Preliminary Summary

Baleen (Blue and Fin) Whale Tagging in Southern California in Support of Marine Mammal Monitoring Across Multiple Navy Training Areas

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Prepared by

Bruce R. Mate, Daniel M. Palacios, C. Scott Baker,
Barbara A. Lagerquist, Ladd M. Irvine, Tomas Follett,
Debbie Steel, Craig Hayslip, and Martha H. Winsor

Oregon State University Marine Mammal Institute,
Hatfield Marine Science Center,
2030 SE Marine Science Drive
Newport, OR

Submitted by:

HDR
San Diego, CA

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A fin whale (*Balaenoptera physalus*) surfaces in southern California, summer 2014. Photograph taken by Craig Hayslip under National Marine Fisheries Service Permit 14856 issued to Dr. Bruce Mate.

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14. ABSTRACT

In 2015 Oregon State University's Marine Mammal Institute (OSU/MMI) conducted a second year of tagging operations in support of the United States (U.S.) Navy's marine mammal studies in the offshore waters of the Southern California Range Complex (SOCAL) portion of the Hawaii-Southern California Training and Testing Study Area as well as the existing 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.

Field work took place off the coast of southern California during one 5-week cruise aboard the research vessel (R/V) Pacific Storm. The cruise took place from July 6 to August 8, 2015, departing from Marina Del Rey and returning to Half Moon Bay. Tagging efforts were conducted on 17 days (d) and tag recovery efforts were conducted on 6 d. Aerial observations to locate whales and direct the tagging vessel into tagging position were conducted for 6 d over the 5-week field effort. Wildlife Computers' Smart Positioning or Temperature Transmitting Tag, version 5 (SPOT5) and Mk10-PATF (advanced dive behavior [ADB]) tags were deployed.

Argos-monitored satellite radio tags were attached to 22 blue whales (Balaenoptera musculus) (18 SPOT5, 4 ADB) , 11

fin whales (Balaenoptera physalus) (9 SPOT5, 2 ADB), 1 blue/fin whale hybrid (SPOT5), and 1 Bryde's whale (Balaenoptera brydei/edeni) (SPOT5) during July 2015. Six tags were still transmitting on 15 November 2015 when the data were summarized for this report.

Locations were received from all 22 tags deployed on blue whales, providing tracking periods ranging from 4.2 to 128.3 days (as of 15 November 2015). Individual blue whales ranged as far north as Coos Bay, Oregon, and as far south as Costa Rica during the reporting period. The most heavily used naval training area for tagged blue whales in 2015 was the Point. Mugu Sea Range (PT MUGU), with all blue whales spending time there. SOCAL was the second most heavily used area for blue whales in terms of number of animals. Four blue whales tagged with ADB tags were tracked for a median of 26.7 d. The location, duration and intensity (i.e., number of lunges per dive) of foraging effort varied by individual and were generally located near areas of high bottom slope .Dive depths during foraging bouts varied widely; however, median values for individuals were generally close to 95 m or 135 m.

A total of 7,381 photographs of blue whales were taken during the 2015 field effort. Good-quality DNA was extracted from 15 samples (collected during various projects) considered to be blue whales based on field observations. All samples provided DNA profiles sufficient for subsequent analyses. The mtDNA sequences resolved seven haplotypes, three of which were reported in other oceans by LeDuc et al. (2007). Two of the haplotypes were found in samples from previous tagging (Sremba 2007) and two were new to our reference database of published and unpublished haplotypes from blue whales. 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. The 15 samples represented seven females and eight males. Matching of the 2015 samples to all available DNA profiles of blue whales from previous tagging in the North Pacific is underway.

Eleven tags (9 SPOT5, 2 ADB) were deployed on fin whales and a fin/blue whale hybrid (SPOT5). Locations were received from nine of the 10 fin whale location-only tags, providing tracking periods ranging from 6.2 to 115.1 days (as of 15 November 2015). The furthest north that a tagged individual moved was to Haida Gwaii (Queen Charlotte Islands) in British Columbia and as far south as Mexican waters. Two fin whales were tagged with ADB tags and tracked for a median of 15.7 days. Only 1 of the 2 ADB tags was recovered; the median foraging bout for this whale was 3.8 hour long and contained 21 dives, with one bout lasting as long as 14.3 h, during which 67 dives occurred. The distribution of average maximum dive depths between foraging bouts was bimodal with the whale generally diving to depths of <100 m or >200 m depths depending on the bout.

The tagged Bryde's whale traveled extensively throughout the Southern California Bight during its 89-day tracking period. Most of this animal's movements were in waters over the continental slope, ranging from Point Conception to San Clemente Island, with occasional forays out over deeper ocean basin waters (maximum distance from shore of 268 km). By mid-October, the whale had crossed into Mexican waters, heading south, and reaching Vizcaino Bay by 21 October, when its tag stopped transmitting.

A total of 3,030 photos of fin whales were taken during the cruise. Good-quality DNA was extracted from nine samples initially considered to be fin whales based on field observations. All samples provided DNA profiles sufficient for subsequent analyses. Initial comparison of mtDNA sequences showed disagreement with field identification of two samples. Based on submission of mtDNA control region sequences to DNA-surveillance and a BLAST search of GenBank®, sample BphCA15002 was identified as a blue whale and sample BphCA15006 was identified as a Bryde's whale Balaenoptera brydei/edeni. Subsequent review of photographic records agreed with the molecular identification of BphCA15006 as a Bryde's whale. For sample BphCA15002, we used a structure analysis with a reference dataset of genotypes from North Pacific blue and fin whales to confirm a high likelihood that the individual is a blue/fin whale hybrid . Given the maternal inheritance of mtDNA and the biparental inheritance of the microsatellite loci, we can also confirm that the parents of the hybrid were a blue whale mother and fin whale father. The blue/fin whale hybrid (BphCA15002) was identified as a male and the Bryde's whale (BphCA15006) was identified as a female. Of the seven fin whales, three were male and four were female. Matching of the other 2015 samples to all available DNA profiles of fin whales from previous tagging in the North Pacific is underway.

This Preliminary Summary focuses on 2015 field efforts, including field survey methods, tag deployments, and summaries of data collected during this time period.

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

ADB	Advanced Dive Behavior
BIA	Biologically Important Area
BLAST	Basic Local Alignment Search Tool
bp	base pairs
cm	centimeter(s)
d	day(s)
DNA	deoxyribonucleic acid
g	gram(s)
GPS	geographic positioning system
h	hour(s)
ID	identification
km	kilometer(s)
km^2	square kilometer(s)
LC	location class
LED	light-emitting diode
m	meter(s)
min	minute(s)
MMI	Marine Mammal Institute
MSA	minimum specific acceleration
mtDNA	mitochondrial deoxyribonucleic acid
Navy	U.S. Navy
NWTRC	Northwest Training Range Complex
W-237	Warning Area 237 of the NWTRC
OSU	Oregon State University
PT MUGU	Point Mugu Range Complex
PTT	platform transmitter terminal
R/V	research vessel
s	second(s)
SD	standard deviation
SOCAL	Southern California Range Complex
SPOT5	Smart Positioning or Temperature Transmitting Tag, Version 5
U.S.	United States

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1. Introduction

In 2015 Oregon State University's Marine Mammal Institute (OSU/MMI) conducted a second year of tagging operations in support of the United States (U.S.) Navy's (Navy) marine mammal studies in the offshore waters of the Southern California Range Complex (SOCAL) portion of the Hawaii-Southern California Training and Testing Study Area as well as the existing 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. In particular, this multi-year project is designed to address the following questions:

1. "What are the movement patterns, occurrence, and residence time/patterns/area restricted searches 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/patterns of blue and fin whales within National Marine Fisheries Service-designated blue and fin whale Biologically Important Areas (BIAs) 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/area restricted search/kernel home ranges along the U.S. West Coast?"

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

A. Determine blue and fin whale distribution and habitat use through deployment of long-term location-only satellite tags to refine our 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 Advanced Dive Behavior (ADB) tags, with sampling resolution of 1 Hertz. This technology will enable us to determine how large-whale behavior changes over time and to better characterize "normal" behavior for individuals and throughout a population.

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.

This Preliminary Summary reports on field efforts, including field survey methods, tag deployments, and summaries of data collected from July through November 15, 2015. While the focus of this Preliminary Summary is on the 2015 field efforts, subsequent reports will include cumulative analyses of data and results for 2014 and 2015 combined. These future reports have been designed to 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 2016.

2. Methods

2.1 Field Efforts

Field work took place off the coast of southern California during one 5-week cruise aboard the research vessel (R/V) *Pacific Storm*. The 26-meter (m) (84-foot) *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, conduct visual observations and tag recovery operations. The cruise took place from July 6 to August 8, 2015, departing from Marina Del Rey and returning to Half Moon Bay. Tagging efforts were conducted on 17 days (d) and tag recovery efforts were conducted on 6 d. Aerial observations to locate whales and direct the tagging vessel into tagging position were conducted for 6 d over the 5-week field effort.

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 and fin whales (maintained by Cascadia Research Collective, Olympia, Washington). Candidates 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. Wildlife Computers' Smart Positioning or Temperature Transmitting Tag, version 5 (SPOT5) and Mk10-PATF (ADB) 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 125 pound force per square inch in the applicator's 70-cubic centimeter pressure chamber.

2.2 Tagging

2.2.1 Satellite Tags

The SPOT5 tags were composed of a main body, a penetrating tip, and an anchoring system. The main body consisted of a certified Argos transmitter, housed in an epoxy-filled stainless steel cylinder (2.02 centimeters [cm] in diameter × 21.3 cm in length). 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 antenna/switch endcap had two perpendicular stops, approximately 0.6 cm in diameter and extending approximately 1.5 cm laterally to prevent tags from embedding too deeply on deployment or migrating inward after deployment. The penetrating tip consisted of a Delrin® nose cone, into which was pressed a 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 209.5 grams (g). Tags were partially coated with a broad-spectrum antibiotic (Gentamycin 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. This tag is designed for nearly complete implantation under the whale's skin and is ultimately shed from the whale due to hydrodynamic drag and the natural migration of foreign objects out of the tissue.

In addition to providing transmissions for location calculation, the SPOT5 tag reports percentage of time at the surface and percentage of time in user-specified temperature ranges. 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 may be 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.

The ADB tag consisted of a certified Argos transmitter and a Wildlife Computers Time-Depth Recorder, with a three-axis accelerometer and magnetometer, cast in an epoxy tube (2.0 cm in diameter and 11.5 cm long). A FastLoc® geographic positioning system (GPS) receiver, encased in syntactic foam (10.0-cm diameter dome with a maximum height of 4.0 cm), was attached to one end of the epoxy tube. Three light-emitting diode (LED) lights were mounted on top of the syntactic foam to facilitate relocation of the tag. The tubular portion of the tag was slid into a cylindrical stainless steel tag housing (2.6 cm in diameter and 14.5 cm long) for deployment. A circular stainless steel plate, or collar, was welded onto the distal end of the housing to protect the syntactic foam during deployment. A penetrating tip and anchoring system, similar to that of the SPOT5 tags, was mounted onto the cylindrical end of the tag housing. The cylindrical portion of the tag housing was designed for implantation beneath the whale's skin while the plate and syntactic foam GPS receiver sat atop the whale's back. The ADB tag and housing weighed approximately 470 g (approximately 240 g for the tag and approximately 230 g for the housing). A plastic “D-ring” was mounted on the bottom of the syntactic foam with a corrodible wire. This “D-ring” passed through a slot in the stainless steel plate and was secured on the backside of the plate with a screw. After a pre-determined time, an electrical current was activated within the tag, oxidizing the corrodible wire, whereupon the tag was ejected from the housing and floated to the surface for recovery. For this study, the electro-mechanical connections between the tags and their housings were programmed to release the tags on August 1, 2015. This allowed one week for tag recovery during the 5-week project.

The ADB tags were programmed to collect a GPS-quality FastLoc® location every 7 minutes (min) or as soon thereafter as the whale surfaced from a dive. Dive depth was recorded every 1 second (s) with 2-m vertical resolution. Body orientation (from the accelerometer) and magnetic compass heading (from the magnetometer) were also recorded at 1-s intervals. These data were all archived onboard the tag and accessible only when the tag was recovered. Qualifying dives (those greater than 2 min in duration and 10 m in depth) were also summarized for transmission through the Argos system along with GPS locations recorded by the tag. Three dive summary histograms were created for qualifying dives every 6 h during tag operation. The histograms summarized the percentage of time spent at different depths (%TADHist), the maximum dive depths (MaxDiveDeptHist), and maximum dive durations (DiveDurHist). Separate summary messages (behavior messages) describing individual qualifying dives were also generated by recording dive duration, maximum dive depth, dive shape (U-, V-, or square-shaped- and whether the U- or V-shaped dives were skewed right, left or centered) and the subsequent surfacing duration. Up to four consecutive summarized dives were transmitted in each behavior message (Wildlife Computers PAT-MK10 User Guide [30 Nov 2015] http://wildlifecomputers.com/wp-content/uploads/manuals/MK10-User-Guide.pdf). A single Argos message from the tag could send either one GPS location, one histogram summary, or one behavior message (summarizing four dives). One of two versions of firmware was installed in the ADB tags, each using a different version of the FastLoc® GPS acquisition program (FastLoc® v. 1 or v. 3).

2.2.2 Argos and GPS 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 error 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. If a speed between two locations exceeded 12 kilometers/hour, one of the two locations was removed, with the location resulting in a shorter overall track length being retained.

The ADB tag's GPS receiver records a snapshot of the radio signals produced by overhead GPS satellites. Snapshots are processed onboard the tag and converted to a compressed format that is optimized for transmission over Argos. Snapshots (either downloaded from Argos or from the archived tag memory after recovery) are then processed using Fast-GPS Solver, part of the Wildlife Computers Data Analysis Package. The GPS Solver calculates locations from snapshots using ephemeris information (the known GPS satellites' positions in the sky) downloaded from the internet, along with the previous known location of the tag (the solution from one snapshot can be used as a seed location of another snapshot). The GPS Solver does not use any statistical movement model or location smoothing. GPS locations then were filtered by the OSU/MMI to remove locations occurring on land. Remaining GPS locations were further filtered by speed using the 12 kilometers/hour criteria described above. GPS Solver does not produce an estimate of location error analogous to LC. Testing on previous ADB tag generations showed that 83 percent of FastLoc® location errors were less than 100 m when compared to a handheld GPS (max = 455 m, Irvine et al in prep.) and 95 percent of locations with four satellites have been shown to have errors < 810 m (Bryant 2007).

2.2.3 Location-only Tag Analysis

This information will be included in the Final Report.

2.2.4 ADB Analysis

To establish a baseline orientation for the position of the tag on the whale, a series of three temporally close FastLoc® GPS locations were identified from each whale's track where the whale was travelling in a consistent direction. Accelerometer and magnetometer readings during surfacing sequences from the dives that occurred between those locations were averaged. Pitch and roll angles were calculated from the baseline tag orientation and the yaw angle was calculated from the whale's true heading as determined from the series of three GPS locations. The resulting angles were used to re-orient the tag data to the whale's frame so that the X-axis was aligned with the longitudinal axis of the whale, the Y-axis was perpendicular to the X-axis (i.e., left-right), and the Z-axis was pointing down toward the center of the earth (up-down) (Johnson and Tyack 2003, Simon et al. 2012). Once the tag data were rotated to the whale's reference frame, the Minimum Specific Acceleration (MSA) and Jerk metrics were calculated from the accelerometer data as described in Simon et al. (2012) to identify lunge-feeding events in the data record. MSA identifies the acceleration beyond standard earth's gravity that the whale is experiencing, and Jerk measures the rate at which the whale is changing orientation. Lunge-feeding events in rorquals are characterized by near coincident peaks in both MSA and Jerk as the whale typically accelerates, then decelerates rapidly and rolls as it opens its mouth to engulf prey (Goldbogen et al. 2006, Simon et al. 2012). Dives >1 min in duration and >10 m in depth were isolated from each track and summarized by calculating maximum dive depth, dive duration, and the number of lunges that occurred during the dive. The dive end times were then matched to the nearest GPS location recorded by the tag. If there was not a location within 10 min of the dive, a location for the dive was estimated by linear interpolation between the two closest GPS locations using the dive time to determine where on the line the dive should fall. This means that tracks with less frequent locations may have linear segments that do not represent the exact movement of the whale.

