UNIVERSITY OF CALIFORNIA SAN DIEGO

Home range and movements of green turtles at a protected estuary in southern California: implications for coastal management and habitat protection

A Thesis submitted in partial satisfaction of the requirements
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Marine Biology

by

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The Thesis of Megan Elizabeth Hanna is approved, and it is acceptable in quality and form for publication on microfilm and electronically.

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Acronyms and Abbreviations

BCI	Body Condition Index
BTM	Brackish Tidal Marsh
CCL	Curved Carapace Length
CP	Capture Pond
CPC	Capture Pond Channel
CRP	Case Road Pond
º	Degree
ESA	Endangered Species Act
FP	Forrestal Pond
GIS	Geographic Information System
GPS	Global Positioning System
HH	Huntington Harbour
IB	Inner Bay
km	Kilometer
m	Meter
NAVFAC SW	Naval Facilities Engineering Command, Southwest
NAVWPNSTA	Naval Weapons Station
NIM	NASA Island Marsh
NMFS	National Marine Fisheries Service
NOAA	National Oceanic Atmospheric Administration
NWC	Northwest Channels
OB	Outer Bay
OFF	Offshore
PIT	Passive Integrated Transponder
PMEP	Pacific Marine & Estuarine Fish Habitat Partnership
PP	Perimeter Pond
PSMFC	Pacific States Marine Fisheries Commission
SBNWR	Seal Beach National Wildlife Refuge
SCL	Straight Carapace Length
SE	Standard Error
SSP	7th Street Pond
TNC	The Nature Conservancy
UD	Utilization Distribution
USFWS	United States Fish and Wildlife Service

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ABSTRACT OF THE THESIS

Home range and movements of green turtles at a protected estuary in southern California: implications for coastal management and habitat protection.

by

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Professor Lihini Aluwihare, Chair

The Naval Weapons Station Seal Beach is undergoing construction to remove and replace an ammunition pier within the same vicinity as resident Seal Beach green sea turtles. The goal of this study was to determine green turtle movements, habitat use, and core areas of activity throughout the Seal Beach National Wildlife Refuge (SBNWR) and construction area in Anaheim Bay. Research took place prior to the commencement of construction through approximately six months during construction. Sixteen green turtles were equipped with FastLoc GPS-enabled satellite tags and tracked from November 2018 through July 28th, 2020. Volunteer visual data, hourly movements, and home range analyses determined that the majority of green turtle movements were within the inner portions of the SBNWR, although four turtles transitioned into Anaheim Bay, two turtles continued offshore prior to returning to Anaheim Bay

and a single individual left the SBNWR and visited Huntington Harbour frequently. Core areas of activity (50% Utilization Distributions; UDs) for three spatial strata (SBNWR and Anaheim Bay combined, offshore, and Anaheim Bay only) were found to be 0.95 km^2, 40.95 km^2, and 0.27 km^2, respectively. Individual 50% UDs within SBNWR ranged from 0.02 km^2 to 1.43 km^2 (mean ± SE: 0.36 ± 0.11 km^2), and 95% UDs ranged from 0.18 km^2 and 6.92 km^2 (mean ± SE: 1.96 ± 0.57km^2). These preliminary baseline results provide information on green turtle movements and core areas of activity in SBNWR, Anaheim Bay, and surrounding waters that will help inform conservation efforts to minimize impacts to green turtles.

1.0 Introduction

East Pacific green turtles (*Chelonia mydas*) are a population of green turtles endemic to the eastern Pacific Ocean and are a Distinct Population Segment listed as threatened under the Endangered Species Act (ESA). These turtles range from southern California, USA to northern Chile. The main nesting beaches in southern Mexico have seen a substantial increase in annual nesting activity (Delgado-Trejo and Alvarado-Díaz 2012, Seminoff et al. 2015), which coincides with increased green turtle abundance at foraging areas throughout the range for this population. Within U.S. waters, green turtles are regularly seen in regions as far north as Orange County, California (Crear et al. 2016, 2017). This recent expansion in the population range has presented additional conservation challenges, including exposure to marine pollution (Barraza et al. 2019, 2020), vessel strikes (National Oceanic and Atmospheric Administration [NOAA], unpubl data), and potential interactions with marine development.

The impacts of anthropogenic changes on green turtles in San Diego Bay have been studied for many years. Temporal and spatial data helped evaluate the interaction between the resident population of green turtles in San Diego Bay and a fossil fueled power plant that was in operation from 1960 to 2010 (Stinson 1984, McDonald et al. 1994, Duke Energy South Bay 2004, Eguchi et al. 2010, MacDonald et al. 2012, Turner-Tomaszewicz and Seminoff 2012, Madrak et al. 2016, Eguchi et al. 2020). Prior to decommissioning of the power plant, previous studies showed that the core areas (50% Utilization Distribution [UD]) surrounded warm effluent water from the power plant as well as areas distant from the power plant but with abundant seagrass resources (MacDonald et al. 2012). After the decommissioning of the power plant,

warm effluent water ceased to flow into the bay causing the thermal habitat to revert back to pre-power plant temperatures. The resulting change in temperature from the power plant decommissioning coincided with an increase in turtle core use areas from 0.71 to 1.37 km^2 and a shift away from the former power plant site to areas with robust seagrass pastures (Eguchi et al. 2020).

The growing population of green turtles in southern California continues to expand northward into areas along the California coastline that have become exceedingly urbanized. In areas such as the San Gabriel River (SGR), Anaheim Bay, and the Seal Beach National Wildlife Refuge (SBNWR), traditional wetland and riparian habitat have been replaced by urbanized estuarine environments (Crear et al. 2017). Recent research using acoustic transmitters, along with anecdotal evidence, show that green turtles began establishing these urbanized estuarine environments as foraging areas as early as 2008 (Crear et al. 2017). Results from these studies showed that during winter months green turtles migrate into the concrete lined SGR where warm effluent water is discharged from power plants located upstream. During summertime, green turtles were observed migrating into the SBNWR and Anaheim Bay where there are several shallow, warm-water basins with plentiful seagrass pastures (Crear et al. 2016, 2017).

The Seal Beach National Wildlife Refuge was administered in 1972 by the US Fish and Wildlife Service (USFWS) to protect and conserve threatened and endangered species and their habitats. The Refuge is entirely contained within the boundaries of a Navy installation, Naval Weapons Station (NAVWPNSTA) Seal Beach. The wetlands were initially created to protect habitat for the survival of the endangered California Least Tern (*Sterna antillarum browni*) but

has since become a refuge for other threatened and endangered species such as the green sea turtle. Partnerships between natural resources staff at NAVWPNSTA Seal Beach and USFWS have allowed for successful wildlife management and habitat restoration in the SBNWR. In the early 1990s, four tidal basins, the Forrestal Pond, Case Road Pond, 7th Street Pond and the Perimeter Pond were created in the SBNWR as part of the Port of Long Beach's Pier J Landfill Project that restored 116 acres of wetland habitat. Within the ponds, tides are relatively subtle which supports consistent, shallow, subtidal habitat. The benthic habitat within these ponds consists mostly of eelgrass (*Zostera marina*), a main dietary resource for green turtles, and soft mud substrate, an important habitat for invertebrates that may also be ingested by sea turtles. The wetland area is supported by a large complex tidal channel network that resident turtles are known to traverse on a daily basis.

NAVWPNSTA Seal Beach surrounds Anaheim Bay and the SBNWR and is the U.S. Pacific Fleet's primary weapons station on the West Coast of the United States. The installation services a majority of the Pacific Fleet. NAVWPNSTA Seal Beach has three primary missions: storage of Navy and Marine Corps ammunition, weapons systems maintenance, and munitions loading and unloading of San Diego-based Navy warships and larger U.S. Coast Guard (USCG) vessels at the wharf in Anaheim Bay. Most base infrastructure was built in the 1940s and 1950s. The station's wharf was originally built in 1944 and rebuilt in 1953. The existing wharf at NAVWPNSTA Seal Beach is over 65 years old, is past its design life, and was constructed prior to the introduction of modern seismic (earthquake) codes. As such, the Navy is currently in the process of building a new ammunition pier and associated facilities in Anaheim Bay.

In-water construction of the ammunition pier began in January 2020 and is expected to last for five to six years. The Navy will construct a 1,100 ft by 125 ft pile supported ammunition pier along with associated waterfront facilities. The project includes construction of a break water to reduce wave heights at the pier, pile supported mooring dolphins to divert civilian traffic, a causeway with a truck turnaround, a new public navigation channel leading to Huntington Harbour for civilian boat traffic, dredging for the new pier and navy ship turning basin, and construction of supporting facilities. To date, the majority of construction activities that have occurred in Anaheim Bay are dredging, filling, and rip rap removal and placement. The new public navigation channel has been partially dredged and is anticipated to be opened at the end of October or beginning of November 2020. The channel will not be open for vessel traffic until January 2021.

In accordance with the ESA, the Navy conducted a Section 7(a)(2) consultation with NOAA-National Marine Fisheries Service (NMFS) to evaluate the potential effects from construction of the new ammunition pier and waterfront facilities on the federally-listed green sea turtle and their designated critical habitat. The consultation resulted in a Biological Opinion from NOAA-NMFS (WCR-2018-00044) with a determination that the threatened East Pacific DPS of green sea turtles may be adversely affected as a result of sustained disturbance and disruption of normal foraging and behavior patterns over the course of the entire construction efforts.

As part of the Navy's ESA requirements and management of the species, a study was initiated to evaluate green turtle movements and habitat use in and around SBNWR and Anaheim Bay. In this study, green turtle presence within SBNWR and surrounding waters was determined

using a combination of citizen-science-based sighting records and high-resolution satellite telemetry to evaluate turtle movements, habitat use, and core areas of activity. This report includes tracking data from November 2018 through July 28th, 2020. Future reports will include a synthesis of data from 2018 through the construction of the new pier.

Project Objective:

The purpose of this study is to provide preliminary baseline information on green turtle movements, habitat use, and core areas of activity within the SBNWR and surrounding areas. The findings from this study will be used to aid coastal management and habitat protection in the area.

2.0 Methods

2.1 Study Area

The Seal Beach National Wildlife Refuge encompasses 965 acres within NAVWPNSTA Seal Beach in Orange County, California (Figure 1). The area is a protected wetland habitat characterized by tidal channels varying in size that break up the brackish marsh habitat. There are four man-made tidal basins, the Forrestal Pond, Case Road Pond, 7th Street Pond, and Perimeter Pond. Connected to the Refuge is the Anaheim Bay complex, which consists of a man-made inner and outer bay. Anaheim Bay is primarily used by NAVWPNSTA Seal Beach for storage, loading, and maintenance of ammunition and weapons and provides coastal access to civilian boats to and from Huntington Harbour. Anaheim Bay is also the location of ongoing and future construction of the ammunition pier and turning basin (Figure 2). The study site was defined by 13 subregions: Offshore (OFF), Outer Bay (OB), Inner Bay (IB), Northwest channels (NWC), Brackish Tidal Marsh (BTM), NASA Island Marsh (NIM), Forrestal Pond (FP), Case Road Pond (CRP), Capture Pond Channel (CPC), Capture Pond (CP), 7th Street Pond (SSP), Perimeter Pond (PP) and Huntington Harbour (HH) (Figure 3).

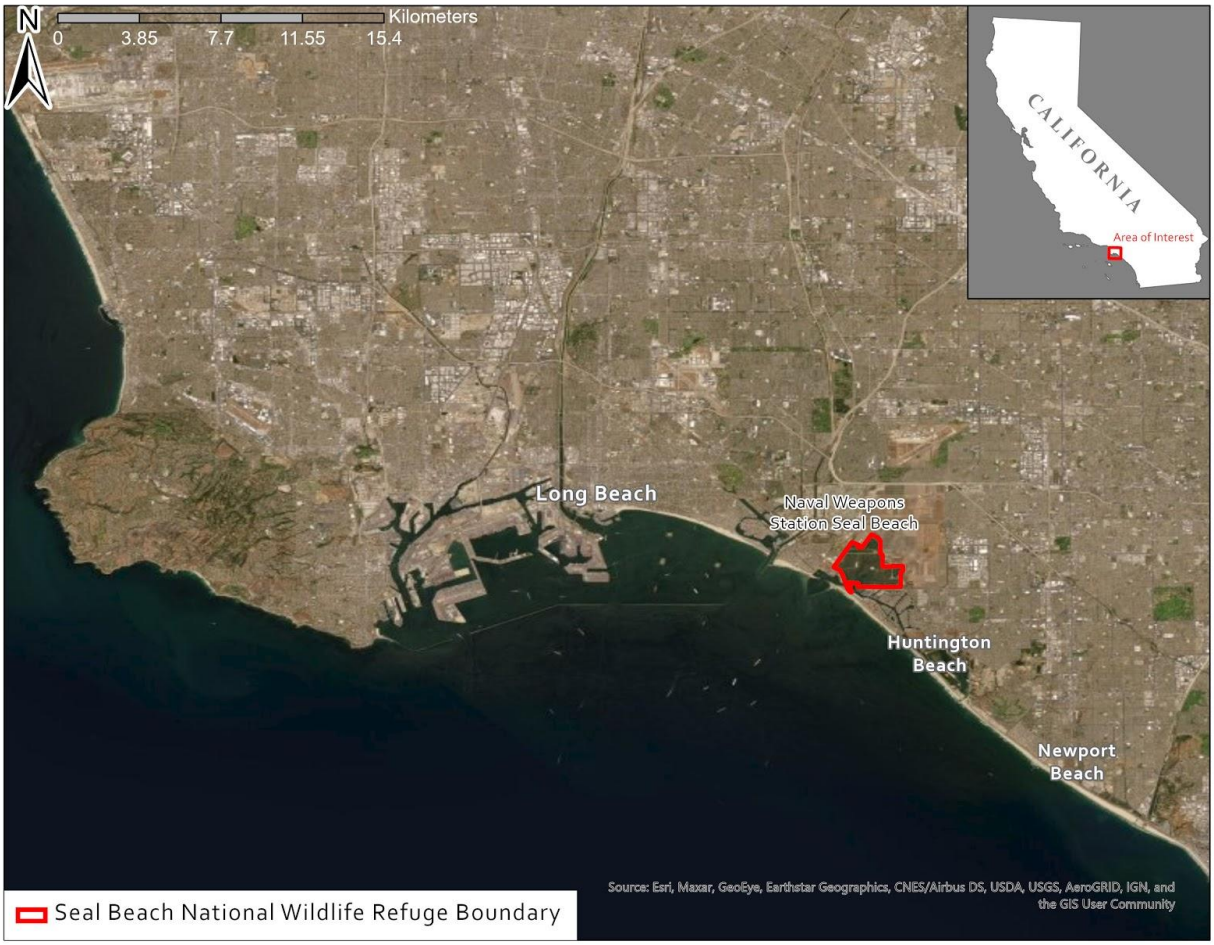

Figure 1. Location of the Seal Beach National Wildlife Refuge study site along the southern California coast.

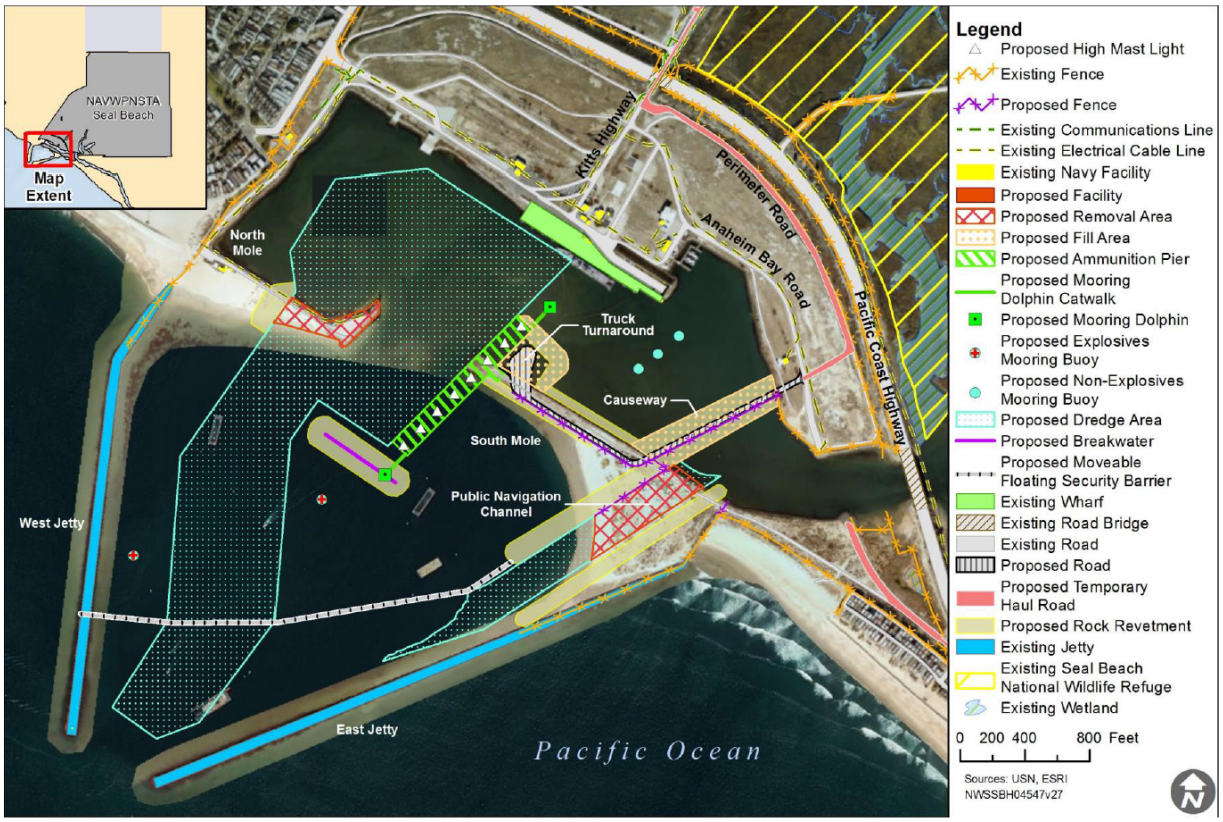

Figure 2. Overview of pier construction activities in Anaheim Bay.

