Preliminary Report

Baleen Whale Tagging in Support of Marine Mammal Monitoring Across Multiple Navy Training Areas

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A blue whale (*Balaenoptera musculus*) raises its flukes at the start of a foraging dive in Southern California, 2016. Photograph taken by Craig Hayslip under National Marine Fisheries Service Permit 14856 issued to Dr. Bruce Mate.

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14. ABSTRACT
In 2016, the Oregon State University Marine Mammal Institute (MMI) conducted a third year of tagging operations in support of the United States (U.S.) Navy's (Navy) marine mammal studies in three areas along the U.S. West Coast: (1) the offshore waters of the Southern California Range Complex (SOCAL) portion of the Hawaii-Southern California Training and Testing Study Area, (2) the Point Mugu Range Complex (PT MUGU), and (3) the Northwest Training Range Complex (NWTRC), Naval Undersea Warfare Center Keyport Range Complex (together known as the Northwest Training and Testing Study Area). This Preliminary Report focuses on 2016 field efforts, including field survey methods, tag deployments, and summaries of data collected during this time period.Two types of tags were used in this study: Wildlife Computers' Smart Positioning or Temperature Transmitting Tag, version 6 (SPOT6, referred to hereafter as Location-Only or LO tags) and Telonics RDW-665 (hereafter referred to as Dive-Monitoring or DM tags).

Blue and fin whale tagging efforts took place off the southern and central coast of California during one 30-day cruise aboard the research vessel (R/V) Pacific Storm. Nineteen tags were deployed on blue whales (11 LO, 8 DM) between July 14 and August 3, 2016. Eleven tags were deployed off southern California; 10 at the west end of San Miguel Island, and one off Palos Verdes Peninsula. The remaining eight tags were deployed off central California, near the continental shelf edge between Half Moon Bay and Pigeon Point. Locations were received from 18 of these tags, providing tracking periods ranging from 0.6 to 120.6 d. Most of the blue whales tagged in southern California remained in southern or

central California waters for their tracking periods. Most of the locations for these whales were over continental slope waters, or over offshore banks or seamounts, such as the Santa Lucia Bank on the central California coast or the Rodriguez Seamount at the west end of the Santa Barbara Channel.The most heavily used Navy training area for tagged blue whales was PT MUGU, with 12 of the 18 tracked whales having from <1 to 100 percent of their total locations there. Four blue whales had between 3 and 56 percent of their total locations within SOCAL, representing between 4 and 62 percent of their total tracking periods. Two blue whales had locations within the NWTRC; 2 percent of total locations and 2 percent of tracking period (2 d) for one whale, and 45 percent of total locations and 43 percent of tracking period (52 d) for the other whale. The track of a third blue whale crossed the NWTRC, representing <1 percent of its tracking period (<1 d), but no locations for this whale occurred within the NWTRC. None of the tagged blue whales were tracked within W237 of the NWTRC, or within the Gulf of Alaska Temporary Maritime Activities Area. Blue whale locations occurred in PT MUGU during all 5 months in which they were tracked (July through November), during 4 months in SOCAL (July, August, September, and October), and during 3 months in the NWTRC (September, October, and November). In 2016, tagging activities were conducted in both southern (ten whales tagged) and central (eight whales tagged) California waters due to a scarcity of “tagable” (i.e., in good body condition) whales in southern California. These two areas, separated by approximately 425 km constitute the two primary hotspots of aggregation for blue whales during the summer and fall (Irvine et al. 2014). The tagging in the two areas in 2016 affords us the opportunity to look at possible differences in movement patterns and habitat use between the two areas during the same year.With a few exceptions, the movements of blue whales tagged in the two areas were quite different.

Fourteen tags were deployed on fin whales (5 LO, 9 DM) between July 28 and August 4, 2015 (UTC dates and times). All tags were deployed off central California, near the continental shelf edge between Half Moon Bay and Pigeon Point. Transmissions were received from 13 of the 14 fin whale tags. Tracking periods for these 13 tags ranged from 1.3 to 104.3 d (as of 30 November 2016), with average fin whale tracking durations of 28.7 d (SD = 8.3 d, median = 26.7 d) for LO tags and 38.6 d (SD = 33.4 d, median = 28.7 d) for DM tags. Fin whale locations ranged over 20 degrees of latitude, from San Nicolas Island in southern California to Hecate Strait in British Columbia, Canada. PT MUGU was the most heavily used training range for fin whales tagged in 2016, with 3 of the 13 tracked whales having between 5 and 46 percent of their total number of locations in the area. These whales spent from 3 to 42 percent of their total tracking periods in the PT MUGU area, representing 1 to 44 d. Locations in PT MUGU occurred in 3 of the 5 months in which these whales were tracked (August, September, and October). Only one fin whale had locations within the NWTRC and W237 training areas, as it traveled from central California to British Columbia . This whale (Tag #23030) had 4 percent of their total number of locations and 11 percent of its tracking period within the NWTRC, representing 6 d. Two percent of the total locations for whale Tag #23030 and 3 percent of their tracking period were spent within area W237 of the NWTRC, representing 2 d. Locations in the NWTRC and W237 for this fin whale occurred during the month of August. None of the tagged fin whales were tracked within the SOCAL or the Gulf of Alaska Temporary Maritime Activities training areas.

Additionally, in 2016 MMI obtained permission from the Navy to deploy DM tags on humpback whales (Megaptera novaeangliae) off Newport, Oregon. Whales using this area likely are part of the recently designated “Distinct Population Segment 6” (DPS 6) by NMFS, with an Endangered Species Act conservation status of “Threatened” (Bettridge et al. 2015, NMFS 2016). The distribution range of DPS 6 extends from the feeding ground in waters off California, Oregon and Washington to the breeding ground off Central America (Bettridge et al. 2015, Federal Register 2015); hence, whales from this population are likely to occupy Navy training and testing areas off the U.S. West Coast during the feeding season in summer and fall. Therefore, the questions and objectives described above for blue and fin whales also apply to humpback whales in this report. Humpback whale field efforts took place on two days (September 15 and October 11, 2016) out of Newport, Oregon, aboard the 6.4-m tagging rigid-hulled inflatable boat, following identical procedures as for blue and fin whale tagging. Two DM tags were deployed on humpback whales on September 15, 2016, off the coast of Newport, Oregon. A third DM tag was launched from the tag applicator, but did not properly deploy and was lost. One of these whales (Tag #5838) was tracked for 7.3 d, spending the majority of its time on Heceta Bank off the central Oregon coast before being last located off Coos Bay, Oregon on September 22. Most locations for this whale were over the continental shelf. The second humpback whale was tracked for 18.9 d, traveling from its tagging location to an area just north of Cape Mendocino in that time, with 1 to 4-d stopovers at the continental shelf edge near Stonewall Bank, Heceta Bank, the shelf edge off Coos Bay, and the shelf waters off Point St. George and Trinidad, California Almost all (95 percent) of the locations for whale Tag #5838 were within the NWTRC, representing 90 percent of its total tracking period. For whale Tag# 5923, only the locations north of Coos Bay, Oregon were far enough offshore to be within the NWTRC. Thirty-four percent of the locations for this latter whale were within the NWTRC, representing 25 percent of its tracking period, or 5 d. Humpback whale locations within the NWTRC occurred only in September. Neither of the tagged humpback whales was tracked in any other Navy training range.

15. SUBJECT TERMS

Monitoring, marine mammal, baleen whales, satellite tagging, biopsy, photo-identification, genetic analyses, Southern California Range Complex, Hawaii Range Complex, Hawaii-Southern California Training and Testing, Point Mugu Sea Range, Northwest Training Range Complex, Northwest Training and Testing

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Acronyms and Abbreviations

ARS	area-restricted searching
BIA	Biologically Important Area
BLAST	Basic Local Alignment Search Tool
bp	base pair
cm	centimeter(s)
d	day(s)
DM	dive monitoring
DNA	deoxyribonucleic acid
DPS 6	Distinct Population Segment 6
g	gram(s)
ID	identification
km	kilometer(s)
km/h	kilometer(s)/hour(s)
LC	location class
LO	location only
m	meter(s)
min	minute(s)
MMI	Marine Mammal Institute
mtDNA	mitochondrial deoxyribonucleic acid
Navy	U.S. Navy
NMFS	National Marine Fisheries Service
NWTRC	Northwest Training Range Complex
PT MUGU	Point Mugu Range Complex
s	second(s)
SD	standard deviation
SOCAL	Southern California Range Complex
SSH	sea surface height
UCT	Universal Coordinated Time
U.S.	United States

1. Introduction

In 2016 the Oregon State University Marine Mammal Institute (MMI) conducted a third year of tagging operations in support of the United States (U.S.) Navy's (Navy) marine mammal studies in three areas along the U.S. West Coast: (1) the offshore waters of the Southern California Range Complex (SOCAL) portion of the Hawaii-Southern California Training and Testing Study Area, (2) the Point Mugu Range Complex (PT MUGU), and (3) the Northwest Training Range Complex (NWTRC), Naval Undersea Warfare Center Keyport Range Complex (together known as the Northwest Training and Testing Study Area). The focus of these studies is to address key science objectives the Navy has committed to complete as part of regulatory requirements promulgated from the National Marine Fisheries Service (NMFS). In particular, this multi-year project is designed to address the following questions:

1. What are the movement patterns, occurrence, and residence time of blue (*Balaenoptera musculus*) and fin (*Balaenoptera physalus*) whales within Navy training and testing areas along the U.S. West Coast as compared to other areas visited by tagged whales outside of Navy training and testing areas?
2. What are the residency time/occupancy patterns of blue whales within NMFS-designated Biologically Important Areas (BIAs) for this species along the U.S. West Coast?
3. Are there bathymetric, annual oceanographic conditions (e.g., sea surface temperature, frontal zones, etc.), and/or climatic and ocean variations (e.g., global warming, North Pacific Gyre Oscillation, Pacific Decadal Oscillation, El Niño/La Niña events, etc.) that can help explain blue and fin whale affinity for any identified areas of high residency along the U.S. West Coast?

In order to address these questions, the project's specific objectives are as follows:

A. Determine blue and fin whale distribution and habitat use through deployment of long-term location-only (LO) satellite tags to refine understanding of short- and long-term movement patterns and, most importantly, to generate metrics for defining residency times, home ranges and core areas, area-restricted searches, and migratory timing.
B. Determine blue and fin whale behavior changes over time by individual, and between individuals, over the course of several weeks by deploying intermediate-duration dive monitoring (DM) tags. This new technology incorporates depth and tri-axial accelerometer sensors into the traditional LO-tag design, enabling us to obtain a relative measure of foraging effort and its changes over time via satellite, without the need to recover the tags.
C. Identify ecological relationships that will help explain/predict spatial and temporal movement patterns from bathymetric and satellite-determined measurements like sea surface temperature, frontal zones, phytoplankton chlorophyll-*a* concentration, salinity, or current information derived from altimetry.
D. Conduct genetic analyses from tissue samples of tagged blue and fin whales to integrate with the tracking results and further expand their interpretation. These analyses include

determination of sex, mitochondrial haplotypic composition, nuclear microsatellite loci composition, individual identification, population structure, and interspecific introgressive hybridization.

Additionally, in 2016 MMI obtained permission from the Navy to deploy DM tags on humpback whales (*Megaptera novaeangliae*) off Newport, Oregon. Whales using this area likely are part of the recently designated “Distinct Population Segment 6” (DPS 6) by NMFS, with an Endangered Species Act conservation status of “Threatened” (Bettridge et al. 2015, NMFS 2016). The distribution range of DPS 6 extends from the feeding ground in waters off California, Oregon and Washington to the breeding ground off Central America (Bettridge et al. 2015, Federal Register 2015); hence, whales from this population are likely to occupy Navy training and testing areas off the U.S. West Coast during the feeding season in summer and fall. Therefore, the questions and objectives described above for blue and fin whales also apply to humpback whales in this report.

This Preliminary Summary reports on field efforts, including field survey methods, tag deployments, and summaries of data collected from July through November 2016. While the focus of this Preliminary Summary is on the 2016 field efforts, subsequent reports will include cumulative analyses of data and results for 2014, 2015 and 2016 combined. These future reports will follow the same section structure outlined in this Preliminary Summary but will include complete details on methods and results not available at present. For this reason, several sections in this Preliminary Summary contain placeholder text indicating that "This information will be included in the Final Report.” It is anticipated the Final Report will be completed and available for review in the summer of 2017.

2. Methods

2.1 Field Efforts

Blue and fin whale tagging efforts took place off the southern and central coast of California during one 30-day cruise aboard the research vessel (R/V) *Pacific Storm*. The 26-meter (m) *Pacific Storm* served as a home base and support vessel for the research crew, as well as an additional platform from which to search for whales and conduct visual observations. The cruise took place from July 6 to August 5, 2016, departing from Santa Barbara and returning to Half Moon Bay. There was one crew change, on July 20, 2016 in Marina Del Rey. Tagging efforts were conducted on 12 days (d). Aerial observations to locate whales were conducted on 7 d between July 1 and July 26, 2016.

All tagging efforts were conducted from a small, 6.4-m rigid-hulled inflatable boat launched with a crane from the back deck of the R/V *Pacific Storm*. The tagging crew consisted of a tagger, biopsy darter, photographer, data recorder, and boat driver. Identification (ID) photos were taken of all tagged whales and will be compared to existing ID catalogs for blue, fin, and humpback whales (maintained by Cascadia Research Collective, Olympia, Washington). Candidate whales for tagging were selected based on visual observation of body condition. No whales were tagged that appeared emaciated or that were extensively covered by external parasites. Satellite tags were deployed using an Air Rocket Transmitter System air-powered applicator following the methods described in Mate et al. (2007). Tags were deployed from distances of 1 to 4 m with 85 to 90 pound force per square inch in the applicator's 70-cubic centimeter pressure chamber.

Humpback whale field efforts took place on two days (September 15 and October 11, 2016) out of Newport, Oregon, aboard the 6.4-m tagging rigid-hulled inflatable boat, following identical procedures as for blue and fin whale tagging. Satellite tags were deployed from distances of 2 m with 95-100 pounds of pressure in the applicator.

2.2 Tagging

2.2.1 Satellite Tags

Two types of tags were used in this study: Wildlife Computers' Smart Positioning or Temperature Transmitting Tag, version 6 (SPOT6, referred to hereafter as Location-Only or LO tags) and Telonics RDW-665 (hereafter referred to as Dive-Monitoring or DM tags). Both tag types were composed of a main body, a penetrating tip, and an anchoring system (**Figures 1 and 2**). The main body consisted of a certified Argos transmitter, housed in a stainless steel cylinder (2.0 centimeters [cm] in diameter × 20.7 cm in length for the LO tag, and 1.9 cm in diameter × 20.7 cm in length for the DM tag). A flexible whip antenna and a saltwater conductivity switch were mounted on the distal endcap of this cylinder, while a penetrating tip was screwed onto the other end. The distal endcap had two perpendicular stops (0.83 cm thick for the LO tag and 0.63 cm thick for the DM tag) extending approximately 1.5 cm laterally to prevent tags from embedding too deeply on deployment or from migrating inward after deployment. The penetrating tip consisted of a Delrin® nose cone, into which was pressed a

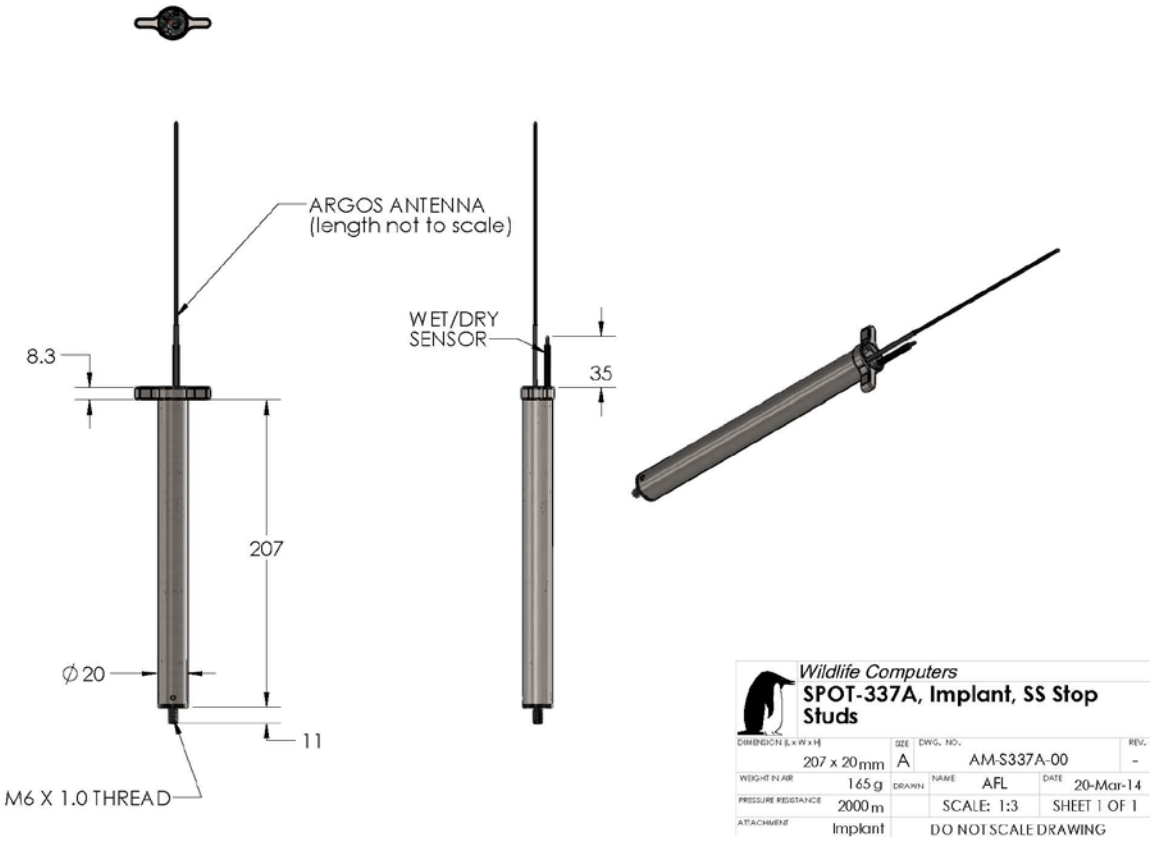

Figure 1. Schematic diagram of the Wildlife Computers SPOT6 (also known as SPOT-337A) LO tag, showing the main body and the distal endcap with the antenna and saltwater conductivity switch.

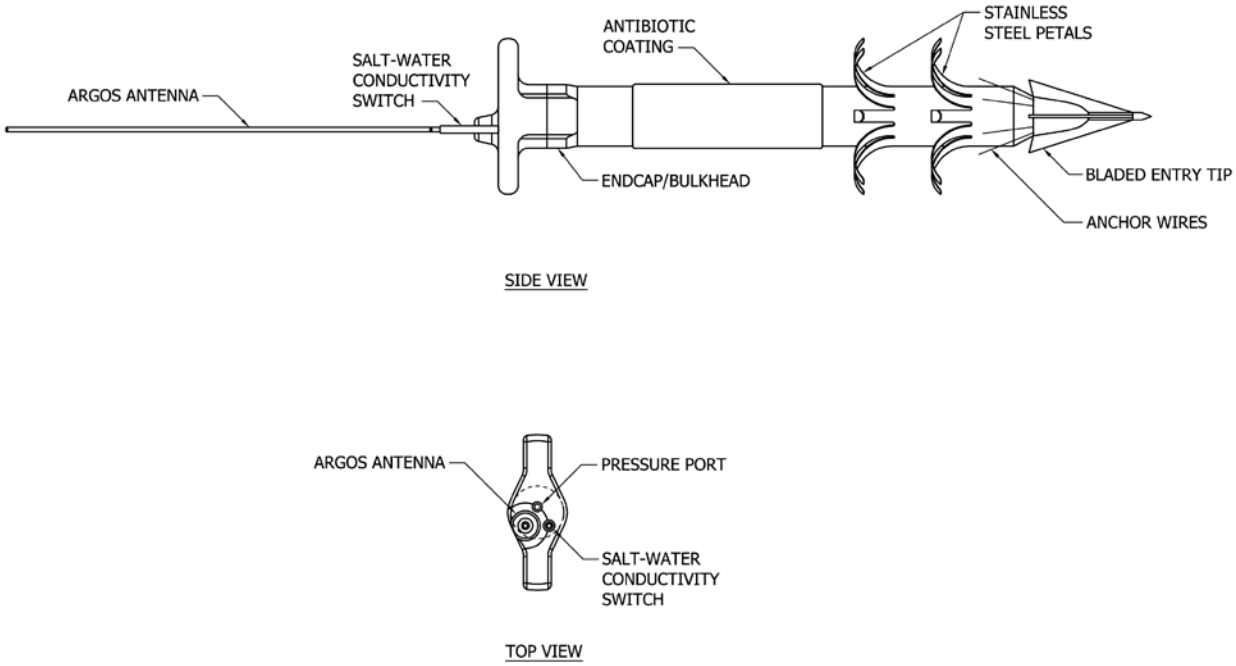

Figure 2. Schematic diagram of the Telonics RDW-665 DM tag showing the main body, the distal endcap with the antenna and saltwater conductivity switch endcap, as well as the penetrating tip and anchoring system.

ferrule shaft with four double-edged blades. The anchoring system consisted of metal wires mounted behind the blades on the penetrating tip and two rows of outwardly curved metal strips mounted on the main body at the nose cone (proximal) end. Total tag weight was 200 grams (g) for the LO tags and 228 g for the DM tags. Tag cylinders were partially coated with a broad-spectrum antibiotic (gentamicin sulfate) mixed with a long-dispersant methacrylate. This allowed for a continual release of antibiotic into the tag site for a period of up to 5 months (Mate et al. 2007). These tags are designed to be almost completely transdermal (except for the perpendicular stops, antenna and saltwater switch) and are ultimately shed from the whale due to hydrodynamic drag and the natural migration of foreign objects out of the tissue (Mate et al. 2007).

In addition to providing transmissions for location calculation, the LO tag reported the percentage of time in user-specified temperature ranges. LO tags were programmed to transmit only when out of the water during four 1-hour (h) periods per day, coinciding with times when satellites were most likely to be overhead. With such a duty cycle, the life expectancy of a tag's battery is over 1 year. However, tags are generally shed sooner, or they may stop functioning due to electronic failure while still attached to a whale. The maximum tracking duration to date for a blue whale is 505 d, but the average duration is 102.5 d (Mate et al. 2015). Tag retention on humpback whales has proved to be shorter, as discussed in Mate et al. (2007).

The DM tag produced Argos locations similar to the LO tag and also incorporated a pressure sensor and a three-axis accelerometer, so it was able to record dive depths, duration and body orientation/acceleration while attached to a whale. During a deployment, dive depth was recorded every 5 seconds (s) with 2-m vertical resolution up to a maximum of 511 m. Accelerometer readings were recorded every 0.25 s. For every dive exceeding a user-specified duration and depth (a "selected dive") the magnitude of the acceleration vector (A; Simon et al. 2012) was calculated as:

$$A = \sqrt{ax^2 + ay^2 + az^2}$$

Where *ax*, *ay*, and *az* are the *x*, *y*, and *z* components of the acceleration vector relative to the Earth's gravitational field.

The rate of change in this acceleration vector, or Jerk (Simon et al. 2012), was then calculated as:

$$\text{Jerk} = A_{(t+1)} - A_{(t)}$$

Peaks in Jerk value are associated with feeding lunges (Simon et al. 2012), so we used Jerk values that exceeded the mean Jerk $\pm$ 2.5 or 3.5 standard deviations (depending on the tag), calculated from all selected dives, to identify feeding lunges. Acceleration data recorded in the first 5 s or final 5 s of a selected dive were not used in these calculations to eliminate spurious peaks from strong fluking at the start or end of a dive. Lunges for each selected dive were then counted if they occurred more than 30 s from the previous lunge.

For this study, selected dives were identified as dives > 1-minute (min) duration and 10-m depth or > 2-min duration and 10-m depth for tags deployed after July 14, 2016. In addition to providing transmissions for location calculation, DM tags reported the start date and time of

each selected dive, duration (1-s resolution up to a maximum of 4,095 s), maximum depth, and number of lunges for 4 to 6 consecutive selected dives depending on data compression. DM tags were programmed to transmit only when out of the water during six 1-h periods per day, also coinciding with times when satellites were most likely to be overhead. With more transmission periods than the LO tags, and the extra power consumed by the tag sensors, the life expectancy of the DM tag's battery was approximately 100 d.