Sequences of dives with no more than three consecutive non-foraging dives (dives with no lunges) were isolated and labeled 'foraging bouts.' Dive summary statistics were calculated for each foraging bout, and minimum convex polygons were created using the corresponding locations to assess the spatial extent of each foraging bout and the overall scale of foraging effort by comparing the area of each foraging bout and the distance between foraging bouts.

2.3 Ecological Relationships

This information will be included in the Final Report.

2.4 Genetics

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 pairs (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. 2013), downloaded from GenBank® and from samples collected during previous tagging efforts. New haplotypes were confirmed by reverse sequencing from a new PCR product following recommendations by (Morin et al. 2010).

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

2.4.1 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 (Aason and Medrano 1990) and primers Y53-3C and Y53-3D to amplify a 224 bp region on the Y chromosome (Gilson et al. 1998).

2.4.2 Individual identification

Individual whales were identified from the multi-locus genotypes using CERVUS v v3.0.3 (Marshall et al. 1998). Mismatches of up to 3 loci were allowed as a precaution against false exclusion due to allelic dropout and other genotyping errors (Waits and Leberg 2000, Waits et al. 2001). Electropherograms from mismatching loci were reviewed and corrected or repeated. A final 'DNA profile' for each sample included up to 17 microsatellites genotypes, sex and mtDNA control region sequence or haplotype.

2.4.3 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®. If species identification from mtDNA did not agree with the field observations, we used the Bayesian clustering program STRUCTURE v2.3.1 to assess the potential for hybrid ancestry (Falush et al. 2003). In this method, individuals are assigned probabilistically to species or population units using allele frequencies of the multi-locus genotypes.

Methods for stock analyses will be included in the Final Report.

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3. Results

Argos-monitored satellite radio tags were attached to 22 blue whales (18 SPOT5, 4 ADB), 11 fin whales (9 SPOT5, 2 ADB), 1 blue/fin whale hybrid (SPOT5), and 1 Bryde's whale (*Balaenoptera brydei/edeni*) (SPOT5) during July 2015. Six tags were still transmitting on November 15 when the data were summarized for this report. All tags were deployed off southern California, between Mugu Canyon (west of Malibu, California) and the west coast of San Miguel Island. The tracking data for the blue/fin whale hybrid is included with the fin whale tracking data for this preliminary report. Transmissions were received from all tags; however, one fin whale tag provided no locations. The average tracking duration for SPOT5 tags was 76.1 d for blue whales and 53.3 d for fin whales (as of November 15, 2015; **Tables 1 and 2**). The blue/fin whale hybrid and the Bryde's whale were tracked for 28.0 and 89.8 d, respectively (**Table 2**). Total tracking periods for all species combined ranged from 0 to 128.3 d for SPOT5 tags (as of November 15, 2015) and 15.4 to 29.9 d for ADB tags. Four ADB tags were recovered (three deployed on blue whales, one on a fin whale), providing information on 10,754 dives.

3.1 Blue Whale

3.1.1 Location-Only Tagging

Twenty-two tags were deployed on blue whales between July 7 and 16, 2015. Locations were received from all 22 of these tags, providing tracking periods ranging from 4.2 to 128.3 d (as of November 15, 2015). Blue whales tagged in 2015 ranged widely along the California coast (**Figure 1**). By the end of July, locations extended from off Mendocino, northern California, to Camalú, Baja California, Mexico, and from near shore out to 350 km. By the end of August, locations extended as far north as Cape Mendocino, with the densest areas of use ranging from the western end of the Channel Islands to the waters off Monterey Bay. Monterey Bay and Point Conception continued to be areas with numerous locations throughout September. One blue whale had also reached the southern Oregon coast by this time, with locations off Cape Blanco and Coos Bay. Two other blue whales headed south in September, spending time off Vizcaino Bay along the central Baja California coast. Five tags continued to transmit into late October and by the end of that month, one tag was located off the Oregon/California border, one was located in the Santa Barbara Channel, two made it south of San Ignacio Lagoon in Baja California, and one was off Guatemala. By mid-November, all five blue whales were south of the U.S./Mexico border—three were located between San Ignacio Lagoon and Magdalena Bay, one was off Acapulco, and one was approximately 500 km off Costa Rica.

The most heavily used naval training area for tagged blue whales in 2015 was the Point Mugu Sea Range (PT MUGU), with all blue whales spending time there and their individual percentage of locations in PT MUGU ranging from 13 to 100 percent ($\bar{x}$ = 56 $\pm$ SD 28.2 percent; (**Figure 2; Table 3**).

Blue whale locations occurred in PT MUGU in all tracking months covered in this preliminary summary (July through mid-November). SOCAL was the second most heavily used area for blue whales in terms of number of animals, with 14 whales having locations there, and individual percentages of locations ranging from 1 to 41 percent ($\bar{x}$ = 11 $\pm$ SD12.2 percent; **Figure 3**). As with locations in PT MUGU, blue whale locations occurred in SOCAL during all 5 months covered in this summary. Only two blue whales had locations in the NWTRC; 1 percent of locations for one whale, and 29 percent of locations for the other (**Figure 4**). These locations occurred in the NWTRC in August, September, and October. No blue whales were located in Warning Area 237 (W-237) of the NWTRC.

The amount of time blue whales spent in Navy training and testing ranges and in BIAs, as well as the results of state space modeling and home range analyses, will be presented in the Final Report.

3.1.2 ADB Tagging

Four blue whales tagged with ADB tags were tracked for a median of 26.7 d (**Table 4**). One tag was deployed near Point Mugu, California, while the other three were deployed off the west end of San Miguel Island, California. All four tags reached their programmed release dates while still attached to the whales but did not release as scheduled. Three of the tags eventually released from their housings and were recovered but the fourth tag was shed while still attached to the housing and never surfaced. One of the four ADB-tagged blue whales (Tag # 838) spent the majority of the tracking period near the southern California coast, ranging from the tagging location (Point Mugu, California) to Ensenada, Mexico (**Figure 1b**). The other three ADB-tagged blue whales used waters further offshore after leaving the tagging area, with two of the three whales leaving southern California waters and travelling as far north as off San Francisco, California, before the tags released.

All four ADB tags each recorded more than 2,000 dives, with a median of 86 dives/d (**Table 4**). The number of FastLoc® GPS locations recorded by the three recovered tags ranged from approximately 1,500 to 2,300 locations (median = 63 locations/d; **Table 4**). A total of 69 FastLoc® GPS locations were received through Service Argos, Inc. from the tag that was not recovered (3 locations/d) due to an increased priority placed on dive behavior message transmission during programming.

The location, duration and intensity (i.e., number of lunges per dive) of foraging effort varied by individual and were generally located near areas of high bottom slope (**Figure 5**). Foraging bouts identified from the data were temporally distinct (median = 2.2 h apart) and generally small in area (median = 1.7 km^2) with a median foraging bout containing 11 dives over 2.2 h (**Table 5**). Size of the foraging bout areas is likely an overestimate as the bouts were relatively linear in many cases. Foraging bout duration was generally short (<2 h) with a smaller number of long duration bouts (**Figure 6**). Average number of foraging lunges per dive within bouts varied substantially and was correlated to the duration of a foraging bout ($p<0.001$, $R2 = 0.37$ from linear regression; **Figure 7**). Dive depths during foraging bouts varied widely; however, median values for individuals were generally close to 95 m or 135 m (**Table 5**). One whale (Tag # 840) made foraging bouts whose median duration was over three times as long as the median bout duration for other tagged whales (7.5 h *vs* 1.9 h; **Table 5**). This whale foraged almost continuously during daylight hours for multiple days in an area near a seamount. However, another ADB-tagged whale (Tag # 4177) passed through the same area within 1 day of Tag # 840 and did not forage there at all (**Figure 8**).

3.1.3 Behavioral Responses to Tagging

Only one of the 22 tagged blue whales exhibited short-term startle responses to the tagging/biopsy process (**Table 6**).

3.1.4 Wound Healing

Five blue whales tagged in 2015 were photographed 1 to 7 days after tagging with some showing moderate swelling at the tag sites (**Table 7**). Two blue whales tagged in 2014 by our group were resighted during our tagging efforts in 2015. A whale tagged in 2014 with platform transmitter terminal (PTT) 10834 was resighted on July 8, 2015, 319 d after the tag was deployed and 231 d after its last transmission. A white round protrusion was visible at the tag site that may have been a remnant of the tag covered by growth. There was a shallow divot around the protrusion, with a slightly swollen edge (**Figure 9**).

A whale tagged with PTT 10827 in 2014 was resighted on July 10, 2015, with the tag still present, 301 d after the tag was deployed and 3 d before we stopped receiving locations. The tag protruded from the whale by approximately three quarters of its length (approximately 15 cm; **Figure 10**). No obvious swelling or other signs of reaction to the tag were seen.

3.1.5 Photo-ID

A total of 7,381 photographs of blue whales were taken during the 2015 field effort. Photo IDs were obtained of all 22 tagged blue whales, with both left- and right-side photos of seven of these, seven with right-side photos only, and eight with left-side photos only.

3.1.6 Ecological Relationships

This information will be included in the Final Report.

3.1.7 Genetics and Species Identification

Good-quality DNA was extracted from 15 samples considered to be blue whales based on field observations. All samples provided DNA profiles sufficient for subsequent analyses. The mtDNA sequences resolved seven haplotypes, three of which were reported in other oceans by LeDuc et al. (2007). Two of the haplotypes were found in samples from previous tagging (Sremba 2007) and two were new to our reference database of published and unpublished haplotypes from blue whales.

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.

3.1.7.1 SEX DETERMINATION

The 15 samples represented seven females and eight males.

3.1.7.2 INDIVIDUAL IDENTIFICATION

All 15 individuals were represented by unique multi-locus genotypes and the probability of identity for the 17 loci was very low, 7.6×10^{-15} (i.e., there was a very low probability of a match by chance). Consequently, we are confident that the 15 unique multi-locus genotypes represented 15 individuals. This was consistent with sex and mtDNA haplotypes, as provided in the full DNA profile.

Matching of the 2015 samples to all available DNA profiles of blue whales from previous tagging in the North Pacific is underway and will be included in the Final Report.

3.1.7.3 Stock Identification

Further identity of subspecies and stock identification will be included in the Final Report.

3.2 Fin Whale

3.2.1 Location-Only Tagging

Nine tags were deployed on fin whales and one on a fin/blue whale hybrid between 8 and 28 July 2015. Locations were received from nine of these 10 tags, providing tracking periods ranging from 6.2 to 115.1 d (as of November 15, 2015). By the end of July, one fin whale had traveled as far north as Coos Bay in southern Oregon (**Figure 11**). The other eight whales were spread out between the Southern California Bight and Monterey Bay, California, with locations ranging from near the shore and out to 300 km. During August, two of the whales had ventured south into Mexican waters, but by the end of the month they were back in southern California waters. The other four whales still being tracked ranged from San Nicolas Island, California, to the Olympic Peninsula in Washington. Most of the fin whale locations (including the fin/blue whale hybrid) were further from shore than the blue whales being tracked at the same time, occurring mostly in waters over the continental slope. Toward the end of September, the four whales still being tracked were all located off northern California or southern Oregon -- one off Point Reyes, California, one off Cape Mendocino, California, and two off Cape Blanco, Oregon. By the middle of November, one fin whale tag was still transmitting and the whale was located off the island of Haida Gwaii (Queen Charlotte Islands) in British Columbia.

The tagged Bryde's whale traveled extensively throughout the Southern California Bight during its 89-d tracking period (**Figure 12**). Most of this animal's movements were in waters over the continental slope, ranging from Point Conception to San Clemente Island, with occasional forays out over deeper ocean basin waters (maximum distance from shore of 268 km). By mid-October, the whale had crossed into Mexican waters, heading south, and reaching Vizcaino Bay by October 21, when its tag stopped transmitting.

PT MUGU was the most heavily used training range for fin whales, with all whales having locations in the area and individual percentage of locations ranging from 10 to 90 percent ($\bar{x}$ = 50 $\pm$ SD 30.7 percent; **Figure 13; Table 8**). The blue/fin whale hybrid had 66 percent of its locations in the MUGU area. Fin whale (and blue/fin whale hybrid) locations occurred in PT MUGU during July, August, and September. Only three fin whales had locations in SOCAL, with the majority of these occurring in August. Individual percentage of locations for these fin whales ranged from 3 to 29 percent ($\bar{x}$ = 17 $\pm$ SD 13.1 percent; **Figure 14**). Four fin whales had locations in the NWTRC and individual percentage of locations ranged from 5 to 75 percent ($\bar{x}$ = 39 $\pm$ SD 30.7 percent; **Figure 15**). One of these latter fin whales also had 2 percent of its locations in W-237 of the NWTRC (**Figure 16**). Locations in the NWTRC occurred during the months of July through October; however, locations in W-237 of the NWTRC occurred only in August, September, and October.

The Bryde's whale had 68 percent of its locations in PT MUGU and 18 percent of its locations in SOCAL, with none in the other training ranges. This animal was located in PT MUGU in July, August, September, and October, but was located in the SOCAL area predominantly in October.

The amount of time that fin whales and the blue/fin hybrid spent in Navy training and testing ranges and BIAs, as well as the results of state space modeling and home range analyses, will be presented in the Final Report.

3.2.2 ADB Tagging

Two fin whales were tagged with ADB tags and tracked for a median of 15.7 d (**Table 9**). Both tags were deployed off the west end of San Miguel Island, California. One tag reached its programmed release date while still attached to the whale and released from the housing successfully but the other was shed while still attached to the housing. The latter surfaced after spending 51 d on the bottom but drifted too far offshore for recovery and was lost. After some initial movements near the tagging area, both tagged whales traveled north, generally staying offshore from the continental slope (>30 km from shore), until the tags released or were shed off San Francisco, California, and south of Cape Mendocino, California (**Figure 11b**).

The two ADB tags recorded 406 and 910 dives >2 min in duration and >10 m in depth, respectively (**Table 9**).

The recovered tag (Tag # 5654) recorded 1,591 FastLoc® GPS locations (99 locations/d) while 12 locations were received through Service Argos, Inc. from the tag that was not recovered (Tag # 5644; **Table 9**) due to an increased priority placed on dive behavior message transmission during programming. For the one tag that was recovered (Tag # 5654), most of the foraging occurred in the offshore portions of the Southern California Bight, from the tagging area west of San Miguel Island, California, south to San Nicolas Island, California (**Figure 17**). Foraging was infrequent and of short duration after the whale moved to the north. The median foraging bout for this whale was 3.8 h long and contained 21 dives, with one bout lasting as long as 14.3 h, during which 67 dives occurred (**Table 10**). The distribution of average maximum dive depths between foraging bouts was bimodal with the whale generally diving to depths of <100 m or >200 m depending on the bout. The bout duration was strongly correlated to the average number of foraging lunges made per dive within a bout (p<0.001, R2=0.59, linear regression) but average maximum dive depth had no additional effect after accounting for the number of lunges per dive (p = 0.69; **Figure 18**).

3.2.3 Behavioral Responses to Tagging

Three of the twelve tagged fin whales responded to the tagging/biopsy process. The short-term startle responses consisted of small fluke kicks by two of the whales and a slow roll to the side by the third.

