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**Daniel M. Palacios, Bruce R. Mate**



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# Summary of Humpback Whale Satellite Tagging Efforts in The North Pacific Ocean, 1995–2019

Daniel M. Palacios and Bruce R. Mate

*Marine Mammal Institute and Department of Fisheries,  
Wildlife, and Conservation Sciences, Oregon State University,  
Newport, Oregon, USA*

Contact email: [daniel.palacios@oregonstate.edu](mailto:daniel.palacios@oregonstate.edu)

## ABSTRACT

Oregon State University has conducted satellite tagging studies on humpback whales (*Megaptera novaeangliae*) at several locations in the North Pacific Ocean over the period 1995–2019. The results from these efforts have recently been presented in two comprehensive technical reports to the U.S. Navy focusing on two areas: Hawaii and the U.S. West Coast, respectively. Here we provide a brief summary of the key information in these two reports for consideration during the SC68C meeting, with particular reference to humpback whales movements, migration, habitat use, and residence time as inferred through satellite tagging.

KEYWORDS: HUMPBACK WHALE; SATELLITE TAGGING; BREEDING GROUND; FEEDING GROUND; MIGRATION; MOVEMENTS; HAWAII; U.S. WEST COAST; NORTH PACIFIC

## INTRODUCTION

The history of remote tracking of humpback whales (*Megaptera novaeangliae*) with radio-frequency implantable tags in the North Pacific dates back to the late 1970s, as recently reviewed by Mizroch et al. (2011). These early efforts occurred prior to the inception of the technology for monitoring radio tags from satellites, so tracking relied on surface monitoring of VHF signals using an automatic radio direction finder from a boat following the whales (Schevill and Watkins 1966, Watkins 1978, 1979, 1981, Watkins et al. 1980). As part of a collaboration between Woods Hole Oceanographic Institution, the National Marine Fisheries Service, and The Johns Hopkins University, five whales were tagged in southeastern Alaska in 1976 and 1977, and two whales were tagged in Prince William Sound, Alaska, in 1978. The southeastern Alaska whales were tracked for periods of up to 6 days and 75 km, while the Prince William Sound whales were tracked for 16 days (Watkins et al. 1981). The long-term survival of all seven tagged whales over periods greater than 20-30 years was recently documented through photo-identification by Mizroch et al. (2011), who also showed no lasting detrimental effect of the tags beyond superficial scarring.

As part of the development of the technology for tracking large whales via satellite, Oregon State University (OSU) conducted tagging operations on humpback whales in Hawaii between 1995 and 2000 (total tags deployed: n = 58). In the first year, OSU was successful in tracking two animals of unknown sex that headed almost due north in the direction of the Aleutian Islands, traveling for 1,610 km and 1,860 km in 14.7 and 17 days, respectively, at an average speed of 4.5 km/h (Mate et al. 1998). A third animal (a mother with a calf) also was tracked for 670 km in 4.5 days, moving northward at an average speed of 6.2 km/h (Mate et al. 1998). In subsequent years, several more animals were tracked, revealing the complete migration from Hawaii to feeding areas off Kamchatka, the Aleutians, and southeastern Alaska with unprecedented detail (Mate et al. 2007).

The trajectories of partial tracks (from tags that failed early) also pointed in the direction of the various known feeding areas for Hawaiian humpbacks and hinted at the complex nature of their movements and navigational capabilities in the open ocean. For instance, one animal used the Kermit-Roosevelt Seamount as an apparent feeding station halfway through the migration, and subsequently changed its direction of travel from a presumed destination in southeastern Alaska to one in the Aleutians (Mate et al. 2007).