2.2.2 Argos Tracking

Tagged whales were tracked using the Argos satellite-based system that assigns a location quality to each location, depending, among other things, on the number and temporal distribution of transmissions received per satellite pass (Collecte Localisation Satellites 2015). The accuracy associated with each Argos satellite location is reported as one of six possible location classes (LCs) ranging from less than 200 m (LC=3) to greater than 5 kilometers (km) (LC=B) (Vincent et al. 2002). Tag transmissions were processed by Argos using the Kalman filter to calculate locations (Collecte Localisation Satellites 2015). Received Argos locations were then filtered by the MMI to remove locations occurring on land. Remaining Argos locations were further filtered by LCs and speeds. Locations of class Z were removed from analyses because of the large errors frequently associated with this class. Lower-quality LCs (LC=0, A, or B) were not used if they were received within 20 min of higher-quality locations (LC=1, 2, or 3). Speeds between remaining locations were computed, and if a speed between two locations exceeded 12 km/h, one of the two locations was removed, with the location resulting in a shorter overall track length being retained.

2.2.3 Tracking Analysis

2.2.3.1 CALCULATION OF DISTANCE FROM SHORE

Geodesic distances to the closest point on the mainland were computed for each whale location, using the NEAR ARC Tool function in ESRI® ArcMap v.10.3. Vancouver Island, British Columbia, Canada, was used as the land reference for whale locations west of the island.

2.2.3.2 OCCURRENCE IN NAVY AREAS AND BIAS

Numbers of locations occurring inside versus outside Navy areas were computed for each whale track, with the percentage of locations inside reported as a proportion of the total number of locations obtained for each whale. Four recognized blue whale BIAs (Calambokidis et al. 2015) overlapped completely or partially with the SOCAL area: Santa Monica Bay to Long Beach; San Nicolas Island; Tanner-Cortez Bank; and San Diego. Two blue whale BIAs overlapped with the PT MUGU area: Santa Barbara Channel and San Miguel BIA and Point Conception/Arguello BIA. Numbers of blue whale locations and corresponding percentages were also computed for these six BIAs. The other three recognized blue whale BIAs (Calambokidis et al. 2015) did not overlap Navy areas and were not considered in this report.

To compute estimates of residence time inside Navy areas and overlapping BIAs, interpolated locations were derived at 10-min intervals between filtered Argos locations, assuming a linear track and a constant speed. These interpolated locations provided evenly spaced time segments from which reasonable estimates of residence times could be generated and were especially useful when tracklines crossed training area or BIA boundaries. Residence time was

calculated as the sum of all 10-min segments from the interpolated tracks that were completely within each area of interest. Percentage of time spent in these areas was expressed as a proportion of the total track duration.

2.2.3.3 STATE-SPACE MODELING

A Bayesian switching state-space model developed by Jonsen et al. (2005) was applied to the unfiltered Argos locations (except removal of Z-class locations) for each track, using the software R v. 2.12.1 and WinBUGS v. 1.4.3. The model provided a regularized track with one estimated location per day, after accounting for Argos satellite location errors (based on Vincent et al. 2002) and movement dynamics of the animals. The state-space model ran two Markov Chain Monte Carlo simulations each for 30,000 iterations, with the first 10,000 iterations being discarded as a burn-in, and the remaining iterations being thinned, removing every fifth one to reduce autocorrelation (Bailey et al. 2010). Included in the model was the classification of locations into two behavioral modes based on mean turning angles and autocorrelation in speed and direction: transiting (mode 1) and area-restricted searching (ARS, mode 2). Even though only two behavioral modes were modeled, the means of the Markov Chain Monte Carlo samples provided a continuous value from 1 to 2 (Bailey et al. 2010). As in Bailey et al. (2010) and Irvine et al. (2014), we chose behavioral modes greater than 1.75 to represent ARS locations and behavioral modes lower than 1.25 to represent transiting. Locations with behavioral modes in between these values were considered uncertain.

2.2.3.4 HOME RANGE ANALYSIS

This information will be included in the Final Report.

2.2.4 Dive Analysis

Analysis methodologies will be refined for the Final Report. The goal of these analyses was to better understand the diving behavior of tagged whales over their tracking duration and examine how it changed temporally and spatially. For this purpose, a more restrictive location filtering protocol (compared to the tracking analysis) was needed in order to be confident of where identified behaviors were occurring. Argos locations received from DM tags were filtered to remove the lowest-quality locations (LCs Z and B from one message). Locations from redundant satellite passes were also removed and a 12 km/h swim speed filter was applied to remove locations that would require the whale to travel at an unreasonably high speed. A location was assigned to each dive based on the start time of the dive and the temporally closest filtered Argos location. Locations of dives more than 10 min from an Argos location were estimated by linear interpolation between the temporally closest location before and after the dive occurred using the dive time to determine where on the line the dive should fall.

Summary plots showing dive depth and number of feeding lunges over time and versus time of day were generated for each individual to visualize temporal trends in the dive data. Due to the large number of plots generated, examples from one individual are presented to illustrate the trends that are described in the results. The number of feeding lunges was also mapped onto a 0.15 degree hexagonal grid where each grid cell showed the total number of lunges that occurred within that cell across all tagged whales of each species. The result shows the spatial distribution of where higher feeding effort occurred, indicating where DM-tagged whales were more likely to be found and/or spend time.

DM tags occasionally reported abnormally long duration dives lasting up to the maximum possible value recorded by the tag (4,095 s or 68.3 min)[1]. Such instances were limited to less than 5 percent of all transmitted dives; however, in extreme cases such "dives" appeared to have lasted for over 1 d. To account for these abnormally long dives in the analyses, dives with durations > 25 min were identified and removed from the DM transmitted dive summaries as no dives longer than that were recorded by the Advanced Dive Behavior tags we deployed on blue and fin whales in 2014 and 2015 (Mate et al. 2016) or have been reported in the literature (Acevedo-Gutiérrez et al. 2002).

After the initial deployment of five DM tags, we observed that the maximum number of lunges per dive being reported by some tags was higher than expected and that dives with no lunges were also rarely reported. This suggested that the lunge detection threshold (2.5x the standard deviation) was set too low and the tag was recording non-feeding behavior in addition to feeding lunges. Subsequent deployments used a lunge detection threshold of 3.5x the standard deviation, and work is ongoing to determine how to best interpret the data. Despite apparently recording non-feeding events, dives with larger numbers of lunges were also of deeper depth and generally during the day, which corresponds to known whale feeding behavior (Acevedo-Gutiérrez et al. 2002, Mate et al. 2016). This suggests that the tags were able to record feeding behavior. However, the number of lunges recorded by the tag should be interpreted as a relative measure of feeding "effort,"' rather than a specific number of feeding lunges that occurred during a dive.

2.3 Ecological Relationships

This information will be included in the Final Report.

2.4 Genetics

2.4.1 DNA extraction and mtDNA sequencing

Total genomic deoxyribonucleic acid (DNA) was extracted from skin tissue following standard proteinase K digestion and phenol/chloroform methods (Sambrook et al. 1989) as modified for small samples by Baker et al. (1994). An approximate 800-base-pair (bp) fragment of the mitochondrial deoxyribonucleic acid (mtDNA) control region was amplified with the forward primer M13Dlp1.5 and reverse primer Dlp8G (Dalebout et al. 2004) under standard conditions (Sremba et al. 2012). Control region sequences were edited and trimmed to a 410-bp consensus region in Sequencher vs4.6. Unique haplotypes were then aligned with previously published haplotypes (LeDuc et al. 2007, Attard et al. 2015, Sremba et al. 2012, Archer et al.

[1] Diagnostic information on this problem is unfortunately limited; however, the most likely explanation is related to the tag's saltwater conductivity switch, which detects when the tag breaks the surface of the water, allowing it to set the start and end times of a dive. Anecdotally, the abnormally long dives seemed to occur more frequently during periods of bad weather in the region whales were occupying, so we believe waves sloshing onto the whale's back (and therefore, the tag) during a surfacing may have somehow compromised the saltwater conductivity switch. To mitigate this, the threshold value where the tag senses a change in conductivity has been modified to make it more likely to sense a change from salt water to fresh water/dry air; however, none of the tags in this report were deployed with the updated threshold.

2013, Baker et al. 2013), downloaded from GenBank® and from samples collected during previous tagging efforts.

2.4.2 Microsatellite genotypes

Up to 17 microsatellite loci will be amplified for each sample using previously published conditions (LeDuc et al. 2007, Sremba et al. 2012; Baker et al. 2013). For humpback whales, these will include the following loci: EV14, EV21, EV37, EV94, EV96, EV104 (Valsecchi and Amos 1996); GATA28, GATA417, (Palsbøll et al. 1997); rw31, rw4-10, rw48 (Waldick et al. 1999); GT211, GT23, GT575 (Bérubé et al. 2000); and 464/465 (Schlötterer et al. 1991). For fin and blue whales, these will include an additional two loci GATA98 (Palsbøll et al. 1997) and DlrFCB17 (Buchanan et al. 1996). Microsatellite loci will be amplified individually in 10-microliter reactions and co-loaded in four sets for automated sizing on an ABI3730xl (Applied Biosystems™). Microsatellite alleles will be sized and binned using Genemapper vs4.0 (Applied Biosystems™) and all peaks will be visually inspected.

2.4.3 Sex determination

Sex was identified by multiplex PCR using primers P1-5EZ and P2-3EZ to amplify a 443–445-bp region on the X chromosome (Aasen and Medrano 1990) and primers Y53-3C and Y53-3D to amplify a 224-bp region on the Y chromosome (Gilson et al. 1998).

2.4.4 Individual identification

Individual whales will be identified from the multi-locus genotypes using CERVUS v v3.0.3 (Marshall et al. 1998).

2.4.5 Species and Stock identification

Species identity from field observations was confirmed by submitted mtDNA sequences to the web-based program *DNA-surveillance* (Ross et al. 2003) and by Basic Local Alignment Search Tool (BLAST) search of GenBank®.

Stock identity of the tagged blue and fin whales will be investigated by comparison of mtDNA haplotypes to reference databases developed for this 2016 study. Stock identity of the tagged humpback whales will be investigated by comparison of mtDNA haplotypes and nuclear microsatellite loci to the large reference database of North Pacific humpback whales collected during the SPLASH (Structure of Populations, Levels of Abundance and Status of Humpback Whales in the North Pacific) program (Baker et al. 2013).

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3. Results

3.1 Blue Whale

3.1.1 Tracking Analysis

Nineteen tags were deployed on blue whales (11 LO, 8 DM) between July 14 and August 3, 2016 (Universal Coordinated Time [UTC] dates and time). Eleven tags were deployed off southern California; 10 at the west end of San Miguel Island, and one off Palos Verdes Peninsula. The remaining eight tags were deployed off central California, near the continental shelf edge between Half Moon Bay and Pigeon Point. Locations were received from 18 of these tags, providing tracking periods ranging from 0.6 to 120.6 d (as of November 30, 2016; **Table 1**). The average tracking duration for LO tags was 69.6 d (standard deviation [SD] = 42.2 d, median = 61.7 d) and for DM tags was 49.5 d (SD = 35.9 d, median = 61.7 d). Maximum distances to shore for both types of tags ranged from 37 to 416 km (median = 87 km; **Table 2**).

Blue whale locations ranged over 20 degrees of latitude, from Magdalena Bay in southern Baja California, Mexico, to Coos Bay, Oregon (**Figure 3**). The individual with the longest range (Tag #5685) was tracked between Magdalena Bay, Mexico and Cape Mendocino, California, with a distance between northern and southern most locations of more than 2,100 km. This whale (tagged off central California on August 1) traveled south across the California/Mexico border on October 15, 2016 and was last located off Magdalena Bay on November 6, 2016. Only one other blue whale (Tag #5878), tagged in southern California on July 17, 2016 traveled to Sebastián Vizcaíno Bay on the central coast of Baja California, where it spent 2 days in mid-October before heading back into California waters.

Most of the blue whales tagged in southern California remained in southern or central California waters for their tracking periods (**Figure 4**). Most of the locations for these whales were over continental slope waters, or over offshore banks or seamounts, such as the Santa Lucia Bank on the central California coast or the Rodriguez Seamount at the west end of the Santa Barbara Channel. Six blue whales spent extensive periods of time (from 7 to102 d) at the western end of the Santa Barbara Channel, from Santa Rosa Island to Point Conception, with the majority of locations to the west of San Miguel Island. One whale (Tag #5790) also spent approximately 8 d over the deeper water of the San Clemente Canyon south of San Clemente Island. One other whale (Tag #836) traveled north after tagging, spending time at multiple locations along the way, including 12 d near Cordell Bank off Point Reyes and 49 d off Cape Mendocino, before reaching Point St. George on the northern California coast by the end of October. On the central and northern California coast, locations for this latter whale occurred over both continental shelf and slope waters in almost equal proportions.

The locations of blue whales tagged off central California (**Figure 5**) were concentrated in several areas along the California and southern Oregon coast, with the Gulf of the Farallones and Cordell Bank being the most heavily used, followed by the area around Point Arena and off Fort Bragg, as well as the area off Pigeon Point. Aside from whale Tag #5685, who traveled south to Mexico, only one other blue whale tagged off central California traveled to southern California (Tag #5746). This latter whale spent at least 3 d in an area approximately 100 km

Table 1. Deployment and performance data for satellite-monitored radio tags deployed on blue whales in southern and central California, 2016. In the Sex column, U = unknown sex, in cases when no biopsy sample was collected. See Section 2.2.2 for location filtering method.

Tag #	Sex	Tag Type	Deployment Date	Most Recent Location	# Days Tracked	# Filtered Locations	# Argos Locations	Total Distance (km)
836	U	LO	16-Jul-16	28-Oct-16	103.2	354	433	3,724
843	U	LO	1-Aug-16	13-Nov-16	103.2	431	535	3,687
4172	U	LO	2-Aug-16	29-Sep-16	57.7	251	349	2,486
4173	U	LO	16-Jul-16	19-Jul-16	2.3	10	9	38
5784	U	LO	19-Jul-16	24-Jul-16	4.3	16	20	366
5826	M	LO	17-Jul-16	27-Oct-16	102.6	397	512	2,940
5843	M	LO	3-Aug-16	4-Oct-16	61.7	260	316	2,548
5878	U	LO	17-Jul-16	8-Nov-16	113.8	349	462	5,759
5938	U	LO	1-Aug-16	16-Sep-16	45.3	195	260	2,162
10825	M	LO	2-Aug-16	30-Nov-16	120.6	552	732	5,704
10827	F	LO	17-Jul-16	7-Sep-16	51.4	187	233	1,995
Mean		**LO**			**69.6**	**273**	**351**	**2,855**
Median		**LO**			**61.7**	**260**	**349**	**2,548**
833	F	DM	14-Jul-16	19-Jul-16	4.3	33	35	163
839*	U	DM	14-Jul-16	-	0	-	-	-
5685	M	DM	1-Aug-16	6-Nov-16	96.9	425	528	5,952
5701	M	DM	14-Jul-16	28-Aug-16	44.7	178	205	1,482
5746	F	DM	31-Jul-16	30-Sep-16	61.7	145	171	2,223
5790	M	DM	14-Jul-16	29-Sep-16	76.4	396	533	4,919
23032	F	DM	14-Jul-16	15-Sep-16	62.2	349	403	1,989
23033	M	DM	3-Aug-16	3-Aug-16	0.6	7	7	13
Mean		**DM**			**49.5**	**219**	**269**	**2,391**
Median		**DM**			**61.7**	**178**	**205**	**1,989**

KEY: DM = Telonics RDW-665 Dive-Monitoring tag; F = Female; km = kilometer(s); LO = Wildlife Computers SPOT6 Location-Only tag, M = Male; # = number; * No transmissions were received for Tag# 839. This tag is not included in summary statistics.

Table 2. Geodesic distances to nearest point on land for blue whales tagged off southern and central California, 2016. The number of locations includes filtered locations (see Section 2.2.2 for filtering method) plus deployment location.

Tag #	Tag Type	# Locations	Median (km)	Mean (km)	SD (km)	Minimum (km)	Maximum (km)	Deploy Location Distance (km)
836	LO	354	13.7	18.1	14.0	0.1	86.0	34.0
843	LO	431	21.4	23.3	11.3	2.6	74.7	32.9
4172	LO	251	10.2	11.7	7.9	0.3	42.5	35.5
4173	LO	10	42.3	42.2	2.9	35.5	45.7	41.9
5784	LO	16	179.5	157.5	65.2	8.5	261.5	8.5
5826	LO	397	46.2	49.0	13.2	11.2	87.3	35.1
5843	LO	260	26.4	25.1	13.1	0.0	59.5	35.3
5878	LO	349	47.9	55.8	32.3	2.3	207.7	32.5
5938	LO	195	9.0	11.3	9.2	0.3	63.0	33.0
10825	LO	552	26.6	32.6	23.8	0.5	107.6	33.0
10827	LO	187	43.3	43.5	9.3	13.8	77.8	33.7
833	DM	33	45.0	44.1	4.8	33.4	58.7	41.3
839*	DM	-	-	-	-	-	-	-
5685	DM	425	25.3	44.9	58.2	0.7	416.3	16.8
5701	DM	178	113.7	103.9	33.3	36.3	173.0	42.9
5746	DM	145	84.7	73.7	32.4	5.9	131.6	34.3
5790	DM	396	49.1	62.7	36.6	7.4	184.2	40.9
23032	DM	349	45.0	48.6	14.7	14.6	111.6	42.9
23033	DM	7	34.9	34.8	1.4	32.7	36.7	35.3
Mean		**252**	**49.1**	**48.0**	**21.3**	**11.4**	**123.6**	**33.9**
Median		**256**	**43.8**	**42.8**	**13.6**	**6.7**	**86.6**	**34.7**

KEY: DM = Telonics RDW-665 Dive-Monitoring tag; km = kilometer(s); LO = Wildlife Computers SPOT6 Location-Only tag; SD = standard deviation; # = number; * No transmissions were received for Tag# 839. This tag is not included in summary statistics.

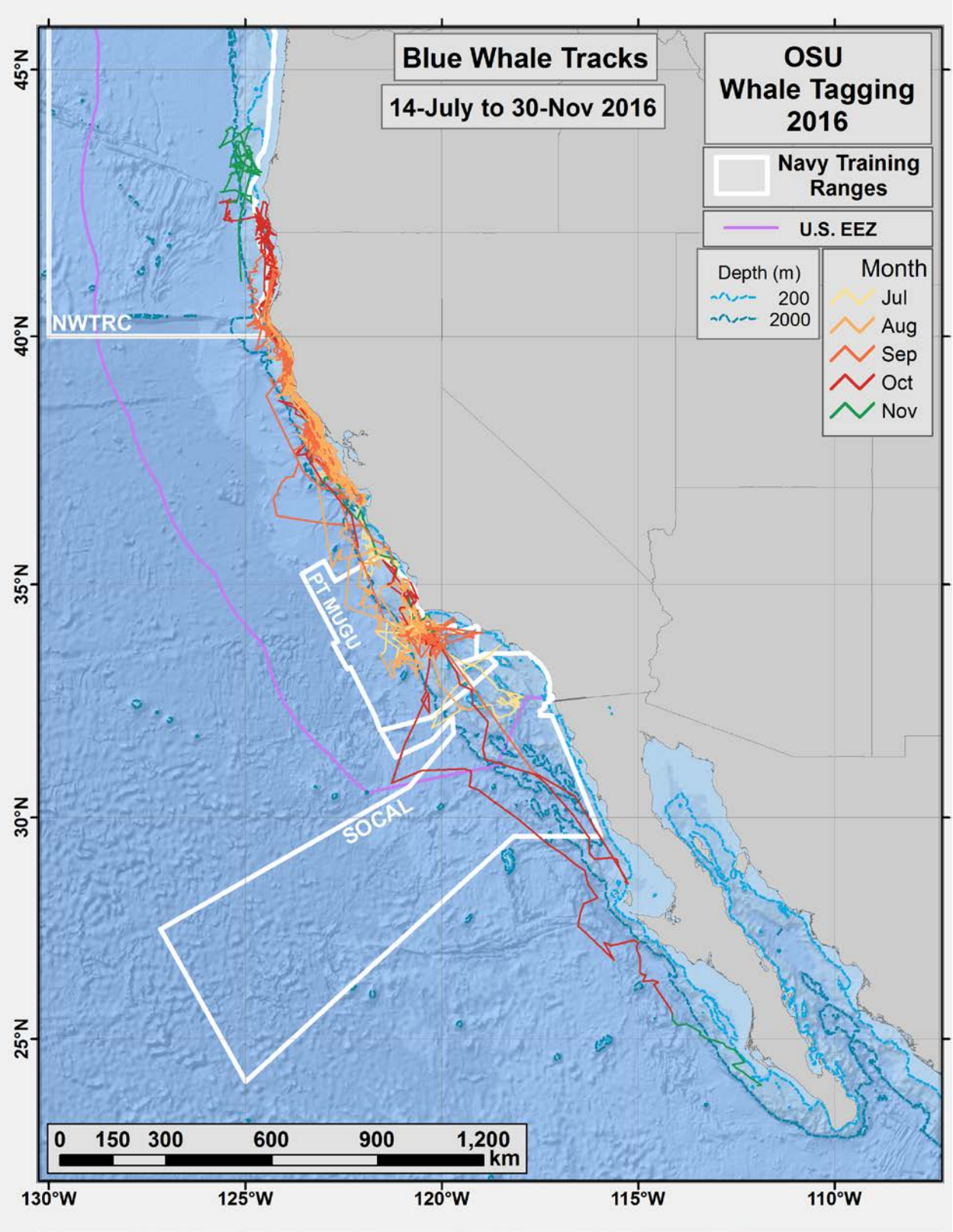

Figure 3. Satellite-monitored radio tracks for blue whales tagged off southern and central California in July and August 2016 (11 LO tags, 8 DM tags).

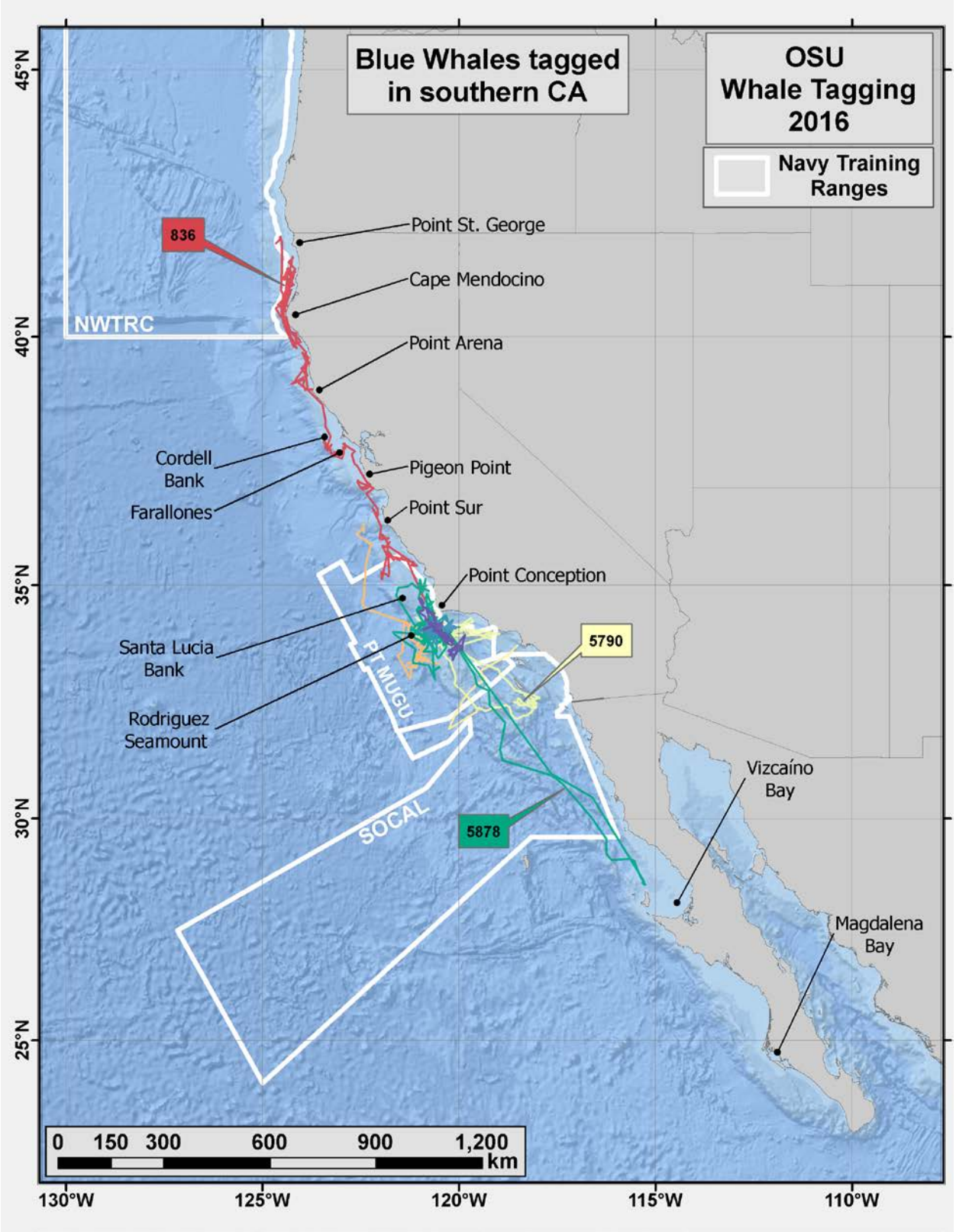

Figure 4. Satellite-monitored radio tracks for blue whales tagged off southern California in July 2016 (6 LO tags, 5 DM tags).

