time getting things changed over to this new boat, pulling the old boat out of the water and launching the new one.
- 9/30 Departed Neah Bay at 08:10 in the new RHIB boat. Searched the entire area where we have been working with whales and saw VERY few despite very good conditions. Searched to the west and south, encountering widely scattered whales. We probably saw no more than 15 whales all day, but we were able to tag two of them (no biopsy from one) and collect an additional biopsy from an untagged whale that was deemed too small to tag. Returned to Neah Bay at 18:45.
- 10/1 Departed Neah Bay at 08:00 and worked out toward Swiftsure bank. Few whales and they were widely scattered and moving long distances while underwater, making close approaches difficult. We eventually collected one biopsy from a whale that was too small to tag. No tags deployed. Returned to Neah Bay at 18:40.
- 10/2 Departed Neah Bay at 08:10. Started toward Swiftsure but found a group of 10 to 12 whales near a local fishing spot called the "Garbage Dump". Worked those whales all morning with numerous close approaches that were seemingly always spoiled at the last minute by the whales' behavior. In one instance a whale surfaced somewhat unexpectedly in a taggable position and then rolled to expose its belly just as the tag was about to be deployed. Attempted

to search out to Swiftsure at noon, but winds were much stronger than predicted and we turned around to continue working in the Strait where the seas were less choppy. After working with the same whales again for a while we searched east up the Strait but did not find anything and returned to Neah Bay at 16:00 as the winds had not subsided.

- 10/3 High winds and rain all day. No tagging.
- 10/4 High winds and rain all day. No tagging. Ken Serven departed due to another obligation and Barb Lagerquist arrived to take biopsy samples.
- 10/5 Departed Neah Bay at 09:00 due to rain in the morning. Searched toward Swiftsure Bank and ended up working east of there for the whole day. Winds were higher than forecasted until the afternoon when they calmed down. The difference in whale behavior was interesting today with the whales mostly staying in fairly large groups (three to six whales per group) with multiple groups in fairly close proximity (~500 m). There was also a lot of social behavior with side fluking and a lot of head lifts. Also, multiple whales were playing with balls of kelp that were floating around, lifting them onto their heads and backs. Five whales tagged. All tagged whales were also hit with the biopsy darts, but in two cases no sample was collected for unknown reasons. Returned to Neah Bay at 18:30.
- 10/6 Departed Neah Bay at 08:00 and traveled out to Swiftsure Bank. Winds were higher than forecasted and built significantly upon reaching Swiftsure, making conditions unworkable. We ran back to stay in the lee of Tatoosh Island to see if the winds would subside but eventually returned to Neah Bay at 11:00. By 15:00 the winds had subsided somewhat, so we departed Neah Bay again and traveled back to Swiftsure. Whales were somewhat spread out but we found a group of six and were able to deploy the last two tags. A biopsy was collected from the first tagged whale but on the second deployment the dart struck very close to the tag, remained attached to the whale, and was subsequently lost as the dart came off while the whale was underwater. Returned to Neah Bay at 19:10.
- 10/7 Packed and pulled the boat out of the water, then departed Neah Bay at 09:00 to travel back to Newport.

Weather summary for OSU fieldwork in Washington, 2019

Observations during the humpback whale tagging study in Washington in 2019, including wind direction, wind speed, and wave height recorded at NOAA (10 nautical miles of Cape Flattery, Washington). Local wind speed and wave height recorded by the OSU field crew are also listed, along with the weather photos taken on the water each day. Photo number can be cross-referenced to its image in Table A2. Buoy observations were chosen as representative (second column) to the time of each weather photo. Local weather observations were typically recorded by the field crew twice a day and were not necessarily taken at the same time as the weather photos. Days when the OSU field crew was not able to get on the water are shaded light blue. Average and maximum values recorded at the NOAA Data Buoy are given.