Figure 3. Subregions within and near the Seal Beach National Wildlife Refuge. Offshore (OFF), Outer Bay (OB), Inner Bay (IB), Northwest channels (NWC), Brackish Tidal Marsh (BTM), NASA Island Marsh (NIM), Forrestal Pond (FP), Case Road Pond (CRP), Capture Pond Channel (CPC), Capture Pond (CP), 7th Street Pond (SSP), Perimeter Pond (PP) and Huntington Harbour (HH).

2.2 Eelgrass Data

Eelgrass data are vital for understanding green turtle biology, as seagrass is an important food for green turtles and also provides a benthic habitat for other green turtle prey such as sponges and mollusks (Lemons et al. 2011, Eguchi et al. 2020). Several eelgrass surveys have been conducted in the Seal Beach area but they have occurred at different times and scales and were conducted for varying purposes. Therefore, a combination of eelgrass data were used for the analyses in this report; they are described as follows.

In 2014, The Nature Conservancy (TNC) and the Pacific Marine & Estuarine Fish Habitat Partnership (PMEP) conducted a survey that compiled approximately 130 eelgrass (*Zostera marina*) survey datasets into one standardized dataset. The survey included numerous areas along the U.S. West Coast, including Anaheim Bay and the SBNWR.

Merkel & Associates conducted a pre-construction survey covering all of Anaheim Bay and the lower area of the Brackish Tidal Marsh, just northeast of the Pacific Coast Highway Bridge. The survey area was broken up into six defined areas of potential effect (APE) as well as two reference sites. Across all six APE's there was a combined total of 24,908 square meters of eelgrass and across both reference sites there was a total of 19,587 square meters of eelgrass. Merkel & Associates documented a total of 44,495 square meters of eelgrass (APE's and Reference areas combined).

A combination of 2014 PMEP and 2019 pre-construction (Merkel & Associates) eelgrass layers were used for visual mapping and analysis purposes throughout this report (Figure 4).

Eelgrass layers from the PMEP database, TNC, Pacific States Marine Fisheries Commission (PSMFC) GIS, National Oceanic and Atmospheric Administration's (NOAA) Office of Habitat Conservation) and Channel boundary layers from Merkel & Associates (Ammunition Pier and Turning Basin EA) were imported to ArcPro 2.5 and clipped to each study site within the SBNWR Refuge and Anaheim Bay boundary (Figure 3). Individual site areas of eelgrass and channels were calculated in the attribute table using PMEP eelgrass layers and Merkel & Associates channel layers specifically.

Figure 4. Subset of Seal Beach eelgrass data from the 2014 PMEP West Coast, U.S.A. and 2019 Merkel & Associates survey.

2.3 Green Turtle In-Water Capture

In order to capture green sea turtles, entanglement nets (50-100 m length × 8 m depth, mesh size=40 cm knot-to-knot) were deployed by permitted researchers from the Marine Turtle Ecology and Assessment Program at NOAA Southwest Fisheries Science Center. Green turtles were captured in the Capture Pond (33°73' N, 118°06' W) within the SBNWR. Net-soak time ranged from 1 to 3 h during diurnal periods and nets were continuously monitored. Upon capture, green turtles were disentangled and transported to shore (<500 m) where they were kept under shaded protection during processing (e.g., identification, body measurements, general health assessment, tagging, tissue sampling). Each individual was tagged with an internal Passive Integrated Transponder (PIT) tag (Avid, Norco, CA) and a flipper ID tag (Style 681, National Band and Tag Company, KY) if not already tagged from previous captures. Straight carapace length (SCL; ± 0.1 cm) was measured using a Forester's caliper and curved carapace length (CCL; ± 0.1 cm) using a flexible measuring tape; both were measured from the nuchal notch to the posterior-most edge of the marginal scutes. Body weight was measured (± 0.5 kg) using an electronic hanging scale. A body condition index (BCI=body weight/curved carapace length) was calculated to evaluate the size to weight relationship of each turtle. During examinations, turtles were also assessed for shell conditions and keratin depth to determine their potential as candidates for satellite transmitter application. Only turtles with no shell injuries or anomalies, and only those possessing a sufficiently thick keratin layer were selected, as these turtles tend to have longer tag retention due to stronger adhesion of epoxy adhesives.

2.4 Volunteer Sightings and Volunteer Effort

Volunteer visual observation data were collected from May 2018 through September 2019 in the Forrestal Pond, Case Road Pond, 7th Street Pond, Perimeter Pond, and Capture Pond

study site locations. Some locations were not included in the study because they were not easily accessible to volunteers; these included the inner and outer Anaheim Bay, NASA Island Marsh, brackish tidal marsh, capture pond channel, northwest channels, Huntington Harbour and offshore areas. Volunteers visited each of the five locations for 10 to 15 minutes and documented turtle activity (i.e. sighting data) using established protocols. Given the nature of volunteer observation, there were differences in data collection methods across all volunteers. To avoid biases, data were used to determine presence/absence of turtles at each location per unit search effort. Presence indicating that one or more sightings were observed, and absence indicating that no turtles were observed during the observation period. Effort was determined by the number of hours spent observing at each site out of total hours of effort spent observing.

2.5 Satellite Tag Attachment and Telemetry

FastLoc GPS-enabled satellite transmitters (satellite tags hereafter, Wildlife Computers, model SPLASH 10-F-385A) were used to monitor short-term and fine-scale movements of green turtles within the study site. Transmitters were adhered to the highest point of the carapace with quick-setting epoxy (Gorilla brand, 5-minute quickset). High placement of GPS tags maximizes successful satellite transmissions from the transmitters, as green turtles often spend little time at the water surface and antennas must be out of the water for effective transmission of data to orbiting ARGOS and GPS satellites.

The advantages of FastLoc transmissions are increased location accuracy and increased frequency of transmissions from a larger satellite system. FastLoc-based location data were filtered to include location data for locations containing six or more satellites. In addition, only relocation points with residual values <30.0 were included (25.64% of relocations fell on land,

relocation data that fell on land were removed). Data were then grouped into six 4-hour periods (00:00−03:59, 04:00−07:59, 08:00−11:59, 12:00−15:59, 16:00−19:59, and 20:00−23:59 h), and the smallest residual within each period was extracted (Eguchi et al. 2020).

2.6 Daily Movement Speeds and Distance

Overall hourly vagility (i.e. movement distance) was calculated for all turtles combined, for each individual, and each study site location using the same filtered data that were used to calculate home range. Hourly vagility was compared among subregions, which had varying eelgrass coverage. Channel area (km^2) and eelgrass coverage were determined using ArcGIS software (ESRI, ArcPro 2.5) and eelgrass shapefiles from the 2013 eelgrass survey (SBNWR) and 2019 preconstruction survey (Anaheim Bay; Merkel & Associates, Inc.). Proportion of eelgrass coverage for each area was determined by dividing eelgrass coverage for each area by the area of each channel, marsh or pond. This value was then compared to overall hourly vagility for each subregion. Hourly vagility was computed from the distance between two relocations, which was calculated using the distHaversine function from the geosphere package in R (Hijmans 2019), and the elapsed time between the two relocations. These values were averaged for each individual and by study site location. For plotting purposes, daytime data included relocations that occurred between local sunrise and local sunset, while night-time data included relocations between local sunset and local sunrise. Local sunrise and sunset time were determined using study site location coordinates and the suncalc package in R (Thieurmel 2019).

2.7 Utilization Distributions (Home Ranges)

Utilization Distributions (UDs; 50% and 95%) were separately determined for three strata: 1) relocations solely within SBNWR; 2) relocations that included offshore locations; and 3) relocations that fell only within Anaheim Bay and SBNWR. Before computing UDs each data set was subset by clipping a polygon shapefile of each specific area to the different data sets in order to exclude relocations that fell outside the polygon boundaries. Next, UDs were estimated using fixed kernel density methods (Worton 1989) via the adeHabitatHR package (Calenge 2006) in R (v. 4.0.1, R Development Core Team 2019). Optimal bandwidth for kernel density estimation was determined using the ad hoc method (Kie 2013). In this method, the reference bandwidth (href) is multiplied by increments of 0.05 from 0.05-0.95. The best multiplier was identified as the multiplier that estimated a contiguous 95% UD with no holes present within the home range. This multiplier was separately determined for each different dataset (SBNWR and Anaheim Bay, only Anaheim Bay, and offshore) and each individual. The best multiplier was applied to href in order to compute the most appropriate bandwidth. A smaller grid size of 500 and extent parameter of 1 were selected for this dataset because home range areas were relatively small and the effects of variability in home range size are reduced when grid sizes are much larger than the area of the home range. Thus, a smaller grid size was needed.

3.0 Results

3.1 Study Animals

A total of 24 green turtles were captured and 16 of those turtles were tagged with FastLoc GPS-enabled satellite transmitters (satellite tags hereafter, Wildlife Computers, model SPLASH 10-F-385A) from November 2018 to January 2020. All of the following results are reported only

for the 16 turtles that were outfitted with satellite tags. Straight carapace lengths ranged from 51.9 to 89.7 cm and body mass ranged from 17 to 98 kg (Table 1).

Table 1. GPS tag serial number (tag), mass, Straight Carapace Length (SCL), individual 50% and 95% Utilization Distributions (UD), satellite tag deployment date, the first and last FastLoc relocation dates, the total number of days that the satellite tag was transmitting relocations, the number of filtered relocations that had six or more satellites and a residual value of <30, and the number of sites that each turtle visited.

Tag	Mass (kg)	SCL (cm)	Individual 50% UD km²	Individual 95% UD km²	Deployment date	First FastLoc Transmission	Last FastLoc Transmission	Number of Days Transmitting FastLoc Locations	Number of Filtered Relocations	Number of Study Site Locations Used
152310	17.0	51.9	1.07	6.92	11/27/18	11/27/18	3/7/19	100	294	5
152318	46.0	70.6	0.07	0.43	11/27/18	11/27/18	5/15/19	169	73	4
152317	73.0	81.7	0.11	0.45	4/18/19	4/18/19	9/9/19	144	328	4
152320	20.0	54.6	0.08	0.33	4/18/19	4/18/19	5/3/19	15	45	3
177761	52.0	74.9	0.09	0.65	4/18/19	4/18/19	9/1/19	136	75	5
177763	41.0	65.5	0.13	0.66	5/16/19	5/16/19	7/6/19	51	90	4
177764	71.0	84.7	0.17	0.99	5/16/19	5/26/19	10/19/19	146	132	5
177765	60.0	76.4	0.19	1.18	5/16/19	5/16/19	9/10/19	117	112	5
177762	45.0	68.4	0.22	1.22	7/23/19	7/24/19	5/29/20	310	128	4
182985	35.0	73.7	0.74	3.67	7/23/19	7/24/19	8/20/19	27	97	5
182986	58.0	77.1	0.12	0.66	7/23/19	7/23/19	7/19/20	362	475	6

Table 1. GPS tag serial number (tag), mass, Straight Carapace Length (SCL), individual 50% and 95% Utilization Distributions (UD), satellite tag deployment date, the first and last FastLoc relocation dates, the total number of days that the satellite tag was transmitting relocations, the number of filtered relocations that had six or more satellites and a residual value of <30, and the number of sites that each turtle visited, Continued.

Tag	Mass (kg)	SCL (cm)	Individual 50% UD km²	Individual 95% UD km²	Deployment date	First FastLoc Transmission	Last FastLoc Transmission	Number of Days Transmitting FastLoc Locations	Number of Filtered Relocations	Number of Study Site Locations Used
182988	55.8	73.5	0.24	1.05	10/9/19	10/10/19	7/17/20	281	311	5
182989	64.5	77.0	1.06	6.26	10/9/19	10/10/19	6/27/20	261	777	8
182984	98.0	89.7	1.43	5.49	1/30/20	1/31/20	8/6/20	188	594	8
182987	51.0	73.1	0.16	1.14	1/30/20	1/31/20	7/8/20	159	317	6
182990	47.0	71.1	0.02	0.18	1/30/20	1/30/20	5/7/20	98	238	3

3.2 Volunteer Sightings and Volunteer Effort

The most time and highest proportion of volunteer observational effort were at the 7th Street Pond and Capture Pond. This also corresponded with the highest rate of overall observation data and greatest presence of turtles in the 7th Street Pond and Capture Pond. There was a small overlap in observations (~20 hours) between 7th Street Pond and Capture Pond, where volunteers stood on a small strip of land between the two locations and simultaneously observed both locations in the same recorded time period. In this case, time and effort were contributed to both locations for those observations.

A total of 119.6 hours of observation effort were recorded (Figure 5). Total time spent in each area ranged from 5.5 h in the Forrestal Pond to 46.96 h in the 7th Street Pond. Total effort ranged from 6.80% in the Forrestal Pond to 58.06% in the 7th Street Pond (Figure 6). Finally,

out of 152 total sightings, the greatest presence of turtles was seen in the 7th Street Pond with 61 sightings and the lowest presence of sea turtles was seen in the Forrestal Pond with only three positive sightings (Figure 7).

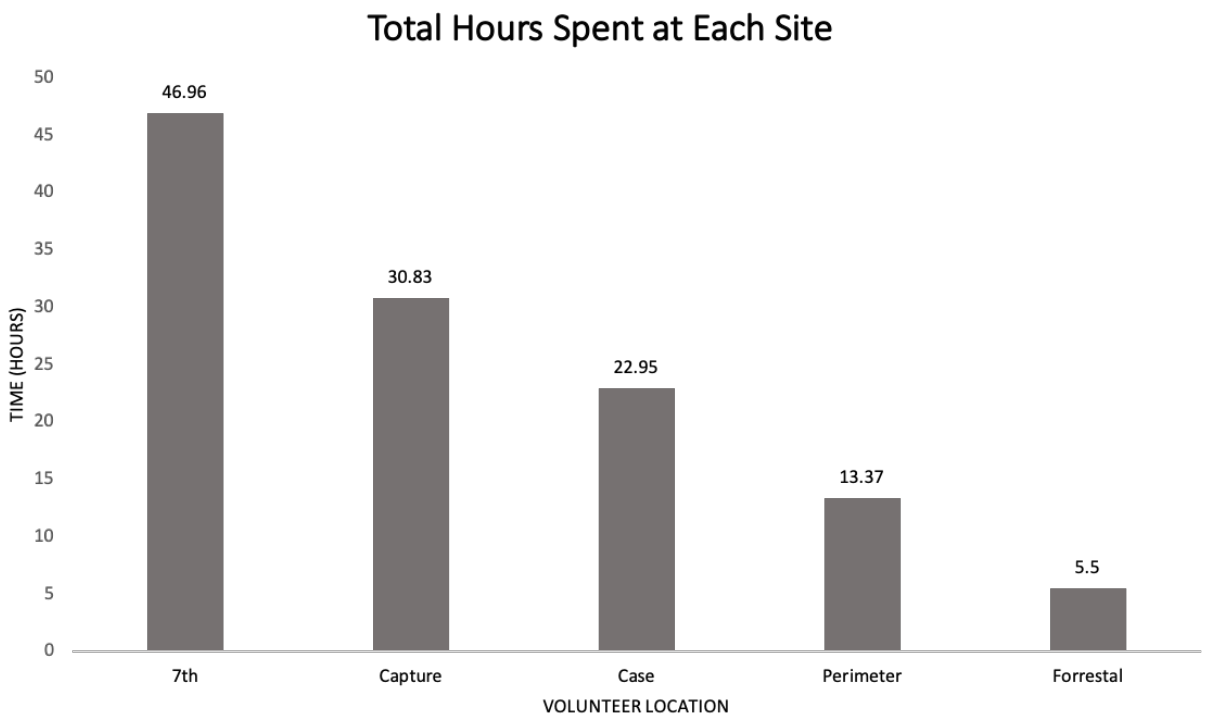

Figure 5. Summary of volunteer visual observation data; proportion of search effort at each site. The number at the top of each bar represents the total number of hours spent observing at each site.