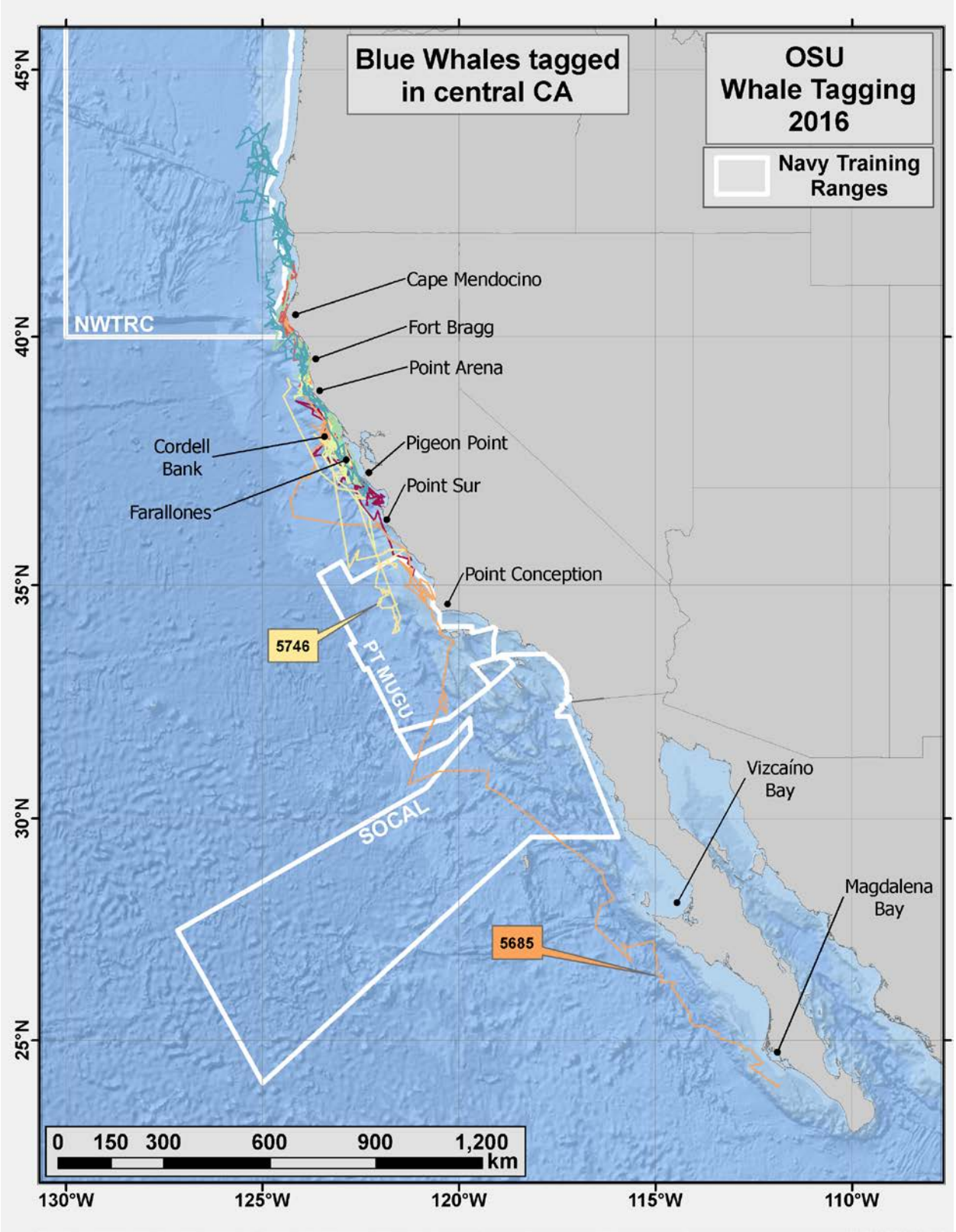

Figure 5. Satellite-monitored radio tracks for blue whales tagged off central California in July and August 2016 (5 LO tags, 3 DM tags).

west of San Miguel Island at the end of August before returning north to Point Arena. Locations for four of the tagged blue whales were primarily over continental slope waters (and some over deeper water), whereas the locations for three other blue whales were predominantly over continental shelf waters and the shelf edge. The blue whale that traveled into southern Oregon spent most of its time off Oregon over slope and deeper waters, but had locations over both shelf and slope waters while in California.

The most heavily used Navy training area for tagged blue whales was PT MUGU, with 12 of the 18 tracked whales having from <1 to 100 percent of their total locations there (**Table 3, Figure 6**). This represented from <1 to 100 percent of their total tracking periods or <1 to 102 d in PT MUGU. Four blue whales had between 3 and 56 percent of their total locations within SOCAL, representing between 4 and 62 percent of their total tracking periods (3 to 13 d; **Table 3**, **Figure 7**). Two blue whales had locations within the NWTRC; 2 percent of total locations and 2 percent of tracking period (2 d) for one whale, and 45 percent of total locations and 43 percent of tracking period (52 d) for the other whale (**Figure 8**). The track of a third blue whale crossed the NWTRC, representing <1 percent of its tracking period (<1 d), but no locations for this whale occurred within the NWTRC (**Table 3**). None of the tagged blue whales were tracked within W237 of the NWTRC, or within the Gulf of Alaska Temporary Maritime Activities Area. Blue whale locations occurred in PT MUGU during all 5 months in which they were tracked (July through November), during 4 months in SOCAL (July, August, September, and October), and during 3 months in the NWTRC (September, October, and November).

The amount of time spent in BIAs by tagged blue whales ranged from <1 to 96 percent of their total tracking periods (**Table 4**). The two most heavily used BIAs (of the six overlapping Navy training ranges), in terms of number of whales having locations there, were Santa Barbara Channel and San Miguel BIA and Point Conception/Arguello BIA (**Figures 9 and 10**). Ten blue whales had locations in the Santa Barbara Channel and San Miguel BIA, spending 1 to 96 percent of their total tracking time there, or 1 to 64 d. This represented 1 to 97 percent of the total number of locations for these 10 whales. Seven blue whales had locations in the Point Conception/Arguello BIA, spending 1 to 7 percent of their total time there, or <1 to 6 d. For these seven whales, this represented 1 to 6 percent of their total number of locations. Blue whale locations occurred in these former two BIAs during all 5 months in which blue whales were tracked (July through November). One blue whale had locations within the Tanner-Cortez Bank BIA and the track of another blue whale crossed this same area, representing <1 of the total number of locations and 1 percent of the tracking period (1 d) for the former whale, and <1 percent of the tracking period (<1 d) for the latter whale (**Figure 11**). Blue whale locations/tracks occurred in the Tanner-Cortez Bank BIA in August, September, and October. One blue whale had 7 percent of its locations in the Santa Monica Bay to Long Beach BIA (**Figure 12**), but this represented just 1 percent of the total tracking period (<1 d). One other blue whale had 1 percent of its locations within the San Nicolas Island BIA, representing <1 percent of its total tracking period, or <1 d (**Figure 13**). Blue whale locations occurred in the Santa Monica to Long Beach BIA and the San Nicolas Island BIA in July. None of the blue whales tagged in 2016 were tracked within the San Diego BIA.

Table 3. Percentage of filtered locations and time spent inside the SOCAL, PT MUGU, NWTRC, and W237 areas for blue whales tagged off southern and central California, 2016. See Section 2.2.2 for location filtering method.

Filtered Locations																
Tag #	Tag Type	Total		SOCAL			PT MUGU			NWRTC			W237			
		# Locs	# Days	% Locs	% of Days	# Days	% Locs	% of Days	# Days	% Locs	% of Days	# Days	% Locs	% of Days	# Days	
836	LO	354	103.2	0	0	0	7	6	6.5	2	2	1.8	0	0	0	
843	LO	431	103.2	0	0	0	<1	<1	<1	0	0	0	0	0	0	
4172	LO	251	57.7	0	0	0	0	0	0	0	0	0	0	0	0	
4173	LO	10	2.3	0	0	0	100	100	2.3	0	0	0	0	0	0	
5784	LO	16	4.3	56	62	2.6	44	45	1.9	0	0	0	0	0	0	
5826	LO	397	102.6	0	0	0	99	99	101.6	0	0	0	0	0	0	
5843	LO	260	61.7	0	0	0	0	0	0	0	0	0	0	0	0	
5878	LO	349	113.8	4	10	11.5	91	84	95.6	0	0	0	0	0	0	
5938	LO	195	45.3	0	0	0	0	0	0	0	<1	0.1	0	0	0	
10825	LO	552	120.6	0	0	0	0	0	0	45	43	52.3	0	0	0	
10827	LO	187	51.4	0	0	0	0	0	0	0	0	0	0	0	0	
833	DM	33	4.3	0	0	0	97	100	4.3	0	0	0	0	0	0	
839*	DM	0	0	-	-	-	-	-	-	-	-	-	-	-	-	
5685	DM	425	96.9	3	4	4.0	15	16	15.8	0	0	0	0	0	0	
5701	DM	178	44.7	0	0	0	92	96	42.8	0	0	0	0	0	0	
5746	DM	145	61.7	0	0	0	49	32	20.0	0	0	0	0	0	0	
5790	DM	396	76.4	23	17	13.1	76	80	60.8	0	0	0	0	0	0	
23032	DM	349	62.2	0	0	0	99	97	60.1	0	0	0	0	0	0	
23033	DM	7	0.6	0	0	0	0	0	0	0	0	0	0	0	0	
Mean+		**252**	**61.8**	**21**	**23**	**7.8**	**64**	**63**	**34.3**	**16**	**15**	**18.1**	-	-	-	
Median+		**256**	**61.7**	**13**	**14**	**7.8**	**84**	**82**	**17.9**	**2**	**2**	**1.8**	-	-	-	

KEY: DM = Telonics RDW-665 Dive-Monitoring tag; LO = Wildlife Computers SPOT6 Location-Only; Locs = Locations; # = number; * No transmissions were received for Tag# 839. This tag is not included in summary statistics; +Summary statistics do not include zero values in their calculation.

Table 4. Percentage of filtered locations and time spent inside the BIAs for blue whales tagged off southern and central California, 2016. See Section 2.2.2 for location filtering method.

Filtered Locations																					
Tag #	Tag Type	Total		Santa Monica Bay			San Diego			San Nicolas			Tanner Cortez			Santa Barbara			Point Conception		
		# Locs	# Days	% Locs	% of Days	# Days	% Locs	% of Days	# Days	% Locs	% of Days	# Days	% Locs	% of Days	# Days	% Locs	% of Days	# Days	% Locs	% of Days	# Days
836	LO	354	103.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
843	LO	431	103.2	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1.1	1	1	0.8
4172	LO	251	57.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4173	LO	10	2.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5784	LO	16	4.3	6	1	0.03	0	0	0	0	0	0	0	0	0	63	55	2.4	0	0	0
5826	LO	397	102.6	0	0	0	0	0	0	0	0	0	0	0	0	62	63	64.1	1	1	1.0
5843	LO	260	61.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5878	LO	349	113.8	0	0	0	0	0	0	0	0	0	<1	1	0.8	30	29	33.2	6	5	6.2
5938	LO	195	45.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10825	LO	552	120.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10827	LO	187	51.4	0	0	0	0	0	0	0	0	0	0	0	0	74	74	38.0	0	0	0
833	DM	33	4.3	0	0	0	0	0	0	0	0	0	0	0	0	94	96	4.1	3	7	0.3
839*	DM	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5685	DM	425	96.9	0	0	0	0	0	0	0	0	0	0	0	0	2	1	1.1	5	5	4.6
5701	DM	178	44.7	0	0	0	0	0	0	0	0	0	0	0	0	10	14	6.1	0	0	0
5746	DM	145	61.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5790	DM	396	76.4	0	0	0	0	0	0	1	<1	0.3	0	<1	0.1	48	48	36.8	2	1	1.0
23032	DM	349	62.2	0	0	0	0	0	0	0	0	0	0	0	0	69	71	44.5	3	3	2.0
23033	DM	7	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mean+		**252**	**61.8**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**<1**	**<1**	**0.5**	**45**	**45**	**23.1**	**3**	**3**	**2.3**
Median+		**256**	**61.7**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**<1**	**<1**	**0.5**	**55**	**52**	**19.6**	**3**	**3**	**1.0**

KEY: DM = Telonics RDW-665 Dive-Monitoring tag; LO = Wildlife Computers SPOT6 Location-Only tag; Locs = Locations; # = number; * No transmissions were received for Tag# 839. This tag is not included in summary statistics; + Summary statistics do not include zero values in their calculation.

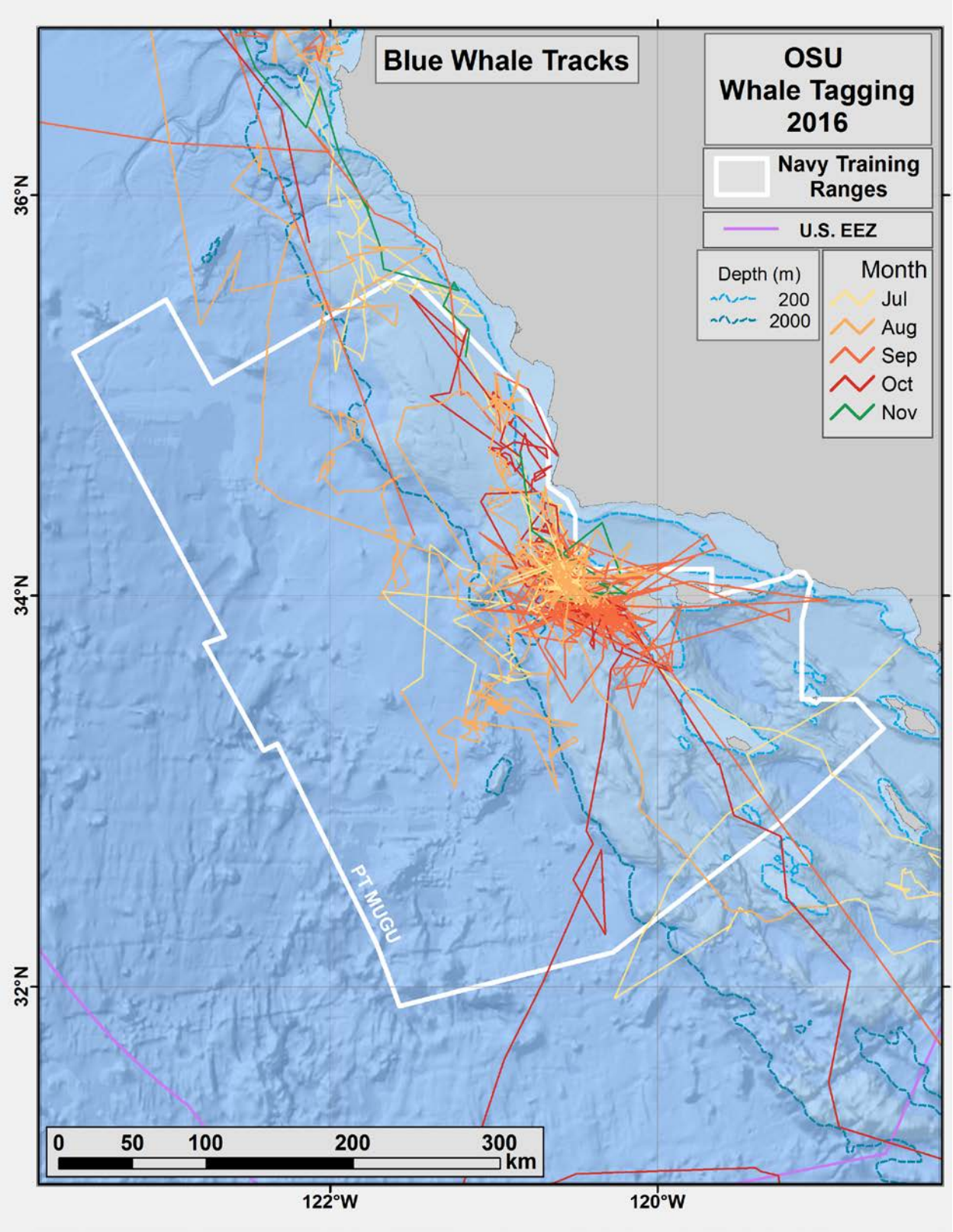

Figure 6. Satellite-monitored radio tracks in PT MUGU for blue whales tagged off southern and central California in July and August 2016 (6 LO tags, 6 DM tags).

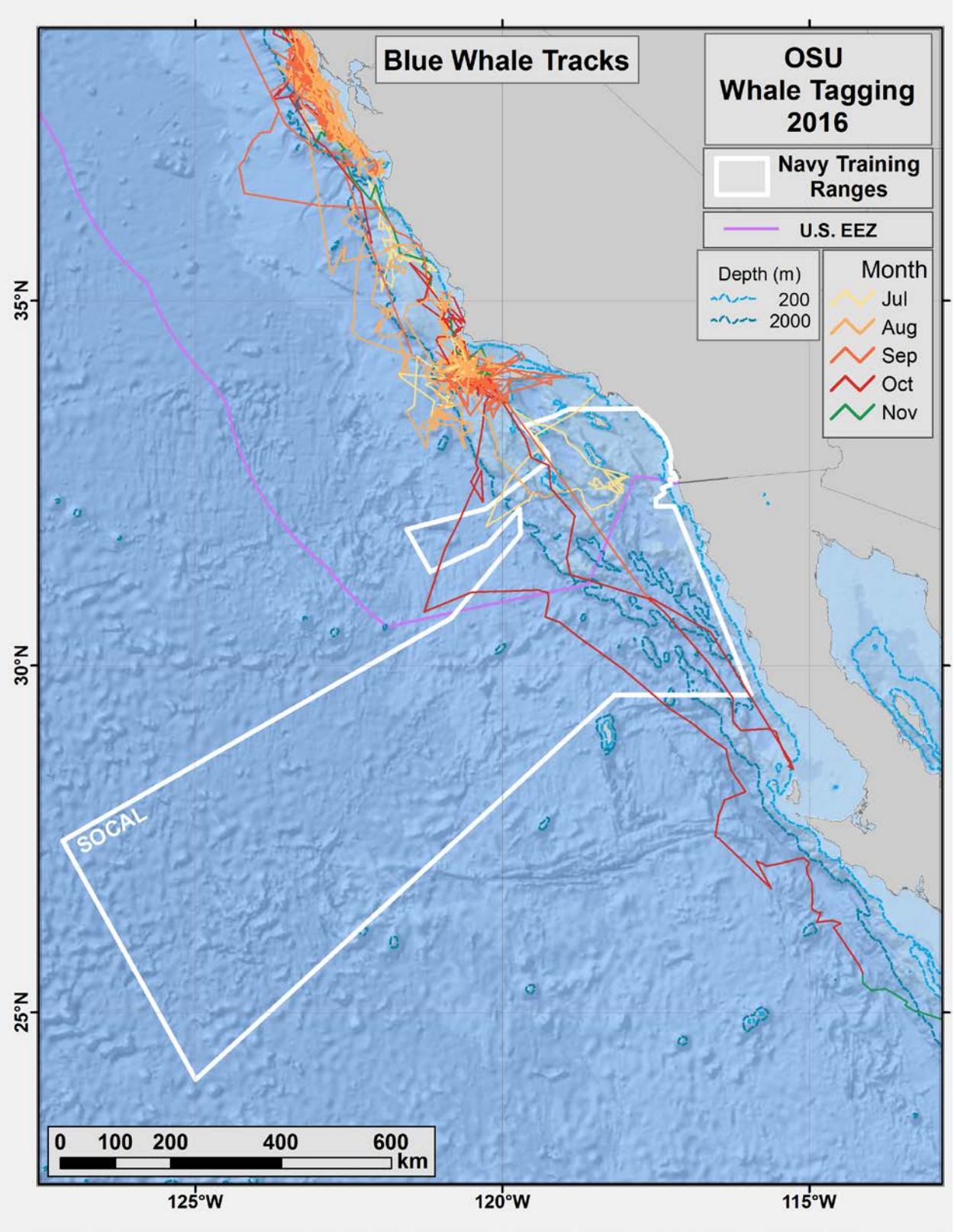

Figure 7. Satellite-monitored radio tracks in SOCAL for blue whales tagged off southern and central California in July and August 2016 (2 LO tags, 2 DM tags).

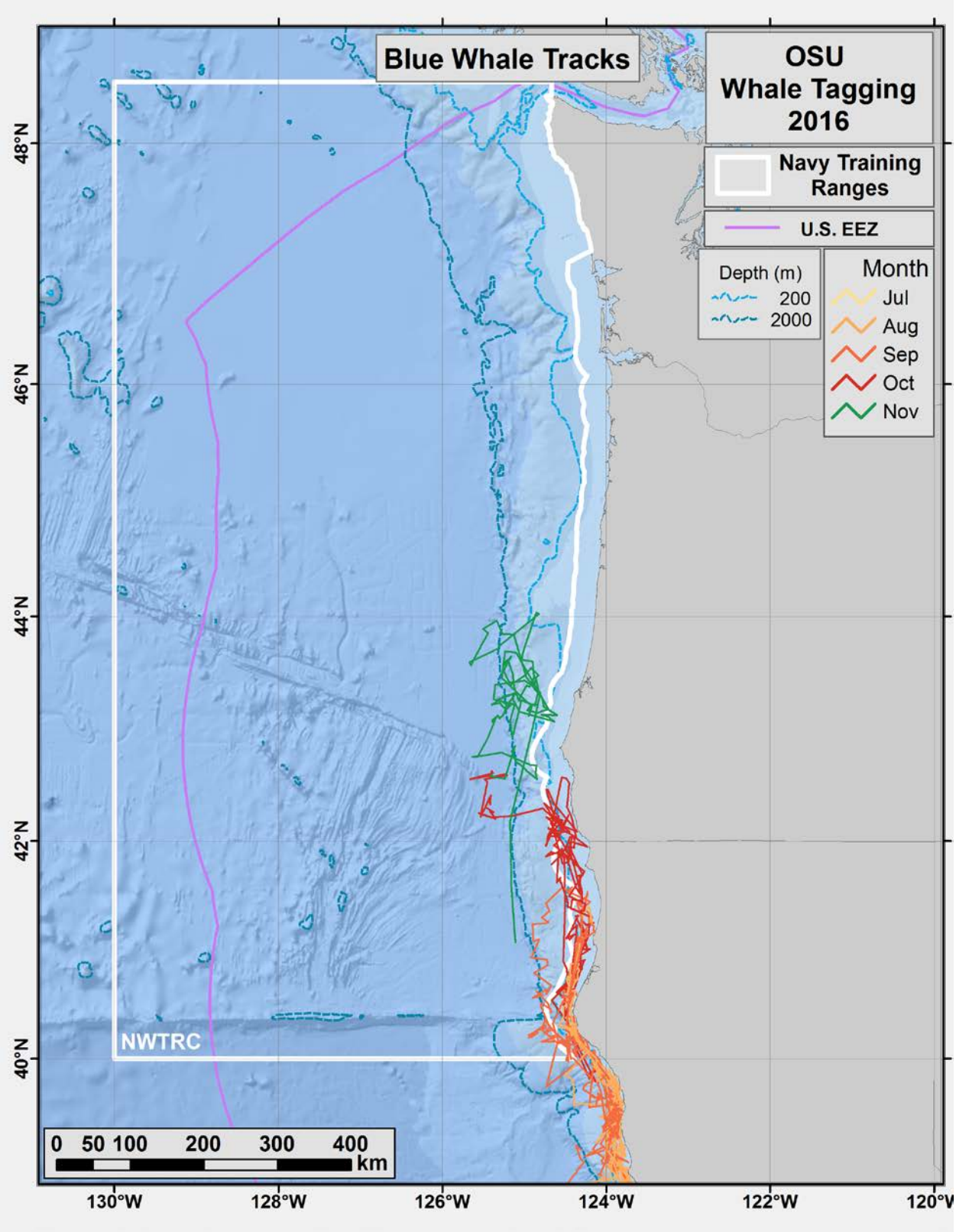

Figure 8. Satellite-monitored radio tracks in NWTRC for blue whales tagged off southern and central California in July and August 2016 (3 LO tags).