Buoy Observation (PDT)	Buoy Wind Direction (degrees)	Buoy Wind Speed (knots)	Buoy Wave Height (meters)	Time of Photo (PDT)	Photo Number	Time of Field Observation (PDT)	Field Wind Speed (knots)	Field Wave Height (meters)
0	290	0.8	2.08	12:27	WA2019a-0005	8:37	4-6	0.9-1.2
0	293	5.1	2.30	17:32	WA2019a-0028	12:45	4-6	1.2-1.5
0	95	8.4	1.79	8:39	WA2019a-0043	9:04	4-6	1.2-1.5
0	202	8.9	1.88	15:10	WA2019a-0084	13:31	4-6	0.9-1.2
0	96	8.5	1.09	10:32	WA2019a-0095	9:20	4-6	0.6-0.9
0	204	5.8	1.07	16:09	WA2019a-0185	No weather recorded		
/max		6.4/12.1	1.31/1.70	Not on the water				
/max		10.7/18.9	2.15/3.17	Not on the water				
/max		11.5/18.9	2.04/2.49	Not on the water				
0	249	9.7	2.22	8:43	WA2019a-0202	9:43	7-10	0.9-1.2
0	256	11.9	1.64	13:41	WA2019a-0331	13:43	4-6	0.6-0.9
0	87	9.7	3.19	10:27	WA2019a-0388	9:23	7-10	1.8-2.4

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9-25-2019	17:20	234	7.6	2.68	17:13	WA2019a-0441	No weather recorded		
9-26-2019	Average/max		11.9/25.7	2.76/3.36			Not on the water		
9-27-2019	Average/max		15.4/22.3	2.59/3.26			Not on the water		
9-28-2019	Average/max		5.6/12.2	2.02/2.54			Not on the water		
9-29-2019	Average/max		7.8/16.9	1.53/1.92			Not on the water		
9-30-2019	11:20	88	7.6	0.96	11:33	WA2019a-0520	No weather recorded		
9-30-2019	17:20	341	4.1	0.78	17:28	WA2019a-0580	No weather recorded		
10-1-2019	10:20	57	1.4	0.71	10:06	WA2019a-0763	9:42	1-3	0.3-0.6
10-1-2019	15:20	221	6.4	0.80	15:25	WA2019a-0834_1	12:17	7-10	0.3-0.6
10-2-2019	8:20	77	11.5	0.67	8:28	WA2019a-0867	8:43	4-6	0.6-0.9
10-2-2019	13:50	98	12.8	0.68	13:42	WA2019a-0892	12:21	11-16	0.9-1.2
10-3-2019	Average/max		12.8/24.5	2.00/2.92			Not on the water		
10-4-2019	Average/max		10.3/21.0	1.66/2.06			Not on the water		
10-5-2019	9:50	122	5.8	1.1	9:43	WA2019a-0909	10:59	7-10	0.9-1.2
10-5-2019	16:20	118	5.4	0.9	16:14	WA2019a-0945	12:57	7-10	0.9-1.2
10-6-2019	8:50	104	12.4	1.0	8:38	WA2019a-0960	No weather recorded		
10-6-2019	18:20	99	9.1	1.29	18:09	WA2019a-1003	16:04	11-16	1.2-1.5

Key: PDT = Pacific Daylight Time.

Table A2. Representative photos of weather conditions encountered by the OSU field team during humpback whale tagging studies out of Neah Bay, Washington, September and October 2019. These photos are typically taken with passing ships in the background for scale. Photo numbers can be cross-referenced to Table A1.