Within Hawaii, the tracking data revealed the pattern of inter-island movements from Kaua'i to O'ahu to Maui Nui (i.e., the group of islands comprised by Maui, Molokai, Lāna'i, and Kaho'olawe; also known as the "four-islands region"), including the whales' use of the windward side of the islands and of the offshore Penguin Bank; areas where traditional fieldwork is precluded due to prevalence of high winds (Mate et al. 1998, Mate et al. 2007). These data further indicated that the whales' remaining residence time in the islands after tagging was, on average, only 13.4 days regardless of the month of tagging (December, February, March or April) (Mate et al. 1998), lending support to earlier studies that found that there is a rapid turnover of individuals in the breeding area during the winter season (Craig et al. 2003, Darling 2009).

In 2003, OSU tagged 11 whales in the Revillagigedo Islands, an oceanic archipelago off Mexico, including a mother-calf pair that was tracked to the Gulf of Alaska for a total duration of 150 days (Lagerquist et al. 2008). Another animal arrived in British Columbia, while the trajectories of three other partial tracks suggested a destination in the Aleutians (Lagerquist et al. 2008). These tracks indicated average speeds of 4 km/h during migration (Lagerquist et al. 2008). The tracking data also demonstrated extensive use of areas adjacent to the Mexican mainland by the animals tagged at the Revillagigedos before initiating migration to the high-latitude feeding areas (Lagerquist et al. 2008).

Subsequent to these studies, OSU has conducted additional humpback whale tagging at several locations in the North Pacific, including southeastern Alaska (1997: n = 10; 2014: n = 20; 2015: n = 17), Cabo San Lucas, Mexico (1998: n = 7), California (2004: n = 8; 2005: n = 7), Aleutian Islands (2008; n = 5), and Hawaii (2015: n = 20). Finally, between 2016 and 2019, in support of the U.S. Navy's monitoring efforts in their training and testing ranges, OSU tagged humpback whales in Oregon (2016: n = 2; 2017: n = 4; 2018: n = 5), California (2017: n = 14), Hawaii (2018: n = 25; 2019: n = 25), and Washington (2018: n = 20; 2019: n = 24). The results from these efforts have recently been presented in two comprehensive technical reports to the U.S. Navy focusing on two areas: Hawaii (Palacios et al. 2020a) and the U.S. West Coast (Palacios et al. 2020b). The purpose of this paper is to provide a brief summary of the key information in these two reports for consideration during the SC68C meeting, with particular reference to humpback whale movements, migration, habitat use, and residence time as inferred through satellite tagging.

The full reports to the U.S. Navy can be accessed at the following Google Drive locations:

Hawaii:

[https://drive.google.com/file/d/118Sc2\\_2KMQfBY\\_BX3DW1c33o8PMGJgqi/view?usp=sharing](https://drive.google.com/file/d/118Sc2_2KMQfBY_BX3DW1c33o8PMGJgqi/view?usp=sharing)

U.S. West Coast:

<https://drive.google.com/file/d/12wl20wp3Kb0lk96KergDdQ8LWNKCuMzt/view?usp=sharing>

## **HAWAII TAGGING**

The aggregate tracking results within the Hawaiian Islands support results of previous photo-ID studies and aerial surveys, showing highest densities of whales in the Maui Nui region (the inner waters of the "four-island region" of Maui, Molokai, Lanai, and Kahoolawe), where most of the whales were tagged, as well as Penguin Bank, and extensive inter-island movements. The results

also identify high use of Middle Bank and the Papahānaumokuākea Marine National Monument by some whales in 2019. Mean residence time in the Hawaiian Islands from tagging to departure (for whales with known departure date from the islands) for the aggregate tracking data was 13.1 d (range = 1.1-42.8 d, SD = 9.4 d, n = 39), lending support to earlier studies that found that there is a rapid turnover of individuals in this breeding area during the winter season.

Migratory destinations were tracked for 12 humpback whales tagged off Maui, with seven whales going to northern British Columbia and southeastern Alaska, one going to southern British Columbia, and four going to the eastern Aleutian Islands, supporting the findings of previous telemetry, genetic, and photo-ID studies (Figure 1). One of the latter four whales continued on to the Kamchatka Peninsula (Russia), 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 (Figure 1).