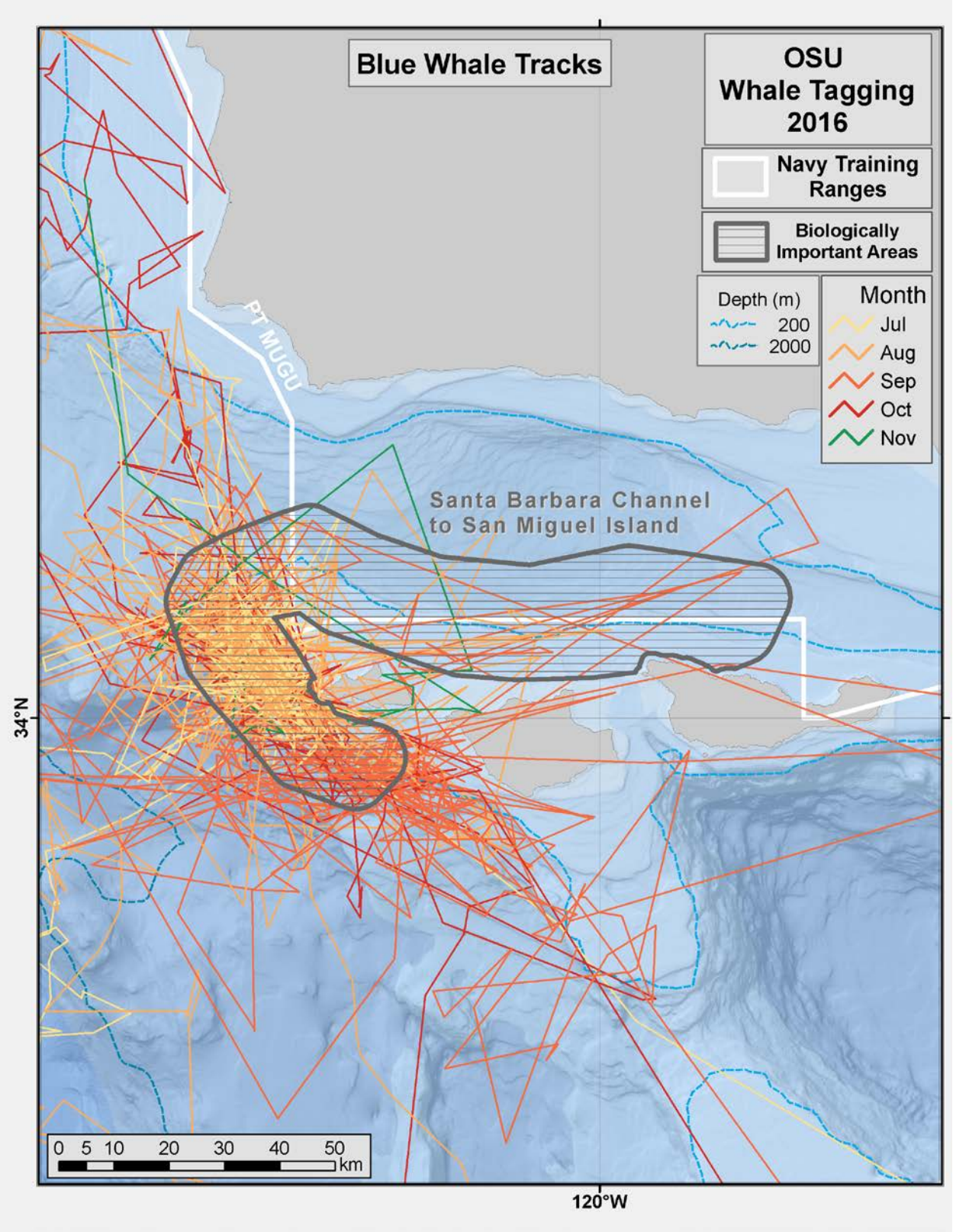

Figure 9. Satellite-monitored radio tracks in the Santa Barbara Channel and San Miguel BIA for blue whales tagged off southern and central California in July and August 2016 (5 LO tags, 5 DM tags).

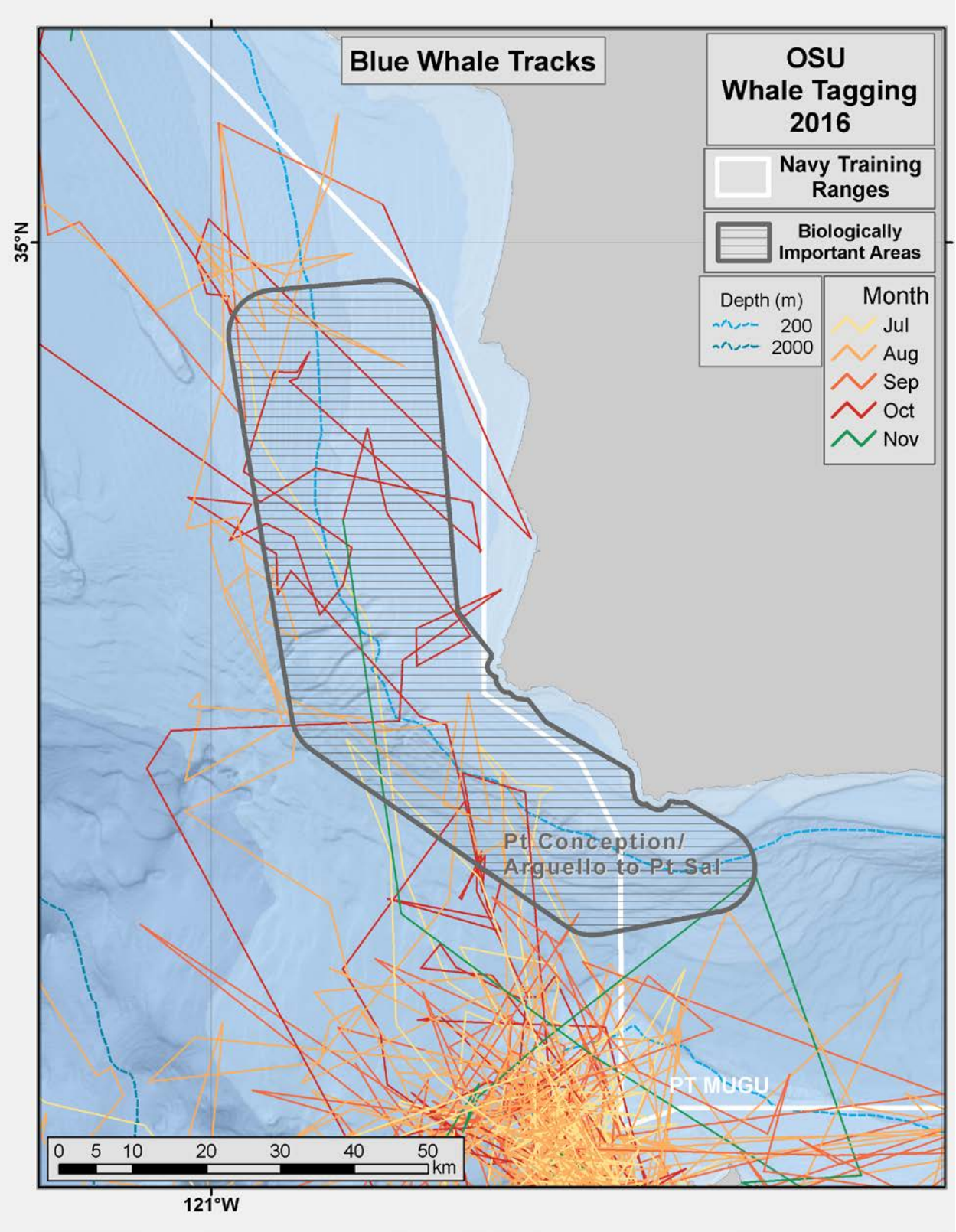

Figure 10. Satellite-monitored radio tracks in the Point Conception/Arguello BIA for blue whales tagged off southern and central California in July and August 2016 (3 LO tags, 4 DM tags).

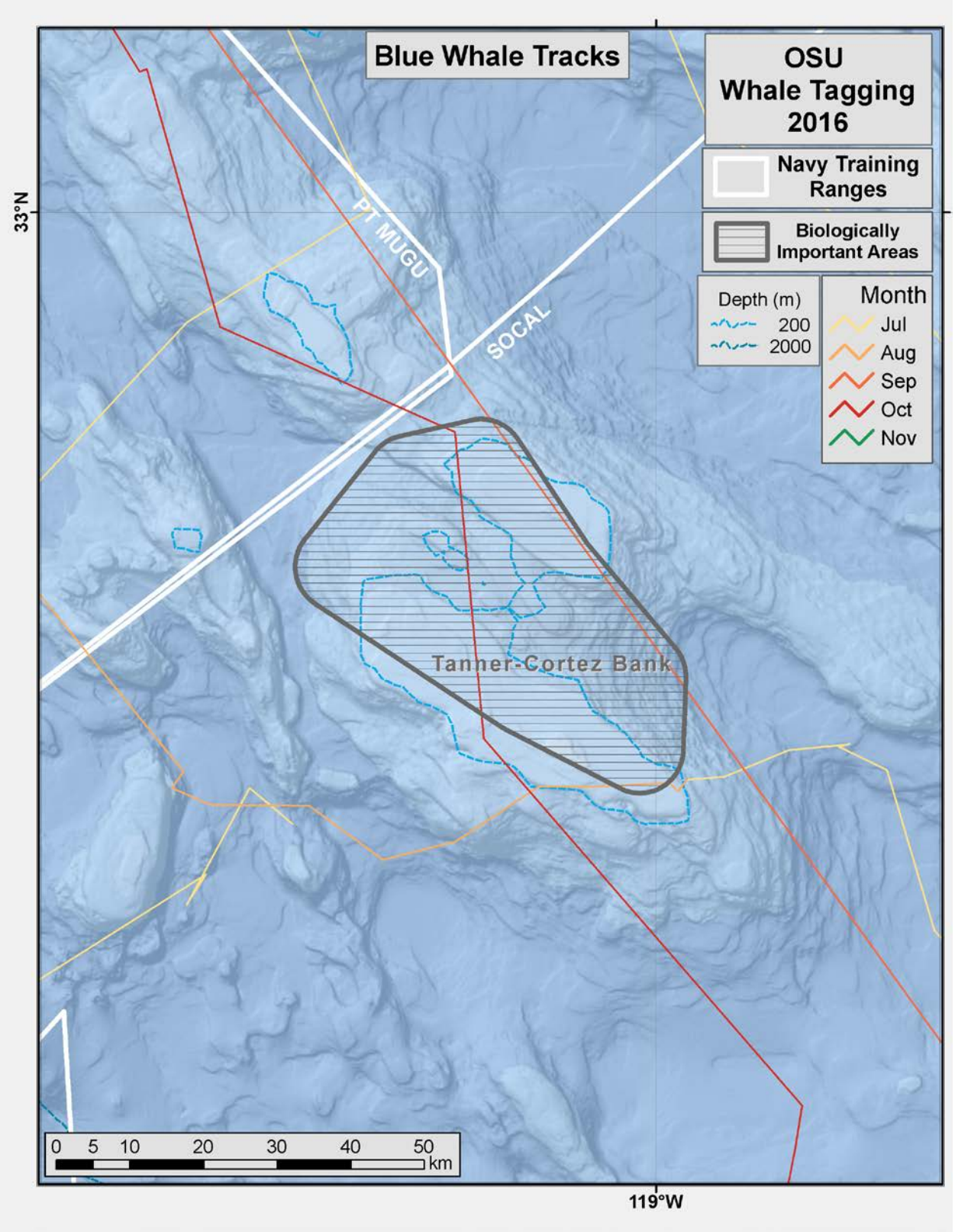

Figure 11. Satellite-monitored radio tracks in the Tanner-Cortez Bank BIA for blue whales tagged off southern California in July 2016 (1 LO tag, 1 DM tag).

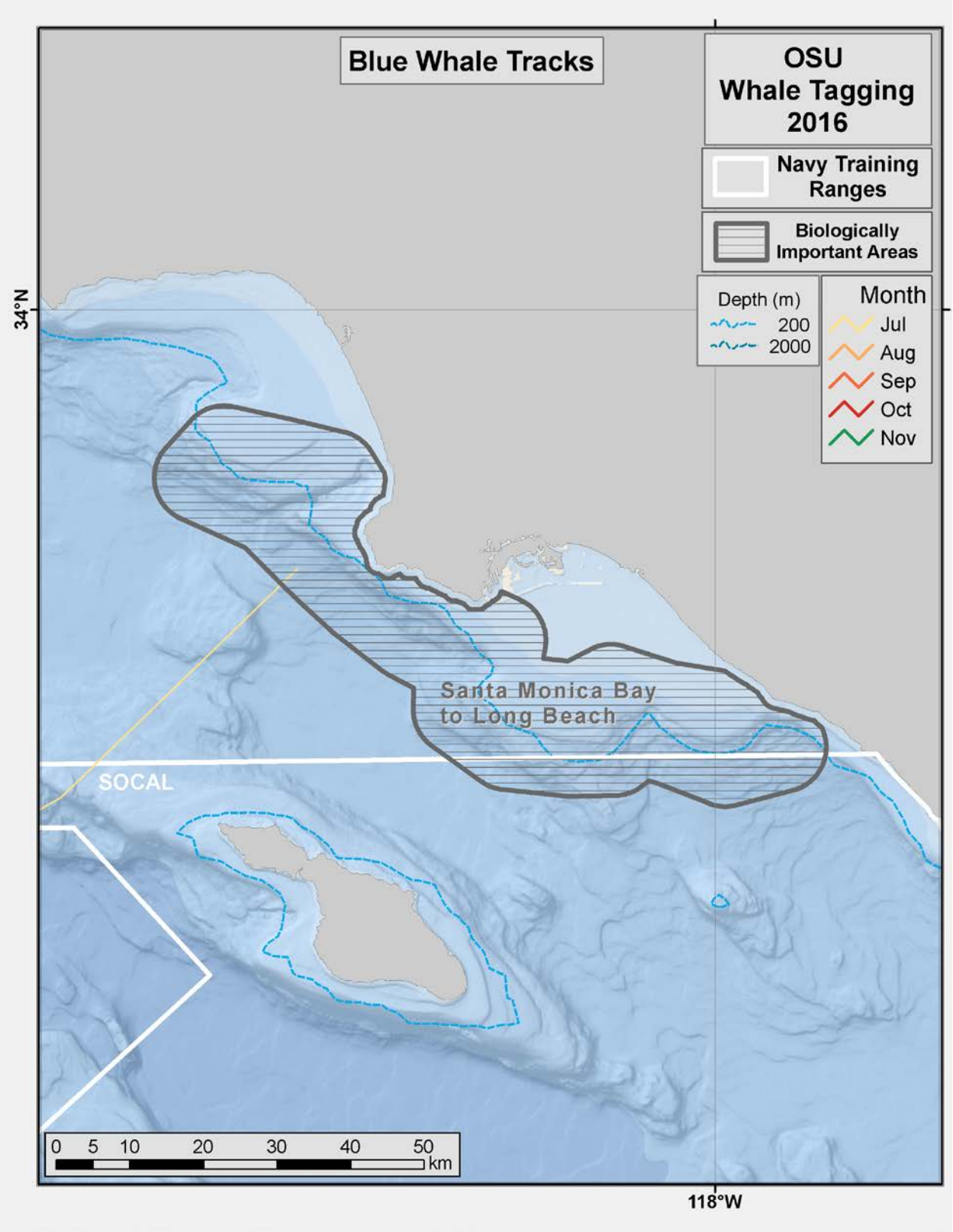

Figure 12. Satellite-monitored radio tracks in the Santa Monica Bay to Long Beach BIA for a blue whale (Tag #5784) tagged off southern California in July 2016 (1 LO tag).

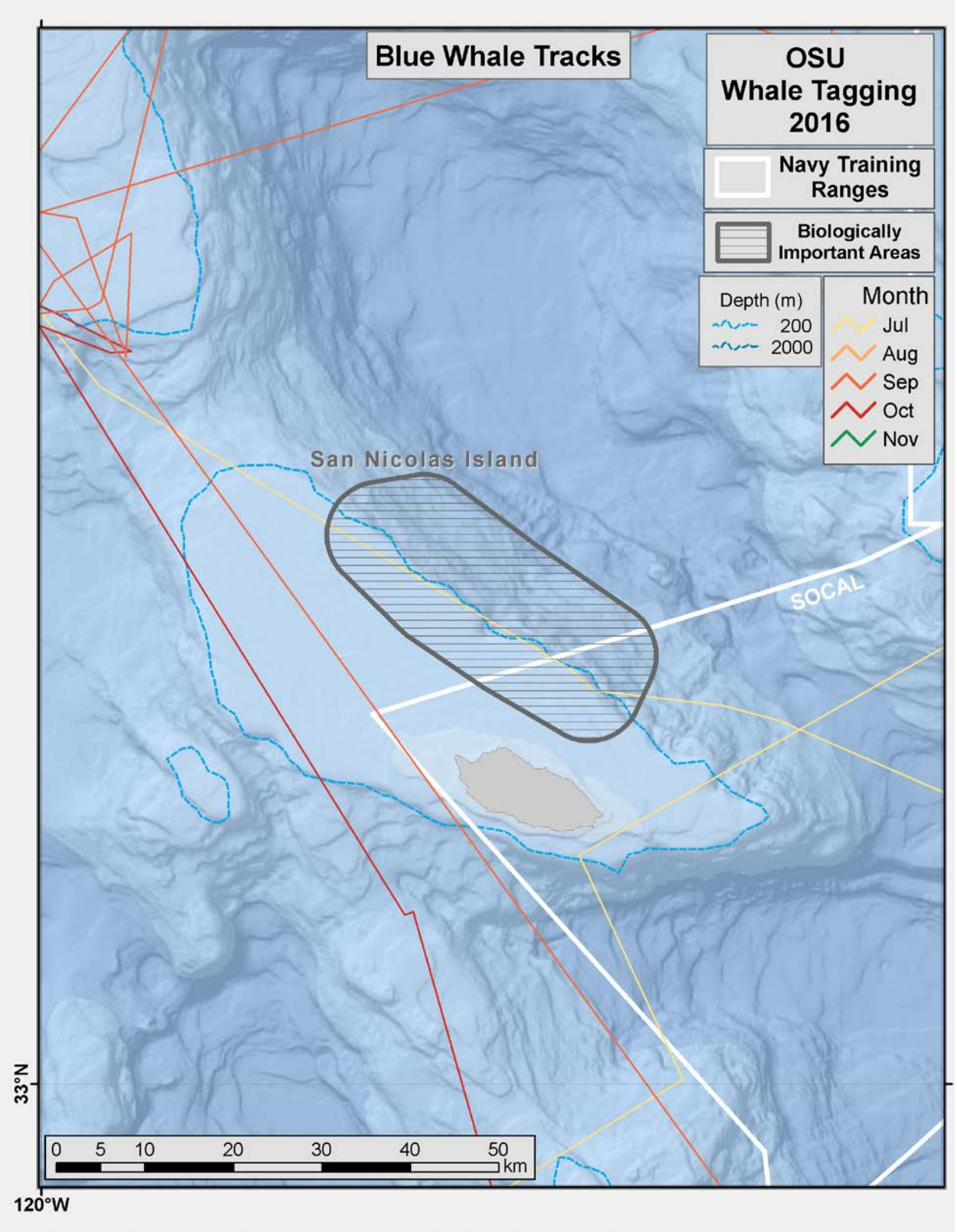

Figure 13. Satellite-monitored radio tracks in the San Nicolas Island BIA for a blue whale (Tag #5790) tagged off southern California in July 2016 (1 LO tag).

3.1.2 Dive Analysis

Telonics DM tags were deployed on eight blue whales off central and southern California during July and early August 2016. One tag was not heard from. For the remaining seven, median tracking duration was 61.7 d (range = 0.6–96.9 d; **Table 5**) and the tags provided a median of 2,294 dive summaries (range = 88–7,480) and 178 filtered Argos locations (range = 7–425). Five whales were tagged off San Miguel Island, California and generally remained in that area for the duration of the tracking period with the exception of one whose tag stopped transmitting off Point Sur, California (Tag #5701), and another (Tag #5790) that made a loop south to waters south of San Clemente Island before returning to San Miguel Island. Three whales were tagged off central California and, of the two whose tags lasted an extended period of time, both subsequently moved to the waters west of San Francisco Bay. From there, one whale meandered south to an area approximately 100 km west of San Miguel Island before returning north to an area off Point Arena, while the other whale moved north as far as Cape Mendocino, before moving south and eventually beginning their southward migration with the tag stopping off southern Baja California, Mexico.

Table 5. Summary statistics of DM tags deployed on blue whales off southern and central California, 2016.

Tag #	Sex	Tag Type	Deployment Date	# Days Tracked	Locs per Day	Distance (km)	# Dives Transmitted	Filtered Locs
833	Female	DM	14-Jul-16	4.3	7.7	163	672	33
5790	Male	DM	14-Jul-16	76.4	5.2	4,919	7,480	396
5701	Male	DM	14-Jul-16	44.7	4.0	1,482	2,294	178
839*	Unknown	DM	14-Jul-16	0	-	-	-	-
23032	Female	DM	14-Jul-16	62.2	5.6	1,989	4,438	349
5746	Female	DM	31-Jul-16	61.7	2.4	2,223	983	145
5685	Male	DM	1-Aug-16	96.9	4.4	5,952	4,511	425
23033	Male	DM	3-Aug-16	0.6	11.4	13	88	7
Mean				**49.5**	**5.8**	**2,391**	**2,924**	**219**
Median				**61.7**	**5.2**	**1,989**	**2,294**	**178**

KEY: DM = Telonics RDW-665 Dive-Monitoring tag; km = kilometer(s); Locs = Locations; Tx = Transmitting; # = number; * No transmissions were received for Tag# 839. This tag is not included in summary statistics.

Dive depths reported by all DM tags showed a diel trend with fewer lunges and shallower dives occurring at night and while the whales were traveling linearly (**Figures 14 and 15**). Daytime dive depths were highly variable within and across individuals with whales tagged off central California generally making shallower dives than those tagged off San Miguel Island. Most feeding effort was concentrated near the tagging area west of San Miguel Island, California, and off Point Reyes, California, near Cordell Bank with other areas from Point Arena to Cape Mendocino and offshore of San Diego (**Figure 16**).