WA2019a-0005 – 18 Sep 2019, 12:27



WA2019a-0028 – 18 Sep 2019, 17:32



WA2019a-0043 – 19 Sep 2019, 8:39



WA2019a-0084 – 19 Sep 2019, 15:10



WA2019a-0095 – 20 Sep 2019, 10:32



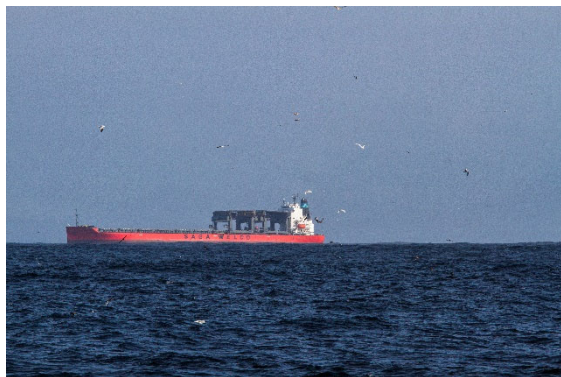
WA2019a-0185 – 20 Sep 2019, 16:09



WA2019a-0202 – 24 Sep 2019, 8:43



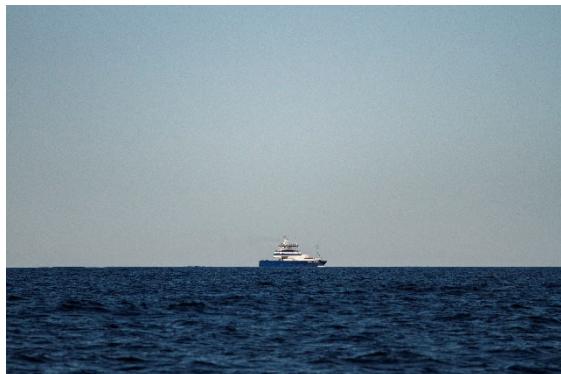
WA2019a-0331 – 24 Sep 2019, 13:41



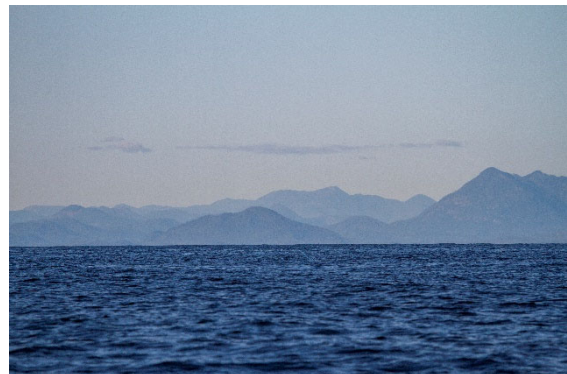
WA2019a-0388 – 25 Sep 2019, 10:27



WA2019a-0441 – 25 Sep 2019, 17:13



WA2019a-0520 – 30 Sep 2019, 11:33



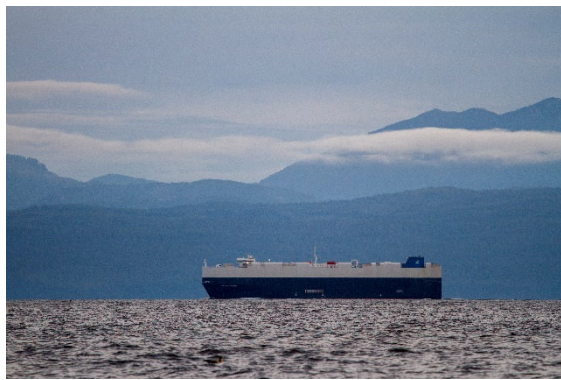
WA2019a-0580 – 30 Sep 2019, 17:28



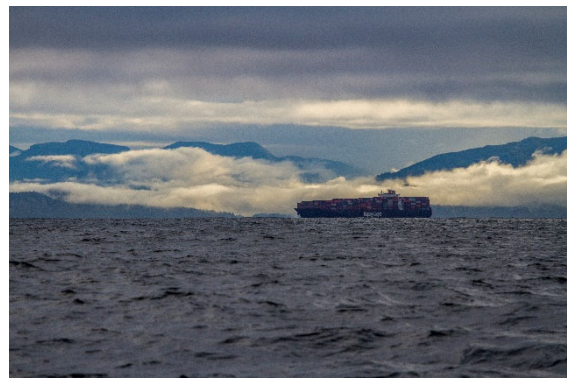
WA2019a-0763 – 1 Oct 2019, 10:06



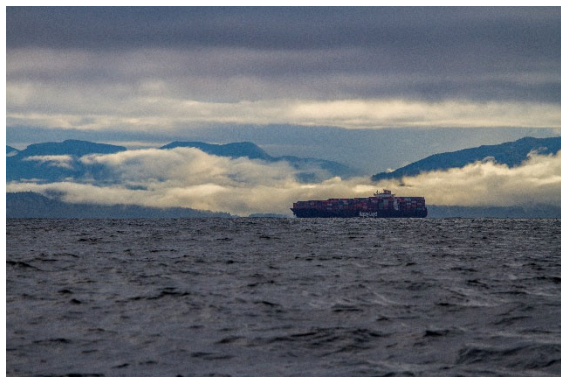