3.2.4 Wound Healing

Three fin whales where seen 1 to 2 d after tagging with two having slight swelling (**Table 11**). The blue/fin whale hybrid was resighted 4 d after tagging, but the tag site was not visible at this sighting.

3.2.5 Photo-ID

A total of 3,030 photos of fin whales were taken during the cruise. Photo-IDs were obtained of 10 of the 11 tagged fin whales, with one whale having poor-quality photos that could not be used for an ID. Seven whales have both left- and right-side photographs, one whale had a left-side photo only, and two whales had right-side photos only.

A total of 70 photos were taken of the tagged blue/fin whale hybrid. ID photos were taken of both its left and right side.

Photo ID was obtained for the right-side of the tagged Bryde's whale.

3.2.6 Ecological Relationships

This information will be included in the Final Report.

3.2.7 Genetics and Species Identification

Good quality DNA was extracted from nine samples initially considered to be fin whales based on field observations. All samples provided DNA profiles sufficient for subsequent analyses. Initial comparison of mtDNA sequences showed disagreement with field identification of two samples. Based on submission of mtDNA control region sequences to *DNA-surveillance* and a BLAST search of GenBank®, sample BphCA15002 was identified as a blue whale and sample BphCA15006 was identified as a Bryde's whale *Balaenoptera brydei/edeni*. Subsequent review of photographic records agreed with the molecular identification of BphCA15006 as a Bryde's whale. For sample BphCA15002, we used a structure analysis with a reference dataset of genotypes from North Pacific blue and fin whales to confirm a high likelihood that the individual is a blue/fin whale hybrid (see below and Steiger et al. 2009). Given the maternal inheritance of mtDNA and the biparental inheritance of the microsatellite loci, we can also confirm that the parents of the hybrid were a blue whale mother and fin whale father.

3.2.7.1 SEX DETERMINATION

The blue/fin whale hybrid (BphCA15002) was identified as a male and the Bryde's whale (BphCA15006) was identified as a female. Of the seven fin whales, three were male and four were female.

3.2.7.2 Individual Identification

All nine individuals were represented by unique multi-locus genotypes and the probability of identity for the 17 loci was very low, 3.7 $\times 10^{-18}$ (i.e., there was a very low probability of a match by chance). Consequently, we are confident that the nine unique multi-locus genotypes represented nine individuals. This was consistent with sex and mtDNA haplotypes, as provided in the full DNA profile.

Given the interest in the blue/fin whale hybrid, we reviewed the DNA profile of a previous blue/fin whale hybrid conducted in collaboration with researchers from Cascadia Research Collective, as reported by Steiger et al. (2009). The comparison of the DNA profiles confirmed a match with this individual, first sampled on September 22, 2004, providing an 11-year resighting record. In keeping with the collaborative agreement with Cascadia Research Collective, the information on this 'genotype recapture' was shared with John Calambokidis on September 22, 2015, and then with HDR, Naval Facilities Engineering Command Pacific and Commander, U.S. Pacific Fleet by email on September 24, 2015.

Matching of the other 2015 samples to all available DNA profiles of fin whales from previous tagging in the North Pacific is underway and will be included in the Final Report.

3.2.7.3 STOCK IDENTIFICATION

These analyses will be completed for the Final Report.

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4. Discussion

4.1 Blue Whale

4.1.1 Tagging

The tracking results from blue whales tagged in 2015 expand our knowledge on the long-term movements and distribution of blue whales in the eastern North Pacific, providing more information on blue whale occurrence and use of Navy training and testing ranges.

ADB-tagged blue whales ranged widely and, with the exception of the coastal movements of Tag #838, occupied areas further offshore than has been observed in past years where the areas of highest use were more limited to the upper continental slope (Bailey et al. 2010, Irvine et al. 2014). While it may be coincidental, it should be noted that the coastally oriented whale (Tag #838) was tagged close to shore near Point Mugu, California, while the other three whales were tagged at the west end of the Santa Barbara Channel. The sample size is too limited for any conclusions; however, it does hint that different individuals may preferentially use different portions of the southern California waters.

Whales tracked by the three recovered ADB tags foraged extensively near the tagging area, then intermittently after departing the tagging area. Foraging bouts were generally brief and the duration was correlated to the number of lunges per dive that occurred within a foraging bout. Blue whales have been shown to adjust their behavior and number of lunges made per dive based on the density of prey in the area (Goldbogen et al. 2015, Hazen et al. 2015), so the correlation between bout duration and number of lunges per dive indicates the whales quickly left lower density prey patches and stayed longer, and foraged more intensely, in higher density patches.

The relatively linear nature of many foraging bouts was surprising as whales would be expected to turn in order to forage within a patch, thereby creating a cluster of locations over the prey patch. Some of the foraging bouts extended across >20 km which would far exceed the known dimensions of krill patches off southern California.

Tag #840 foraged extensively in an area 100 km southwest of San Miguel Island for over 1 week while Tag #4177 passed through the same area without foraging at all. The extensive foraging of Tag #840 would suggest that prey was abundant throughout the area, which makes the lack of foraging effort by Tag #4177 puzzling. It is unlikely that prey was depleted or advected away by the time Tag #4177 passed through, and, though we do not know how whales locate their prey, it is also unlikely that Tag #4177 was unable to locate prey if it was available. This suggests that Tag #840 was either somehow able to exploit prey in the area at a lower density than was available for Tag #4177 or that prey was available in moderate densities and the whales made search choices. Blue whales have been shown to adjust their dive behavior and number of lunges made per dive based on the density of prey in the area (Goldbogen et al. 2015, Hazen et al. 2015). It is therefore, not unreasonable to hypothesize that the criteria for an ‘acceptable’ density of prey for a whale to feed on may vary between individuals and may even be related to the whale’s body condition.

4.1.2 Genetics

The genetic analyses to date have provided new information on the diversity of mtDNA haplotypes for blue whales in the North Pacific, as well as sex of tagged individuals, and confirmed individual identification. Subsequent analyses will investigate potential for stock structure and genotype recaptures, using published data on mtDNA haplotypes and genotypes from previous tagging.

4.1.3 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 Tagging

As with the blue whale tracking data, the tracking data obtained from fin whales in 2015 add to our sample sizes from 2014, providing a richer data set of information on long-term movements of fin whales in the eastern North Pacific as well as providing occurrence and use of Navy training and testing ranges. The tagging study also provides the first-ever tracking information of a blue/fin whale hybrid as well as some of the first information on movements of a Bryde's whale in southern California.

While both ADB tagged fin whales left southern California waters after tagging, Tag # 5654 foraged extensively in the area before doing so; however, it remained well offshore, staying to the west of San Nicolas and San Miguel Islands. As with ADB-tagged blue whales, foraging bouts appear to have been located near areas of steep bottom topography, which have been shown to both increase and concentrate prey (Genin 2004, Croll et al. 2005).

The duration of foraging bouts made by the tagged fin whale was almost twice the median duration of foraging bouts made by ADB tagged blue whales; however, other aspects of the bouts (e.g., average depth, number of lunges) were very similar, suggesting that the greater duration may have reflected the fin whale finding more profitable foraging areas than the tagged blue whales. The fin whale also showed the same correlation between the number of lunges made per dive within a foraging bout and the duration of a foraging bout, suggesting it also left poor=quality prey patches quickly and stayed to forage longer in good-quality patches.

4.2.2 Genetics

The genetic analyses to-date identified the hybrid origin of one of the tagged whales (Tag #10831) and, through a collaborative relationship with Cascadia Research Collective, documented a previous biopsy sampling of this individual (a male) in 2004 during photo-ID surveys conducted under NOAA/Southwest Fisheries Science Center funding (Steiger et al. 2009). The genetic analyses also confirmed identification of a Bryde's whale, initially identified in the field as a fin whale. Initial analysis indicates that this individual represented the '*brydei*' subspecies or type, as described by Yoshida and Kato (1999)

Subsequent analyses will investigate potential for stock structure and genotype recaptures of fin whales, using published data on mtDNA haplotypes and genotypes from previous tagging.

4.2.3 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

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. DOI: 10.1098/rsbl.2014.1037.

Bailey H., B. R. Mate, D. M. Palacios D., 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.

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.

Bryant, E. 2007. 2D location accuracy statistics for Fastloc cores running firmware versions 2.2 & 2.3. Technical Report TR01. Wildtrack Telemetry Systems Ltd., Redmond, WA. 5 pp.

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.

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.

Croll D. A., B. Marinovic, S. Benson, F. P. Chavez, N. Black, R. Ternullo and B. R. Tershy. 2005. From wind to whales: trophic links in a coastal upwelling system. Marine Ecology Progress Series 289: 117–130.

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

Falush, D., M. Stephens and J.K. Pritchard. 2003. Inference of population structure using multilocus genotype data: linked loci and correlated allele frequencies. Genetics 164: 1567–1587.

Ferguson, M. C., C. Curtice, J. Harrison and S. M. Van Parijs. 2015. Biologically Important Areas for Cetaceans Within U.S. Waters – Overview and Rationale. Aquatic Mammals 41:2-16. doi:10.1578/AM.41.1.2015.2

Genin, A. 2004. Bio-physical coupling in the formation of zooplankton and fish aggregations over abrupt topographies. Journal of Marine Systems 50: 3–20.

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.

Goldbogen J. A., J. Calambokidis, R. E. Shadwick, E. M. Oleson, M. A. McDonald and J. Hildebrand. 2006. Kinematics of foraging dives and lunge-feeding in fin whales. Journal of Experimental Biology 209: 1231–1244.

Goldbogen J. A., E. L. Hazen, A. S. Friedlaender, J. Calambokidis, S. L. DeRuiter, A. K. Stimpert and B. L. Southall. 2015. Prey density and distribution drive the three-dimensional foraging strategies of the largest filter feeder. Functional Ecology 29: 951–961.

Hazen, E.L., A. S. Friedlaender and J. A. Goldbogen. 2015. Blue whales (*Balaenoptera musculus*) optimize foraging efficiency by balancing oxygen use and energy gain as a function of prey density. Science Advances 1(9): e1500469. DOI: 10.1126/sciadv.1500469.

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.

Irvine, L., D. M. Palacios, J. Urban-Ramirez and B. R. Mate. In prep. Using a novel medium-duration tag to characterize the diving behavior of sperm whales in the Gulf of California.

Johnson M. and P. L. Tyack. 2003. A digital acoustic recording tag for measuring the response of wild marine mammals to sound. IEEE Journal of Oceanic Engineering 28: 3–12.

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 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.

Morin, P. A., K. K. Martien, F. I. Archer, F. Cipriano, D. Steel, J. Jackson and B. L. Taylor. 2010. Applied conservation genetics and the need for quality control and reporting of genetic data used in fisheries and wildlife management. Journal of Heredity 101: 1–10.

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, NY

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.

Steiger, G. H., J. Calambokidis, A. E. Douglas, E. A. Falcone, T. E. Chandler, D. Steel and C. S. Baker. 2009. Physical and behavioral characteristics and genetic confirmation of live hybrid blue-fin whales in the Eastern North Pacific. Abstracts, 18th Biennial Conference on the Biology of Marine Mammals, 12-16 October 2009.Quebec City, Quebec.

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.

Waits, J. L. and P. L. Leberg. 2000. Biases associated with population estimation using molecular tagging. Animal Conservation 3: 191–199.

Waits, L. P., G. Luikart and P. Taberlet. 2001. Estimating the probability of identity among genotypes in natural populations: cautions and guidelines. Molecular Ecology 10(1): 249–256

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.

Yoshida, H. and H. Kato. 1999. Phylogenetic relationships of Bryde's whales in the western North Pacific and adjacent waters inferred from mitochondrial DNA sequences. Marine Mammal Science 15: 1269–1286.

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Table 1. Deployment and performance data for satellite-monitored radio tags deployed on blue whales in southern California, 2015. In the Sex column, F = female, M = male, and U = unknown sex, because no biopsy sample was collected.

Tag #	Argos Locations							GPS Locations				
	Sex	Tag Type	Deployment Date	Most Recent Location	# Days Tracked	# Filtered Locations	Total Distance (km)	Recovered	Last Location	# Days Tracked	# Locations	Total Distance (km)
825*	F	SPOT5	10-Jul-15	15-Nov-15	128.1	395	10,838					
831	U	SPOT5	9-Jul-15	2-Sep-15	54.6	177	4,215					
849	U	SPOT5	9-Jul-15	30-Sep-15	84.0	296	5,255					
1385	M	SPOT5	9-Jul-15	9-Sep-15	62.0	253	2,230					
5640*	M	SPOT5	16-Jul-15	15-Nov-15	122.1	505	7,013					
5678*	M	SPOT5	9-Jul-15	14-Nov-15	128.3	524	7,481					
5700	U	SPOT5	8-Jul-15	4-Oct-15	87.8	338	3,831					
5701	F	SPOT5	16-Jul-15	3-Sep-15	48.8	197	3,016					
5726	U	SPOT5	8-Jul-15	4-Sep-15	57.8	118	2,554					
5736	F	SPOT5	9-Jul-15	13-Jul-15	4.2	18	195					
5801	M	SPOT5	10-Jul-15	15-Aug-15	35.3	15	675					
5823*	U	SPOT5	10-Jul-15	14-Nov-15	126.5	116	4,121					
5838	M	SPOT5	17-Jul-15	26-Aug-15	40.7	157	2,238					
5840	F	SPOT5	17-Jul-15	18-Sep-15	63.2	187	2,171					
5841	F	SPOT5	9-Jul-15	3-Sep-15	56.2	257	3,085					
10839	U	SPOT5	16-Jul-15	20-Sep-15	65.8	210	3,536					
23031*	F	SPOT5	16-Jul-15	15-Nov-15	122.2	423	7,534					
23033	M	SPOT5	8-Jul-15	29-Sep-15	83.0	338	4,350					
838[+++]	F	ADB	7-Jul-15	2-Aug-15	25.9	529	2,134	No	1-Aug-15	25.1	71	1,123
840[+]	U	ADB	8-Jul-15	2-Aug-15	24.8	271	1,606	Yes	2-Aug-15	24.7	1,633	1,417
4177[+++]	M	ADB	8-Jul-15	5-Aug-15	27.2	334	2,558	Yes	5-Aug-15	27.1	1,515	2,211
5650[+++]	M	ADB	8-Jul-15	7-Aug-15	29.8	464	2,509	Yes	7-Aug-15	29.8	2,446	2,328

KEY: ADB = Advanced Dive Behavior; km = kilometer(s); GPS = geographic positioning system; SPOT5 = Smart Positioning or Temperature Transmitting Tag, Version 5; # = number; *Tag is still transmitting as of 15 Nov 2015; [+]Tag is FastLoc®, Version.1; and [+++]Tag is FastLoc®, Version.3.

Table 2. Deployment and performance data for satellite-monitored radio tags deployed on fin whales, a blue/fin whale hybrid, and a Bryde's whale in southern California, 2015. In the Sex column, F = female, M = male, and U = unknown sex, because no biopsy sample was collected.