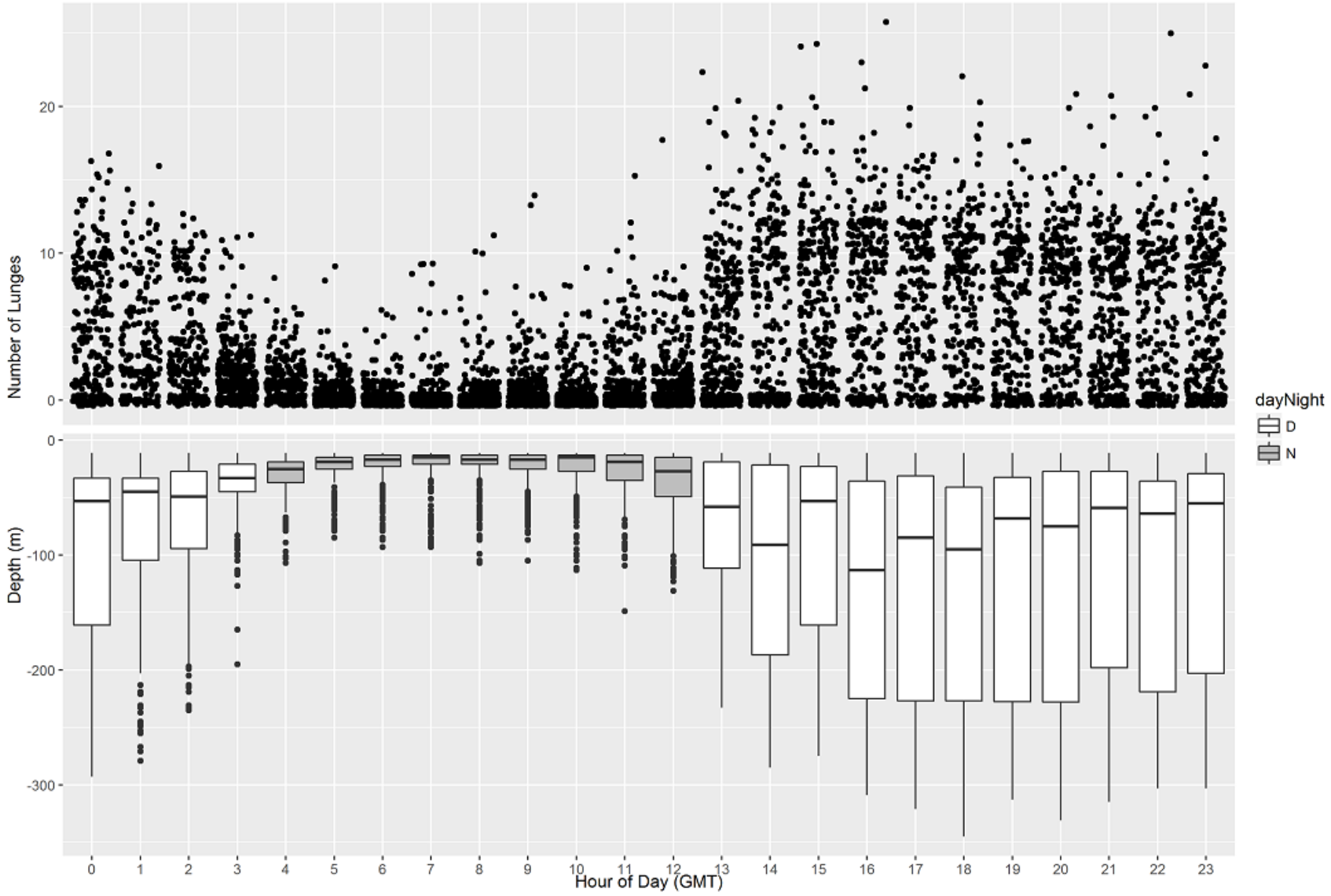

Figure 14. Number of lunges per dive (upper panel) and maximum dive depth (lower panel) of a DM-tagged blue whale (Tag #5790 shown here as an example) tracked off southern California during July–September 2016. Data are presented by hour of day to better visualize diel variability.

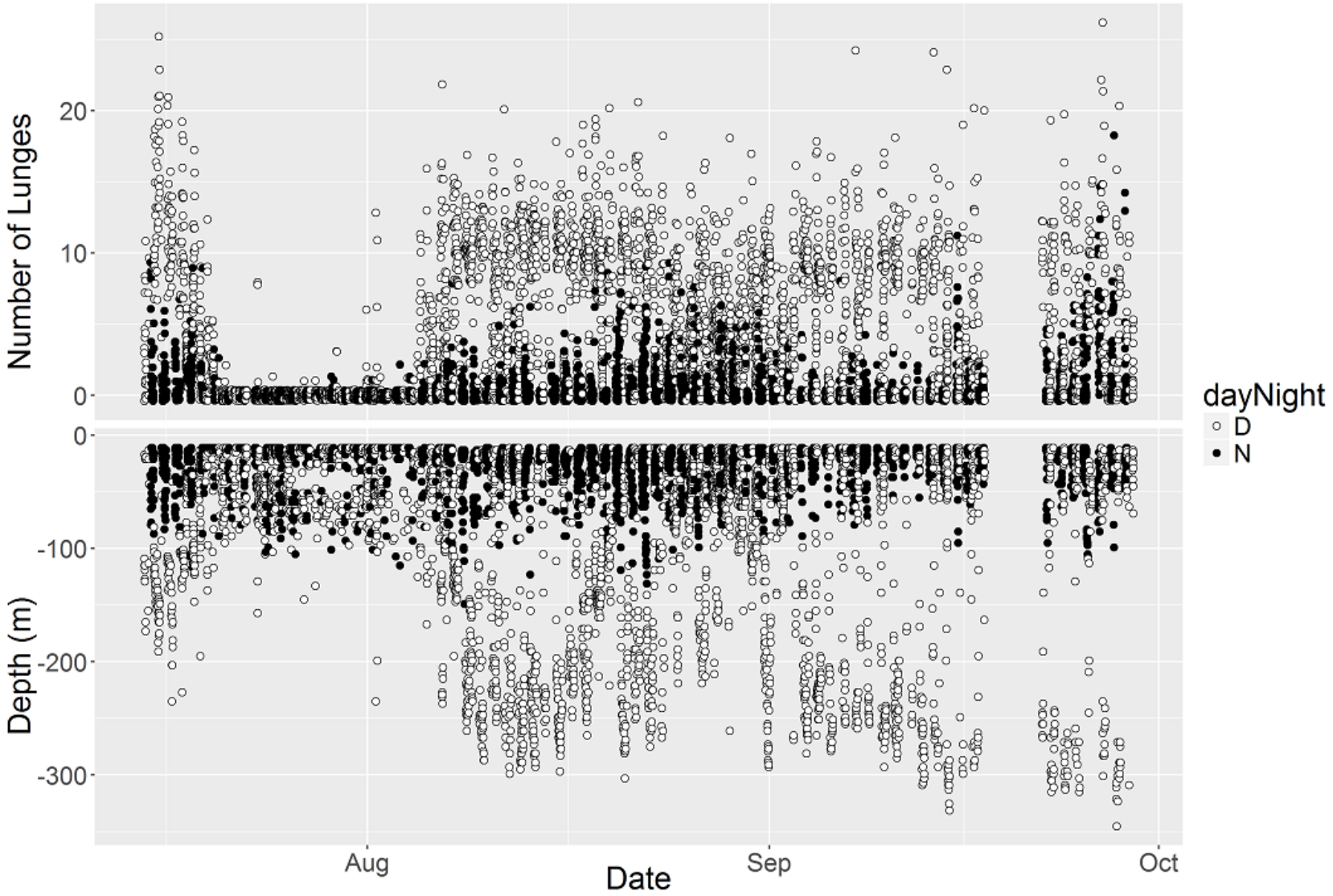

Figure 15. The number of lunges per dive (top panel) and max depth of dives (bottom panel) made by a DM-tagged blue whale (Tag #5790 shown here as an example) off southern California showing a strong diel trend of deeper dives with more lunges during the daytime. The greatly reduced number of lunges in late July–early August coincides with the whale moving to an area offshore of San Diego before returning to the tagging area off San Miguel Island.

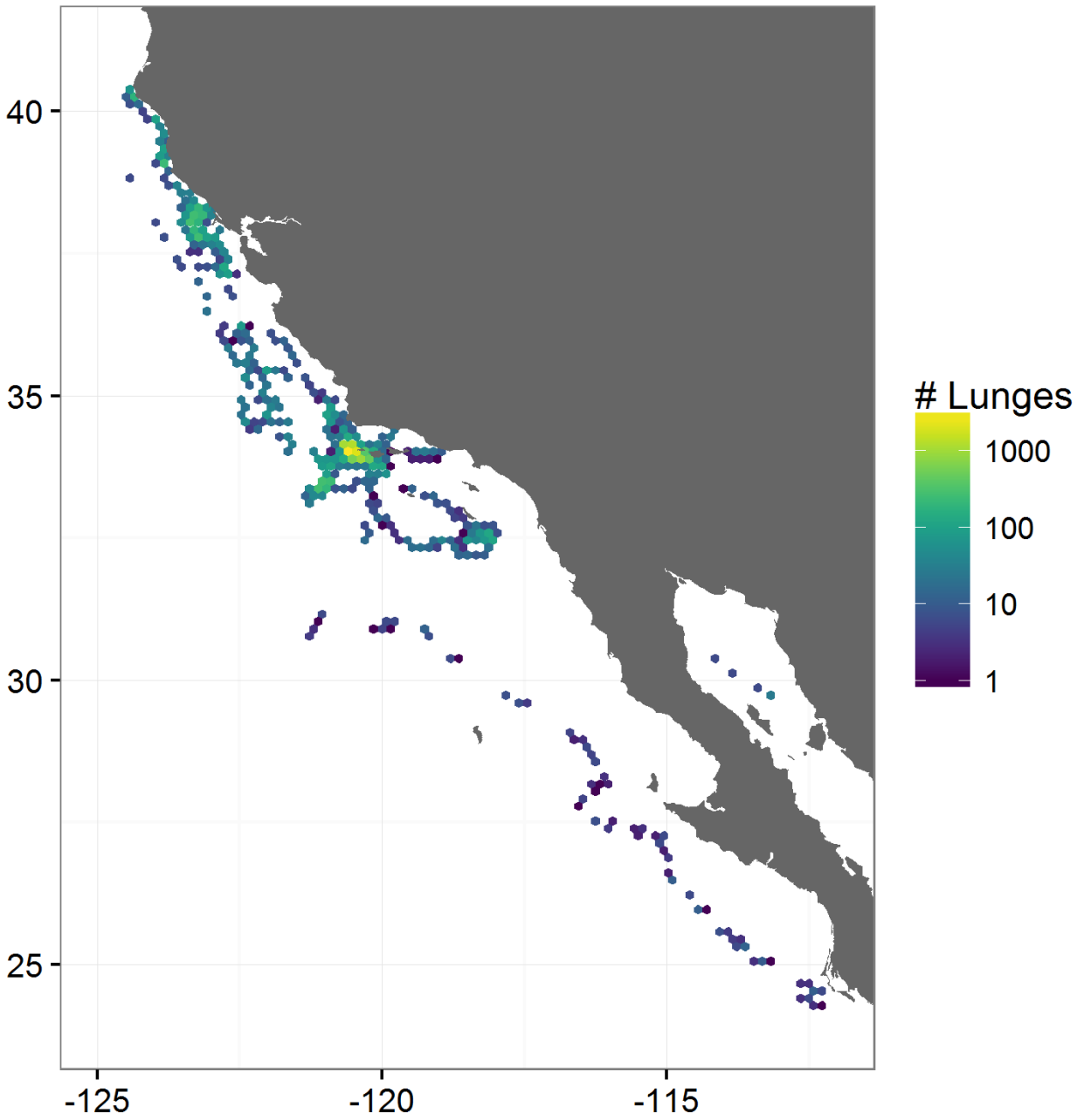

Figure 16. The total number of lunges reported by DM-tagged blue whales on a 0.15 degree hexagonal grid.

3.1.3 Behavioral Responses to Tagging

Two of the 19 tagged blue whales exhibited short-term startle responses to the tagging/biopsy process. One of these responses consisted of a quick surfacing and the other consisted of the whale rolling on their side upon tagging and giving a moderate fluke kick.

3.1.4 Wound Healing

Five blue whales tagged in 2016 were photographed 1 to 2 d after tagging, with two of these showing slight swelling at the tag site (**Table 6**). No blue whales tagged in 2014 or 2015 were resighted during our tagging efforts in 2016.

Table 6. Resightings and tag site descriptions for blue whales satellite-tagged off southern and central California, 2016. Wound size estimates are approximate.

Tag # (Type)	Days After Tagging	
	1	2
833 (DM)		Swelling 5 × 5 cm, 2 cm high
5701 (DM)		Swelling 25 × 15cm, 2 cm high
5826 (LO)	no change	
10825 (LO)	no change	
23032 (DM)	no change	

KEY: cm = centimeter(s); DM = Telonics RDW-665 Dive-Monitoring tag; LO = Wildlife Computers SPOT6 Location-Only tag; # = number

3.1.5 Photo-ID

A total of 6,026 photographs of blue whales was taken during the field efforts in 2016, from which 100 individual whales were identified. Seven of these IDs (six from southern California, one from central California) represented resightings of blue whales photographed in 2014 or 2015 (289 individuals), resulting in a resight rate of 2.4 percent. Photo-IDs were obtained of all 19 tagged blue whales in 2016, with both left- and right-side photos of nine of these, four with right-side photographs only, and six with left-side photographs only. Fluke photographs also were obtained for two of the tagged blue whales.

3.1.6 Ecological Relationships

This information will be included in the Final Report.

3.1.7 Genetics

Skin biopsy samples were collected from 12 of the tagged whales, considered to be blue whales based on field observations (**Figure 17**).

The mtDNA sequences of 10 samples resolved seven haplotypes for a consensus region of 410 bp in length. One sample remains to be sequenced.

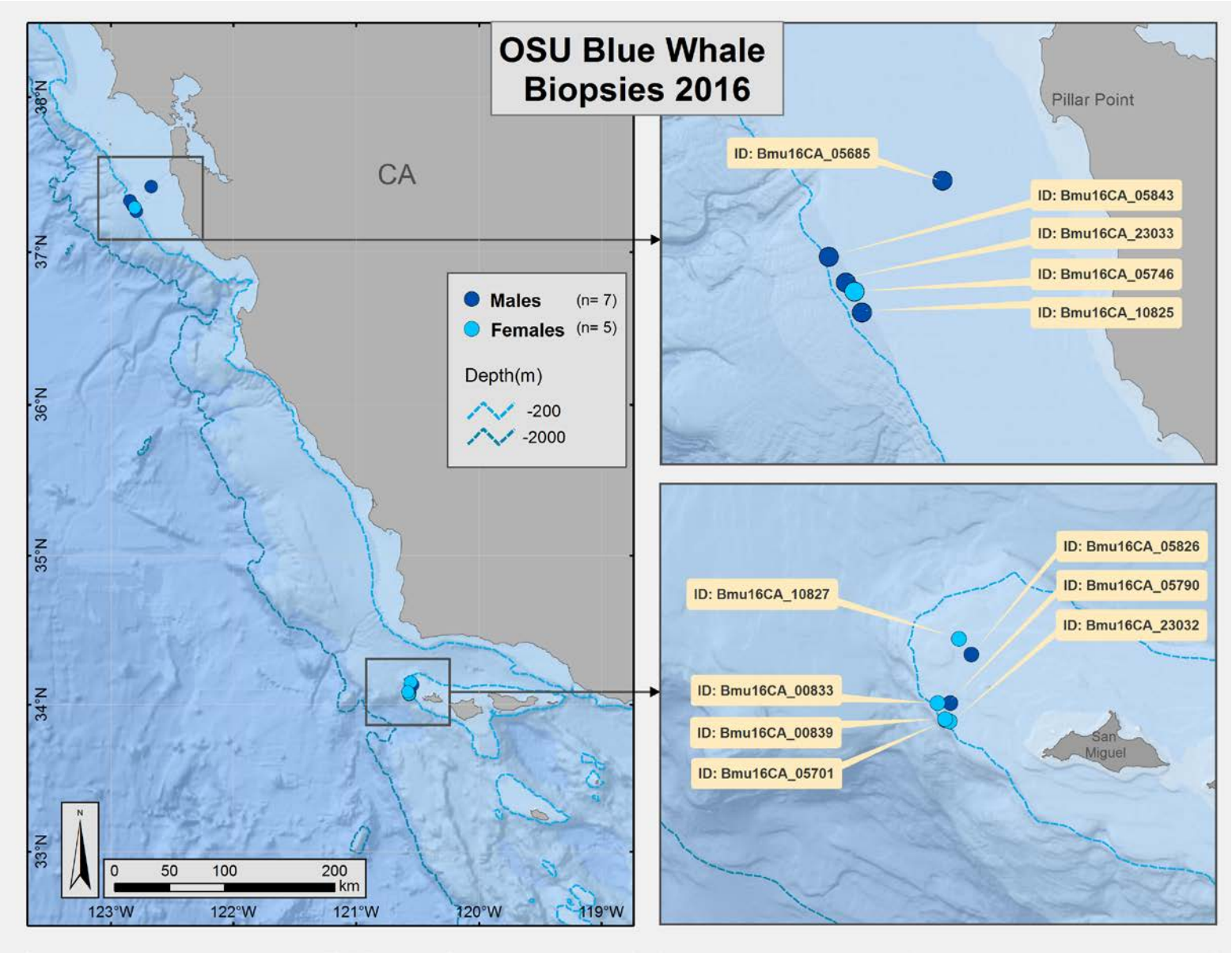

Figure 17. The locations of biopsy sample collections from blue whales tagged in 2016.

3.1.7.1 SEX DETERMINATION

The 11 blue whale samples represented five females and six males (**Table 1**).

3.1.7.2 INDIVIDUAL IDENTIFICATION

This information will be included in the Final Report.

3.1.7.3 STOCK IDENTIFICATION

Based on submission to *DNA-surveillance* and a BLAST search of GenBank®, all of the mtDNA haplotypes were consistent with field identification of blue whales. Results of stock identification will be included in the Final Report.

3.2 Fin Whale

3.2.1 Tracking Analysis

Fourteen tags were deployed on fin whales (5 LO, 9 DM) between July 28 and August 4, 2015 (UTC dates and times). All tags were deployed off central California, near the continental shelf edge between Half Moon Bay and Pigeon Point. Transmissions were received from 13 of the 14 fin whale tags. Tracking periods for these 13 tags ranged from 1.3 to 104.3 d (as of 30 November 2016), with average fin whale tracking durations of 28.7 d (SD = 8.3 d, median = 26.7 d) for LO tags and 38.6 d (SD = 33.4 d, median = 28.7 d) for DM tags (**Table 7**). Maximum distances to shore for both tag types ranged from 40 to 265 km (median = 114 km; **Table 8**).

Fin whale locations ranged over 20 degrees of latitude, from San Nicolas Island in southern California to Hecate Strait in British Columbia, Canada (**Figure 18**). One fin whale (Tag #23030) contributed to this long range, traveling from Pigeon Point in central California to Hecate Strait between Haida Gwaii (formerly Queen Charlotte Island) and mainland British Columbia, with a distance between northern and southern-most locations of over 1,900 km. This latter whale spent 39 d in Hecate Strait before their tag stopped transmitting on 22 September. The other 13 tracked fin whales covered ranges between approximately 25 and 515 km. Most fin whale locations were concentrated along the central California coast, between Monterey Bay and Point Reyes, with lesser concentrations off Point Arena and Point Buchon. Few fin whale locations occurred over continental shelf waters, with the majority being over the continental slope and deeper offshore water.

PT MUGU was the most heavily used training range for fin whales tagged in 2016, with 3 of the 13 tracked whales having between 5 and 46 percent of their total number of locations in the area (**Table 9 and Figure 19**). These whales spent from 3 to 42 percent of their total tracking periods in the PT MUGU area, representing 1 to 44 d. Locations in PT MUGU occurred in 3 of the 5 months in which these whales were tracked (August, September, and October). Only one fin whale had locations within the NWTRC and W237 training areas, as it traveled from central California to British Columbia (**Figures 20 and 21**). This whale (Tag #23030) had 4 percent of their total number of locations and 11 percent of its tracking period within the NWTRC, representing 6 d. Two percent of the total locations for whale Tag #23030 and 3 percent of their tracking period were spent within area W237 of the NWTRC, representing 2 d. Locations in the NWTRC and W237 for this fin whale occurred during the month of August. None of the tagged fin whales were tracked within the SOCAL or the Gulf of Alaska Temporary Maritime Activities training areas.

Table 7. Deployment and performance data for satellite-monitored radio tags deployed on fin whales in central California, 2016. In the Sex column, U = unknown sex, in cases when no biopsy sample was collected. See Section 2.2.2 for location filtering method.

Tag #	Sex	Tag Type	Deployment Date	Most Recent Location	# Days Tracked	# Filtered Locations	# Argos Locations	Total Distance (km)
5709	U	LO	3-Aug-16	30-Aug-16	26.7	30	39	524
5719	U	LO	2-Aug-16	25-Aug-16	22.3	79	103	946
5883	U	LO	1-Aug-16	7-Sep-16	36.6	140	170	1,288
10836	U	LO	3-Aug-16	23-Aug-16	19.7	28	39	661
23039	F	LO	4-Aug-16	11-Sep-16	38.2	103	134	1,831
Mean		**LO**			**28.7**	**76**	**97**	**1,050**
Median		**LO**			**26.7**	**79**	**103**	**946**
831*	U	DM	29-Jul-16	-	0	-	-	-
5655	U	DM	28-Jul-16	10-Nov-16	104.3	374	442	5,805
5700	F	DM	29-Jul-16	26-Sep-16	58.9	272	322	2,729
5726	M	DM	29-Jul-16	29-Aug-16	31.2	114	139	1,385
5743	F	DM	30-Jul-16	24-Aug-16	24.1	135	175	1,238
10829	F	DM	29-Jul-16	24-Aug-16	26.2	62	72	951
10839	U	DM	28-Jul-16	5-Aug-16	7.1	35	34	229
23030	M	DM	28-Jul-16	22-Sep-16	55.8	359	510	4,427
23035	U	DM	3-Aug-16	5-Aug-16	1.3	7	8	45
Mean		**DM**			**38.6**	**170**	**213**	**2,101**
Median		**DM**			**28.7**	**125**	**157**	**1,311**

KEY: DM = Telonics RDW-665 Dive-Monitoring tag; F = Female; km = kilometer(s); LO = Wildlife Computers SPOT6 Location-Only tag; M = Male; # = number; * No transmissions were received for Tag# 831. This tag is not included in summary statistics.

Table 8. Geodesic distances to nearest point on land for fin whales tagged off central California, 2016. The number of locations includes filtered locations (see Section 2.2.2 for filtering method) plus deployment location.

Tag #	Tag Type	# Locations	Median (km)	Mean (km)	SD (km)	Minimum (km)	Maximum (km)	Deploy Location Distance (km)
5709	LO	30	33.7	51.0	29.9	23.9	114.1	35.9
5719	LO	79	43.6	46.2	13.1	22.9	85.1	34.9
5883	LO	140	27.8	30.5	17.1	5.5	124.5	32.7
10836	LO	28	55.2	54.2	26.5	3.3	106.0	35.5
23039	LO	103	134.5	142.5	63.4	30.7	249.6	33.8
831*	DM	-	-	-	-	-	-	-
5655	DM	374	40.4	50.2	38.3	0.0	265.3	28.8
5700	DM	273	37.3	40.2	17.5	0.3	112.4	27.2
5726	DM	114	62.6	59.7	28.9	11.2	145.8	27.5
5743	DM	135	70.8	77.9	32.5	33.3	164.7	34.1
10829	DM	62	33.4	40.0	18.4	18.7	80.5	31.2
10839	DM	35	46.7	46.0	10.3	26.9	69.5	29.1
23030	DM	359	25.1	31.2	23.0	0.3	161.4	29.7
23035	DM	7	34.4	35.5	3.0	32.2	40.1	34.2
Mean		**134**	**49.7**	**54.2**	**24.8**	**16.1**	**132.2**	**31.9**
Median		**103**	**40.4**	**46.2**	**23.0**	**18.7**	**114.1**	**32.7**

KEY: DM = Telonics RDW-665 Dive-Monitoring tag; km = kilometer(s); LO = Wildlife Computers SPOT6 Location-Only tag; SD = standard deviation; # = number; * No transmissions were received for Tag# 831. This tag is not included in summary statistics.

Table 9. Percentage of filtered locations and time spent inside the SOCAL, PT MUGU, NWTRC, and W237 areas for fin whales tagged off central California, 2016. See Section 2.2.2 for location filtering method.