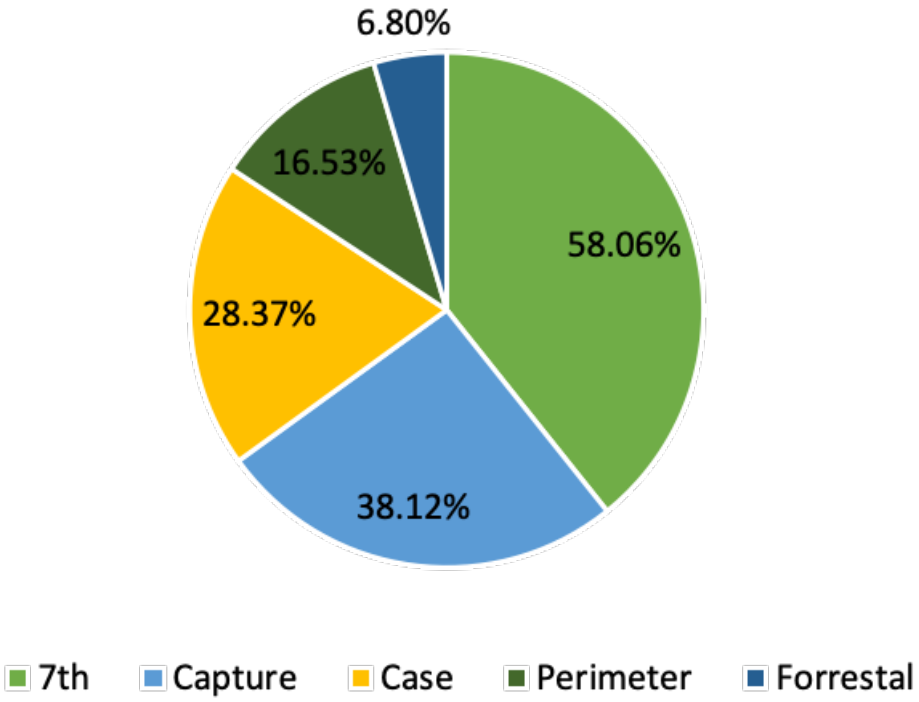

Figure 6. Summary of percent of total effort (119.6 hours) spent at each study site subregion.

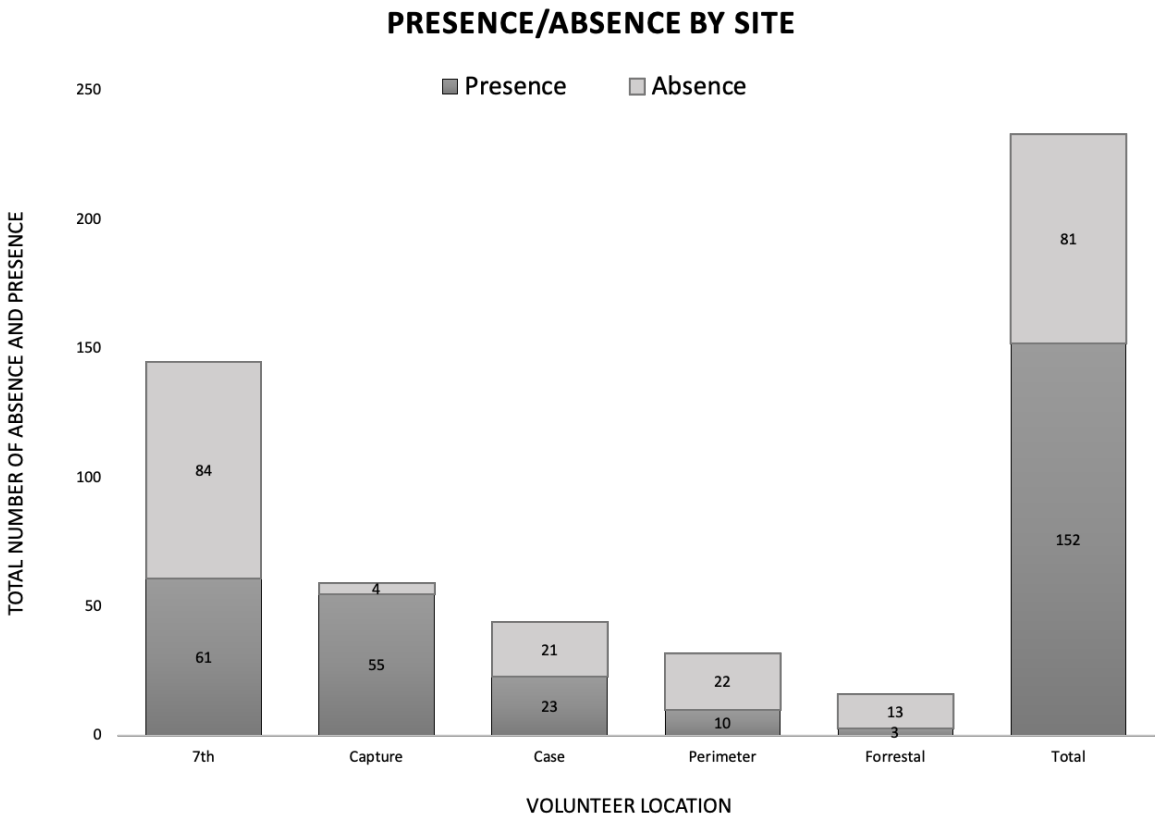

Figure 7. Presence and absence of sea turtles by volunteer observation location. Presence indicating that one or more sightings were observed, and absence indicating that no turtles were observed during the observation period.

3.3 Satellite Telemetry

In general, most turtles remained in the SBNWR (Figures 8-11). Turtles that remained within the SBNWR stayed mostly within the 7th Street Pond, Capture Pond, Capture Pond Channel and Perimeter Pond (152317, 152318, 152320, 177761, 177762, 177763, 177764 and 177765). Some turtles that remained within the SBNWR visited other locations such as the Brackish Tidal Marsh and NASA Island Marsh (182984, 182985, 182987, 182988, and 182989). One individual (182989) visited the Northwest Channel, Case Road Pond, and spent a large amount of time in Huntington Harbour. However, none of the 16 turtles equipped with satellite tags visited the Forrestal Pond. Four individuals (152310, 182984, 182985, and 182986) spent time in the Inner and Outer portions of Anaheim Bay. Two of these turtles (152310 and 182986) went offshore after visiting Anaheim Bay. Individual 152310 travelled north along the coast, as far as Rancho Palos Verde, while 182986 travelled south to Dana Point. Both 152310 and 182986 travelled back into Anaheim Bay and back into the SBNWR.

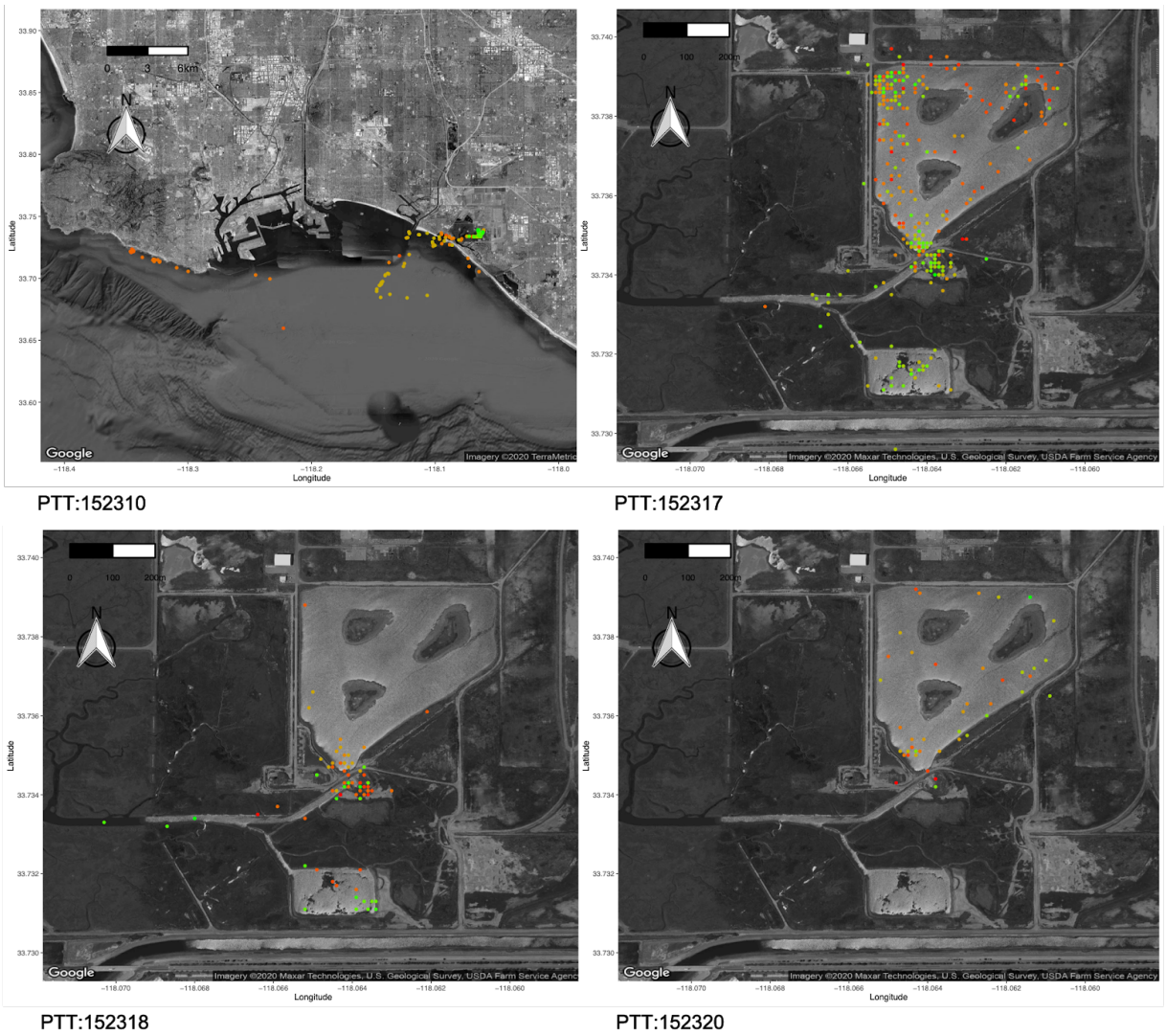

Figure 8. Each individual turtle's FastLoc-GPS tracks within the Seal Beach National Wildlife Refuge and Anaheim Bay. Turtles are listed from left to right: 152310 (November 2018-February 2019), 152317 (April 2019-September 2019), 152318 (November 2018-May 2019), 152320 (April 2019). Relocations are colored on a scale from green to red with green being the earliest dates and red being the last dates of transmission.

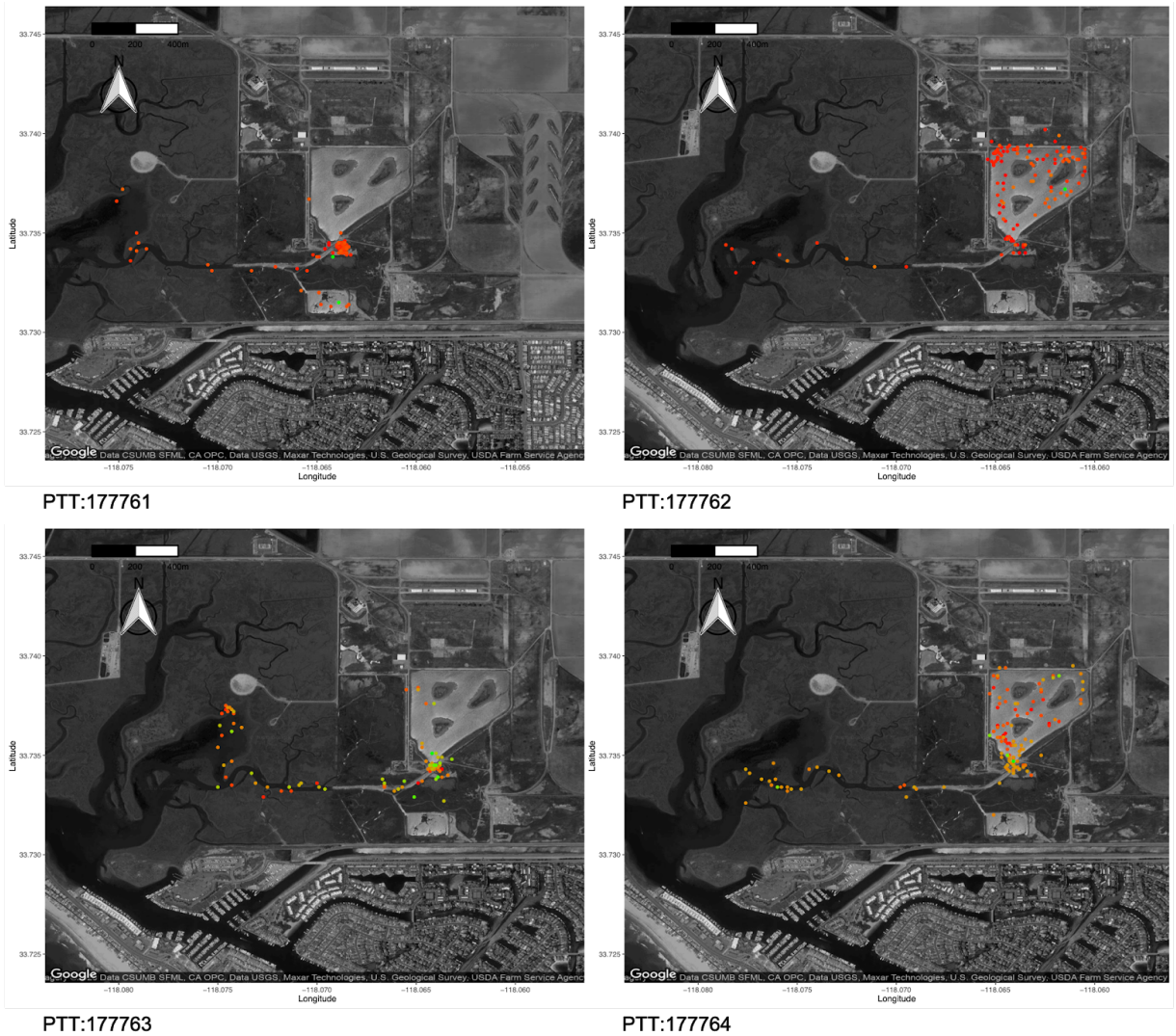

Figure 9. Each individual turtle's FastLoc-GPS tracks within the Seal Beach National Wildlife Refuge and Anaheim Bay. Turtles are listed from left to right: 177761 (April 2019-August 2019), 177762 (July 2019-February 2020), 177763 (May 2019-June 2019), 177764 (May 2019-October 2019). Relocations are colored on a scale from green to red with green being the earliest dates and red being the last dates of transmission.