Tag #	Argos Locations							GPS Locations				
	Sex	Tag Type	Deployment Date	Most Recent Location	# Days Tracked	# Filtered Locations	Total Distance (km)	Recovered	Last Location	# Days Tracked	# Locations	Total Distance (km)
832	F	SPOT5	22-Jul-15	20-Aug-15	28.8	21	1,481					
833[@]	F	SPOT5	23-Aug-15	21-Oct-15	89.8	94	4,587					
839	M	SPOT5	8-Jul-15	24-Sep-15	78.0	271	6,823					
5742*	M	SPOT5	23-Jul-15	15-Nov-15	115.1	365	7,537					
5743	U	SPOT5	9-Jul-15	6-Aug-15	28.2	53	1,322					
5790	F	SPOT5	28-Jul-15	28-Jul-15	0.0	0	0					
5800	F	SPOT5	17-Jul-15	7-Oct-15	81.8	289	5,294					
5923	M	SPOT5	28-Jul-15	21-Sep-15	54.6	96	3,418					
10831[#]	M	SPOT5	16-Jul-15	13-Aug-15	28.0	95	1,444					
10838	U	SPOT5	17-Jul-15	12-Oct-15	86.9	378	5,147					
23032	F	SPOT5	28-Jul-15	3-Aug-15	6.2	29	507					
5644[+]	U	ADB	10-Jul-15	26-Jul-15	15.4	177	1,517	No	24-Jul-15	14.1	11	787
5654[+]	U	ADB	17-Jul-15	2-Aug-15	16.0	306	1,378	Yes	2-Aug-15	15.8	1,727	1,341

KEY: ADB = Advanced Dive Behavior; km = kilometer(s); GPS = geographic positioning system; SPOT5 = Smart Positioning or Temperature Transmitting Tag, Version 5; # = number; [@] Bryde's whale, *Tag is still transmitting as of 15 Nov 2015, [#] Blue/fin whale hybrid, [+] Tag is FastLoc®, Version1

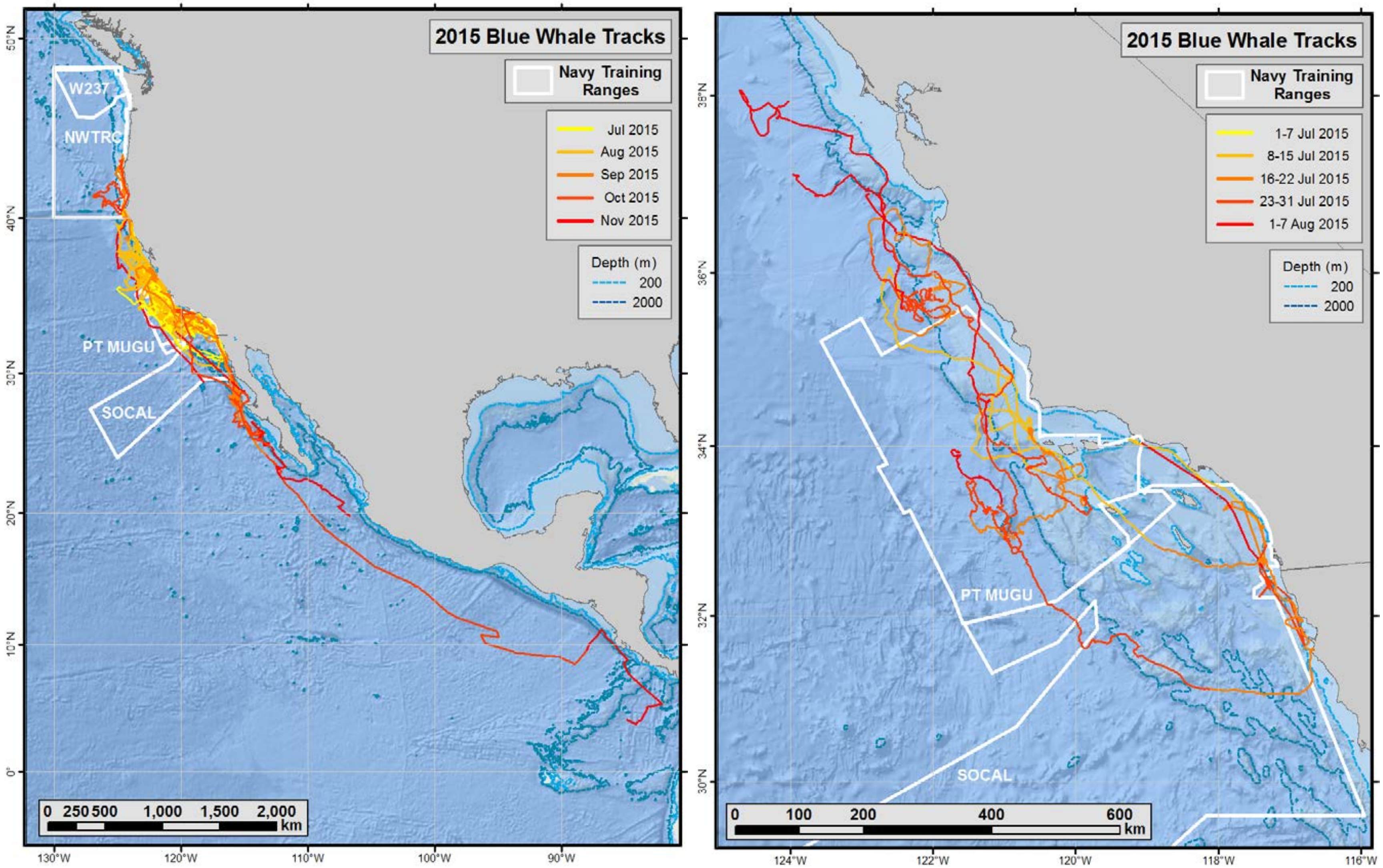

Figure 1. Satellite-monitored radio tracks for blue whales tagged off southern California, 2015: a) Argos locations from SPOT5 (*n*=18) and ADB (*n*=4) tags. b) GPS locations from ADB tags (*n*=4).

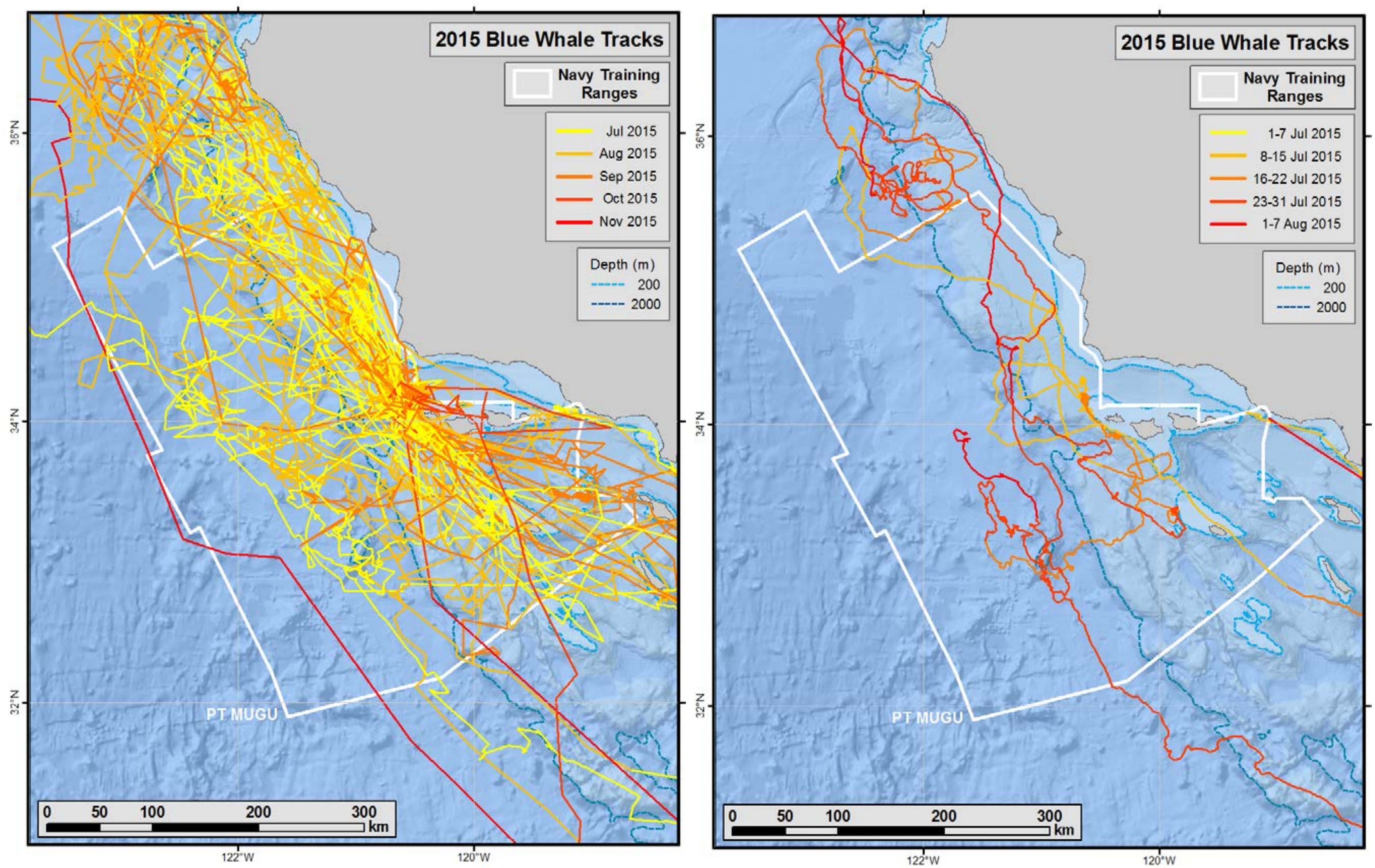

Figure 2. Satellite-monitored radio tracks in PT MUGU for blue whales tagged off southern California, 2015: a) Argos locations from SPOT5 (*n*=18) and ADB (*n*=4) tags. b) GPS locations from ADB tags (*n*=4).

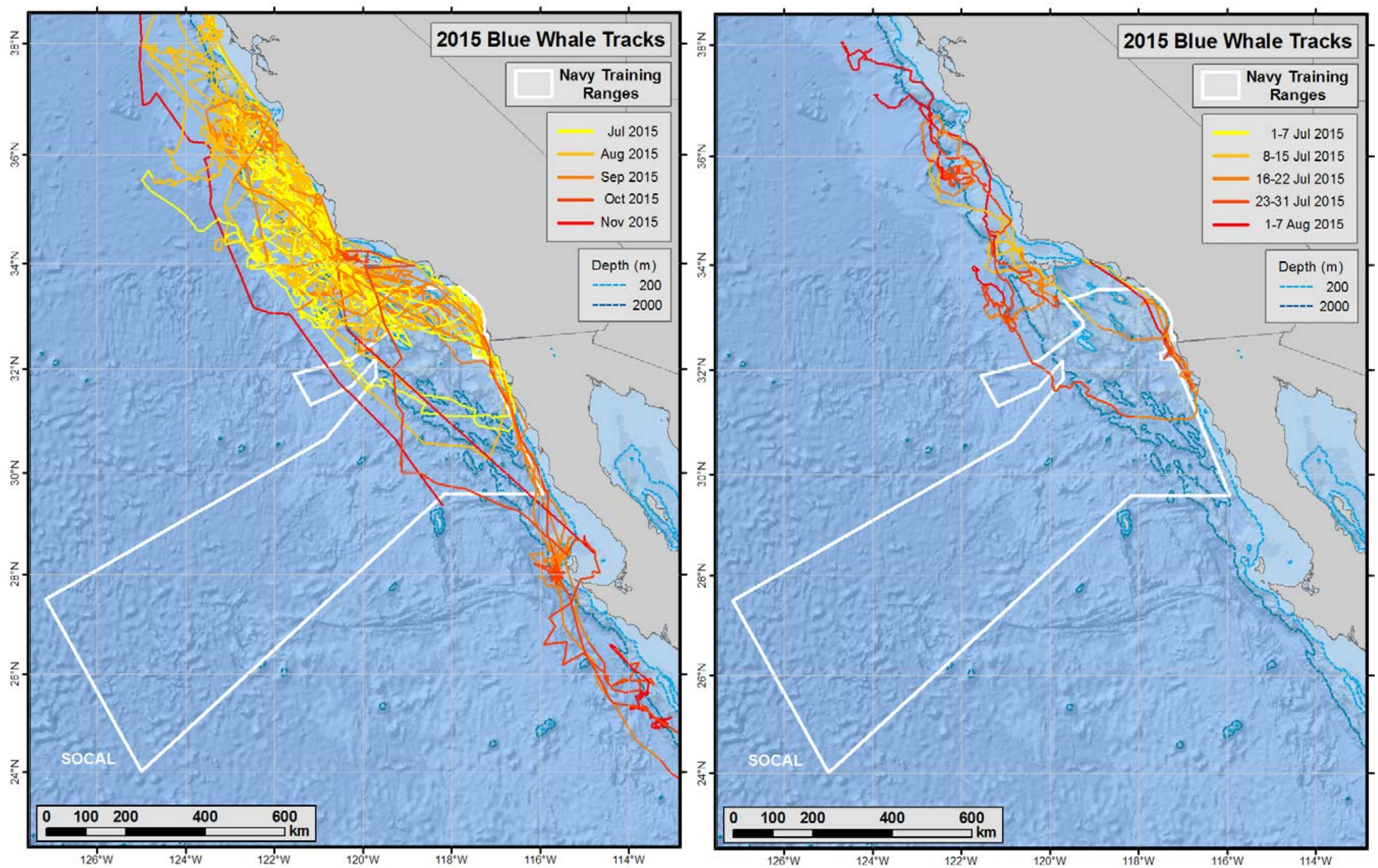

Figure 3. Satellite-monitored radio tracks in SOCAL for blue whales tagged off southern California, 2015: a) Argos locations from SPOT5 (*n*=12) and ADB (*n*=2) tags. b) GPS locations from ADB tags (*n*=2).

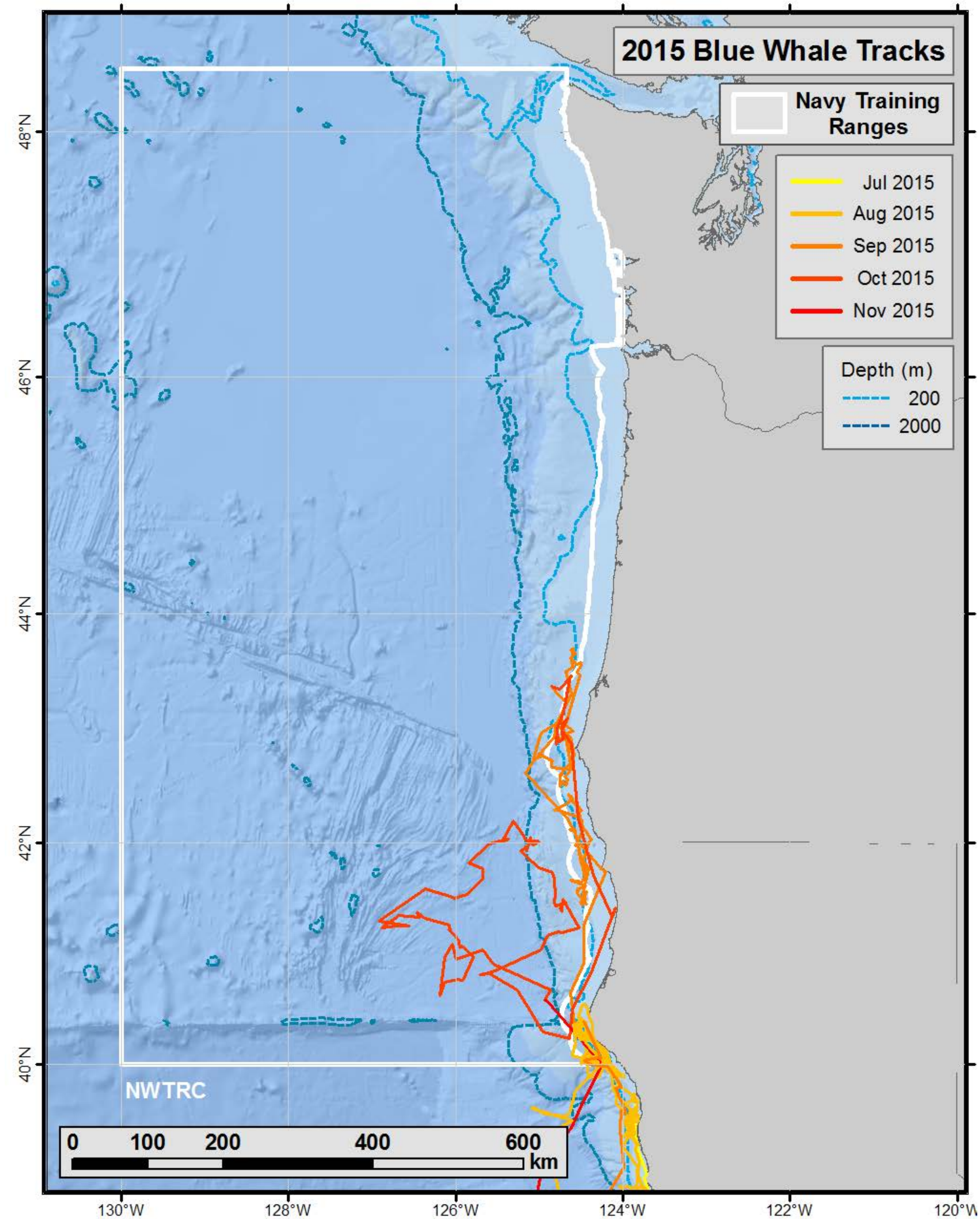

Figure 4. Satellite-monitored radio tracks in the NWTRC for two blue whales tagged with SPOT5 tags off southern California, 2015 (Tag #s 5678 and 5841).