Of the seven humpback whales migrating to the northwestern coast of the U.S. and Canada, four were tracked within Southeast Alaska, with a maximum residency of 70 d (Figure 1). Two whales were tracked within the Aleutian Islands, with a preference for the southern and western side of the Aleutian Island chain (Figure 1). An area of high use approximately 160 km south of Akutan Island and Unimak Pass by two 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, Canada) were also shown to be high-use areas (Figure 1).

In terms of movement behavior, state-space model (SSSM/hSSSM) output for 86 tracks  $\geq 3$  d in duration (range = 3-176 d) indicated that locations classified as “area-restricted searching” (ARS) occurred primarily in the breeding (n = 2,159 SSSM/hSSSM locations; 50.4 percent) as well as feeding (n = 528 SSSM/hSSSM locations; 12.3 percent) areas, while “transiting” locations were the predominant behavioral mode while migrating (n = 1,598 SSSM/hSSSM locations; 37.3 percent). Movement speed was somewhat slower in the feeding areas (mean = 1.42 km/h, median = 0.85 km/h, SD = 1.55 km/h, n = 528 SSSM/hSSSM locations) than in the breeding area (mean = 1.62 km/h, median = 1.20 km/h, SD = 1.38 km/h, n = 2,159 SSSM/hSSSM locations), while it was substantially higher during migration (mean = 4.65 km/h, median = 4.61 km/h, SD = 2.39 km/h, n = 1,598 SSSM/hSSSM locations). However, travel speeds during the migration phase were not sustained but showed variation over time and among individual animals, including both high-frequency oscillations as well as longer periods of increased and decreased speed lasting several days.