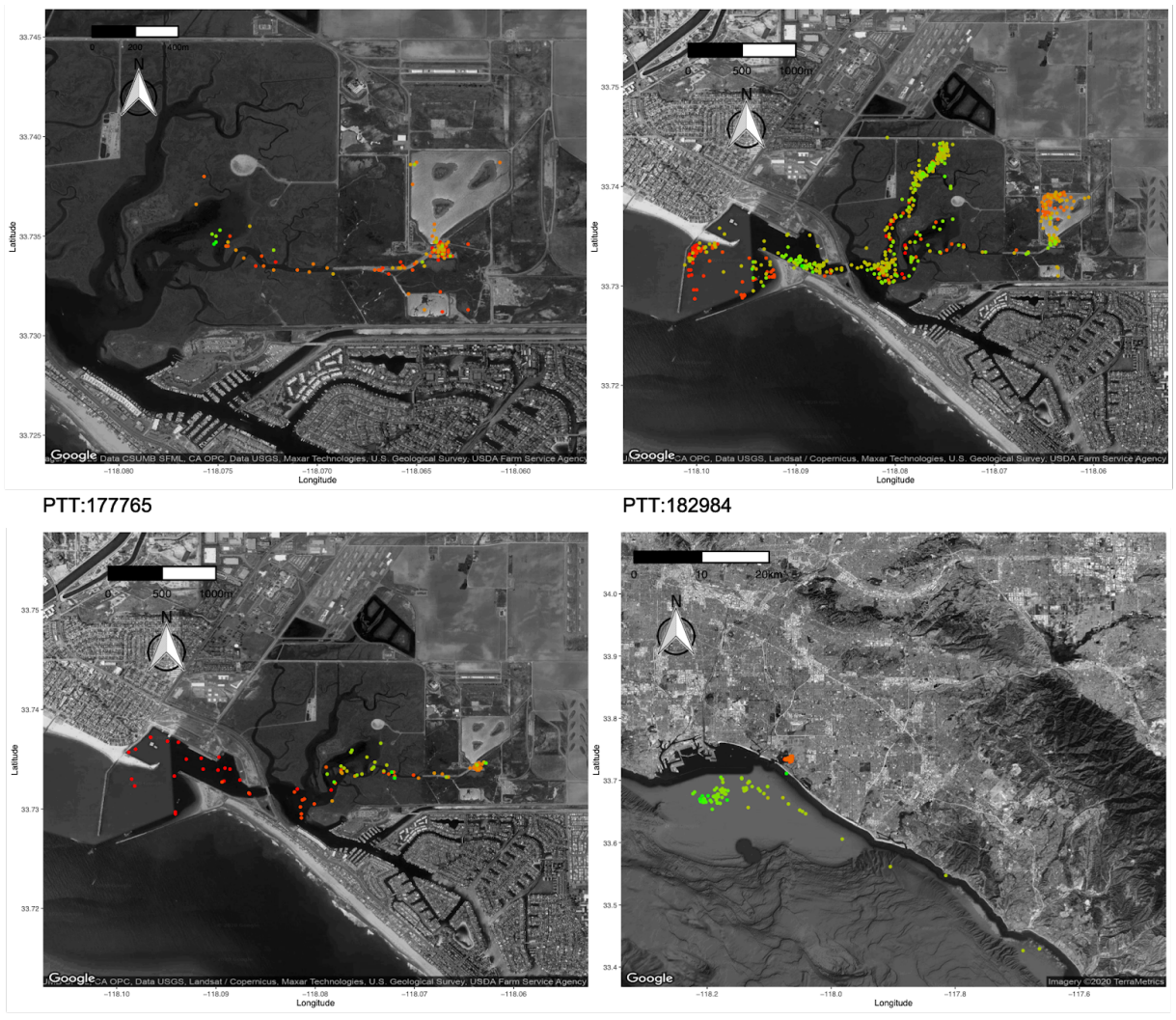

Figure 10. Each individual turtle's FastLoc-GPS tracks within the Seal Beach National Wildlife Refuge and Anaheim Bay. Turtles are listed from left to right: 177765 (May 2019-August 2019), 182984 (January 2020-July 2020), 182985 (July 2019-August 2019), & 182986 (July 2019-March 2020). Relocations are colored on a scale from green to red with green being the earliest dates and red being the last dates of transmission.

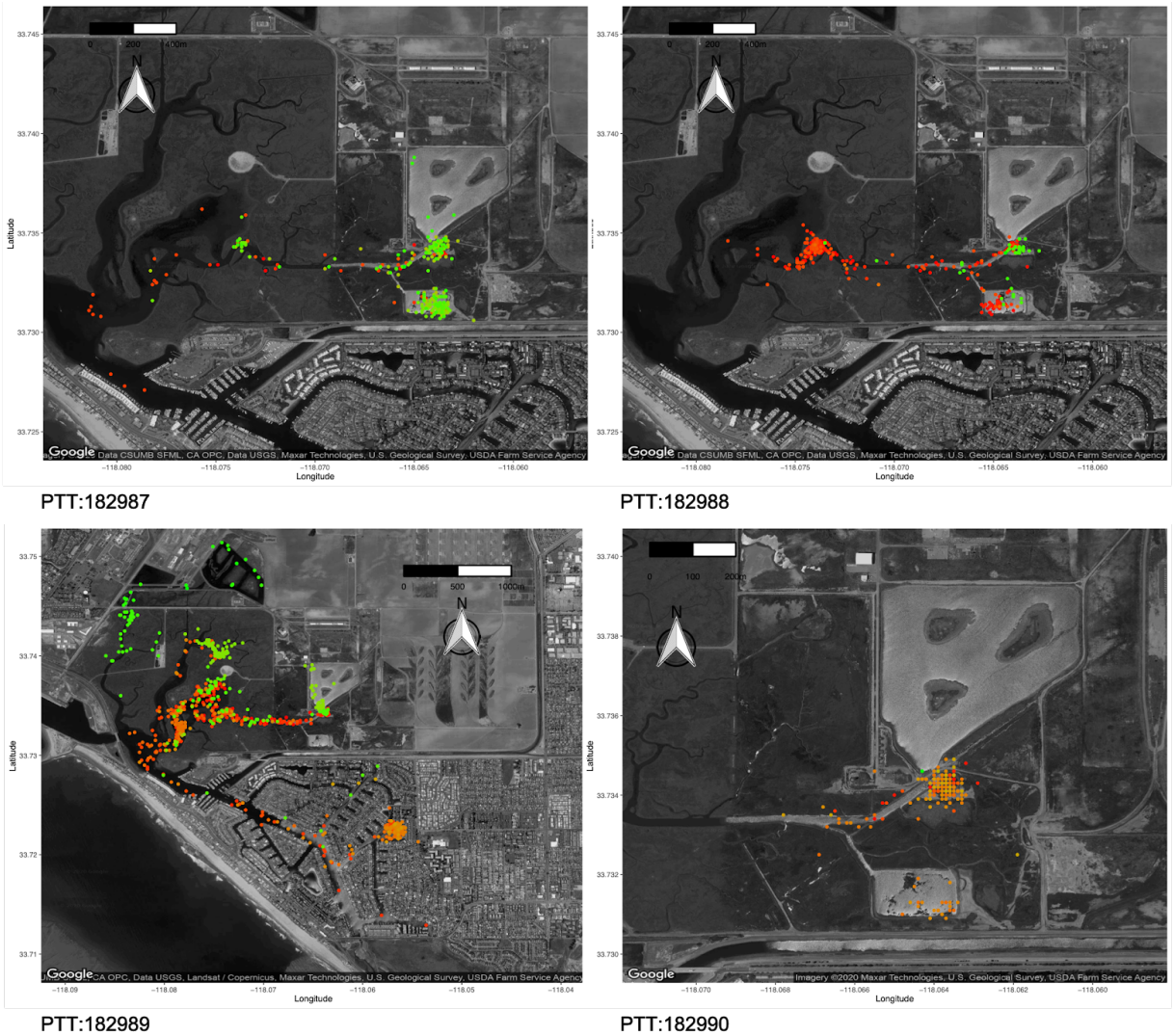

Figure 11. Each individual turtle's FastLoc-GPS tracks within the Seal Beach National Wildlife Refuge and Anaheim Bay. Turtles are listed from left to right: 182987 (January 2020-July 2020), 182988 (October 2019-July 2020), 182989 (October 2019-June 2020), 182990 (January 2020-May 2020). Relocations are colored on a scale from green to red with green being the earliest dates and red being the last dates of transmission.

3.4 Daily Movement Speeds and Distance

Individual hourly vagility ranged from 0.44 to 3.41 m/h (mean ± SE: 1.67 ± 0.24). Hourly vagility by subregion ranged from 1.01 to 5.79 m/h (mean ± SE: 2.78 ± 0.42, [Table 2]). Eelgrass coverage ranged from 1.24 to 84.18% (mean ± SE: 33.0% ± 9.09%; Table 2). Overall hourly vagility was greatest in the Brackish Tidal Marsh, Capture Pond Channel, and Inner area of Anaheim Bay (Figure 12). Daytime vagility was also greatest in the Brackish Tidal Marsh, Capture Pond Channel and Inner area of Anaheim Bay. Most locations had higher daytime vagility and lower night-time vagility with overall vagility decreasing from daytime to night-time hours. However, overall vagility, daytime vagility, and night-time vagility were relatively equal in the NASA Island Marsh, Perimeter Pond, and 7th Street Pond. Night-time vagility was greatest in the Inner Bay area, Northwest Channel, and Offshore area, but lowest in the Capture Pond, Forrestal Pond, NASA Island Marsh, Outer Bay, Perimeter Pond and 7th Street Pond. Finally, hourly vagility in both the Inner and Outer Anaheim Bay area were higher during the pre-construction months than during ongoing construction (Figure 13).

Table 2. Mean hourly vagility for each individual turtle by location with eelgrass coverage by location. CRP hourly vagility was unavailable due to lack of satellite tag relocations present in that area. Perimeter Pond=PP, Forrestal Pond=FP, Case Road Pond=CRP, 7th Street Pond=SSP, NASA Island Marsh=NIM, Brackish Tidal Marsh=BTM, Capture Pond=CP, Capture Pond Channel=CPC, Inner Bay=IB, NW Channels=NWC, Outer Bay=OB, Huntington Harbor=HH.

Location	Channel Area (m^2)	Eelgrass Area (m^2)	% Eelgrass Coverage	Site Hourly Vagility (m/h)
PP	25,568.17	21,523.05	84.18%	1.27
FP	60,297.96	41,300.18	68.49%	2.18
CRP	189,356.25	107,093.80	56.56%	N/A
SSP	170,059.09	89,301.78	52.51%	1.25
NIM	131,410.12	48,675.76	37.04%	1.42
BTM	520,764.61	181,450.76	34.84%	2.78
CP	2620.13	32.49	1.24%	1.01
CPC	29144.84	7,382.89	25.33%	3.38
IB	340,802.85	8,189.40	2.40%	5.79
NWC	144,901.47	22419.28	15.47%	3.90
OB	574,548.73	37,298.12	6.49%	3.03
HH	1,045,890.11	23,589.00	2.26%	3.09

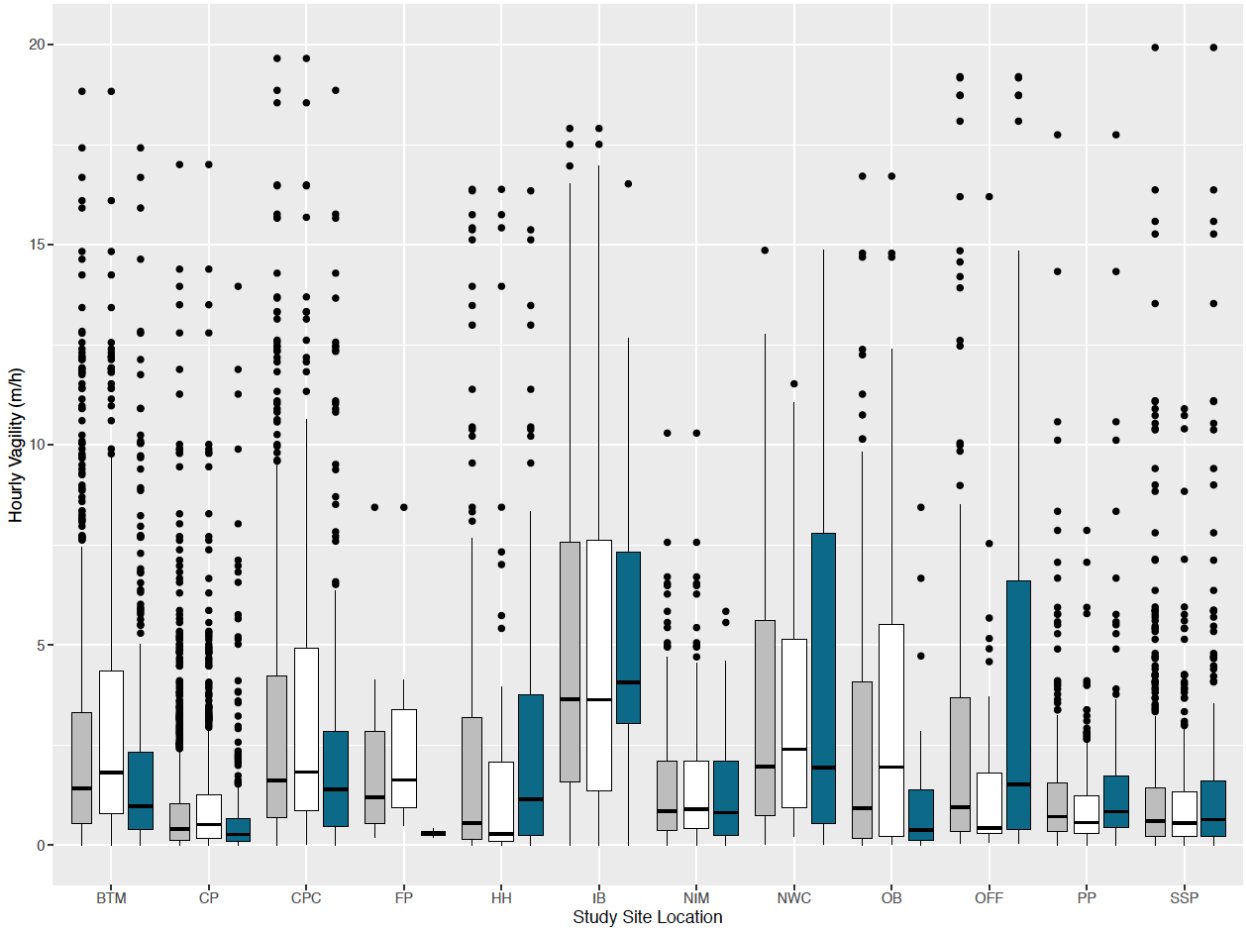

Figure 12. Overall hourly vagility (gray boxes), daytime hourly vagility (white boxes), and nighttime hourly vagility (dark blue boxes) for each study site location. Major outliers were removed. Brackish Tidal Marsh=BTM, Capture Pond=CP, Capture Pond Channel=CPC, Forrestal Pond=FP, Huntington Harbor=HH, Inner Bay=IB, NASA Island Marsh=NIM, NW Channels=NWC, Outer Bay=OB, Offshore=OFF, Perimeter Pond=PP, 7th Street Pond=SSP.

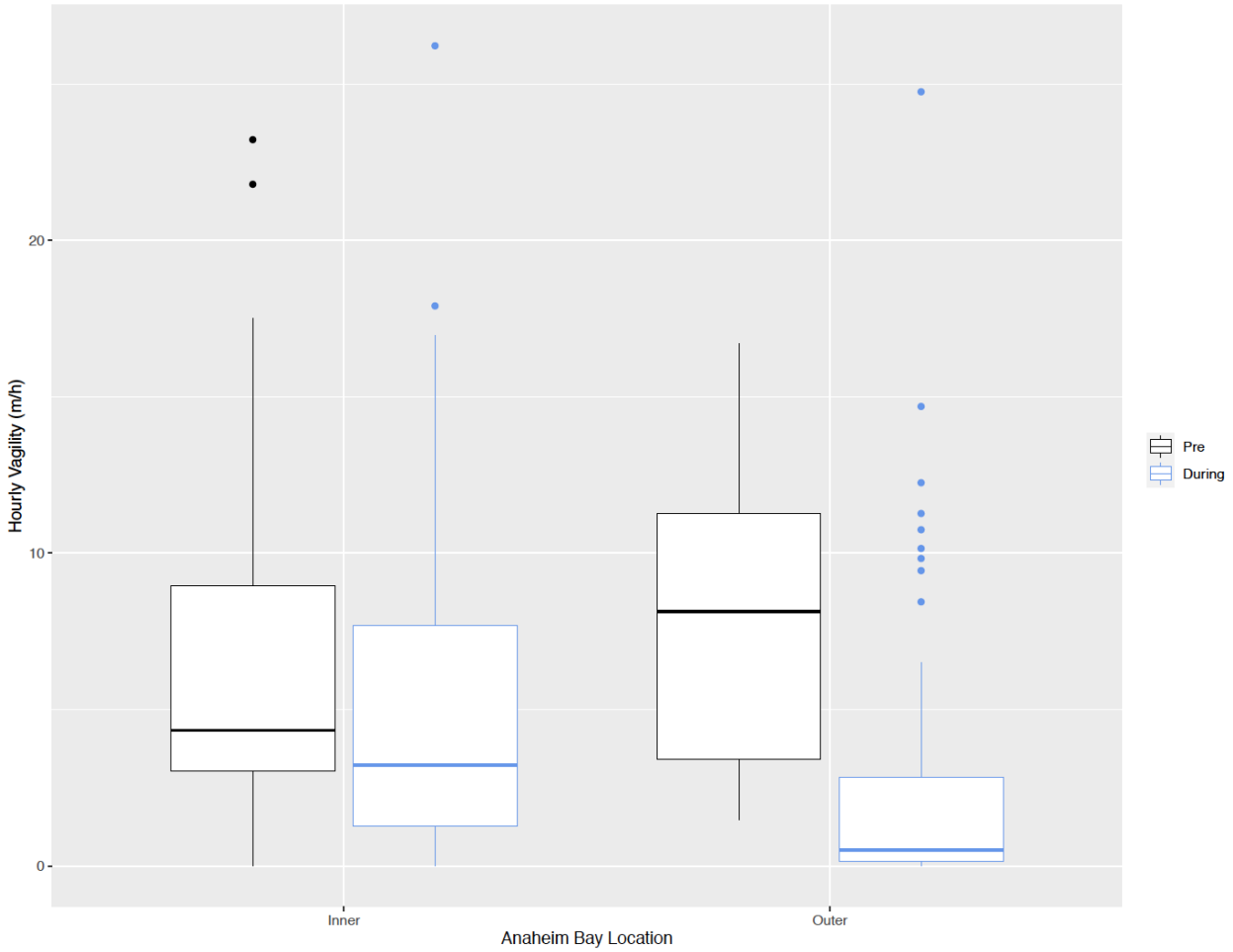

Figure 13. Hourly vagility of the four turtles that spent time in inner and outer Anaheim Bay (152310, 182984, 182985, 182986) before and during construction.