Filtered Locations																
Tag #	Tag Type	Total		SOCAL			PT MUGU			NWRTC			W237			
		# Locs	# Days	% Locs	% of Days	# Days	% Locs	% of Days	# Days	% Locs	% of Days	# Days	% Locs	% of Days	# Days	
5709	LO	30	26.7	0	0	0	0	0	0	0	0	0	0	0	0	
5719	LO	79	22.3	0	0	0	0	0	0	0	0	0	0	0	0	
5883	LO	140	36.6	0	0	0	0	0	0	0	0	0	0	0	0	
10836	LO	28	19.7	0	0	0	0	0	0	0	0	0	0	0	0	
23039	LO	103	38.2	0	0	0	5	3	1.0	0	0	0	0	0	0	
831*	DM	0	0	-	-	-	-	-	-	-	-	-	-	-	-	
5655	DM	374	104.3	0	0	0	46	42	44.3	0	0	0	0	0	0	
5700	DM	272	58.9	0	0	0	0	0	0	0	0	0	0	0	0	
5726	DM	114	31.2	0	0	0	0	0	0	0	0	0	0	0	0	
5743	DM	135	24.1	0	0	0	0	0	0	0	0	0	0	0	0	
10829	DM	62	26.2	0	0	0	40	32	8.3	0	0	0	0	0	0	
10839	DM	35	7.1	0	0	0	0	0	0	0	0	0	0	0	0	
23030	DM	359	55.8	0	0	0	0	0	0	4	11	6.1	2	3	1.7	
23035	DM	7	1.3	0	0	0	0	0	0	0	0	0	0	0	0	
Mean+		**134**	**34.8**	**-**	**-**	**-**	**30**	**26**	**17.8**	**4**	**11**	**6.1**	**2**	**3**	**1.7**	
Median+		**103**	**26.7**	**-**	**-**	**-**	**40**	**32**	**8.3**	**4**	**11**	**6.1**	**2**	**3**	**1.7**	

KEY: DM = Telonics RDW-665 Dive-Monitoring tag; LO = Wildlife Computers SPOT6 Location-Only tag; Locs = Locations; # = number; * No transmissions were received for Tag# 831. This tag is not included in summary statistics; +Summary statistics do not include zero values in their calculation.

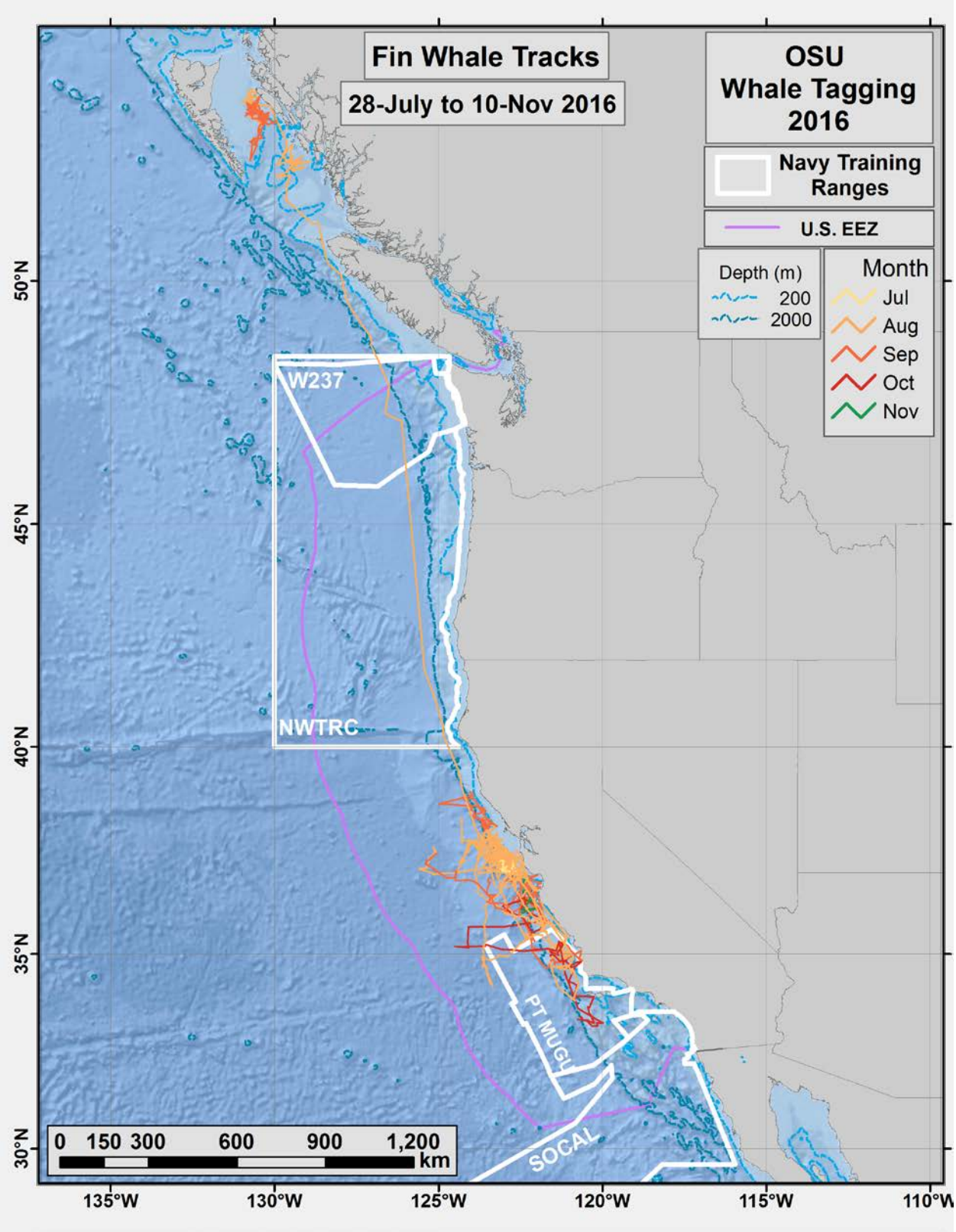

Figure 18. Satellite-monitored radio tracks for fin whales tagged off central California in July and August 2016 (5 LO tags, 9 DM tags).

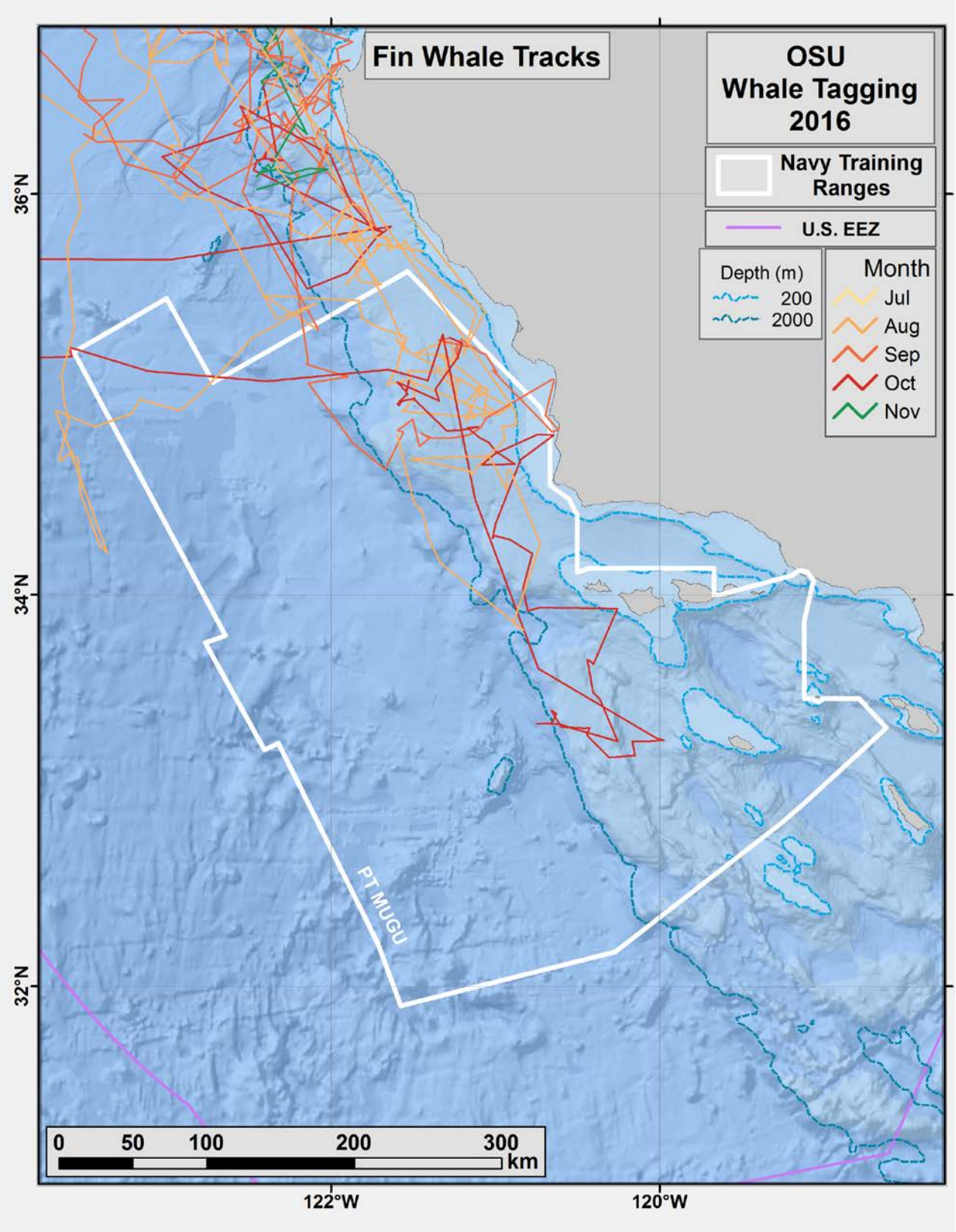

Figure 19. Satellite-monitored radio tracks in PT MUGU for fin whales tagged off central California in July and August 2016 (1 LO tag, 2 DM tags).

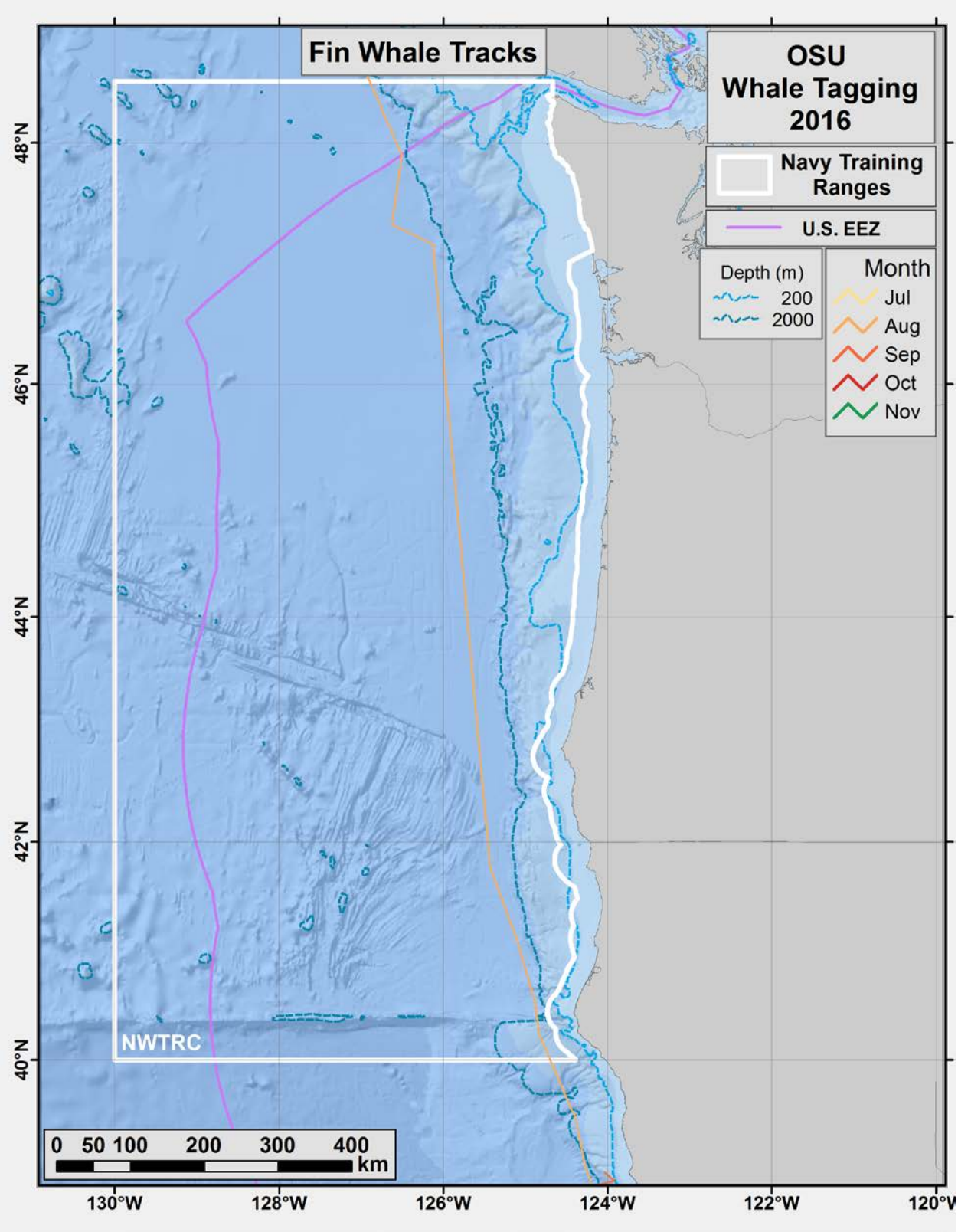

Figure 20. Satellite-monitored radio tracks in NWTRC for a fin whale (Tag# 23030) tagged off central California in July 2016 (DM tag).

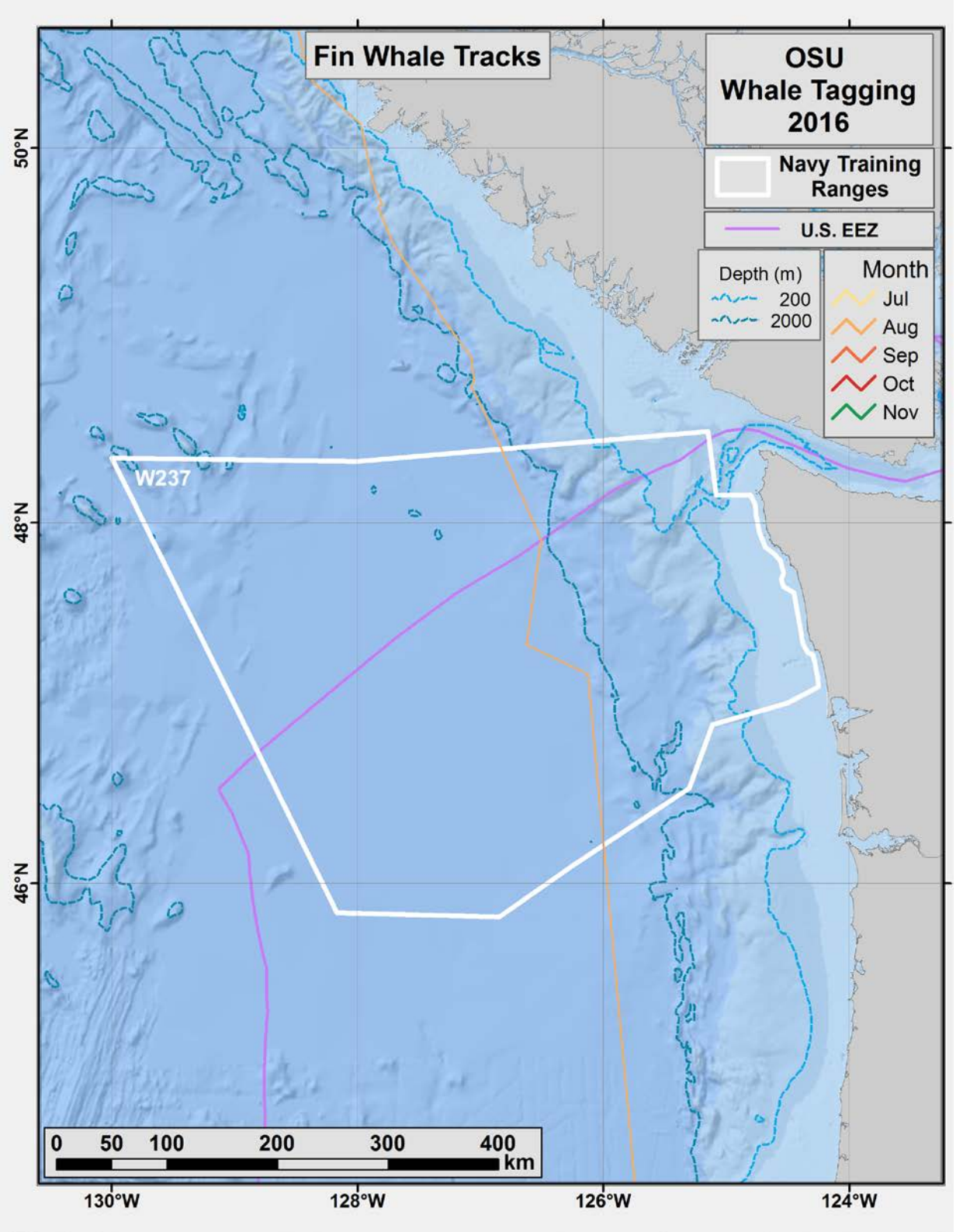

Figure 21. Satellite-monitored radio tracks in area W237 of NWTRC for a fin whale (Tag# 23030) tagged off central California in July 2016 (DM tag).

3.2.2 Dive Analysis

Telonics Dive Monitoring tags were deployed on nine fin whales off central California from late July to early August 2016. Median tracking duration was 28.7 d (range = 1.3 – 104.3 d; **Table 10**), and the tags provided a median of 1,670 dive summaries (range = 8–3,964) and 125 Argos locations (range = 7–374). All nine whales were tagged off central California from late July to early August and generally occupied the waters over the continental slope from Monterrey Bay to Point Arena. While most of the whales remained off central and southern California, one whale (Tag #23030) travelled north to an area east of Haida Gwaii, British Columbia, in the Hecate Strait and remained there for 39 days until their tag stopped transmitting.

Table 10. Summary statistics of DM tags deployed on fin whales off central California in July 2016.

Tag #	Sex	Tag type	Deployment Date	# Days Tracked	Locs per Day	Distance (km)	# Dives Transmitted	Filtered Locs
831*	Unknown	DM	29-Jul-16	0	-	-	-	-
5655	Unknown	DM	28-Jul-16	104.30	3.6	5,805	2,164	374
5700	Female	DM	29-Jul-16	58.9	4.6	2,729	3,790	272
5726	Male	DM	29-Jul-16	31.2	3.7	1,385	1,601	114
5743	Female	DM	30-Jul-16	24.1	5.6	1,238	1,738	135
10829	Female	DM	29-Jul-16	26.2	2.4	951	766	62
10839	Unknown	DM	28-Jul-16	7.1	4.9	229	182	35
23030	Male	DM	28-Jul-16	55.8	6.4	4,427	3,964	359
23035	Unknown	DM	3-Aug-16	1.3	5.3	45	8	7
Mean				**38.6**	**4.6**	**2,101**	**1,777**	**170**
Median				**28.7**	**4.8**	**1,311**	**1,670**	**125**

KEY: DM = Telonics RDW-665 Dive-Monitoring tag; km = kilometer(s); Locs = Locations; Tx = Transmitting; # = number; * No transmissions were received for Tag# 831. This tag is not included in summary statistics.

Dive depths reported by all tags showed a diel trend with fewer lunges and shallower dives occurring at night (**Figure 22**) although there were not always large differences. Daytime dive depths were highly variable within and across individuals with the majority of dives limited to 150 m or less in depth. Feeding effort was relatively consistent across a wide area with the most effort occurring from Monterrey Bay to Point Arena and in the Hecate Strait east of Haida Gwaii, Canada (**Figure 23**).

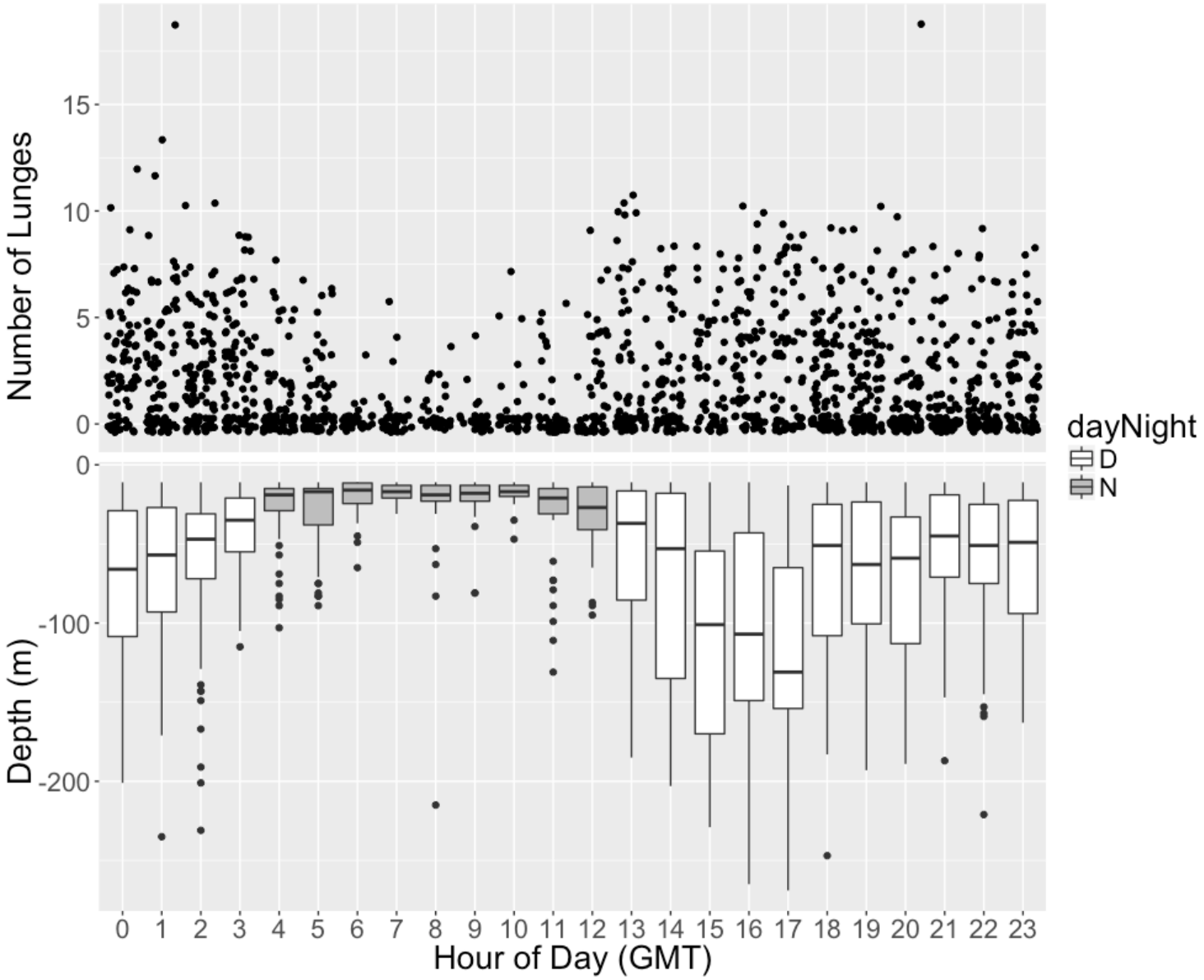

Figure 22. Number of lunges per dive (upper panel) and maximum dive depth (lower panel) of a DM-tagged fin whale (Tag #5726 shown here as an example) tracked off central California during July–August 2016. Data are presented by hour of day to better visualize diel variability.