Table 3. Percent of tagged blue whale locations located inside SOCAL, PT MUGU, NWTRC, and W-237 of the NWTRC.

		Argos Locations					GPS Locations				
Tag #	Tag Type	# Filtered Locations	Inside SOCAL	Inside PT MUGU	Inside NWTRC	Inside NWTRC-W-237	# Locations	Inside SOCAL	Inside PT MUGU	Inside NWTRC	Inside NWTRC-W-237
825*	SPOT5	395	14%	37%	0%	0%					
831	SPOT5	177	12%	62%	0%	0%					
849	SPOT5	296	2%	45%	0%	0%					
1385	SPOT5	253	0%	89%	0%	0%					
5640*	SPOT5	505	4%	47%	0%	0%					
5678*	SPOT5	524	1%	20%	29%	0%					
5700	SPOT5	338	9%	88%	0%	0%					
5701	SPOT5	197	6%	89%	0%	0%					
5726	SPOT5	118	0%	34%	0%	0%					
5736	SPOT5	18	0%	100%	0%	0%					
5801	SPOT5	15	0%	53%	0%	0%					
5823*	SPOT5	116	2%	61%	0%	0%					
5838	SPOT5	157	22%	72%	0%	0%					
5840	SPOT5	187	0%	99%	0%	0%					
5841	SPOT5	257	0%	34%	1%	0%					
10839	SPOT5	210	7%	46%	0%	0%					
23031*	SPOT5	423	4%	44%	0%	0%					
23033	SPOT5	338	1%	27%	0%	0%					
838+++	ADB	529	41%	13%	0%	0%	71	49%	15%	0%	0%
840+	ADB	271	0%	100%	0%	0%	1,633	0%	100%	0%	0%
4177+++	ADB	334	31%	48%	0%	0%	1,515	31%	55%	0%	0%
5650+++	ADB	464	0%	16%	0%	0%	2,446	0%	19%	0%	0%

KEY: ADB = Advanced Dive Behavior; GPS = geographic positioning system; NWTRC = Northwest Training Range Complex; PT MUGU = Point Mugu Sea Range; SOCAL = Southern California Range Complex; SPOT5 = Smart Positioning or Temperature Transmitting Tag, Version 5; W-237 = Warning Area 237; # = number; % = percent; *Tag is still transmitting as of 15 Nov 2015, +Tag is FastLoc® v.1, +++Tag is FastLoc® v.3

Table 4. ADB tag deployment summary information for tags deployed on blue whales off southern California in July 2015.

Species	Year	PTT	Recovered?	Duration (d)	# Dives	# GPS Locations	Dives/d	GPS Locs/d	Total Distance (km)
Blue whale	2015	838+++	No*	25.9	2289	69	88	3	2137
Blue whale	2015	840+	Yes	24.8	2075	1558	84	63	1610
Blue whale	2015	4177+++	Yes	27.5	2794	1480	102	54	2545
Blue whale	2015	5650+++	Yes	28.9	2280	2337	79	81	2509
		Median		26.7	2285	1519	86	58	2323
		Total		**107.1**	**9438.0**	**5444.0**	**352.5**	**200.2**	**8800.9**

KEY: d = day(s); GPS = geographic positioning system; km = kilometer(s); Locs = locations; PTT = Platform Transmitting Terminal; # = number; +Tag is FastLoc® v.1, +++Tag is FastLoc® v.3, *Data were transmitted through Service Argos, Inc.

Table 5. Summary of dives occurring during foraging bouts made by seven ADB-tagged blue whales tagged off southern California in August 2014 and July 2015. Foraging bouts are sequences of dives with no more than three dives in a row with no recorded foraging lunges.

PTT	Year		Cluster Duration (h)	# Dives	Avg Max Dive Depth (m)	Avg Dive Duration (min)	Avg # Lunges	Dives # Lunges	Area Of Cluster (km^2)	Time To Next Cluster (h)	Dist To Next Cluster (km)
5,644	2014	median	2.2	11.0	99.4	8.0	1.7	4.0	1.7	10.6	19.3
# bouts =25		max	12.3	68.0	169.8	17.3	4.9	14.0	111.6	68.3	145.5
		min	0.9	5.0	33.2	3.5	0.4	0.0	0.0	0.0	0.0
5650	2014	median	1.6	10.0	88.2	6.3	1.4	3.0	1.4	2.2	3.2
# bouts =27		max	10.2	52.0	244.2	11.0	3.8	13.0	54.9	179.6	150.4
		min	0.5	4.0	27.7	3.2	0.5	0.0	0.0	0.0	0.0
5803	2014	median	1.6	8.5	131.6	7.3	1.3	3.0	1.8	2.2	7.7
# bouts =38		max	11.3	62.0	251.1	13.2	2.8	14.0	80.9	46.8	243.2
		min	0.5	4.0	26.3	2.8	0.4	0.0	0.0	0.0	0.0
5655	2014	median	2.5	14.5	148.4	7.5	1.7	2.5	0.7	5.3	7.6
# bouts =40		max	13.3	125.0	247.3	10.7	3.6	38.0	94.7	25.0	96.4
		min	0.4	4.0	31.5	2.7	0.4	0.0	0.0	0.0	0.0
840	2015	median	7.5	36.0	130.8	9.9	3.2	3.0	8.3	9.6	2.8
# bouts =25		max	20.0	72.0	260.6	16.0	4.9	13.0	96.4	204.1	121.9
		min	0.4	4.0	50.5	4.9	0.5	0.0	0.0	0.0	0.0
4177	2015	median	1.6	9.0	91.5	9.5	1.3	3.0	0.8	7.5	28.9
# bouts = 27		max	13.7	75.0	224.4	13.9	4.3	14.0	99.4	111.8	246.5
		min	0.7	4.0	30.3	3.9	0.4	0.0	0.0	0.0	0.0
5650	2015	median	2.7	10.5	93.8	11.5	1.9	2.0	3.3	8.8	17.7
# bouts = 30		max	16.6	77.0	195.2	15.9	6.8	22.0	672.5	85.5	152.7
		min	0.9	4.0	36.0	6.0	0.4	0.0	0.0	0.0	0.0

KEY: avg = average; d = day(s); dist = distance; h = hour(s); km = kilometer(s); km^2 = square kilometer(s); Locs = locations; max = maximum; min = minute(s) or minimum; PTT = Platform Transmitting Terminal; # = number

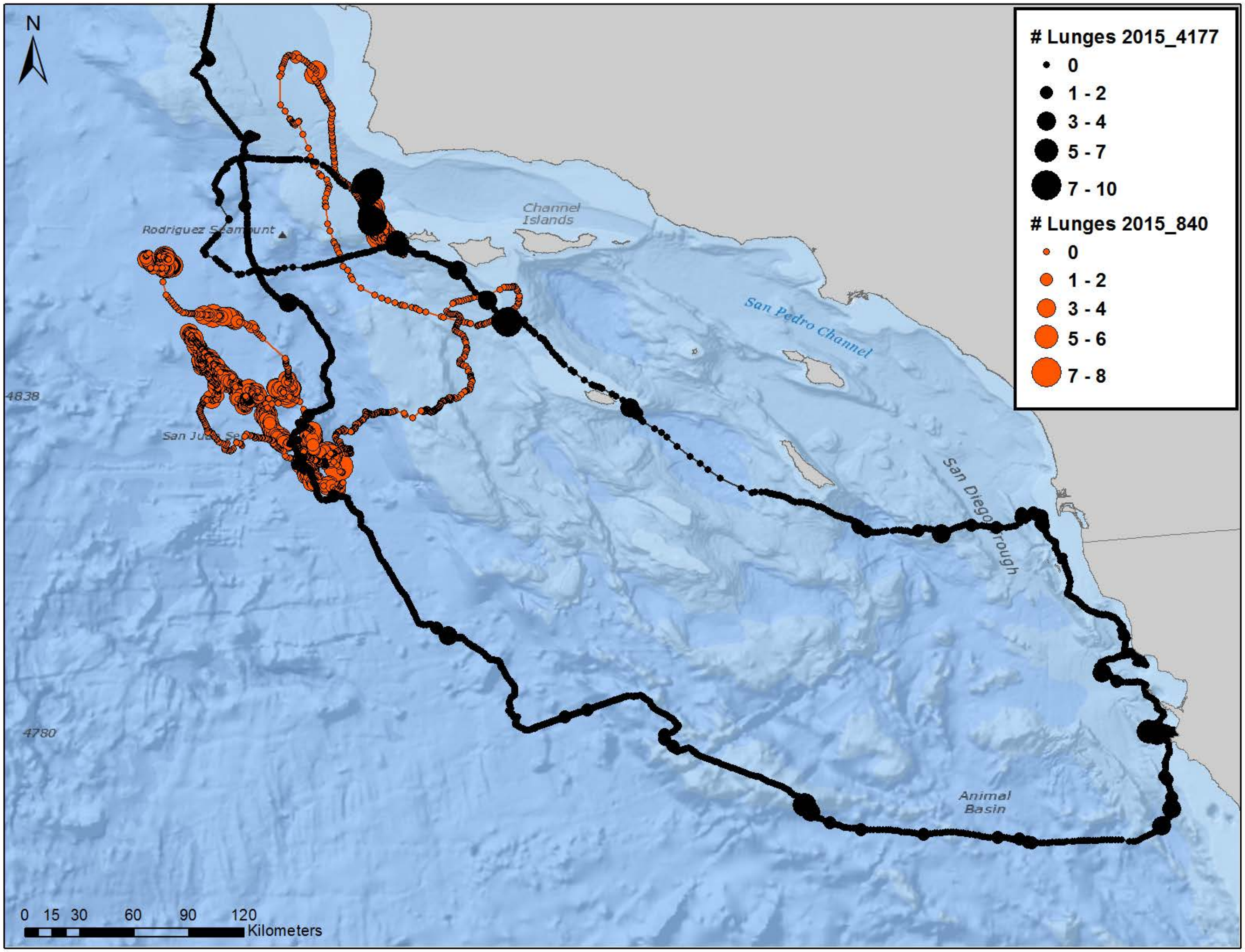

Figure 5. Tracks of two ADB-tagged blue whales off southern California in July 2015 (Tag #s 840 and 4177). Size of the circles represents the number of foraging lunges that occurred during a dive at that location.

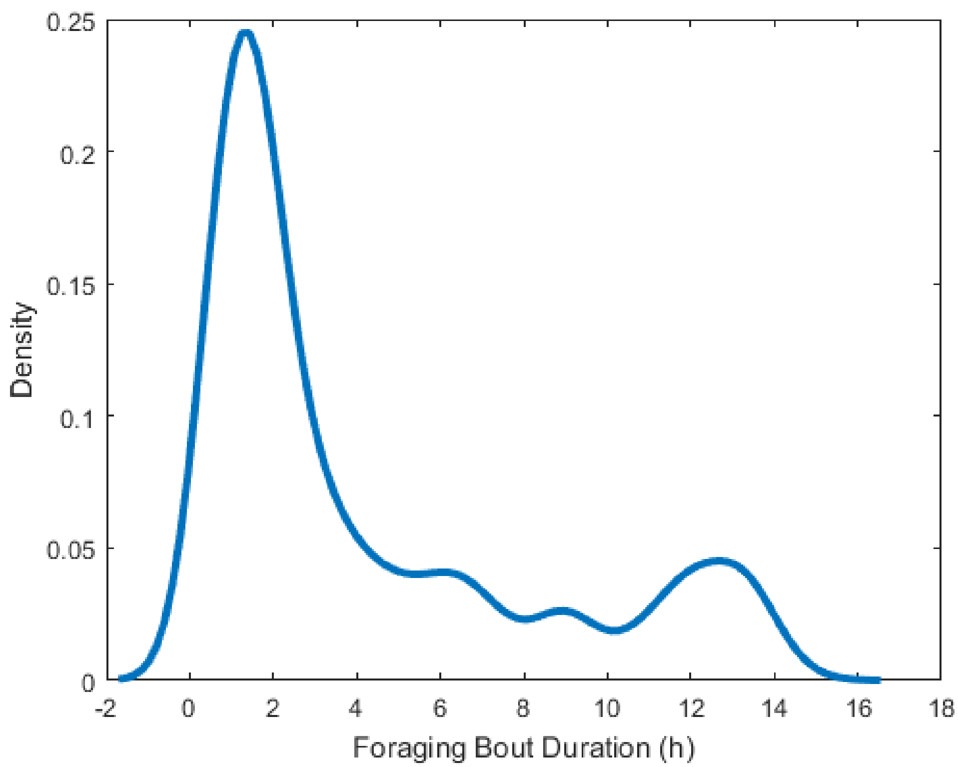

Figure 6. Distribution of foraging bout durations for ADB-tagged blue whales off southern California.

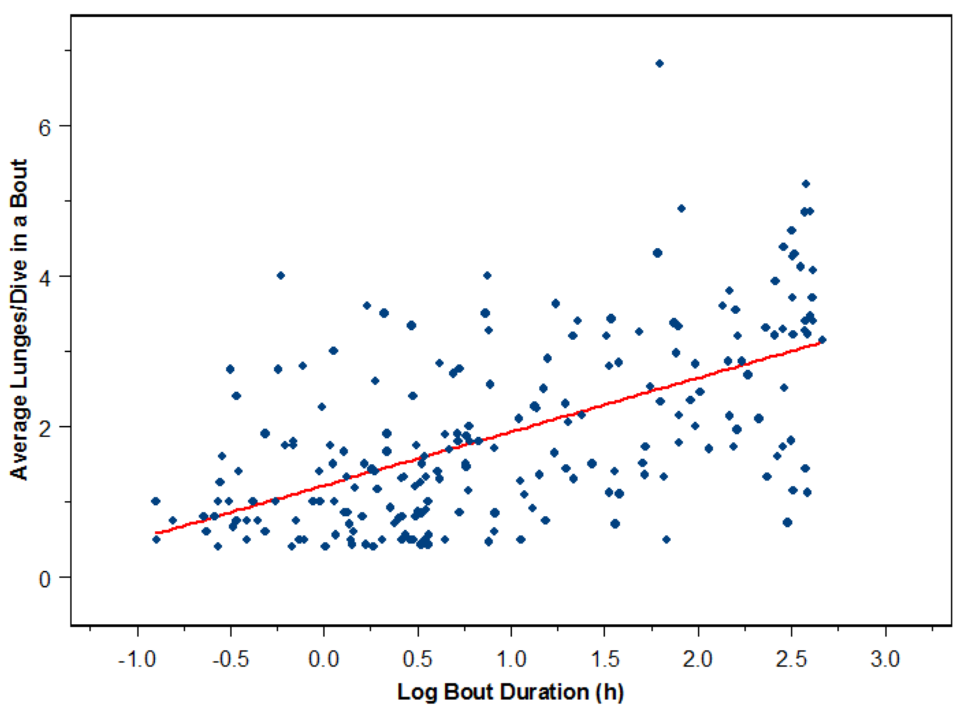

Figure 7. A comparison of the average lunges per dive within a foraging bout compared to the duration of the bout. Bout duration is shown on a log axis as it was transformed prior to being input into a linear regression model (red line). The data are from ADB-tagged blue whales tracked off southern California in August 2014 and July 2015.