3.5 Utilization Distributions (Home Ranges)

Combined home range sizes of all 16 green turtles tracked within the Seal Beach National Wildlife Refuge and Anaheim bay (excluding offshore locations), for the 50% and 95% UDs were 0.95 km^2 and 6.43 km^2, respectively (Figure 14). Four individuals (152310, 182984, 182985, 182986) traveled outside the SBNWR into Anaheim Bay and two of those individuals (152310, 182986) traveled offshore. Anaheim Bay 50% and 95% UDs were 0.27 km^2 and 1.13 km^2, respectively (Figure 15) and offshore UDs were 40.95 km^2 (50%) and 231 km^2 (95%; Figure 16). Utilization Distributions were also calculated for each individual including only relocations within the SBNWR and Anaheim Bay. Individual 50% UDs inside the SBNWR and Anaheim Bay ranged from 0.02 km^2 to 1.43 km^2 (mean ± SE: 0.37 ± 0.11) and 95% UDs ranged from 0.18 km^2 and 6.92 km^2 (mean ± SE: 1.96 ± 0.57 km^2; Table 1). See Supplementary Figures for individual turtle home range maps.

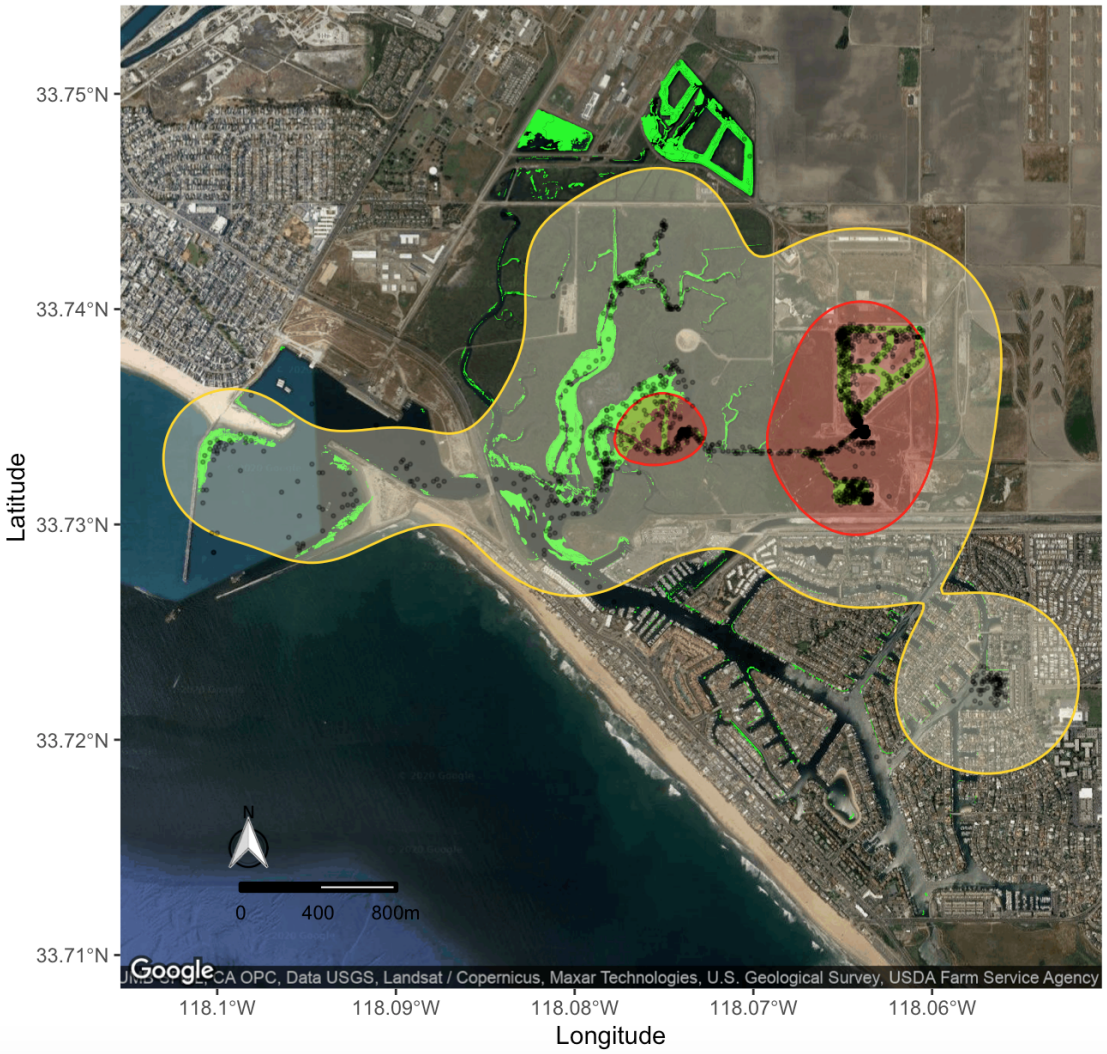

Figure 14. 50% (red), and 95% (yellow) overall home range areas for all 16 tagged turtles with locations in the SBNWR, Anaheim Bay, and Huntington Harbour (no offshore locations) including 2013 and 2019 eelgrass data (PMEP 2014 and Merkel & Associates 2019 eelgrass shapefiles).

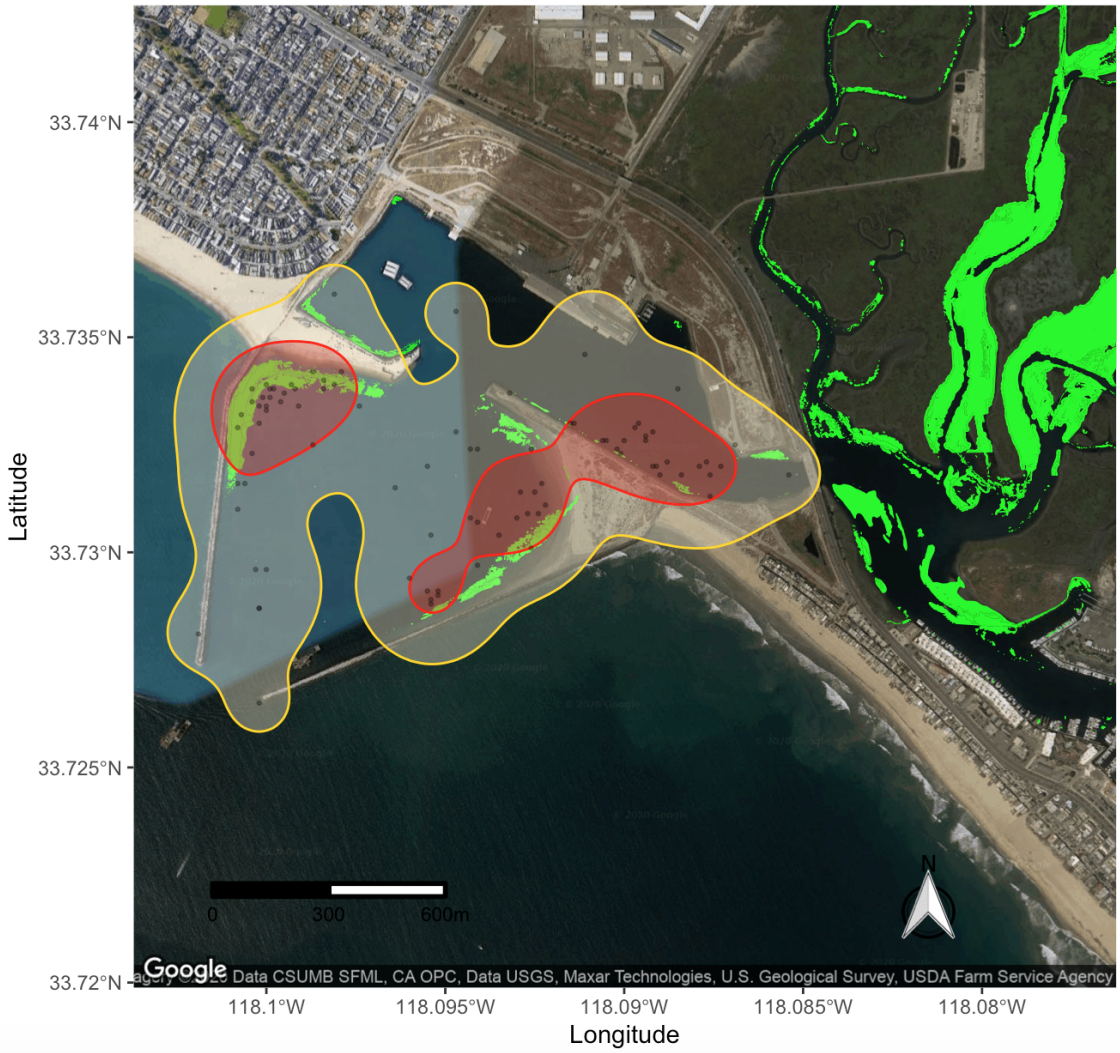

Figure 15. 50% (red) and 95% (yellow) home range areas in Anaheim Bay including 2013 and 2019 eelgrass data (PMEP 2014 and Merkel & Associates 2019 eelgrass shapefiles). This dataset includes the four turtles that utilized Anaheim Bay, tag IDs: 152310, 182984, 182985, and 182986.

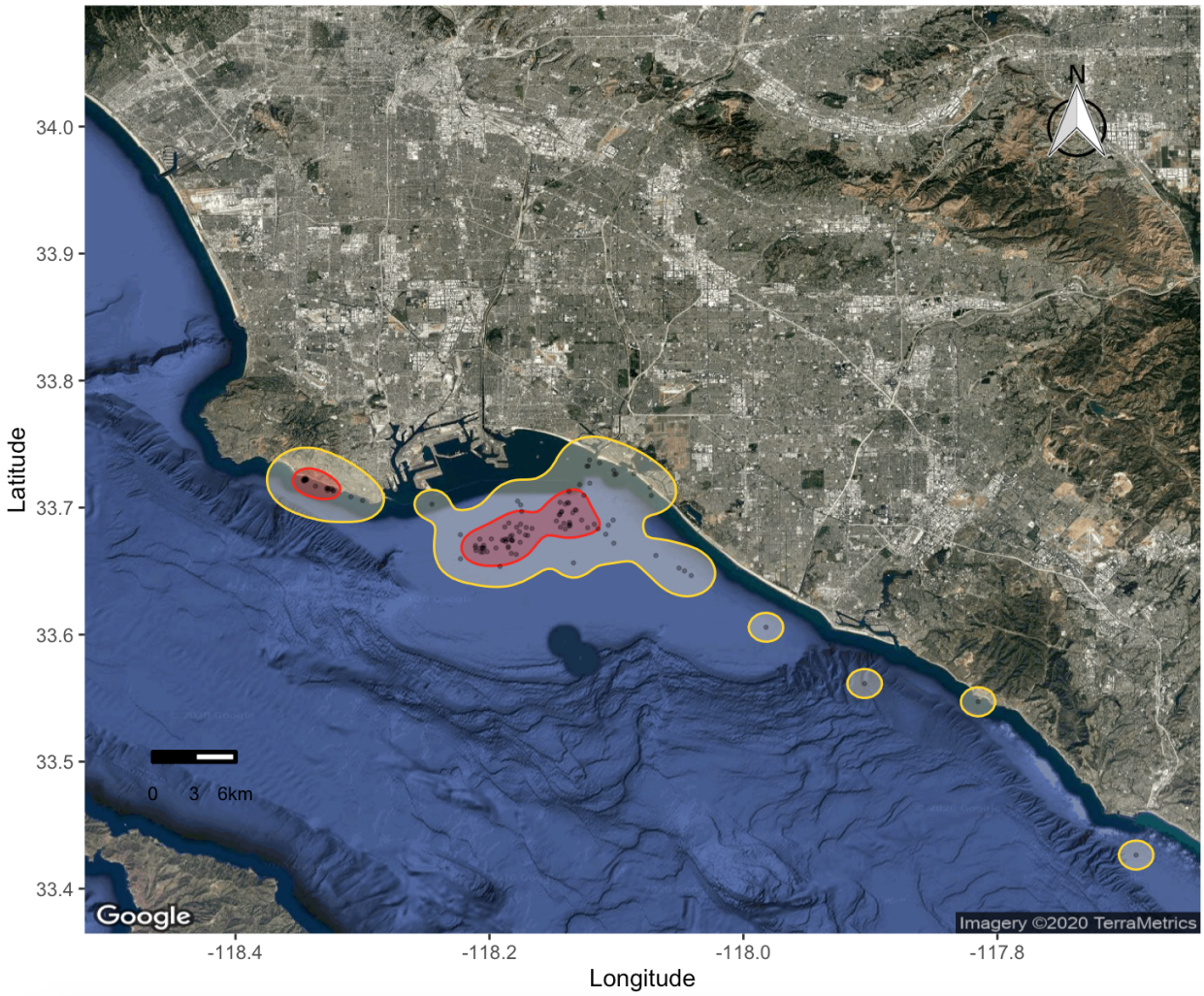

Figure 16. 50% (red), and 95% (yellow) home range area for offshore. This dataset includes the two turtles that left the SBNWR and Anaheim Bay area, tag IDs: 152310, 182986.

4.0 Discussion

East Pacific green turtles have recently become a resident species within the Seal Beach National Wildlife Refuge (SBNWR) and nearby coastal areas (Crear et al. 2017). It is possible that the number of green turtles in the area will increase and their spatial distribution will expand within the Refuge given the large extent of eelgrass coverage throughout the study site, as such a relationship was found in a nearby foraging area (Eguchi et al. 2020). The Seal Beach National Wildlife Refuge is an urbanized estuarine habitat for green turtles where the likelihood of interactions with humans is high. We investigated green turtle home ranges and movements using GPS-enabled satellite tags within the SBNWR and surrounding areas. Understanding the activity hotspots and movement patterns for green turtles in the SBNWR and Anaheim Bay can help to advise efforts in minimizing the impacts of ongoing and future construction on green turtles.

This report is intended to provide an annual summary of fall 2018 to summer 2020 preliminary baseline descriptions of green turtle movements and spatial utilization within the Seal Beach National Wildlife Refuge and Anaheim Bay and should not be used for any trend analyses of the Refuge and bay complex. A comprehensive report will be generated when construction is completed at which time trend and comparative analyses will be conducted.

4.1 Study Animals

Telemetered turtles had the mean weight of 52.1 kg (SE=4.9, n=16) and ranged from 17 to 98 kg, whereas the mean straight carapace length (SCL) was 72.74 cm (SE=2.42, n=16) and

ranged from 51.9 to 89.7 cm (Table 1). East Pacific green turtles are known to shift from a juvenile oceanic stage to a juvenile neritic stage at roughly 34 to 40 cm SCL in Baja California coastal habitats (Nichols 2003, Seminoff et al. 2003). Some studies show SCL of juvenile green turtles range from approximately 20 to 65 cm, whereas sub-adults are on the larger end of this scale, and adults are generally larger than 90 cm SCL (Bresette et al. 2010). However, green turtle maturity and growth rates have been shown to be very dependent on nutrient availability and their physical environment (Bjorndal et al. 2000). The average size at a nearby foraging area, where green turtles have been observed for decades, was larger than those caught in the SBNWR (San Diego Bay; 105.2 kg and 87.8 cm, Eguchi et al. 2020). A previous study in the SBNWR and the adjacent San Gabriel River (n=7) showed mean weight of 35.71 kg ± 3.08 kg and SCL of 61.64 cm ± 4.63 cm (Crear et al. 2017). Comparing the current studies body size information with similar areas, it is likely that the 16 tagged turtles are reflective of a foraging aggregation including mostly juveniles and sub adults.

4.2 Volunteer Sightings and Volunteer Effort

A majority of confirmed sea turtle presence occurred within the 7th Street Pond and Capture Pond, which were areas where volunteers spent their greatest search efforts (58.06% and 38.12%, respectively). However, in ponds with much less effort, such as Case Road Pond, Perimeter Pond, and Forrestal Pond, there were substantial numbers of green turtle sightings (Figure 7). Navigating to the eastern areas of the Refuge requires turtles to swim through culverts and narrow channels over long distances. However, eelgrass coverage (Table 2) in Forrestal Pond, Case Road Pond, and NASA Island Marsh indicates these areas provide substantial foraging habitat. It is possible that eelgrass is a strong motivation for foraging in the eastern

areas of the Refuge, although ease and accessibility of western Refuge areas may be the reason these are more popular foraging sites. Considering the number of turtle sightings in the eastern ponds relative to volunteer effort, it is likely that green turtles may be utilizing other areas in the Refuge than satellite data alone suggest (discussed further in sections below).