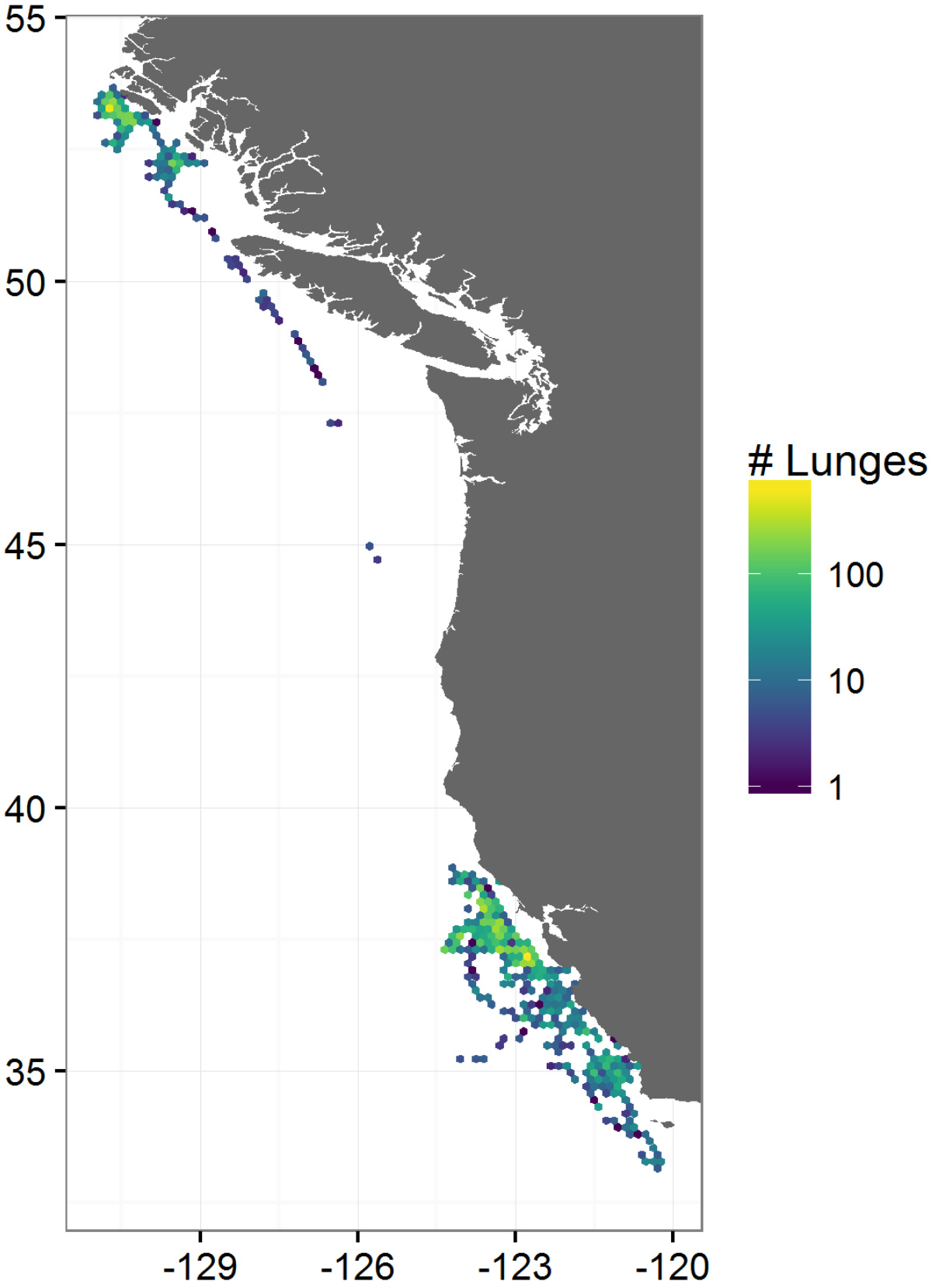

Figure 23. The total number of lunges reported by DM-tagged fin whales on a 0.15 degree hexagonal grid.

3.2.3 Behavioral Responses to Tagging

Only one of the 14 tagged fin whales responded to the tagging/biopsy process, giving a moderate fluke kick and diving upon tagging.

3.2.4 Wound Healing

Only one fin whale tagged in 2016 (Tag #5719) was seen again during our field efforts, 1 d after tagging. No signs of swelling were present. No fin whales tagged in the two previous seasons (2014 and 2015) were resighted in 2016.

3.2.5 Photo-ID

A total of 2,849 photos of fin whales were taken during the 2016 cruise, resulting in IDs for 42 individuals. Two fin whales identified in previous seasons (37 IDs in 2014 and 34 IDs in 2015) were resighted in 2016, which resulted in a 2.8 percent resight rate. Photo-IDs were obtained of all 14 tagged fin whales. Eight IDs included both left- and right-side photographs, five had right-side photos only, and one had only a left side photo.

3.2.6 Ecological Relationships

This information will be included in the Final Report.

3.2.7 Genetics

Skin biopsy samples were collected from six of the tagged whales considered to be fin whales based on field observations (**Figure 24**).

The mtDNA sequences of five samples resolved four haplotypes for a consensus region of 410 bp in length. One sample remains to be sequenced.

3.2.7.1 SEX DETERMINATION

The six fin whale samples represented four females and two males (**Table 7**).

3.2.7.2 INDIVIDUAL IDENTIFICATION

This information will be included in the Final Report.

3.2.7.3 STOCK IDENTIFICATION

Based on submission to *DNA-surveillance* and a BLAST search of GenBank®, all of the mtDNA haplotypes were consistent with field identification of fin whales. Results of stock identification will be included in the Final Report.

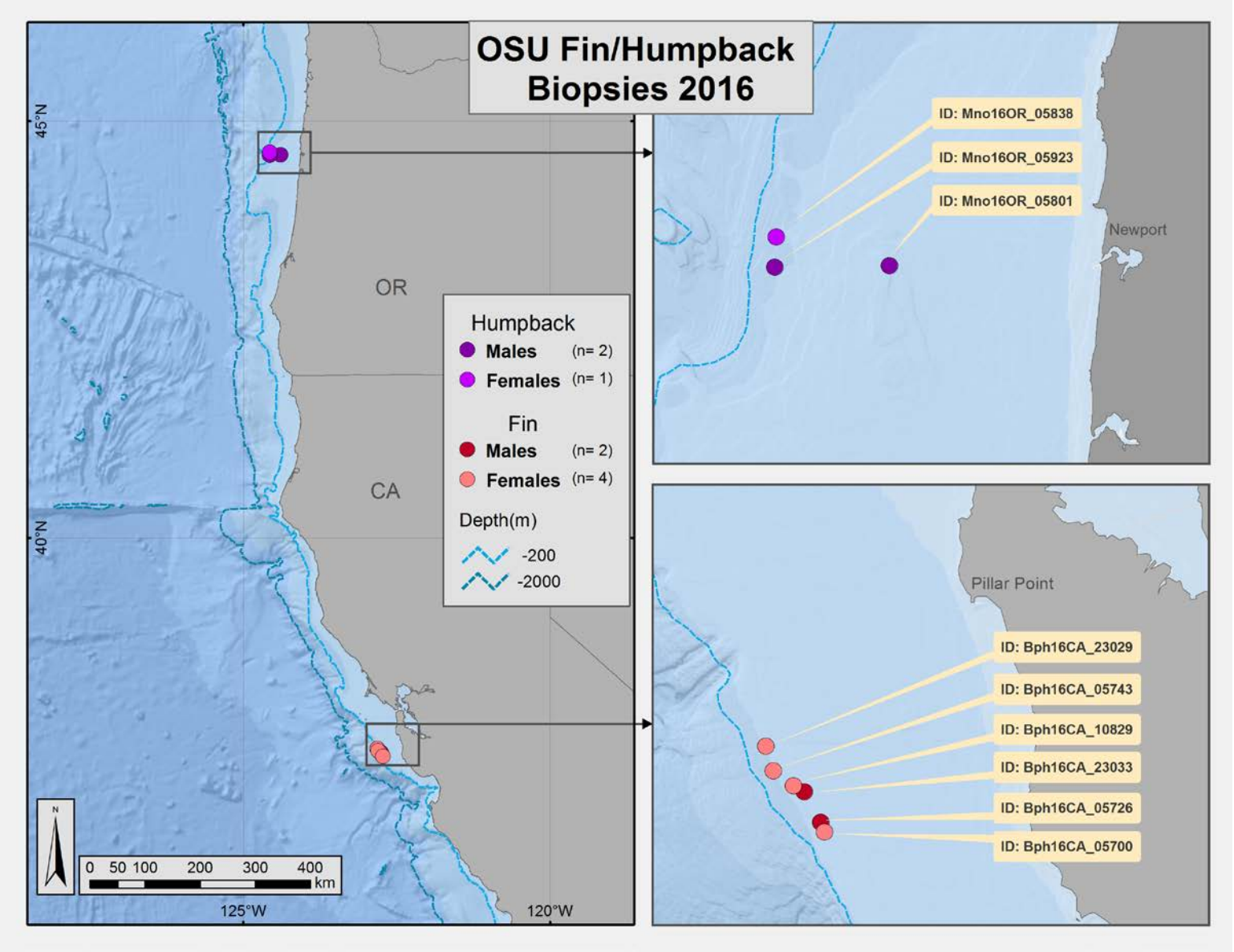

Figure 24. The location of biopsy sample collections from fin and humpback whales tagged in 2016.

3.3 Humpback Whale

3.3.1 Tracking Analysis

Two DM tags were deployed on humpback whales on September 15, 2016 (UTC dates and times; **Table 11**), off the coast of Newport, Oregon. A third DM tag was launched from the tag applicator, but did not properly deploy and was lost. One of these whales (Tag #5838) was tracked for 7.3 d, spending the majority of its time on Heceta Bank off the central Oregon coast before being last located off Coos Bay, Oregon on September 22 (**Figure 25**). Most locations for this whale were over the continental shelf. The second humpback whale was tracked for 18.9 d, traveling from its tagging location to an area just north of Cape Mendocino in that time, with 1 to 4-d stopovers at the continental shelf edge near Stonewall Bank, Heceta Bank, the shelf edge off Coos Bay, and the shelf waters off Point St. George and Trinidad, California (**Figure 25**). Maximum distances to shore ranged from 55 to 62 km (median = 58 km; **Table 12**).

Table 11. Deployment and performance data for satellite-monitored radio tags deployed on humpback whales off central Oregon, 2016. See Section 2.2.2 for location filtering method.

Tag #	Sex	Tag Type	Deployment Date	Most Recent Location	# Days Tracked	# Filtered Locations	# Argos Locations	Total Distance (km)
5838	F	DM	15-Sep-16	23-Sep-16	7.3	36	49	381
5923	M	DM	15-Sep-16	4-Oct-16	18.9	85	112	931
Mean		**DM**			**13.1**	**61**	**81**	**656**
Median		**DM**			**13.1**	**61**	**81**	**656**

KEY: DM = Telonics RDW-665 Dive-Monitoring tag; F = Female; km = kilometer(s); M = Male; # = number

Table 12. Geodesic distances to nearest point on land for humpback whales tagged off central Oregon, 2016. The number of locations includes filtered locations (see Section 2.2.2 for filtering method) plus deployment location.

Tag #	Tag Type	# Locations	Median (km)	Mean (km)	SD (km)	Minimum (km)	Maximum (km)	Deploy Location Distance (km)
5838	DM	37	36.2	36.8	8.7	17.3	55.1	38.5
5923	DM	86	18.2	23.3	14.5	0.9	61.6	39.2
Mean		**62**	**27.2**	**30.0**	**11.6**	**9.1**	**58.3**	**38.9**
Median		**62**	**27.2**	**30.0**	**11.6**	**9.1**	**58.3**	**38.9**

KEY: DM = Telonics RDW-665 Dive-Monitoring tag; km = kilometer(s); SD = standard deviation; # = number

Almost all (95 percent) of the locations for whale Tag #5838 were within the NWTRC, representing 90 percent of its total tracking period (7 d; **Table 13 and Figure 26**). For whale Tag# 5923, only the locations north of Coos Bay, Oregon were far enough offshore to be within the NWTRC. Thirty-four percent of the locations for this latter whale were within the NWTRC, representing 25 percent of its tracking period, or 5 d (**Table 13 and Figure 26**). Humpback whale locations within the NWTRC occurred only in September. Neither of the tagged humpback whales was tracked in any other Navy training range.

Table 13. Percentage of filtered locations and time spent inside the SOCAL, PT MUGU, NWTRC, and W237 areas for humpback whales tagged off central Oregon, 2016. See Section 2.2.2 for location filtering method.

Filtered Locations															
		Total		SOCAL			PT MUGU			NWRTC			W237		
Tag #	Tag Type	# Locs	# Days	% Locs	% of Days	# Days	% Locs	% of Days	# Days	% Locs	% of Days	# Days	% Locs	% of Days	# Days
5838	DM	37	7.3	0	0	0	0	0	0	95	90	6.6	0	0	0
5923	DM	86	18.9	0	0	0	0	0	0	34	25	4.8	0	0	0
Mean		**62**	**13.1**	**-**	**-**	**-**	**-**	**-**	**-**	**64**	**58**	**5.7**	-	-	-
Median		**62**	**13.1**	**-**	**-**	**-**	**-**	**-**	**-**	**64**	**58**	**5.7**	-	-	-

KEY: DM = Telonics RDW-665 Dive-Monitoring tag; Locs = Locations; # = number

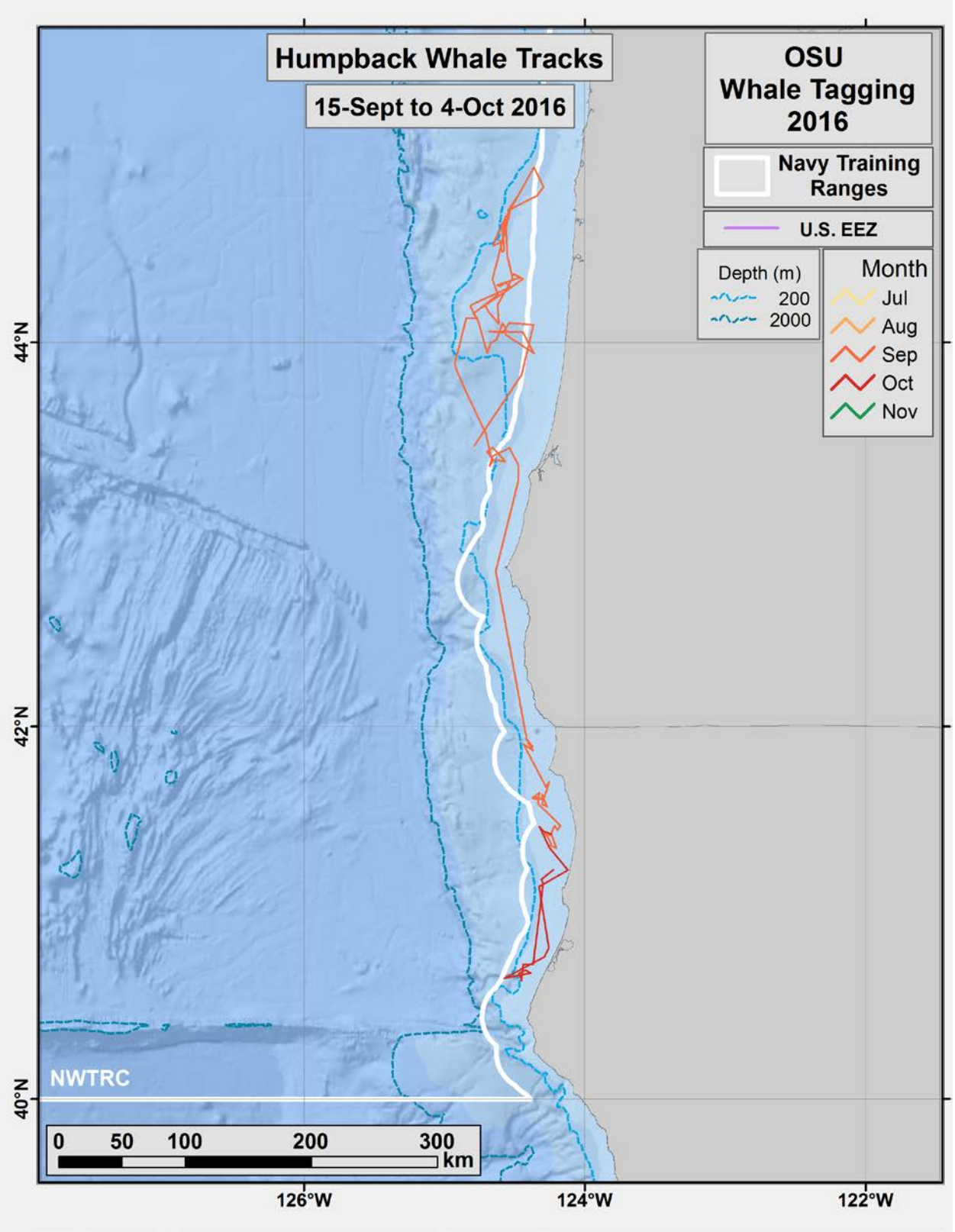

Figure 25. Satellite-monitored radio tracks for two humpback whales tagged off central Oregon in September 2016 (2 DM tags).

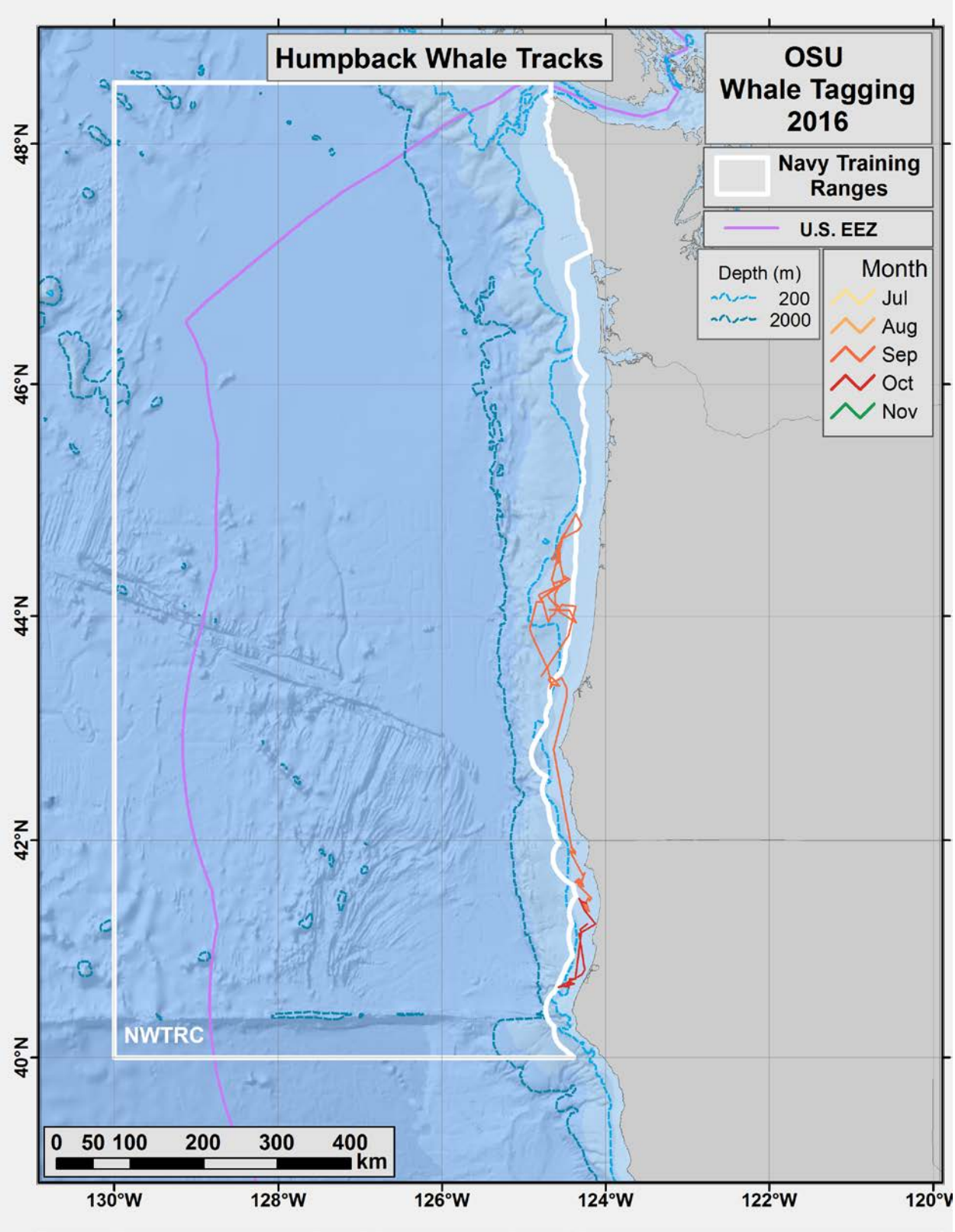

Figure 26. Satellite-monitored radio tracks in NWTRC for two humpback whales tagged off central Oregon in September 2016 (2 DM tags).

3.3.2 Dive Analysis

The two DM tags on humpback whales provided 563 and 1,032 dive summaries, respectively (**Table 14**). Dive depths were generally limited to the upper 100 m of the water column with Tag #5838 making dives as deep as approximately 150 m (**Figure 27**), while Tag #5923 made substantially shallower dives, rarely exceeding 80 m in depth (**Figure 28**). Dives from Tag #5838 showed a diel trend with fewer lunges and shallower dives occurring at night but such a trend was limited, to non-existent in the dives received from Tag #5923 (**Figures 27 and 28**). Daytime dive depths made by Tag #5923 were somewhat deeper off central Oregon compared to northern California (**Figure 29**).

Table 14. Summary statistics of DM tags deployed on humpback whales off central Oregon in September 2016.

Tag #	Sex	Tag type	Deployment Date	# Days Tracked	Locs per Day	Distance (km)	# Dives Transmitted	Filtered Locs
5838	Female	DM	15-Sep-16	7.3	4.9	381	563	36
5923	Male	DM	15-Sep-16	18.9	4.5	931	1,032	85
Mean				**13.1**	**4.7**	**656**	**798**	**81**
Median				**13.1**	**4.7**	**656**	**798**	**81**

KEY: DM = Telonics RDW-665 Dive-Monitoring tag; km = kilometer(s); Locs = Locations; Tx = Transmitting; # = number

3.3.3 Behavioral Responses to Tagging

Both of the tagged humpback whales exhibited short-term startle responses to the tagging/biopsy process. In each case, the response consisted of a moderate fluke kick upon tagging.

3.3.4 Wound Healing

No tagged humpback whales from 2016 were resighted after tagging, so determination of wound healing could not be made.

3.3.5 Photo-ID

A total of 670 photos of humpback whales were taken during the 2 days of tagging off Oregon in 2016, from which 15 were determined to be unique individuals. No ID photographs were obtained from the tagged whales because they did not raise their flukes at any time during our encounters with them. Fluke photos are the current standard of identification for humpback whales.

3.3.6 Ecological Relationships

This information will be included in the Final Report.

3.3.7 Genetics

Skin biopsy samples were collected from the two tagged whales and the third whale for which tagging was unsuccessful, all of which were considered to be humpback whales based on field observations (**Figure 24**).