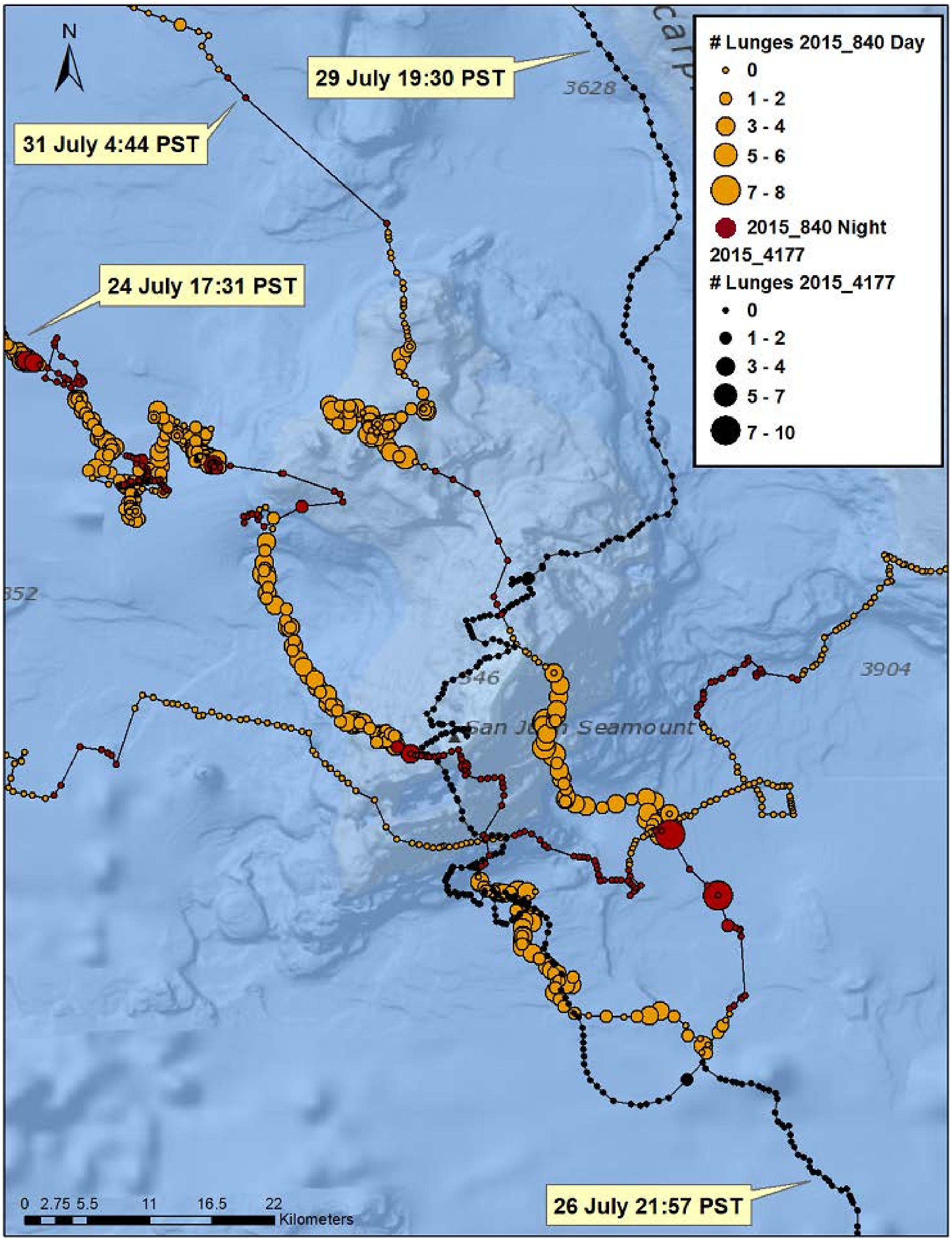

Figure 8. A map showing a portion of the tracks of two ADB-tagged blue whales (Tag #s 840 and 4177; full tracks shown in Figure 5) off southern California for the period 24-31 July 2015. The size of circles represents the number of foraging lunges made during a dive at that location. Darker (red) portions of the track for tag 2015_840 represent night time (20:00 – 06:00 PST). The image shows one whale foraging almost continuously during daylight hours while another whale passes through the same area without feeding.

Table 6. Behavioral responses of blue whales to satellite tagging, southern California, 2015.

Blue whales	
# of	**Response to Tagging/Biopsy Darting**
21	No response
1	Slight roll
	Responses to Biopsy Darting Alone
1	No response

KEY: # = number.

Table 7. Resightings and tag site descriptions for blue whales satellite-tagged off southern California, 2015. Size estimates are approximate.

Tag #	**Tag Type**	**Days After Tagging**						
		1	**2**	**3**	**4**	**5**	**6**	**7**
Blue Whale								
1385	SPOT5	no change						swelling 35x20 cm, 5 cm high
5678	SPOT5		swelling 10x10 cm, 2 cm high					
5700	SPOT5	no change						
23033	SPOT5	swelling 30x20 cm, 5 cm high						
840	ADB*	no change						

KEY: ADB = Advanced Dive Behavior; cm = centimeter(s); SPOT5 = Smart Positioning or Temperature Transmitting Tag, Version 5; # = number; * ADB tag is FastLoc®, Version1.

Figure 9. Tag site on a blue whale resighted 319 d after deployment of a SPOT5 satellite-monitored radio tag (Tag #10834) off southern California in August 2014.

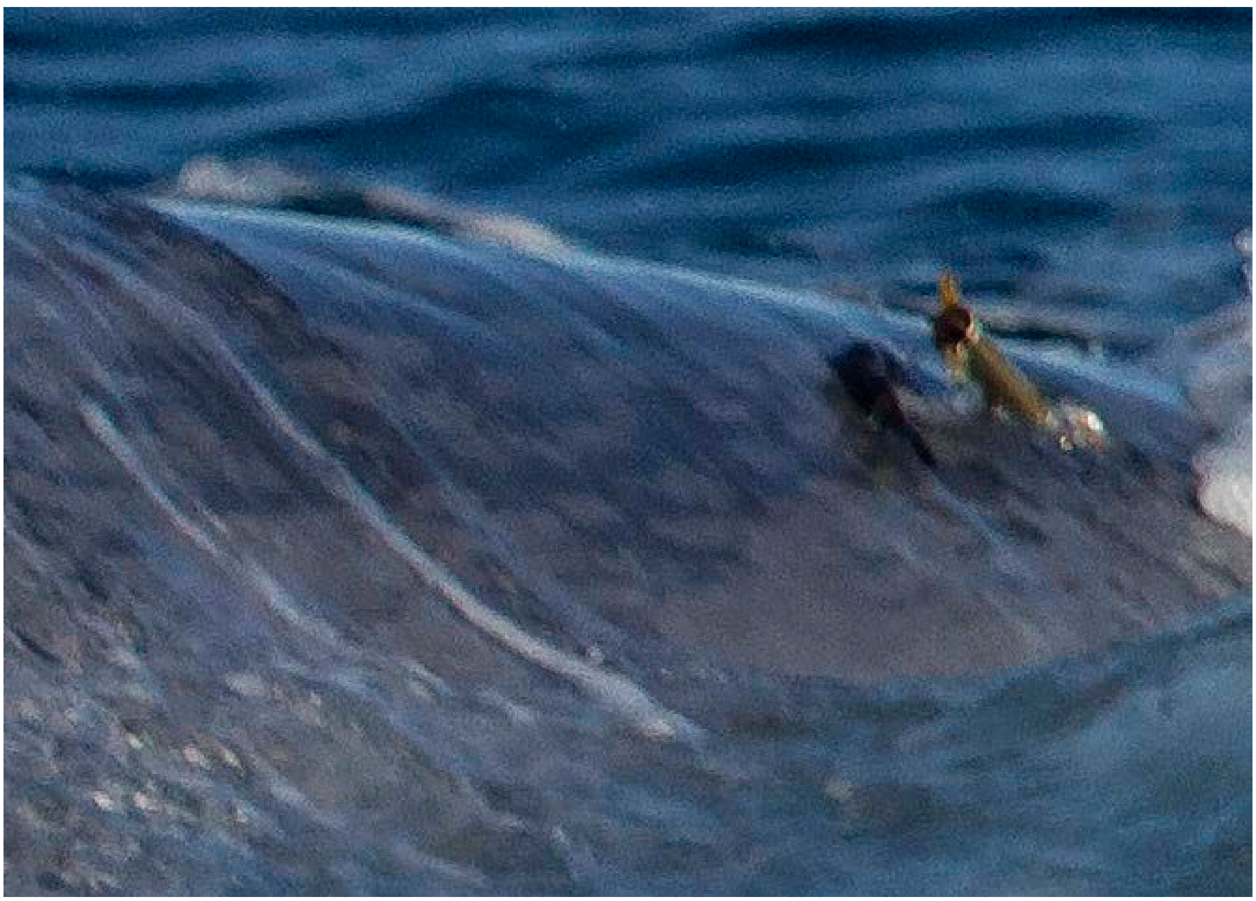

Figure 10. SPOT5 satellite-monitored radio tag (Tag #10827) on a blue whale resighted 301 d after deployment off southern California in September 2014.

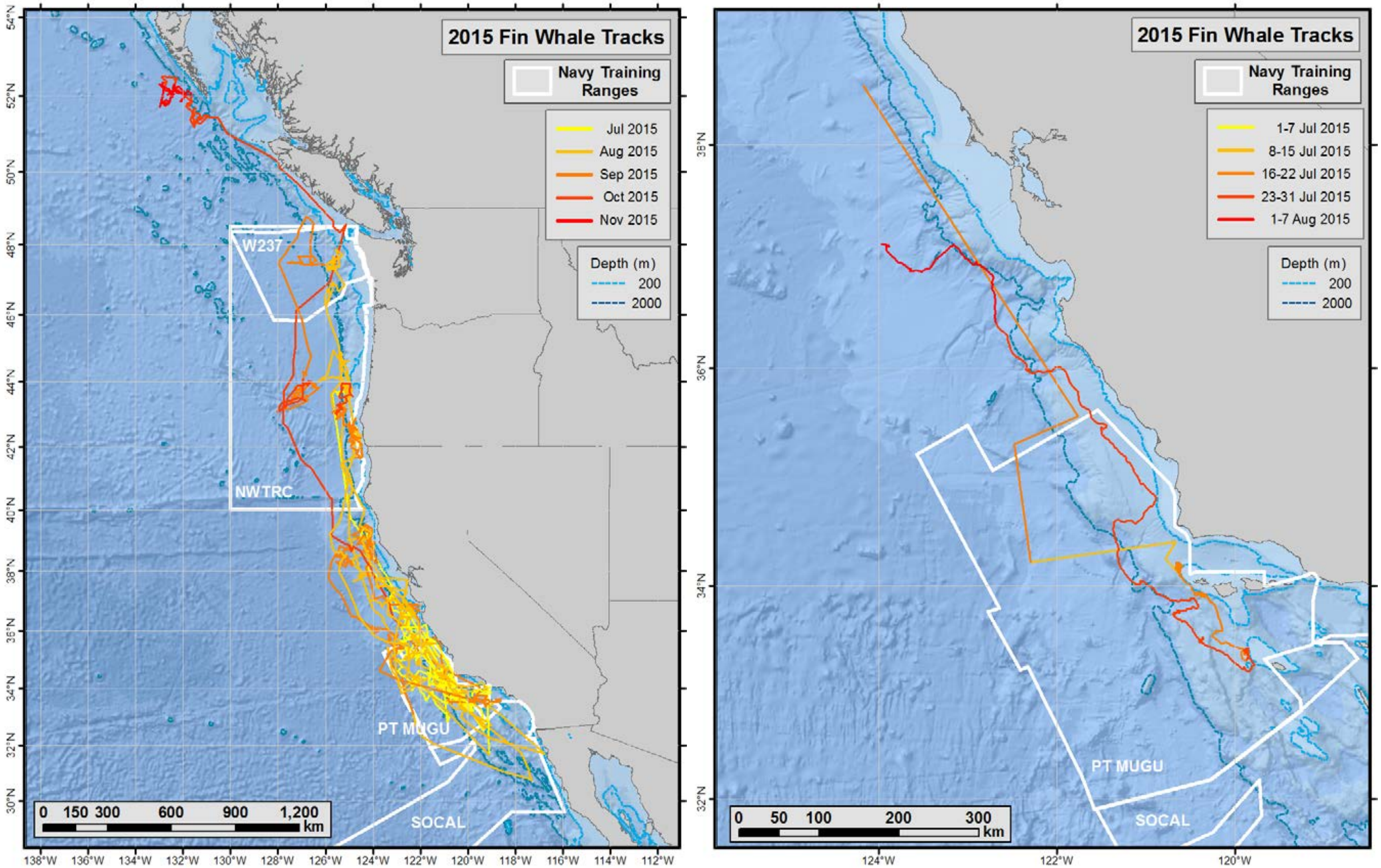

Figure 11. Satellite-monitored radio tracks for fin whales and a blue/fin whale hybrid tagged off southern California, 2015. a) Argos locations from SPOT5 (*n*=10) and ADB (*n*=2) tags. b) GPS locations from ADB tags (*n*=2). One ADB tag was not recovered, so only GPS locations transmitted through Argos are depicted here for that tag (11 locations for Tag #5644).