Because dedicated scientific studies are limited by resources and logistics, citizen science data collection can greatly augment dedicated scientific studies by having extra sets of eyes (Bock et al. 1981). In recent years, southern California marine turtle researchers have used citizen science data to enhance their studies (Eguchi et al. 2018, Hanna et al. in prep.). This project adds to the growing field of citizen science and we hope to continue engaging volunteers for the Seal Beach project.

4.3 Daily Movement Speeds and Distance

Preferred Foraging Areas

Hourly vagility varied greatly across all locations from 1.01 m/h in Capture Pond to 5.79 m/h in the Inner Anaheim Bay area and an average of 2.60 ± 0.48 m/h throughout the entire study area. Turtles in Capture Pond, 7th Street Pond, Perimeter Pond, and Forrestal Pond had some of the slowest movements in the entire study site. Except for the Capture Pond, these areas also have some of the highest eelgrass densities in the study site. Eelgrass coverage in these four ponds ranged from 1.24 to 84.18% (mean ± SE: 51.605% ± 17.99%). These locations are all shallow, semi-enclosed ponds in which water temperatures are likely much warmer than in larger bays and tidal channels within the study site. These warm water ponds presumably provide preferred foraging areas that allow for better digestive efficiencies, as has been reported for

green turtles in the Bahamas (Bjorndal 1980, Penick et al. 1996). The high density of eelgrass in most of these locations makes it likely that turtles foraging in these areas move slower over shorter distances between "grazing plots" (Bjorndal 1980).

In contrast with the shallow, enclosed areas in the study site, the Brackish Tidal Marsh, Capture Pond Channel, North West Channel, Inner Bay, and Outer Bay were areas with high daily movements and lower eelgrass densities. Capture Pond Channel, North West Channel and Brackish Tidal Marsh are much narrower in comparison to the ponds. Considering the lack of eelgrass and space for foraging in the smaller channel areas, it is likely that these areas are less preferable for foraging. It is possible that these areas provide "transitionary" avenues to preferred foraging areas. The inner and outer areas of Anaheim Bay have sufficient space for turtle foraging and consist of smaller eelgrass patches that are limited to the east and west edges of the bay, which may result in increased vagility at these foraging grounds.

Anaheim Bay Movements

Several GPS relocations surrounded eelgrass patches within the bay and it is likely that Anaheim Bay is a preferred foraging site for some individuals. Movement speeds in the Inner Bay represented the fastest speeds in the study (5.79 m/h) while movement speeds in the Outer Bay were slightly faster than other sites (3.03 m/h). Eelgrass patches in the Inner and Outer Bay are spread further apart from each other on opposite sides of the bay. This creates greater distances to travel between foraging pastures, which could possibly increase hourly vagility. Increased vagility in Anaheim Bay may also be a result of turtles transiting through the bay to offshore areas. During this study, hourly vagility in the inner and outer areas of Anaheim Bay differed prior to construction and during construction (Figure 13). Movement speeds decreased

in both the inner and outer bay during construction compared to pre-construction speeds. However, with the limited number of turtles that utilized Anaheim Bay, it is difficult to draw conclusions from these data. Future reports will investigate these differences in greater detail.

Night-Time Movements

In most areas (Brackish Tidal Marsh, Capture Pond, Capture Pond Channel, Forrestal Pond, North-West Channels, and Outer Bay) night-time vagility was lower than mean daytime and mean overall vagility suggesting resting behavior at night in these areas. In the Huntington Harbour, Inner Bay, Offshore, Perimeter Pond and 7th Street Pond areas night-time vagility was higher compared to day-time movements. While resting is known to occur during the night-time hours, green turtles have also been reported foraging in the evening. For example, on Mayotte Island in the Indian Ocean green turtle night-time foraging was associated with evenings in which the night light was high from increased moonlight or increased cloudiness indices (Taquet 2006). Another observation of green turtle night-time foraging activity took place in Hawaii where tidal cycles were more important for determining foraging times (Bjorndal 1997). The results from the Seal Beach study area suggest both types of resting and foraging behaviors may be occurring at night and vary between individuals, however, further investigation is required to confirm these results.

4.4 Utilization Distributions (Home Ranges)

Overall Utilization Distributions (UDs) were calculated using satellite locations within SBNWR and Anaheim Bay and excluded offshore locations (Figure 14). Collectively, the cumulative home range (50% UD: 0.95 km^2, 95% UD: 6.43 km^2) of all tagged turtles covered an expansive area within the Seal Beach National Wildlife Refuge (10 km^2), with turtles visiting 10

of 12 sub areas within the Seal Beach National Wildlife Refuge and Anaheim Bay area (excluding offshore). Core UD areas (50% UDs) for all turtles consisted of the three most popular foraging areas (Capture Pond, Perimeter Pond, and 7th Street Pond) and an area of dense eelgrass coverage within the Brackish Tidal Marsh (the area west of the mouth of Capture Pond Channel). The popular foraging areas identified using hourly vagility data were consistent with core areas (50% UDs) identified through home range analysis. Core UDs were located in areas with high eelgrass coverage, suggesting turtle movements and foraging within the SBNWR and Anaheim Bay area are greatly influenced by eelgrass coverage. Several relocations fell outside of the core areas but were within "transitionary" areas included in the 95% UDs.

Although a majority of tagged turtles remained in the SBNWR over the tracking duration, home ranges for individuals that visited Anaheim Bay (152310, 182984, 182985, 182986) were also examined. Core areas within the bay (50% UD: 0.27 km^2) overlapped with the existing channel for vessels moving in and out of Huntington Harbour just west of the Pacific Coast Highway Bridge and the eastern and western edges of the outer bay. Core areas along the eastern and western edges of the bay overlap with two large patches of eelgrass in the outer bay and a small patch of eelgrass on the eastern side of the inner bay. These core use areas indicate that eelgrass patches on the outer edges of Anaheim Bay are a preferred foraging area for a few individuals. However, few turtle locations overlapped with eelgrass on the west side of the inner bay and on the bayside of the east mole in the outer bay. The core use area on the east side of the outer bay will intersect somewhat with the new navigation channel. Additionally, the core use area in the inner bay overlaps with where the causeway will be constructed that will close off the current route to the SBNWR. Although it is possible for construction activities to impact turtle movements in Anaheim Bay, there have been very few studies to evaluate effects of

anthropogenic changes in turtle foraging areas. Throughout the entirety of the construction process, the Navy will continue to monitor turtles within to better understand movement patterns under these unique conditions.

In addition to SBNWR and Anaheim Bay home ranges, two turtles (152310, 182986) were documented leaving the study site into nearby offshore waters. The 95% offshore UD area ranged from Rancho Palos Verdes to Dana Point (95% UD: 231 km^2). Offshore core home range areas (50% UD) covered 40.95 km^2. One offshore core area was located southwest of SBNWR directly outside the mouth of Anaheim Bay. The other core area was located further north along the coast close to Rancho Palos Verdes about 23 km from the mouth of Anaheim Bay. It is possible that exploratory movements in search of new eelgrass pastures, or shuttling movements between multiple foraging areas may be a motivation for such movements.

Video surveillance has shown green turtles “surveying the water column” and executing exploratory dives to the seafloor to examine prey items (Seminoff et al. 2006). Other species of sea turtles have displayed diel patterns that demonstrate exploratory behavior possibly driven by resource availability or competition (Chambault 2020). Several studies have shown that green turtles using multiple foraging sites engage in “shuttling patterns" between sites and often display revisitation patterns (Mendonça 1983, Senko et al. 2010, Schofield et al. 2010, Christiansen et al. 2017). The evidence that green turtles use multiple foraging areas both in this study and in previous studies is confirmation that “shuttling” behavior can be used to find multiple sites and is not an uncommon behavior in green turtle populations. Data from volunteer sightings suggest the Seal Beach National Wildlife Refuge and Anaheim Bay supports a large foraging aggregation of green turtles. Shuttling behavior and exploratory movements are likely reasons for green turtles

in the SBNWR and Anaheim Bay to have several popular foraging areas, several relocations in "transitionary" areas, and visitation to several locations outside of the SBNWR like Anaheim Bay and Huntington Harbour.

Individual 50% UDs were between 0.02 km^2 and 1.43 km^2 (mean ± SE: 0.37 ± 0.11 km^2) while 95% UDs were between 0.18 km^2 and 6.92 km^2 (mean ± SE: 1.96 km^2 ± 0.57 km^2). Some individual home ranges spanned the SBNWR area with multiple core UDs. A few home ranges included Anaheim Bay and offshore areas in their 50% and 95% UDs, others focused mostly on the popular foraging ponds, and one turtle used Huntington Harbour as a main foraging area (within 50% UD). Major differences in core UDs could be due to personal preferences of each individual; recent studies have shown that core UDs are heavily influenced by patchiness of prey availability and water temperatures (Eguchi et al. 2020). Given the distribution of eelgrass and habitats that potentially have very different temperature characteristics (ponds, channels, bays), it is likely that individual preferences, water temperature, and eelgrass density are major drivers of varying 50% UDs among individuals. Studies in nearby biogeographic areas have shown that home range areas vary greatly across individuals. In Bahia de los Ángeles, Mexico, juvenile green turtle home ranges varied from 4 km^2 to 32 km^2 (Seminoff et al. 2002) and in San Diego Bay home ranges varied from 2.53 km^2 to 6.87 km^2 (Eguchi et al. 2020). Compared to Bahia de los Angeles and San Diego Bay, SBNWR and Anaheim Bay home ranges are much smaller. This may be attributed to the tortuous nature of the SBNWR study site versus the open bays of Bahia de los Angeles and San Diego Bay.

4.5 Summary

This study has provided novel insights on green turtle ecology in a unique study area. Sea turtles are a highly migratory species that are often hard to observe using traditional research methods (Carr et al. 1978, Plotkin 2002). Here we combined GPS-based satellite telemetry with volunteer observations as possible as both methods have their limitations. FastLoc-enabled GPS satellite tags are advantageous for providing fast, high accuracy data (± 20-75 m), and can yield significant amounts of spatial data if affixed to the turtle for substantial periods. However, locations that are suitable to capture turtles are limited and tagging turtles in the same location may bias telemetry data. Our turtle capture efforts were limited to one subsection of the study area, Capture Pond. Satellite tags that were affixed to individuals indicated that animals moved throughout the Refuge but did not visit all subsections of the Refuge. These satellite tracking data were combined with observational presence/absence data collected by volunteers throughout the Refuge, including areas where turtles were not tracked by satellite telemetry. Together, these dual approaches yielded information about green turtle movements and habitat use within the Seal Beach National Wildlife Refuge, Anaheim Bay and offshore areas.

Another possible limitation is that the 16 study animals are not representative of the true population home range. With knowledge of the 7th Street Pond and Capture Pond being areas of frequent visitation, the number of deployed satellite tags may not have captured the full array of behavioral patterns by green turtles in the area. Although capture and tagging efforts are currently on hold due to the COVID pandemic, we are hopeful that field work will resume soon. Currently, at least 10 additional satellite tags are planned to be deployed, which may reveal additional areas of activity for local green turtles.

Overall, volunteer data and telemetry data revealed three main utilization areas in the Seal Beach National Wildlife Refuge, two less frequently utilized areas in Anaheim Bay, and two "transition" areas within the Seal Beach National Wildlife Refuge. The three main utilization areas, Capture Pond, 7th Street Pond and Perimeter Pond were all areas with dense eelgrass coverage and large amounts of space suitable for turtle foraging. Night-time movements were also lowest in these three ponds. It is likely that these ponds provide the main foraging and resting areas for the aggregation. The two utilization areas located in Anaheim Bay were located on the two largest eelgrass patches in outer Anaheim Bay, one on the western boundary of the bay and one on the eastern boundary. It is probable that Anaheim Bay provides a secondary foraging area for green turtles in the study. Given that two of the four turtles that foraged in these Anaheim Bay locations also moved to offshore areas, it is possible that Anaheim Bay provides an access route between offshore areas and the Seal Beach National Wildlife Refuge. Finally, the two "transition" areas within Seal Beach National Wildlife Refuge (Brackish Tidal Marsh and Capture Pond Channel), were areas that had low eelgrass density and consisted of narrow channels and shallow marsh areas that are less suitable for foraging activities. These two areas also had high hourly movements in comparison to the main foraging areas. These data suggest that turtles use Brackish Tidal Marsh and Capture Pond Channel as transition routes between more popular areas like Capture Pond, 7th Street Pond, Perimeter Pond, and Anaheim Bay.

Although the areas discussed above highlight the main utilization areas, it is important to note that places like North-West Channel, Case Road Pond, Forrestal Pond and NASA Island Marsh were used less, but still had several confirmed observations of turtles and GPS relocations. These regions may not be main utilization areas, but are areas frequented by turtles in the Seal Beach National Wildlife Refuge.

The results of this baseline analysis provide a better understanding of turtle hotspots and movement patterns in the SBNWR and Anaheim Bay. These data along with those collected from future field efforts will be analyzed and comprehensive reports will be generated.

4.6 Recommendations

Given the results of this report and further understanding of the green turtle foraging aggregation in the Seal Beach National Wildlife Refuge, recommendations for future direction of the study are essential and are as follows:

- Exploration of eastern areas within the Refuge that could potentially be used for turtle capture
- Deployment of turtle cameras to confirm behaviors (foraging, resting, transiting)
- Examination of seasonal movements and utilization distributions to detect seasonal trends or further expand on preferred foraging locations
- Evaluation of demographic information on all turtles captured (not just tagged turtles) to provide more information on age, size, sex and maturity status of the Seal Beach foraging aggregation

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5.0 Supplementary Figures

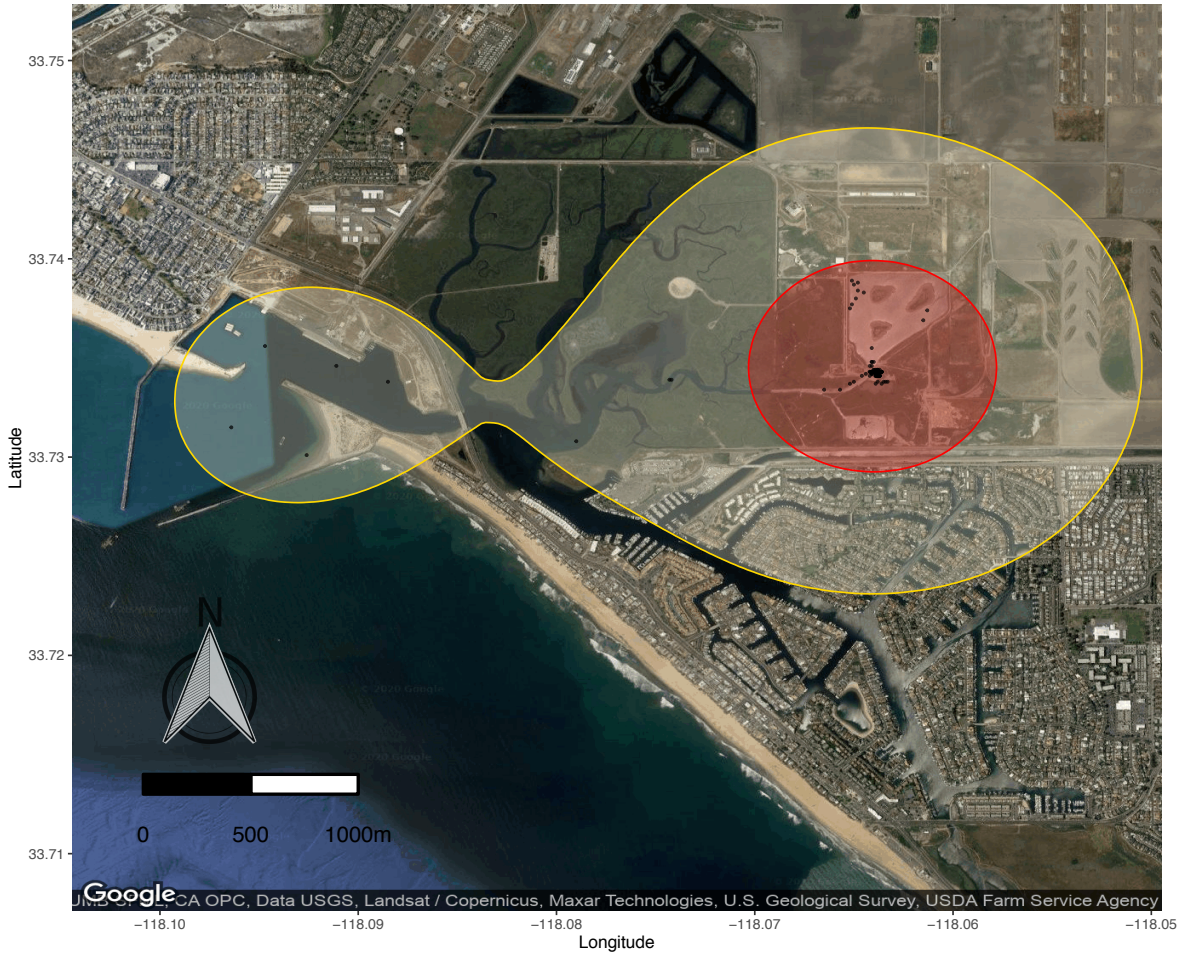


Figure S1. Seal Beach National Wildlife Refuge and Anaheim Bay Home Range for Tag ID 152310