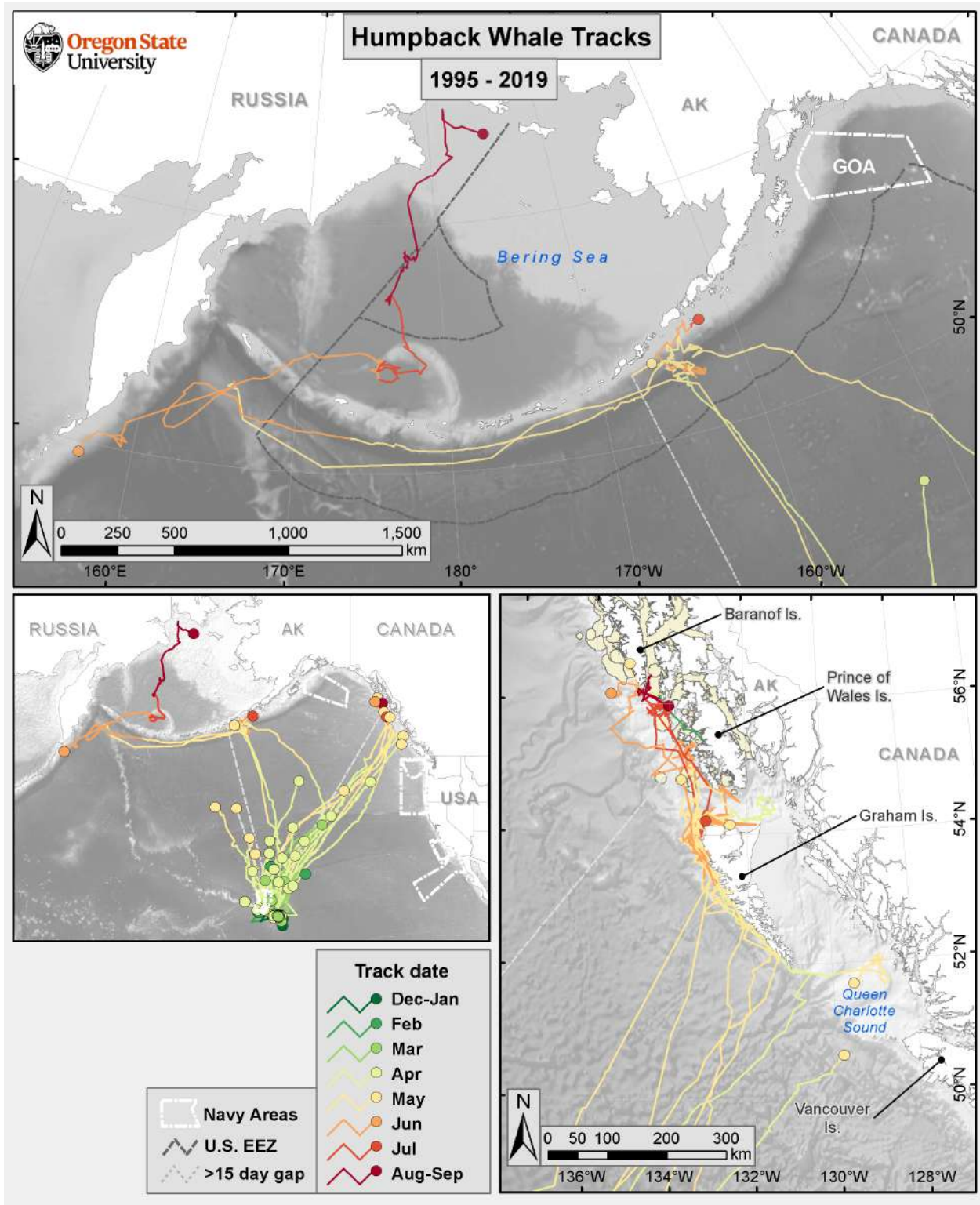


Figure 1. Satellite-monitored tracks for humpback whales tagged by OSU in the Hawaiian Islands from 1995 to 2019, highlighting migration and movement in feeding areas (n = 37 whales). Circles indicate each track's last location. From Palacios et al. (2020a).

## U.S. WEST COAST TAGGING

Tracking data were obtained for a total of 81 whales, with an overall tracking duration ranging from 0.1 to 164.2 d (mean = 39.1 d, SD = 33.6, n = 81). The distribution of the tracked animals supported humpback whale affinity for continental shelf and shelf-edge habitat and documented extensive use of the northwestern coast of Washington and the central coast of California, and to a lesser degree, the northern California coast and the Columbia River mouth at the Oregon/Washington border (Figure 2). The northernmost locations ranged from Queen Charlotte Sound, British Columbia, Canada, for whales tagged in northern Washington, the southwest coast of Vancouver Island, British Columbia, for whales tagged in northern California and Oregon, and off the north-central Oregon coast for whales tagged in central and southern California (Figure 2). The southernmost non-migratory locations ranged from the northern Oregon coast for whales tagged in northern Washington, off Point Sal, central California, for whales tagged in northern California and Oregon, and in the Santa Barbara Channel for whales tagged in southern and central California (Figure 2).

Six whales were tracked on their southbound migration, with departure dates ranging from 1 November to 24 December. Migratory destinations were tracked for five of the six whales, with four (two from northern Washington and two from northern California and Oregon) migrating to the mainland coast of Mexico and one (from southern and central California) migrating to Guatemala (Figure 2). The sixth whale was last located after a 66-d gap in locations off the southwestern coast of Baja California, Mexico. Migration duration was remarkably similar for all five whales, ranging from 27.6 to 31.6 d. Partial migrations were tracked for an additional two whales tagged in northern Washington in 2019, each with a southwest trajectory toward Hawaii (Figure 2).

In terms of movement behavior, SSSM/hSSSMs produced a total of 2,696 daily locations with annotated behavioral mode. Of these, 86.4 percent were classified as ARS, 9.8 percent as uncertain, and 3.8 percent as transiting. While engaged in ARS behavior, tracked humpback whales moved a median of 12.9 km between daily locations, corresponding to a median speed of 0.54 km/h.