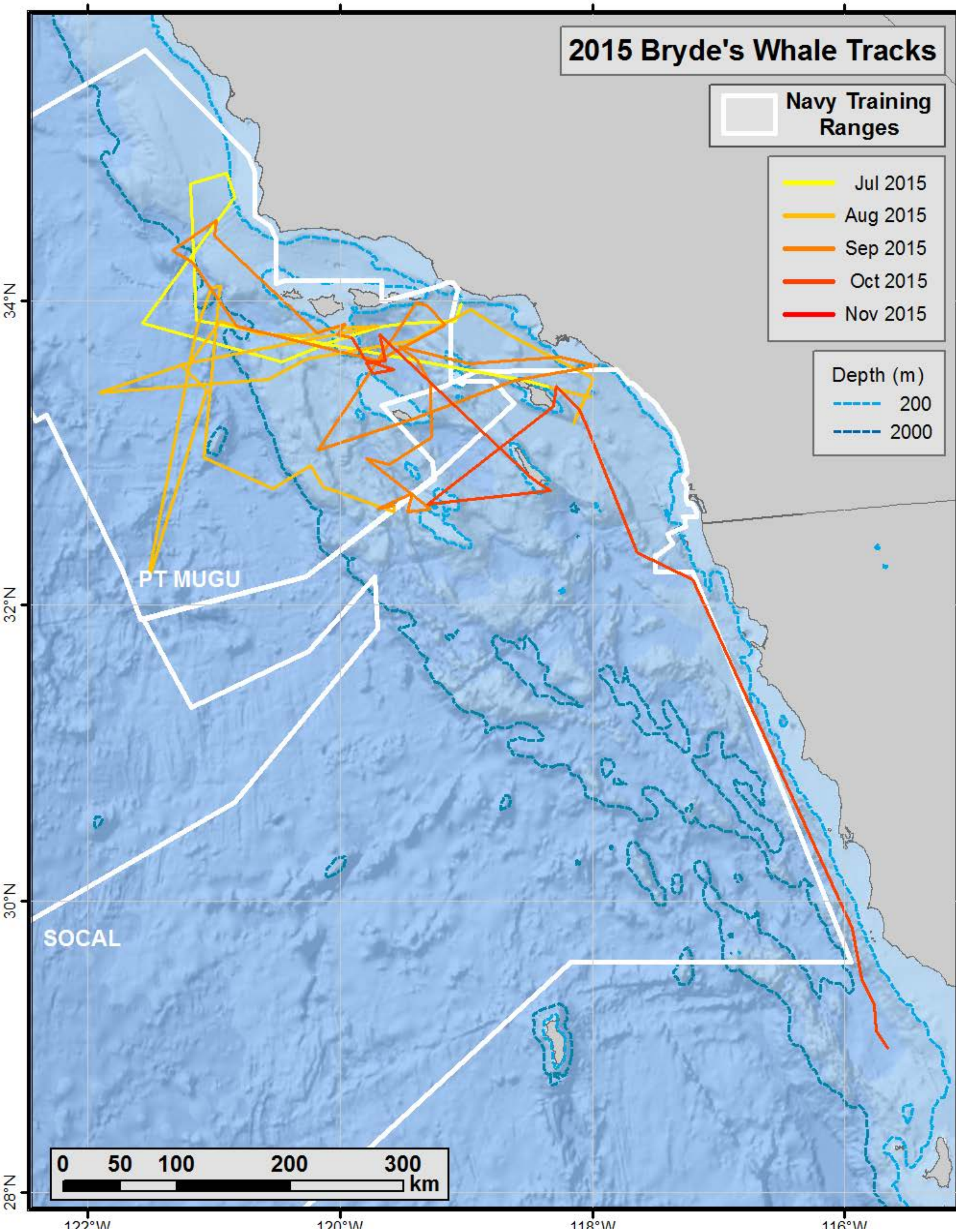

Figure 12. Satellite-monitored radio tracks for a Bryde's whale tagged with a SPOT5 Argos transmitter off southern California, 2015.

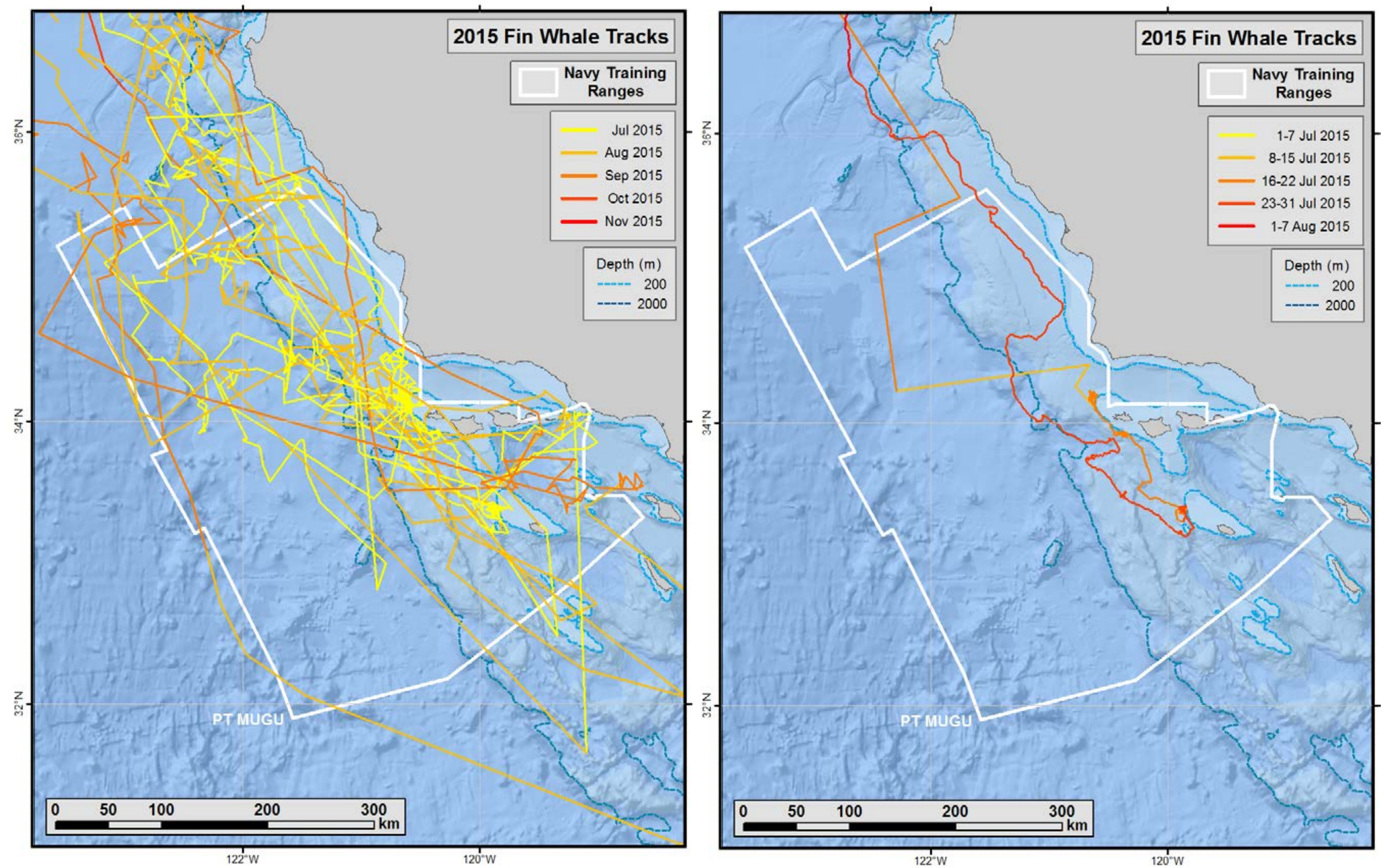

Figure 13. Satellite-monitored radio tracks in PT MUGU for fin whales and a blue/fin whale hybrid tagged off southern California, 2015. a) Argos locations from SPOT5 (*n*=10) and ADB (*n*=2) tags. b) GPS locations from ADB tags (*n*=2). One ADB tag with locations in PT MUGU was not recovered, so only GPS locations transmitted through Argos are depicted here for this tag (8 locations for Tag #5644).

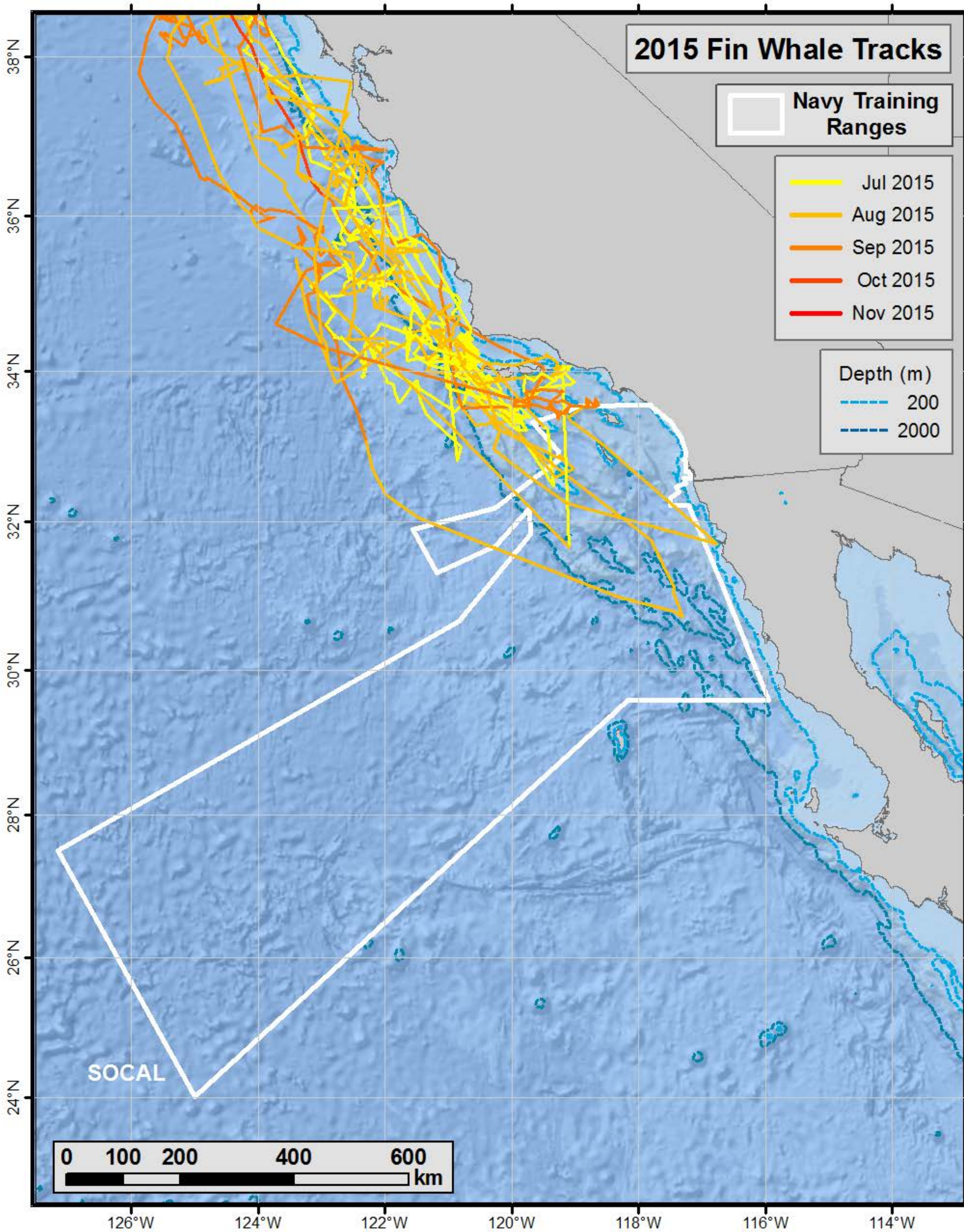

Figure 14. Satellite-monitored radio tracks in SOCAL for three fin whales tagged with SPOT5 Argos transmitters off southern California, 2015 (Tag #s 832, 839, 5923).

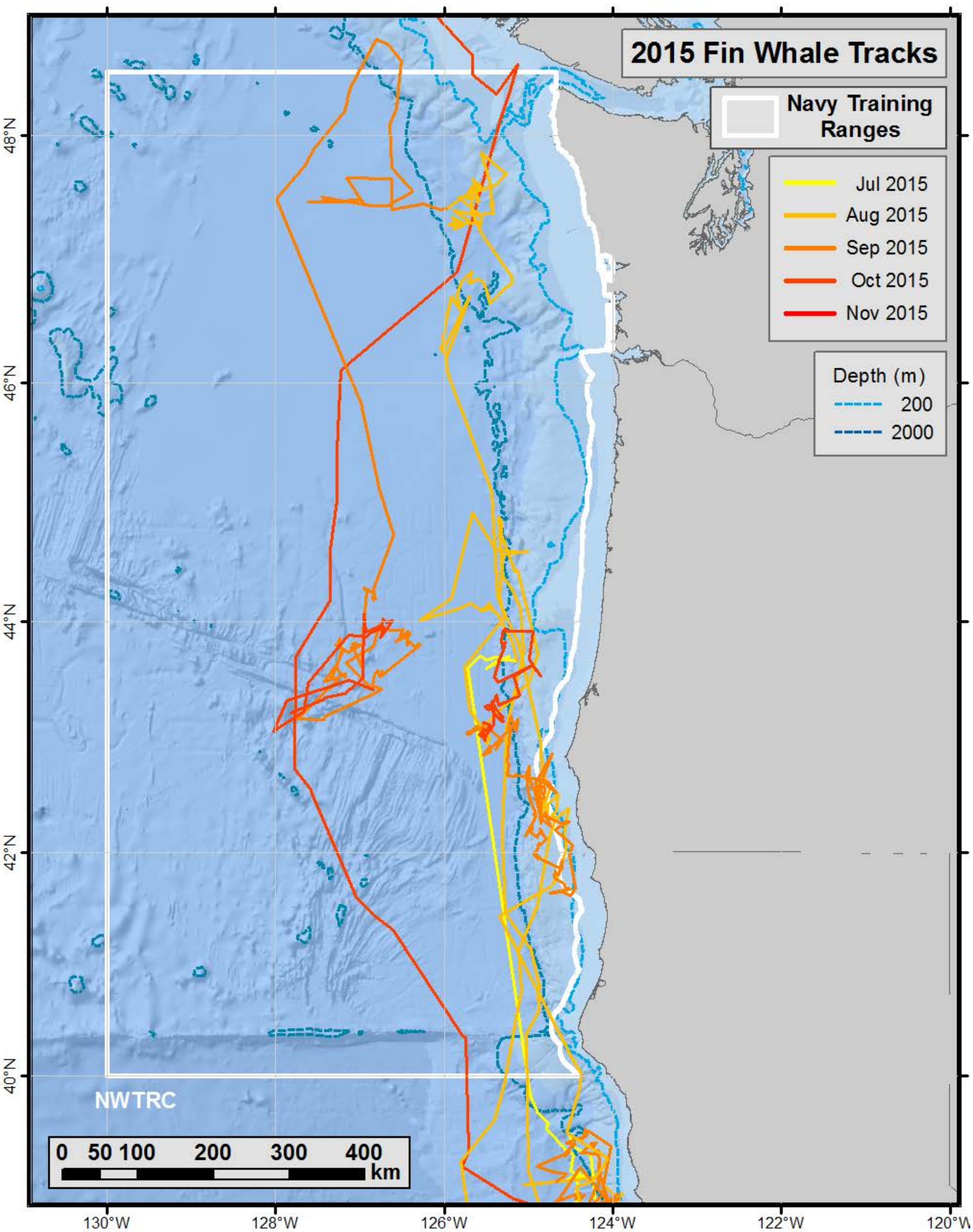

Figure 15. Satellite-monitored radio tracks in NWTRC for four fin whales tagged with SPOT5 Argos transmitters off southern California, 2015 (Tag #s 839, 5742, 5800, 10838).