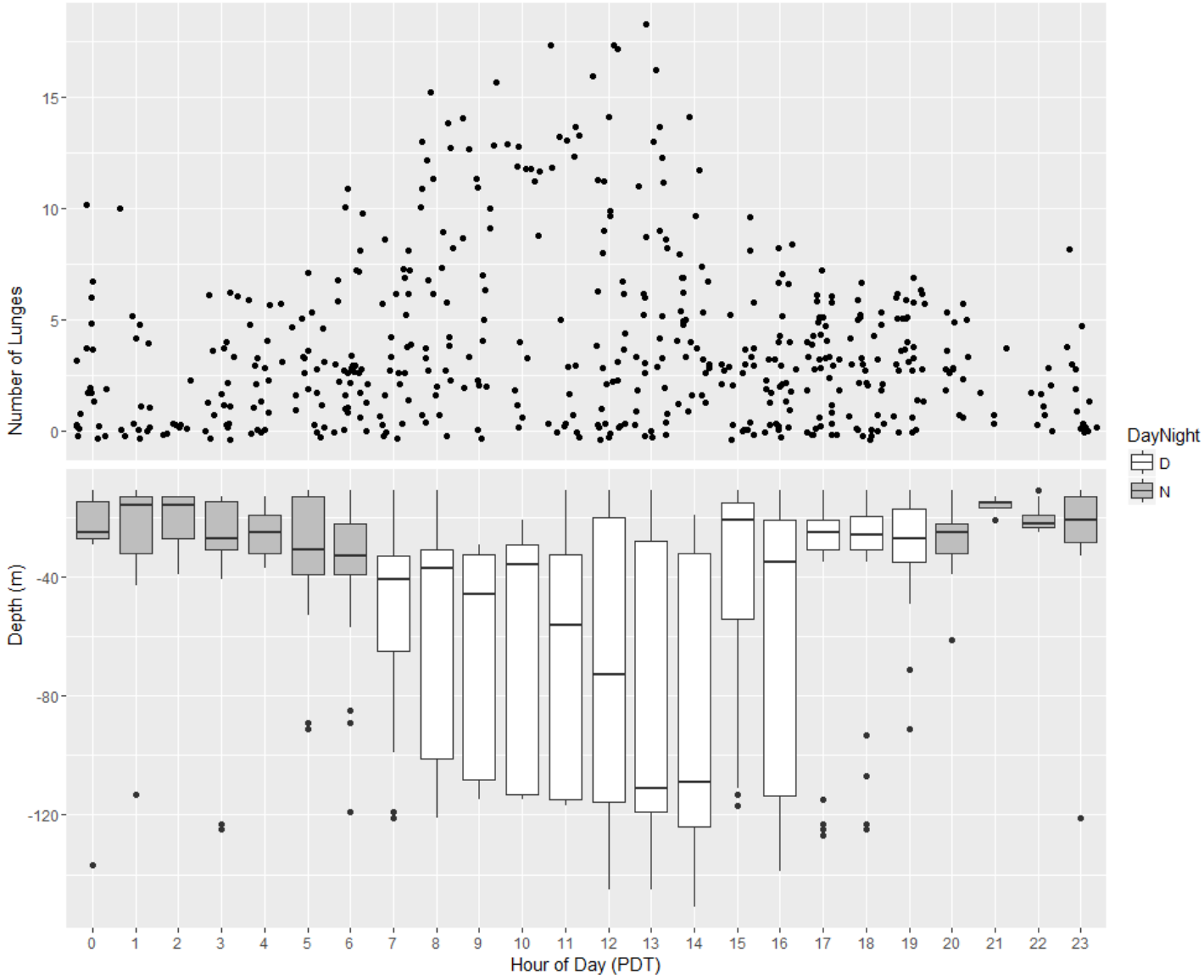

Figure 27. Number of lunges per dive (upper panel) and maximum dive depth (lower panel) of a DM-tagged humpback whale (Tag #5838) tracked off central Oregon during September 2016. Data are presented by hour of day to better visualize diel variability.

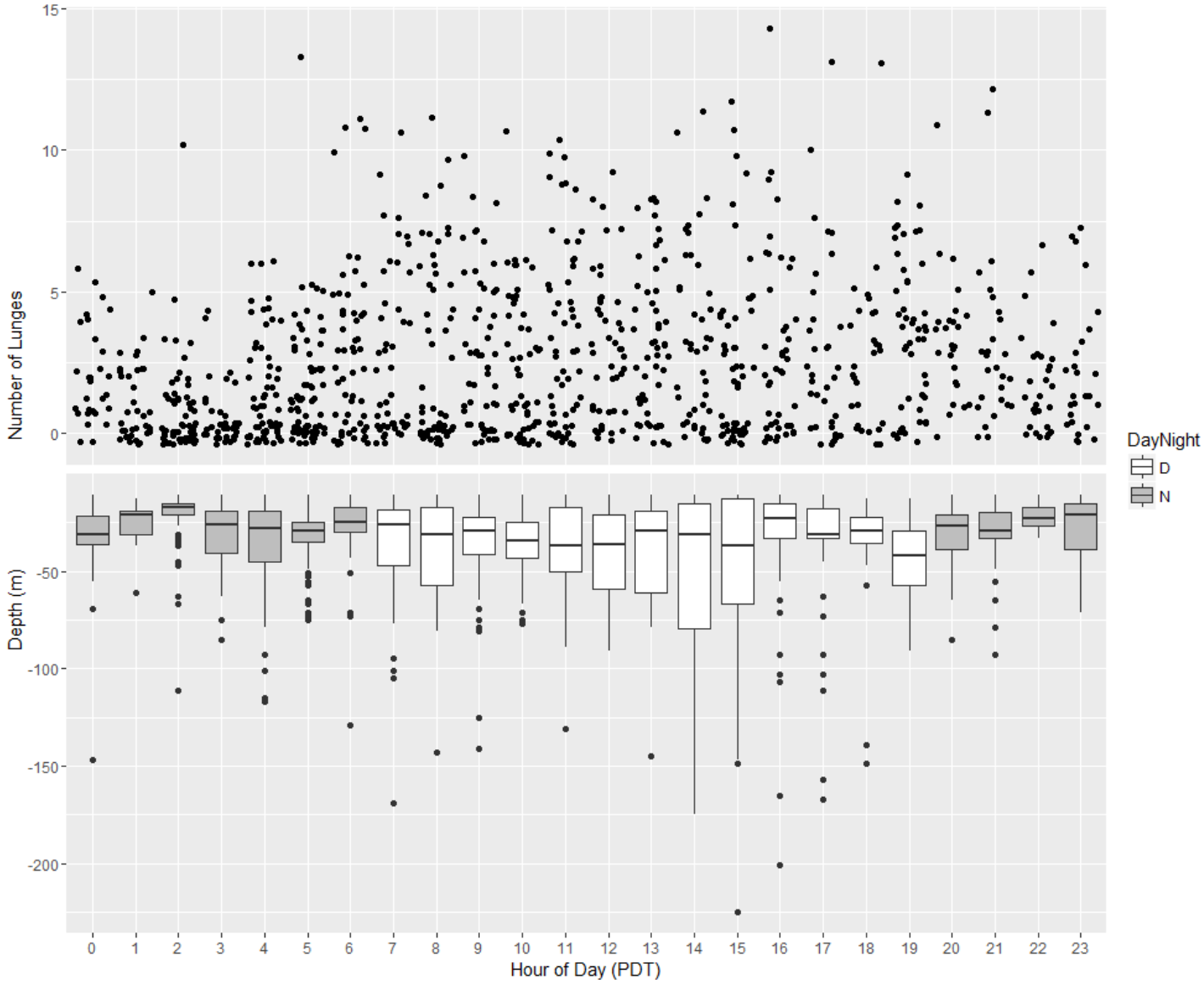

Figure 28. Number of lunges per dive (upper panel) and maximum dive depth (lower panel) of a DM-tagged humpback whale (Tag #5923) tracked off central Oregon during September 2016. Data are presented by hour of day to better visualize diel variability.

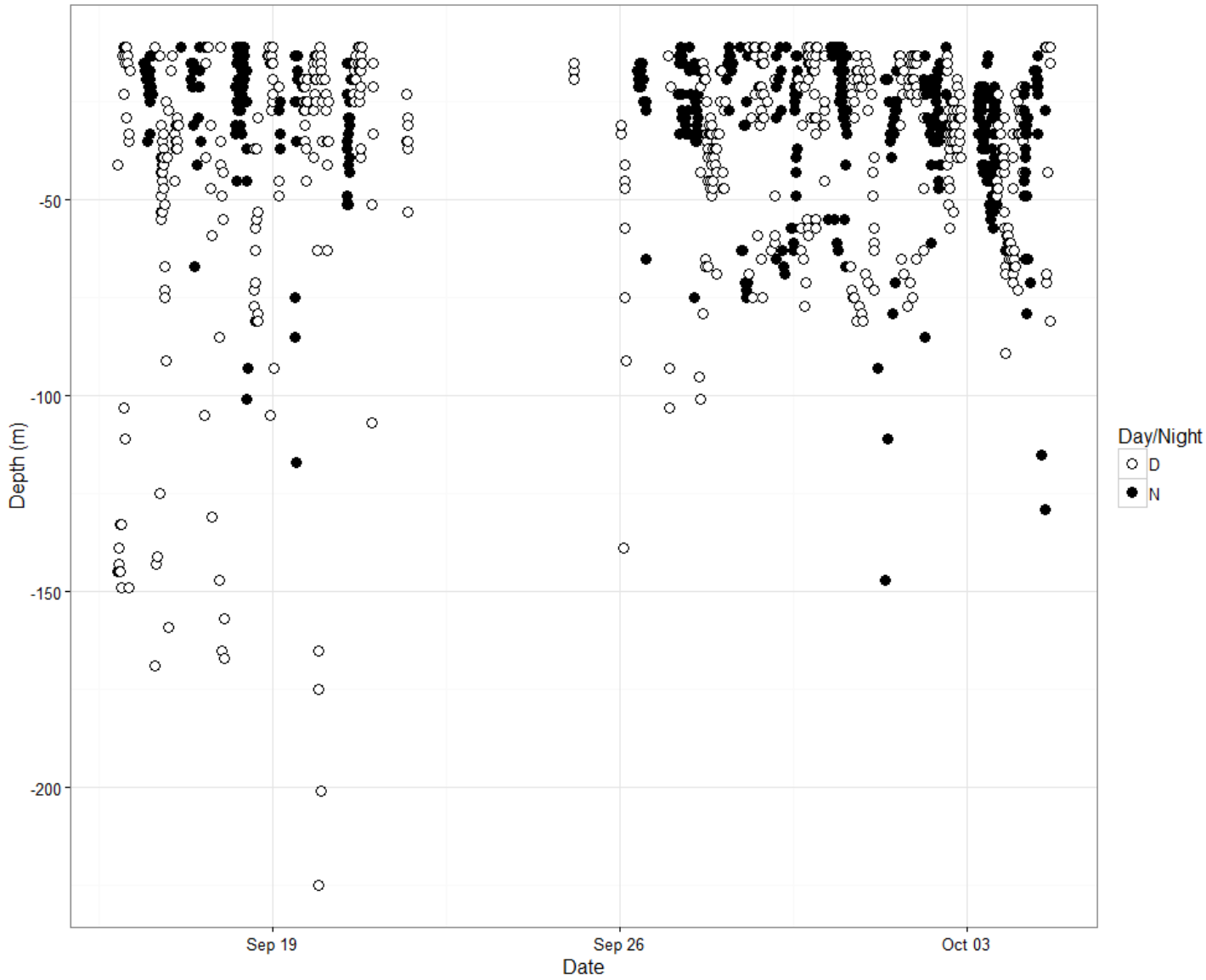

Figure 29. Maximum dive depth of a DM-tagged humpback whale (Tag #5923) tracked off central Oregon and northern California during September–October 2016. The whale was located off central Oregon until September 25 when they moved to northern California.

The mtDNA sequences of three samples resolved two haplotypes for a consensus region of 500 bp in length.

3.3.7.1 SEX DETERMINATION

The three humpback whale samples (one of which came from the whale that was unsuccessfully tagged) represented one female and two males (**Table 11**).

3.3.7.2 INDIVIDUAL IDENTIFICATION

This information will be included in the Final Report.

3.3.7.3 STOCK IDENTIFICATION

Based on submission to *DNA-surveillance* and a BLAST search of GenBank®, all of the mtDNA haplotypes were consistent with field identification of humpback whales. Results of the stock identification will be included in the Final Report.

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4. Discussion

4.1 Blue Whale

4.1.1 Tracking Analysis

The tracking results from blue whales tagged in 2016 continue to expand our knowledge on the long-term movements, distribution, and dive behavior of these whales in the Eastern North Pacific, supplementing information from past years on blue whale occurrence and use of Navy training and testing ranges. In 2016, tagging activities were conducted in both southern (ten whales tagged) and central (eight whales tagged) California waters due to a scarcity of “tagable” (i.e., in good body condition) whales in southern California. These two areas, separated by approximately 425 km constitute the two primary hotspots of aggregation for blue whales during the summer and fall (Irvine et al. 2014). The tagging in the two areas in 2016 affords us the opportunity to look at possible differences in movement patterns and habitat use between the two areas during the same year.

With a few exceptions, the movements of blue whales tagged in the two areas were quite different. All but one of the ten blue whales tagged in southern California remained in waters south of Point Sur on the central California coast (the one exception was whale Tag# 836 that traveled as far north as the California/Oregon border). Only two of the eight blue whales tagged in central California spent time in southern California waters. For whales that were tracked for only a short period of time the different tagging locations and the time of year may have been the reason for this spatial separation, but only four of the 18 whales had tracking durations less than 5 d. Tracking durations for the remaining 14 whales were all greater than 44 d, which was ample time for the whales to range widely had they been so inclined. While some whales were tagged almost three weeks apart, tracking durations were long enough to ensure sufficient overlap in tracking periods between the two tagging groups. The photo-ID results lend support to the idea of spatial group differentiation, as only one whale photographed off central California had been seen in the previous 2 years, when we operated in southern California only, compared to six (of the seven resights) photographed in southern California in 2016.

It is unclear whether the spatial separation was related to some intrinsic variability between the two groups of whales, or whether temporal variation as a result of different tagging dates played a role (since whales arriving earlier in California after the winter-spring migration would tend to be found further up north than those arriving later in the season). To help address this question, for the Final Report we plan to examine the movements patterns of whales tagged in southern California in 2016 relative to those of whales tagged in 2014 and 2015, as well as to those tagged in central California in 2016. The results from the genetic analyses may also shed light into this question, if the genetic composition between two groups indicates differences.

4.1.2 Dive Analysis

This information will be included in the Final Report.

4.1.3 Genetics

This information will be included in the Final Report.

4.1.4 Concluding Thoughts (Integration of Tagging, Ecological and Genetic Information)

This information will be included in the Final Report.

4.2 Fin Whale

4.2.1 Tracking Analysis

As with the blue whale tracking data, the tracking data obtained from fin whales in 2016 add to our sample sizes from the previous 2 years, providing a richer data set of information on long-term movements and dive behavior of fin whales in the Eastern North Pacific as well as increasing our understanding of occurrence and use of Navy training and testing ranges. Very few fin whales were encountered in southern California in 2016, so all tagging took place off the central California coast. Tracking durations for LO tags on fin whales were substantially shorter in 2016 than in previous years, but the reason remains unknown. With the exception of two fin whales in PT MUGU, fin whale use of Navy training areas was not very extensive in 2016. This is likely driven by the shorter tracking periods than in previous years.

4.2.2 Dive Analysis

This information will be included in the Final Report.

4.2.3 Genetics

This information will be included in the Final Report.

4.2.4 Concluding Thoughts (Integration of Tagging, Ecological and Genetic Information)

This information will be included in the Final Report.

4.3 Humpback Whale

4.3.1 Tracking Analysis

The tracking data obtained from humpback whales tagged off Oregon in 2016 provides valuable insight into the localized movements of humpback whale DPS 6 on their feeding grounds. Inclement weather off the Oregon coast in September and October 2016 restricted our tagging opportunities to just 2 days, and only two humpback whales were tagged. Additionally, in our experience, satellite tags do not last as long on humpback whales as they do on other baleen whale species (Mate et al. 2007). Very little detailed information exists for this population segment in Oregon waters, however, so while the results from this study are limited to the relatively short duration tracking periods for two animals, they are still valuable in informing our knowledge of this group of whales. Several areas of importance were identified along the Oregon and northern California coast, including Stonewall and Heceta banks and an area off Coos Bay, Oregon, as well as the continental shelf between Point St. George and Cape Mendocino in northern California. The eastern boundary of the Navy's NWTRC occurs at approximately 20 to 25 km off the coast of Oregon and northern California. Tagged humpback whales in this study occurred within the boundary of the NWTRC, while north of Coos Bay,

Oregon, where shallower continental shelf waters extended offshore. In southern Oregon and northern California where the shelf is narrower, humpback whale locations were not within the NWTRC, as the whales seemed to prefer shallower continental shelf waters.

4.3.2 Dive Analysis

This information will be included in the Final Report.

4.3.3 Genetics

This information will be included in the Final Report.

4.3.4 Concluding Thoughts (Integration of Tagging, Ecological and Genetic Information)

This information will be included in the Final Report.

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5. Acknowledgements

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6. Literature Cited

Aasen, E. and J.F. Medrano. 1990. Amplification of the ZFY and ZFX genes for sex identification in humans, cattle, sheep and goats. Nature Biotechnology 12:1279–1281.

Acevedo-Gutiérrez, A., D.A. Croll, and B.R. Tershey. 2002. the largest whales. Journal of Experimental Biology 205:1747–1753.

Archer, F.I., P.A. Morin, B.L. Hancock-Hanser, K.M. Robertson, M.S. Leslie, M. Bérubé, S. Panigada, and B.L. Taylor. 2013. Mitogenomic phylogenetics of fin whales (*Balaenoptera physalus* spp.): genetic evidence for revision of subspecies. PLoS ONE 8:e63396. doi:10.1371/journal.pone.0063396

Attard, C.R.M., L.B. Beheregaray, K.C.S. Jenner, P.C. Gill, M.N. Jenner, M.G. Morrice, P.R. Teske, and L.M. Möller. 2015. Low genetic diversity in pygmy blue whales is due to climate-induced diversification rather than anthropogenic impacts. Biology Letters 11(5):20141037.

Bailey H., B.R. Mate, D.M. Palacios, L. Irvine, S.J. Bograd, and D.P. Costa. 2010. Behavioural estimation of blue whale movements in the Northeast Pacific from state-space model analysis of satellite tracks. Endangered Species Research 10:93–106.

Baker, C.S., R.W. Slade, J.L. Bannister, R.B. Abernethy, M.T. Weinrich, J. Lien, J. Urban, P. Corkeron, J. Calambokidis, O. Vasquez, and R. Palumbi. 1994. Hierarchical structure of mitochondrial DNA gene flow among humpback whales *Megaptera novaeangliae*, world-wide. Molecular Ecology 3:313–327.

Baker, C.S., D. Steel, J. Calambokidis, E. Falcone, U. González-Peral, J. Barlow, A.M. Burdin, P.J. Clapham, J.K.B. Ford, C.M. Gabriele, D. Mattila, L. Rojas-Bracho, J.M. Straley, B.L. Taylor, J. Urbán., P.R. Wade, D. Weller, B.H. Witteveen and M. Yamaguchi. 2013. Strong maternal fidelity and natal philopatry shape genetic structure in North Pacific humpback whales. Marine Ecology Progress Series 494:291–306.

Bettridge, S., C.S. Baker, J. Barlow, P.J. Clapham, M. Ford, D. Gouveia, D.K. Mattila, R.M. Pace III, P.E. Rosel, G.K. Silber, and P.R. Wade. 2015. Status Review of the Humpback Whale (*Megaptera novaeangliae*) Under the Endangered Species Act. NOAA Technical Memorandum NMFS-SWFSC-540. National Marine Fisheries Service, La Jolla, California. 240 pp.

Bérubé, M., H. Jørgensen, R. McEwing, and P. J. Palsbøll. 2000. Polymorphic di-nucleotide microsatellite loci isolated from the humpback whale, *Megaptera novaeangliae*. Molecular Ecology 9(12):2181–2183.

Buchanan, F.C., M.K. Friesen, R.P. Littlejohn, and J.W. Clayton. 1996. Microsatellites from the beluga whale *Delphinapterus leucas*. Molecular Ecology 5:571–575.

Calambokidis, J., G.H. Steiger, C. Curtice, J. Harrison, M.C. Ferguson, E. Becker, M. DeAngelis, and S.M. Van Parijs 2015. Biologically Important Areas for selected cetaceans within U.S. waters – West Coast Region. Aquatic Mammals 41:39–53.

Collecte Localisation Satellites. 2015. Argos Users Manual. Available at: http://www.argos-system.org/files/pmedia/public/r363_9_argos_users_manual-v1.6.4.pdf.

Dalebout, M.L., C.S. Baker, J.G. Mead, V.G. Cockcroft, and T.K. Yamada. 2004. A comprehensive and validated molecular taxonomy of beaked whales, Family Ziphiidae. Journal of Heredity 95:459–473.

Gilson, A., M. Syvanen, K. Levine, and J. Banks. 1998. Deer gender determination by polymerase chain reaction: validation study and application to tissues, bloodstains, and hair forensic samples in California. California Fish and Game 84:159–169.

Irvine L.M., B.R. Mate, M.H. Winsor, D.M. Palacios, S.J. Bograd, D.P. Costa, and H. Bailey. 2014. Spatial and temporal occurrence of blue whales off the U.S. West Coast, with implications for management. PLoS ONE 9(7):e102959. doi:10.1371/journal.pone.0102959

Jonsen, I.D., J.M. Flemming, and R.A. Myers. 2005. Robust state-space modeling of animal movement data. Ecology 86:2874–2880.

LeDuc, R.G., A.E. Dizon, M. Goto, L.A. Pastene, H. Kato, S. Nishiwaki, C.A. LeDuc, and R.L. Brownell. 2007. Patterns of genetic variation in Southern Hemisphere blue whales and the use of assignment test to detect mixing on the feeding grounds. Journal of Cetacean Research and Management 9:73–80.

Marshall, T.C., J. Slate, L.E. Kruuk, and J.M. Pemberton. 1998. Statistical confidence for likelihood-based paternity inference in natural populations. Molecular Ecology 7:639–655.

Mate, B., R. Mesecar, and B. Lagerquist. 2007. The evolution of satellite-monitored radio tags for large whales: one laboratory's experience. Deep-Sea Research II 54:224–247.

Mate, B., D.M. Palacios, L. Irvine, B. Lagerquist, T. Follett, M. Winsor, and C. Hayslip. 2015. Baleen (Blue & Fin) Whale Tagging in Southern California in Support of Marine Mammal Monitoring Across Multiple Navy Training Areas (SOCAL, NWTRC, GOA). Final Report. Prepared for Commander, U.S. Pacific Fleet. Submitted to Naval Facilities Engineering Command Pacific, Pearl Harbor, Hawaii, under Contract No. N62470-10-D-3011, Task Orders JP03 and KB27 issued to HDR, Inc., San Diego, California. 31 July 2015.

Mate, B.R., D.M. Palacios, C.S. Baker, B.A. Lagerquist, L.M. Irvine, T. Follett, D. Steel, C. Hayslip, and M.H. Winsor. 2016. Baleen (Blue & Fin) Whale Tagging in Southern California in Support of Marine Mammal Monitoring Across Multiple Navy Training Areas. Preliminary Summary. Prepared for Commander, U.S. Pacific Fleet. Submitted to Naval Facilities Engineering Command Pacific, Pearl Harbor, Hawaii under Contract Nos.

N62470-10-D-3011, Task Order KB29, and Contract No. N62470-15-D-8006, Task Order KB01, issued to HDR, Inc., San Diego, California. July 2016.

NMFS (National Marine Fisheries Service). 2016. Endangered and threatened species; identification of 14 distinct population segments of the humpback whale (*Megaptera novaeangliae*) and revision of species-wide listing. *Federal Register* 81:62260-62320.

Palsbøll, P.J., M. Bérubé, A.H. Larsen and H. Jørgensen. 1997. Primers for the amplification of tri- and tetramer microsatellite loci in baleen whales. Molecular Ecology 6:893–895.

Ross, H.A., G.M. Lento, M.L. Dalebout, M. Goode, G. Ewing, P. McLaren, A.G. Rodrigo, S. Lavery, and C.S. Baker. 2003. DNA surveillance: web-based molecular identification of whales, dolphins and porpoises. Journal of Heredity 94:111–114.

Sambrook, J., E.F. Fritsch, and T. Maniatis. 1989. Molecular Cloning: A Laboratory Manual. 2nd ed. Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York.

Schlötterer, C., B. Amos, and D. Tautz. 1991. Conservation of polymorphic simple sequence loci in cetacean species. Nature 354:63–65.

Simon, M., M. Johnson, and P.T. Madsen. 2012. Keeping momentum with a mouthful of water: behavior and kinematics of humpback whale lunge feeding. Journal of Experimental Biology 215:3786–3798.

Sremba, A.L., B. Hancock-Hanser, T.A. Branch, R.L. LeDuc, and C.S. Baker. 2012. Circumpolar diversity and geographic differentiation of mtDNA in the Critically Endangered Antarctic blue whale (*Balaenoptera musculus intermedia*). PLoS ONE 7:e32579. doi:10.1371/journal.pone.0032579

Valsecchi, E. and W. Amos. 1996. Microsatellite markers for the study of cetacean populations. Molecular Ecology 5:151–156.

Vincent, C., B.J. McConnell, V. Ridoux, and M.A. Fedak. 2002. Assessment of Argos location accuracy from satellite tags deployed on captive gray seals. Marine Mammal Science 18:156–166.

Waldick, R.C., M.W. Brown, and B.N. White. 1999. Characterization and isolation of microsatellite loci from the endangered North Atlantic right whale. Molecular Ecology 8:1763–1765.

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