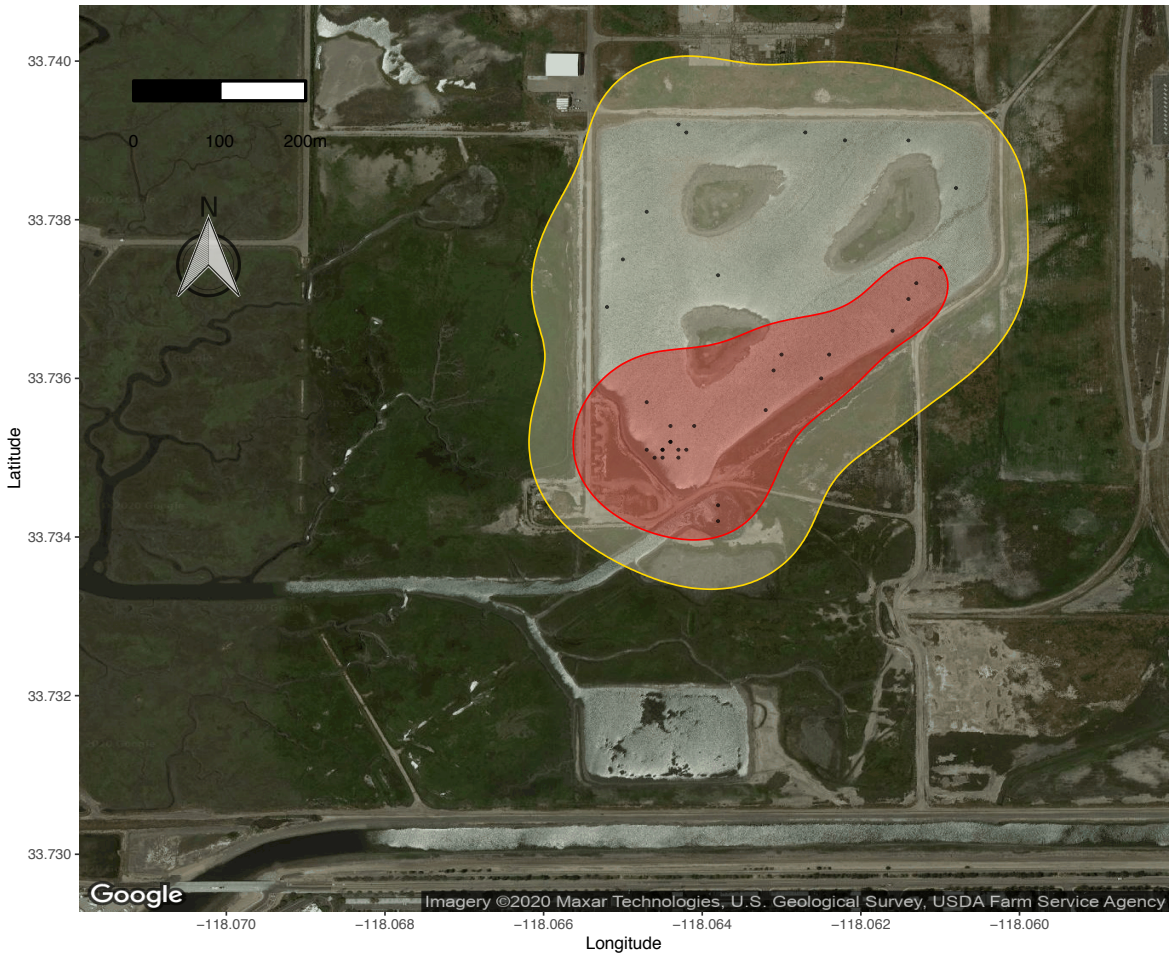


Figure S2. Seal Beach National Wildlife Refuge and Anaheim Bay Home Range for Tag ID152317

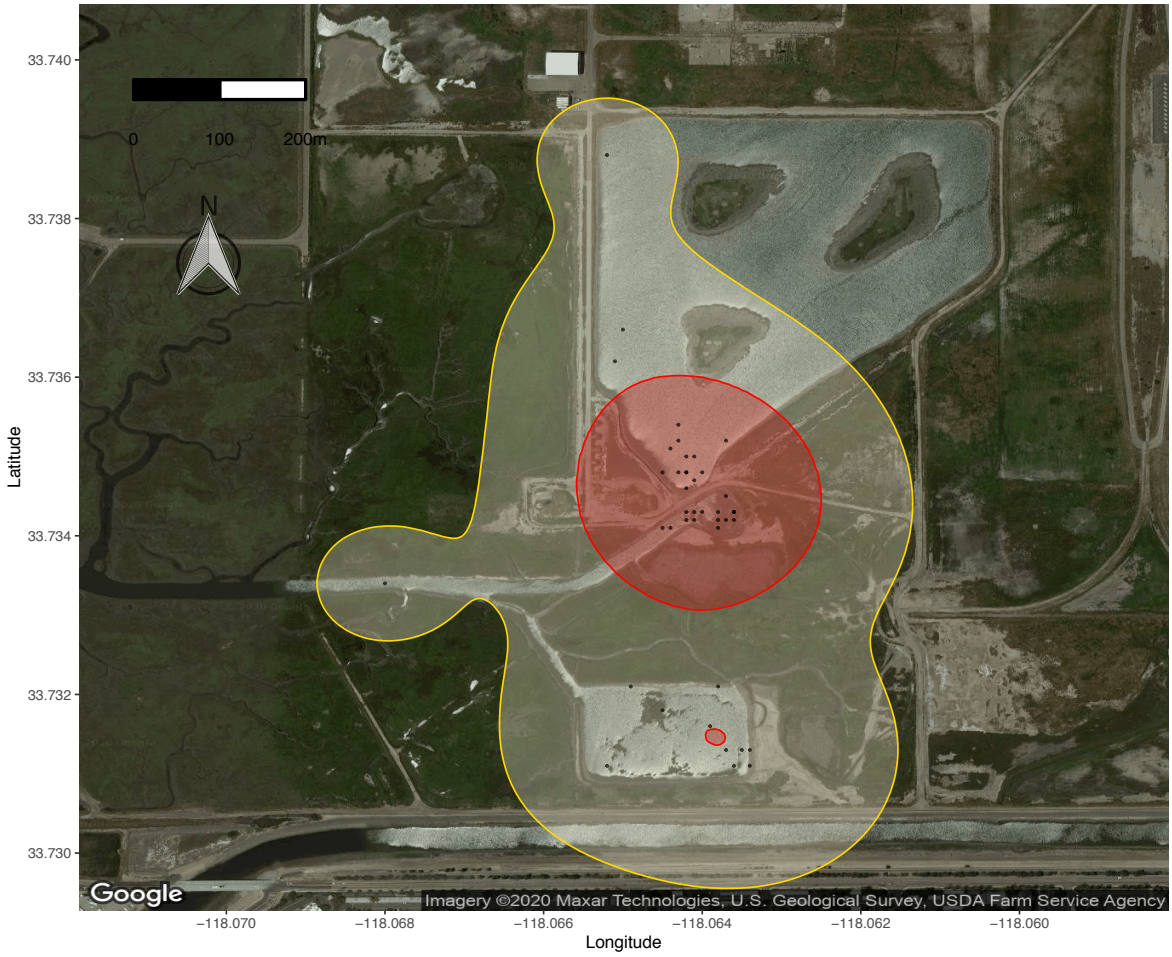


Figure S3. Seal Beach National Wildlife Refuge and Anaheim Bay Home Range for Tag ID 152318

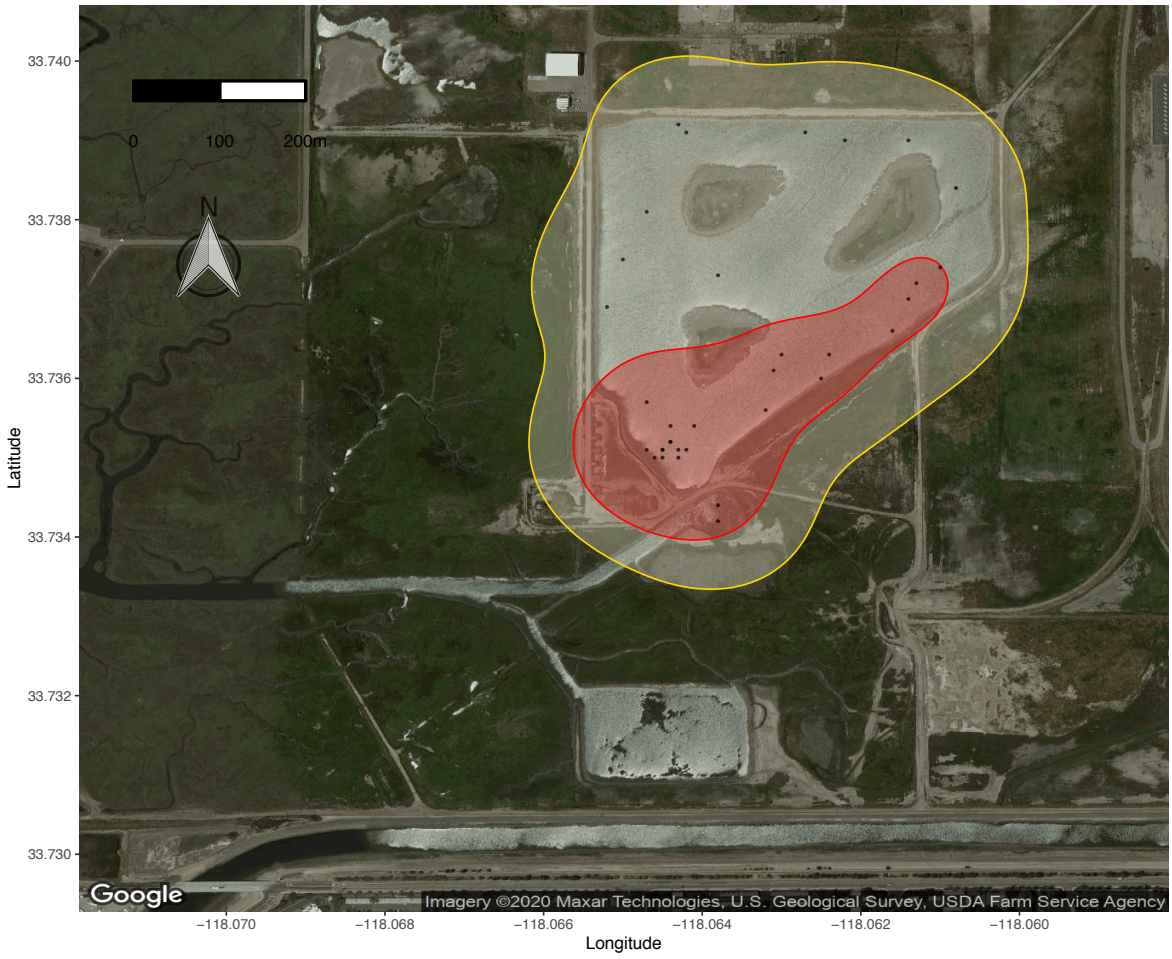


Figure S4. Seal Beach National Wildlife Refuge and Anaheim Bay Home Range for Tag ID 152320

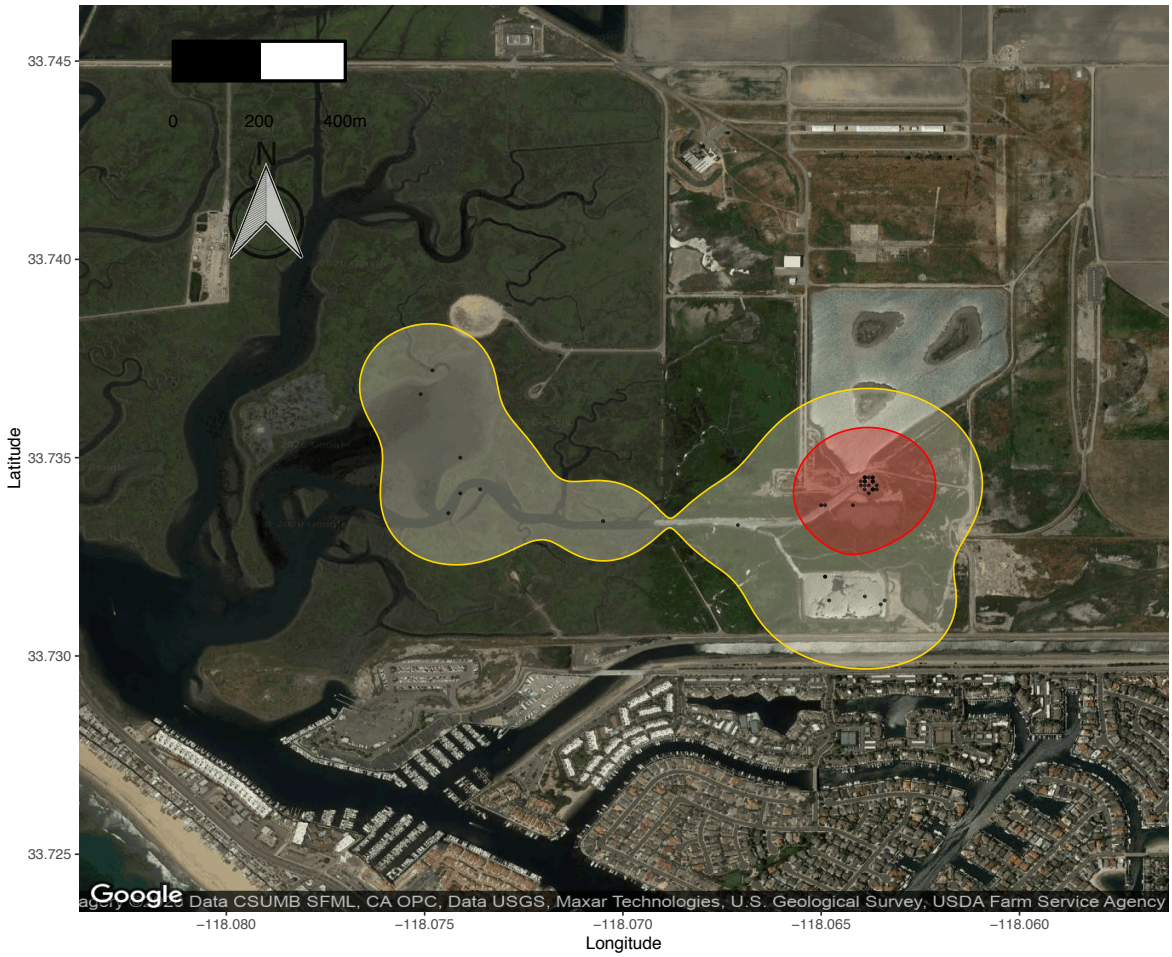


Figure S5. Seal Beach National Wildlife Refuge and Anaheim Bay Home Range for Tag ID 177761