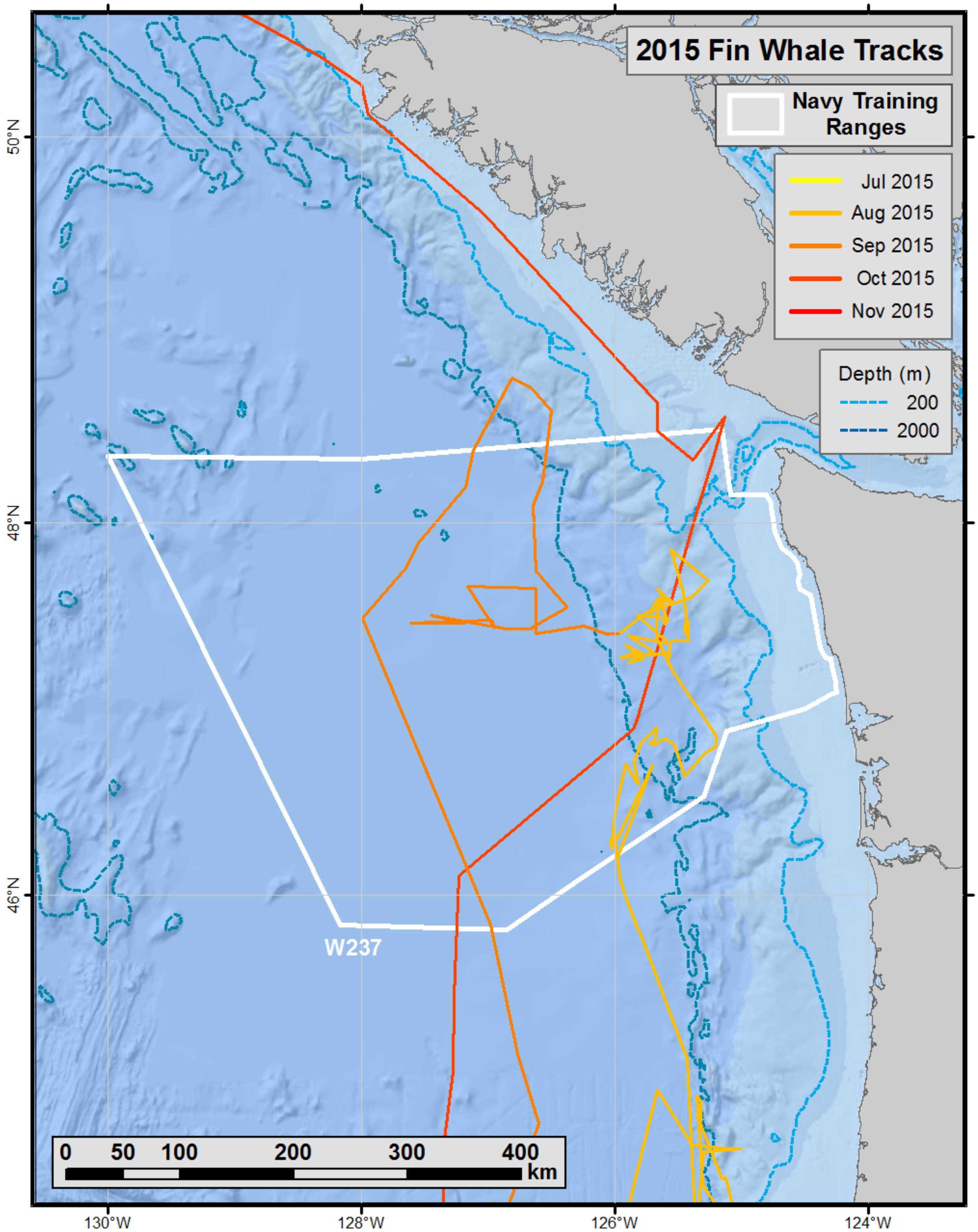

Figure 16. Satellite-monitored radio tracks in area W237 of the NWTRC for one fin whale (Tag #839) tagged with a SPOT5 Argos transmitter off southern California, 2015.

Table 8. Percent of tagged fin, blue/fin hybrid, and Bryde's whale locations located inside SOCAL, PT MUGU, NWTRC, and W-237 of the NWTRC.

Argos Locations							GPS Locations				
Tag #	Tag Type	# Filtered Locations	Inside SOCAL	Inside PT MUGU	Inside NWTRC	Inside NWTRC-W-237	# Locations	Inside SOCAL	Inside PT MUGU	Inside NWTRC	Inside NWTRC-W-237
832	SPOT5	21	29%	81%	0%	0%					
833[@]	SPOT5	94	18%	68%	0%	0%					
839	SPOT5	271	3%	20%	24%	2%					
5742*	SPOT5	365	0%	10%	5%	0%					
5743	SPOT5	53	0%	75%	0%	0%					
5790	SPOT5	0	0%	0%	0%	0%					
5800	SPOT5	289	0%	15%	75%	0%					
5923	SPOT5	96	19%	68%	0%	0%					
10831[#]	SPOT5	95	0%	66%	0%	0%					
10838	SPOT5	378	0%	21%	51%	0%					
23032	SPOT5	29	0%	90%	0%	0%					
5644[+]	ADB	177	0%	55%	0%	0%	11	0%	73%	0%	0%
5654[+]	ADB	306	0%	69%	0%	0%	1,727	0%	76%	0%	0%

KEY: ADB = Advanced Dive Behavior; GPS = geographic positioning system; NWTRC = Northwest Training Range Complex; PT MUGU = Point Mugu Sea Range; SOCAL = Southern California Range Complex; SPOT5 = Smart Positioning or Temperature Transmitting Tag, Version 5; W-237 = Warning Area 237; # = number; % = percent; [@] Bryde's whale, *Tag is still transmitting as of 15 Nov 2015, [#] Blue/fin whale hybrid, [+] Tag is FastLoc®, Version1.

Table 9. ADB tag deployment summary information for tags deployed on fin whales off southern California in July 2015.

Species	Year	PTT	Recovered?	Duration (d)	# Dives	# GPS Locations	Dives/ d	GPS Locs/d	Total Distance (km)
Fin whale	2015	5644	No*	15.4	406	12	26	1	1,517
Fin whale	2015	5654	Yes	16	910	1,591	57	99	1,370
		Median		15.7	658	802	42	50	1,443
		Total		**31.4**	**1,316**	**1,603**	**83**	**100**	**2,887**

KEY: *Data were transmitted through Service Argos, Inc.

Table 10. Foraging bout summary information for an ADB-tagged fin whale (Tag # 5654) tracked during July 2015.

Bout Start	Bout Duration (h)	# Dives	Avg Max Dive Depth (m)	SD Max Dive Depth	Avg Dive Duration (min)	Avg # Lunges/ Dive	Dives # Lunges	Area of Bout (km^2)
7/17/15 19:07	0.9	13	55.0	15.6	2.6	1.3	3.0	0.3
7/18/15 3:32	0.7	5	36.2	27.6	6.0	0.4	3.0	0.2
7/18/15 12:21	14.3	67	248.5	98.9	8.4	4.1	12.0	129.1
7/19/15 12:49	6.8	29	262.4	63.9	9.6	5.5	2.0	8.3
7/19/15 20:01	8.3	48	199.9	107.9	6.9	3.5	10.0	30.4
7/20/15 17:41	6.7	46	67.2	7.2	6.9	3.6	0.0	96.6
7/21/15 3:14	1.1	9	64.0	39.6	5.4	1.0	4.0	0.9
7/21/15 4:26	1.6	16	45.4	14.1	4.0	0.8	7.0	1.6
7/21/15 8:01	1.6	8	132.4	24.3	8.8	1.9	1.0	0.5
7/21/15 11:46	7.6	32	227.6	104.5	8.9	3.6	5.0	22.7
7/22/15 0:40	3.8	18	217.0	109.2	9.5	3.7	2.0	1.7
7/22/15 12:22	3.2	13	236.6	109.8	9.9	3.1	2.0	6.2
7/22/15 22:16	6.6	33	202.7	127.9	8.5	3.3	5.0	5.6
7/23/15 21:28	6.3	29	200.3	28.5	9.8	4.3	1.0	11.1
7/24/15 14:42	9.4	44	201.7	44.6	9.0	4.2	1.0	0.0
7/25/15 17:59	9.8	33	110.3	49.6	8.1	1.7	10.0	127.4
7/28/15 16:17	3.7	21	100.0	19.9	8.4	2.7	2.0	15.4
7/31/15 17:33	2.1	10	100.4	36.2	9.4	1.5	2.0	0.9
8/1/15 22:32	3.6	18	60.8	35.8	7.4	0.8	9.0	9.6
median	3.8	21	132.4	39.6	8.4	3.1	3.0	6.2
min	0.7	5	36.2	7.2	2.6	0.4	0.0	0.0
max	14.3	67	262.4	127.9	9.9	5.5	12.0	129.1

KEY: avg = average; SD = standard deviation; h = hour(s); km^2 = square kilometer(s); max = maxium; min = minute(s) or minimum; # = number.

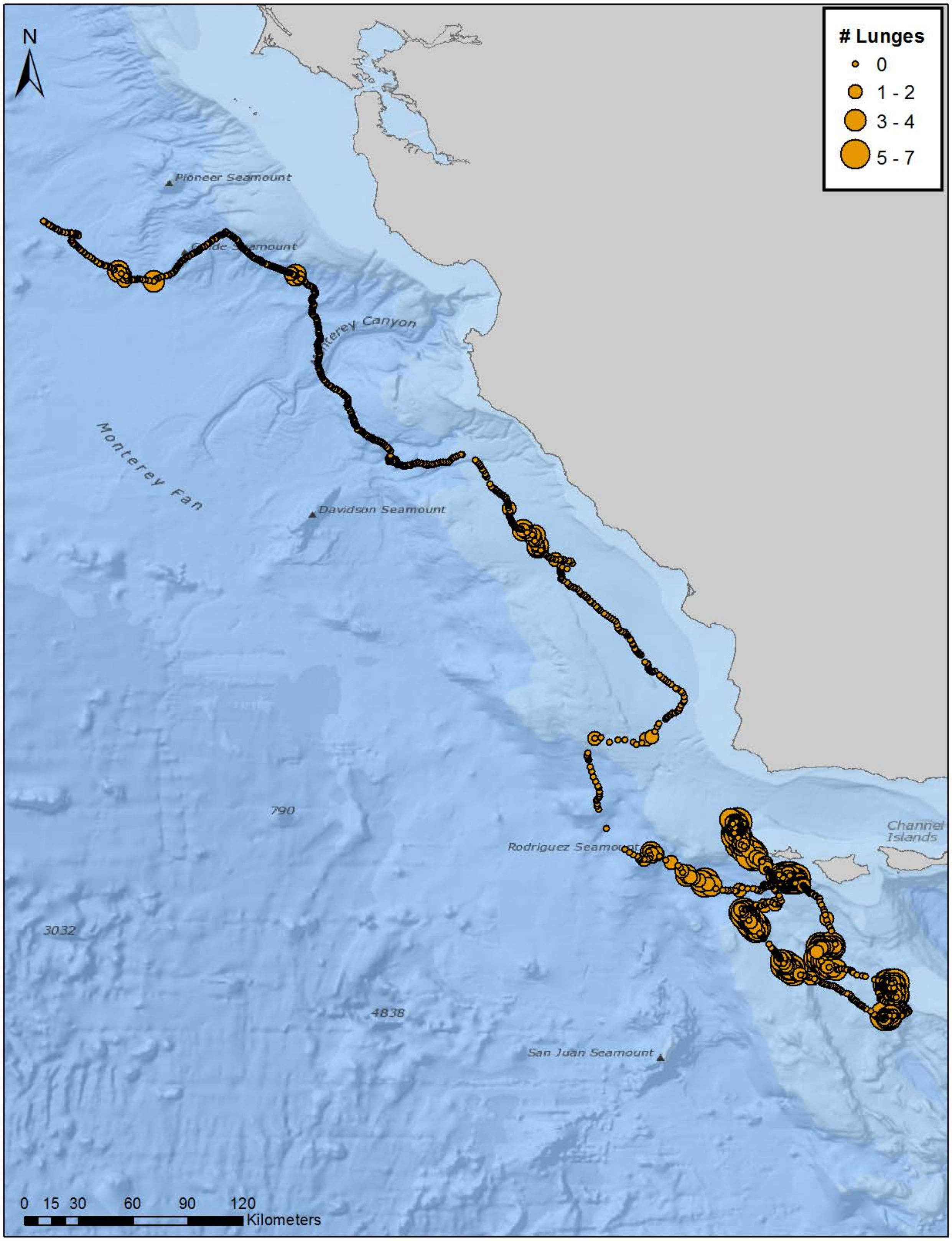

Figure 17. Track of an ADB-tagged fin whale (Tag #5654) tagged off southern California in July 2015. Size of the circles represents the number of foraging lunges that occurred during a dive at that location.

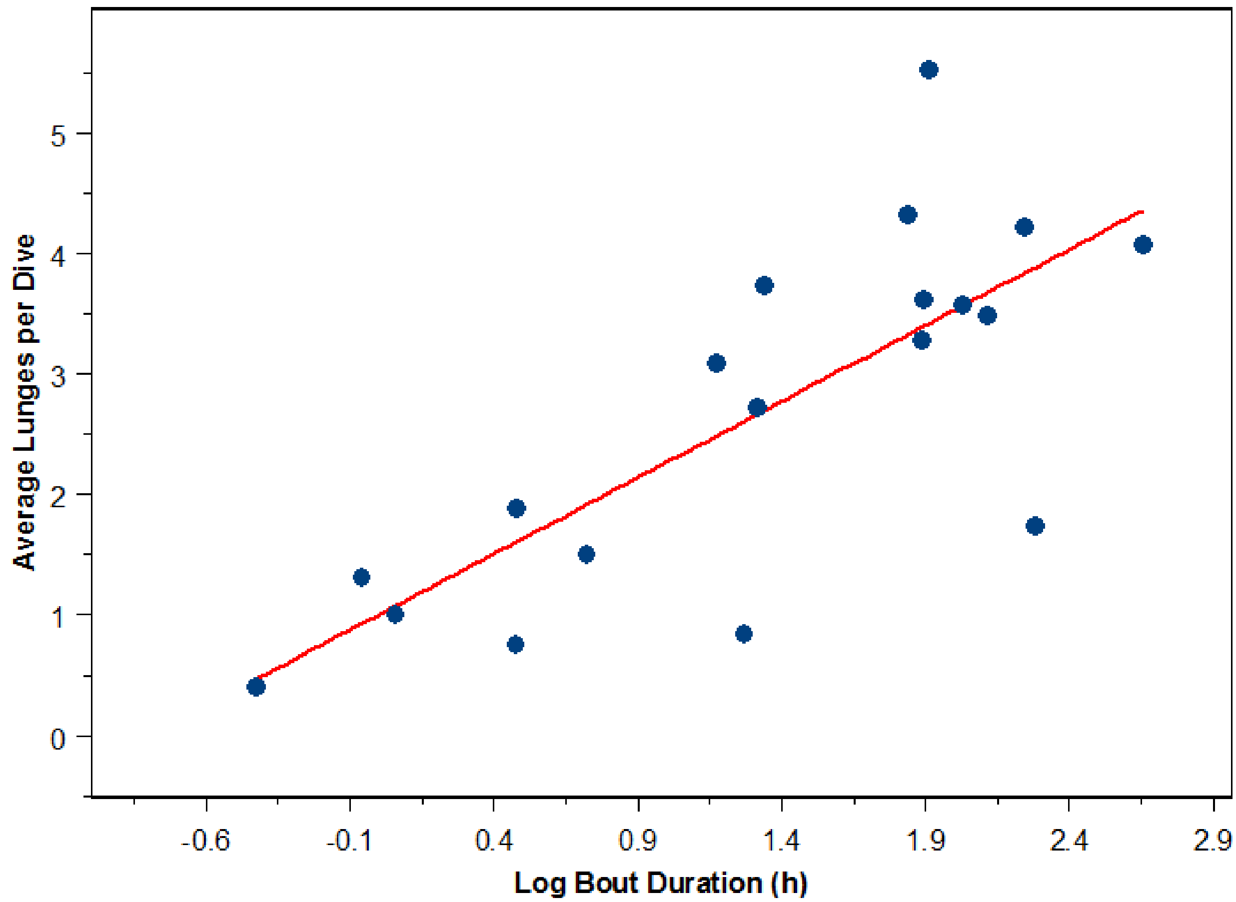

Figure 18. Scatter plot of the average lunges per dive for a fin whale within a foraging bout compared to the duration of the bout. Bout duration is shown on a log axis as it was transformed prior to being input into a linear regression model (red line).

Table 11. Resightings and tag site descriptions for fin whales and the blue/fin whale hybrid satellite-tagged off southern California, 2015. Wound size estimates are approximate.

Tag #	Tag Type	Days After Tagging						
		1	2	3	4	5	6	7
Fin Whale								
5742	SPOT5	swelling 10x10 cm, 3 cm high						
5800	SPOT5	no change						
5743	SPOT5		swelling 10x10 cm, 2 cm high					
Blue/Fin Whale Hybrid								
10831	SPOT5				tag site not seen			

KEY: cm = centimeter(s); SPOT5 = Smart Positioning or Temperature Transmitting Tag, Version 5; # = number;

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