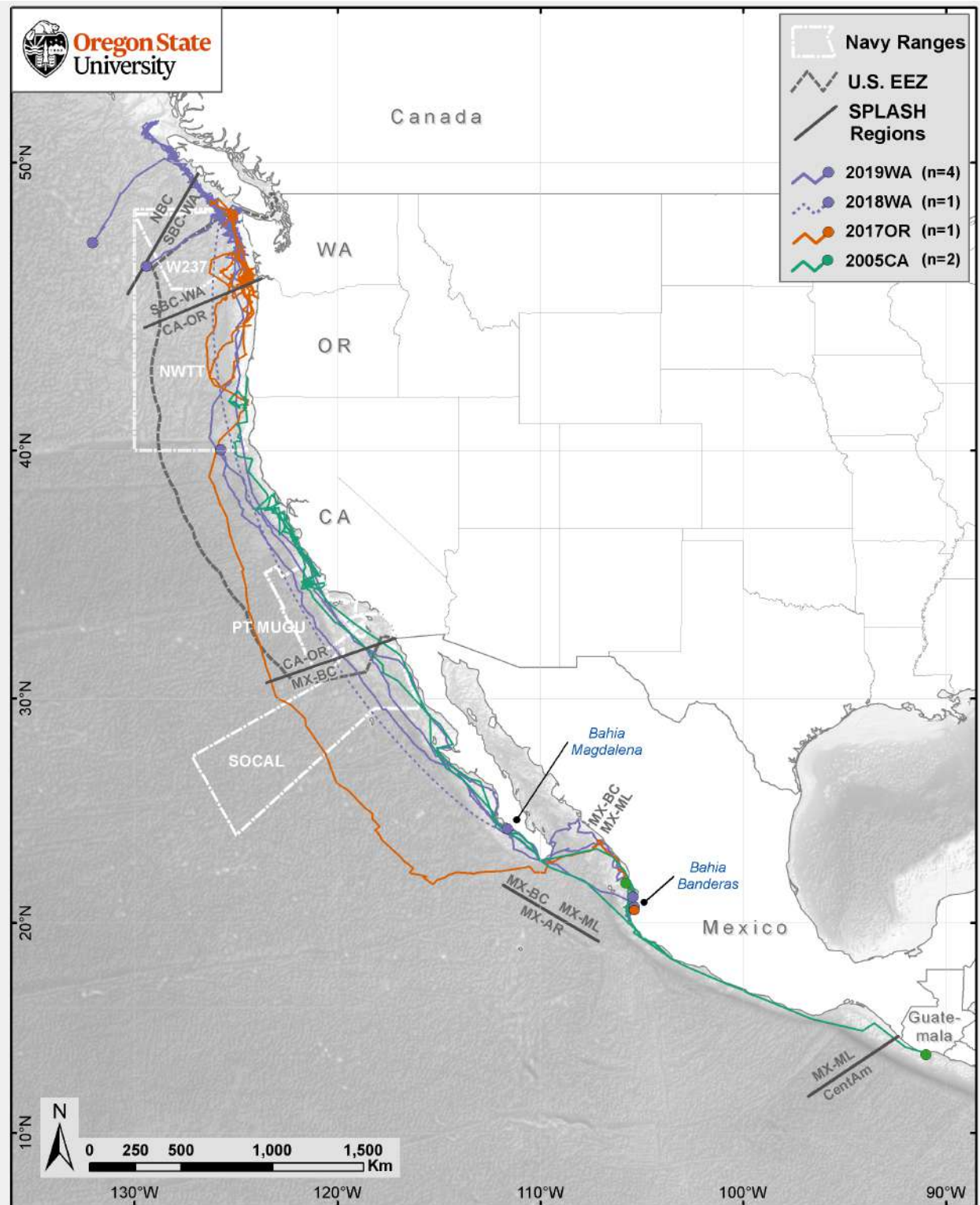


Figure 2. Satellite-monitored tracks for humpback whales tagged by OSU off the U.S. West Coast from 2005 to 2019, highlighting migration routes and destination in breeding areas (n = 8 whales). Circles indicate each track's last location. From Palacios et al. (2020b).

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