WA2019a-0834_1 – 1 Oct 2019, 15:25



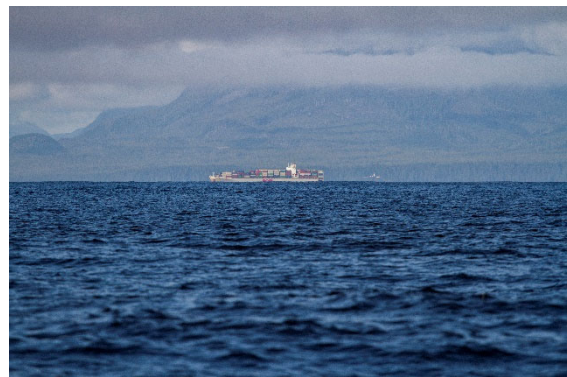
WA2019a-0867 – 2 Oct 2019, 8:28



WA2019a-0892 – 2 Oct 2019, 13:42



WA2019a-0909 – 5 Oct 2019, 9:43



WA2019a-0945 – 5 Oct 2019, 16:14



WA2019a-0960 – 6 Oct 2019, 8:38



WA2019a-1003 – 6 Oct 2019, 18:09

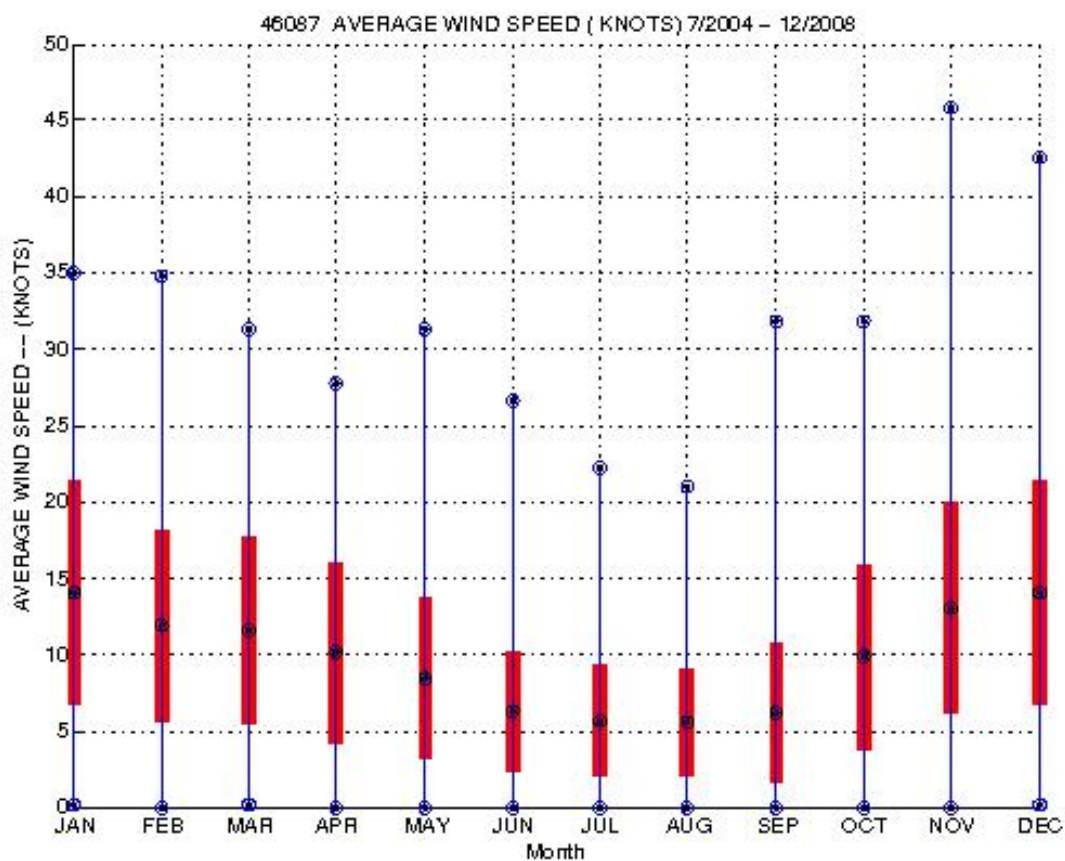


Figure A1. Mean and standard deviation of average wind speeds at NOAA Data Buoy Station 46087 (6 nautical miles north of Cape Flattery, Washington) for the period of July 2004 to December 2008 (available at https://www.ndbc.noaa.gov/view_climplot.php?station=46087&meas=ws), presented here to provide context about local conditions throughout the year. Wind speed directly correlates to sea state using the Beaufort Scale.