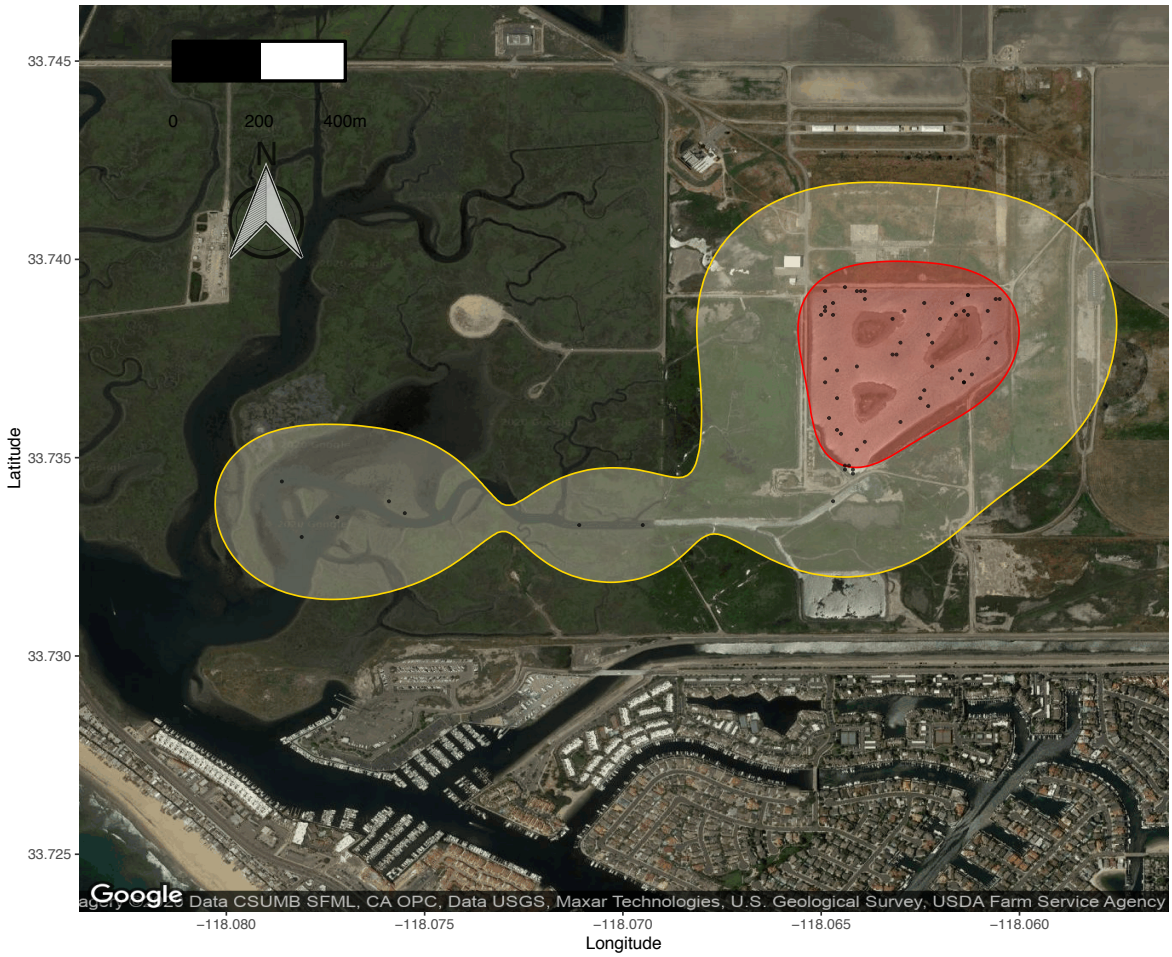
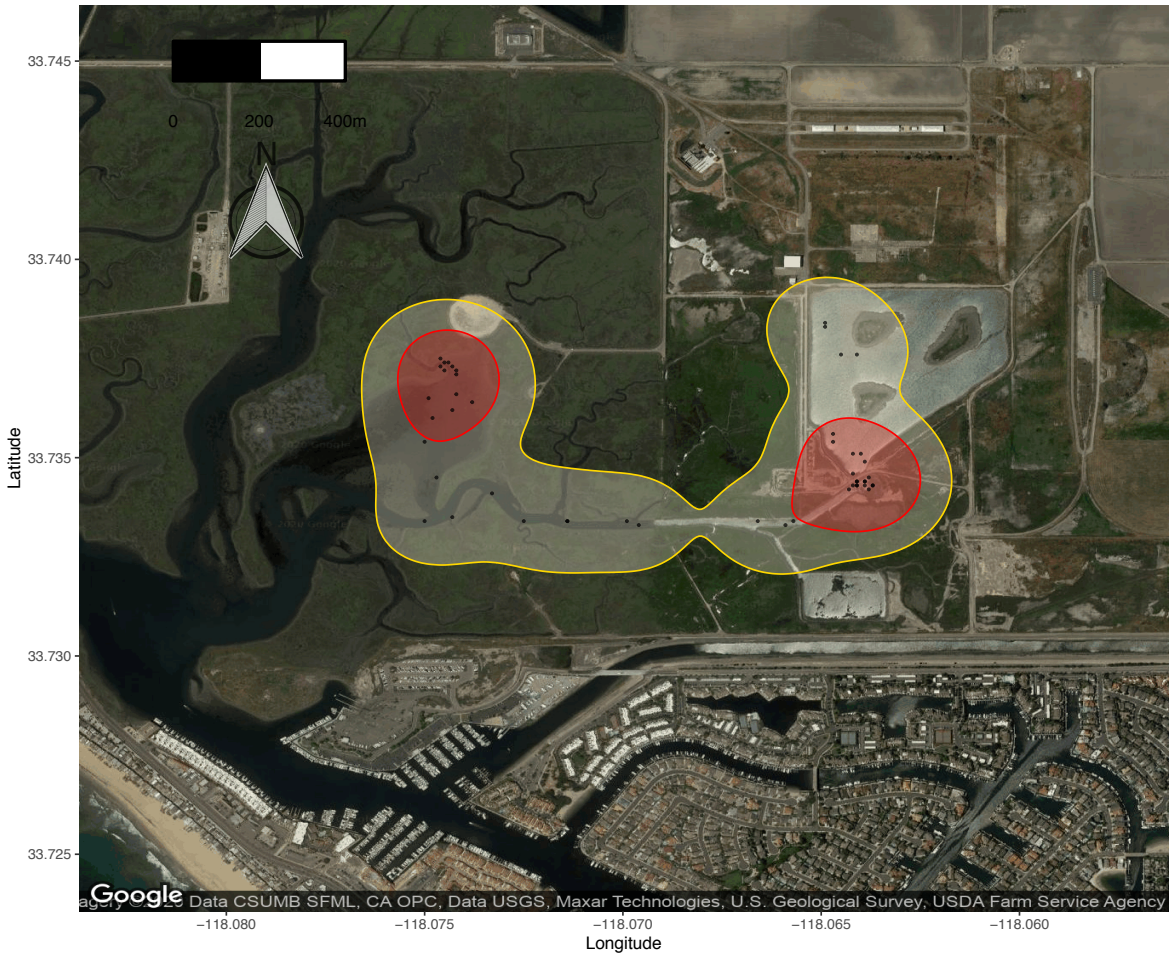


Figure S6. Seal Beach National Wildlife Refuge and Anaheim Bay Home Range for Tag ID 177762



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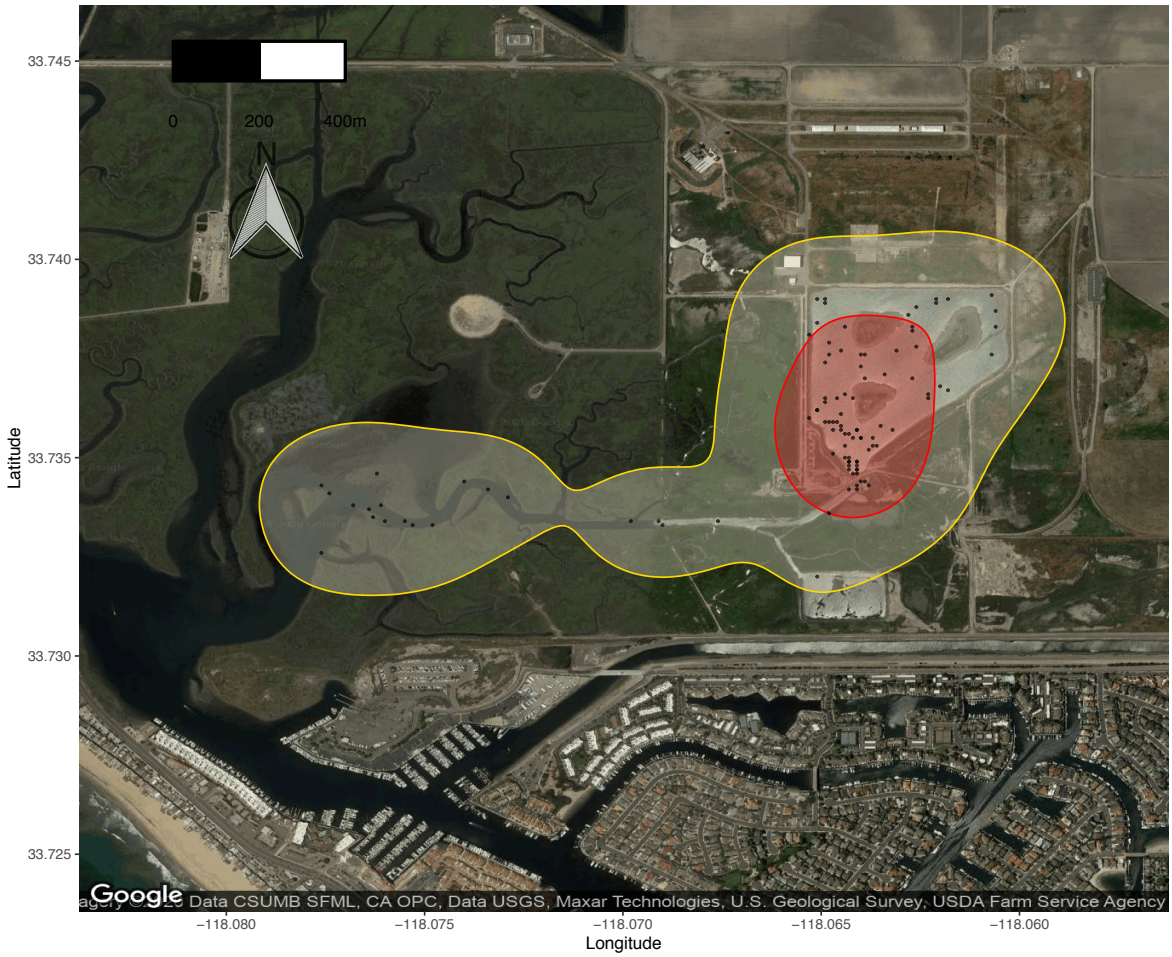

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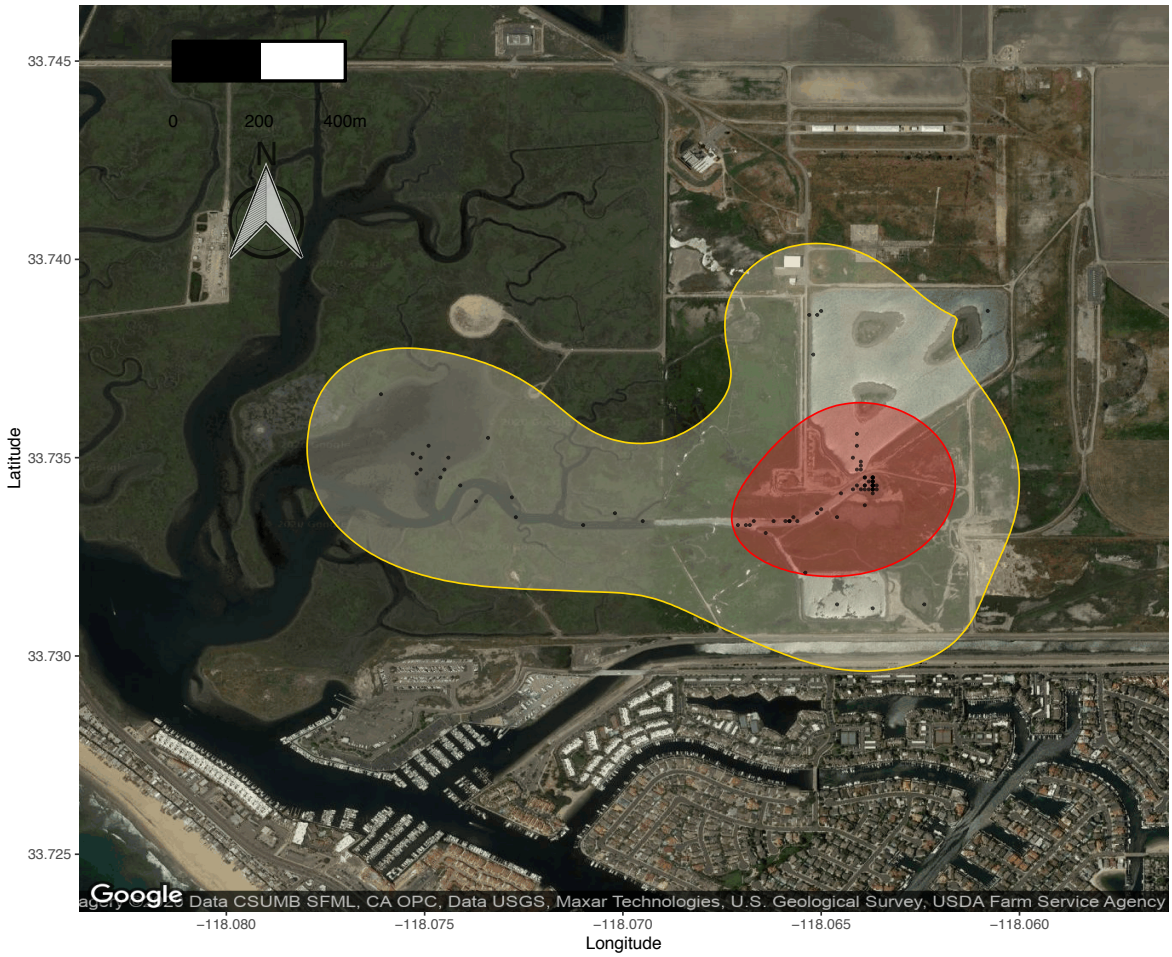


Figure S9. Seal Beach National Wildlife Refuge and Anaheim Bay Home Range for Tag ID 177765

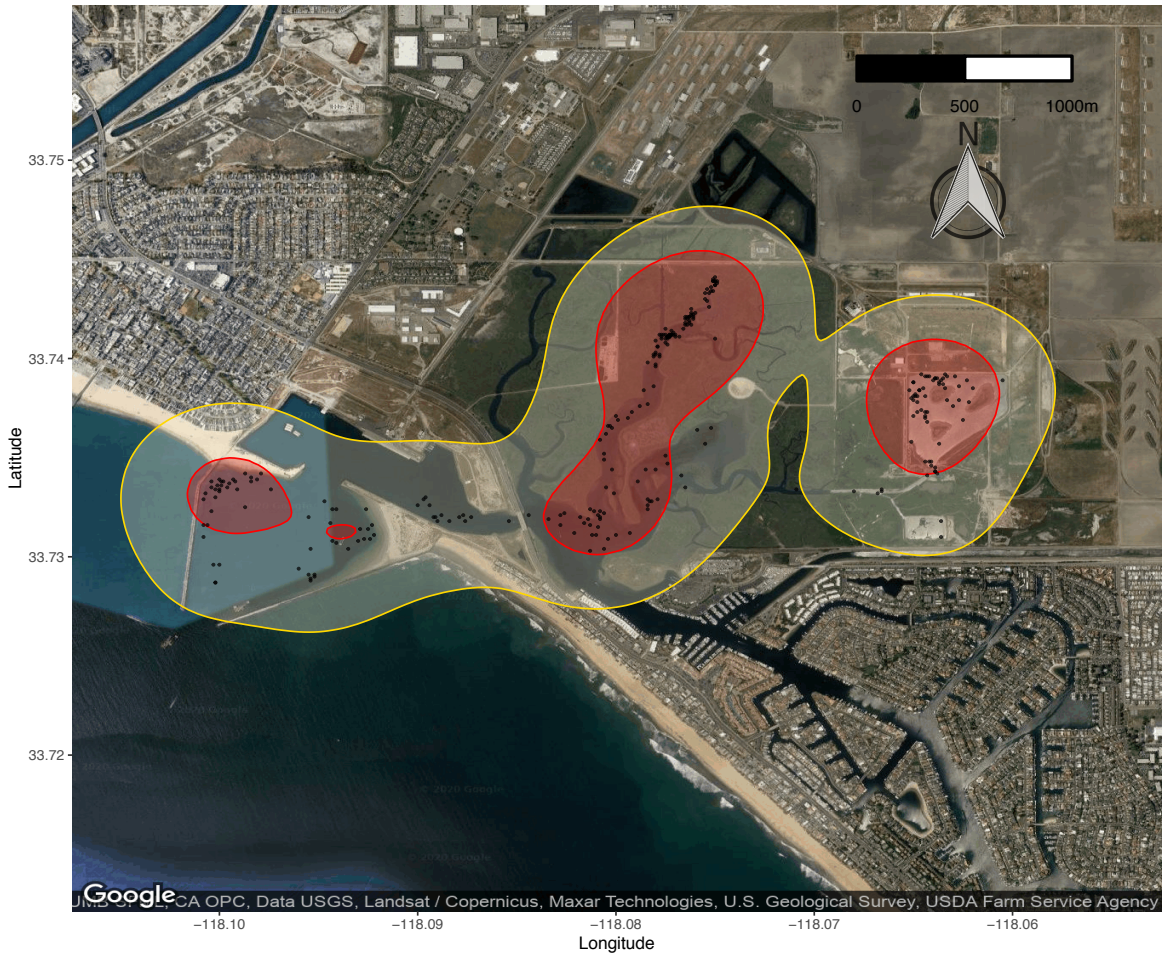


Figure S10. Seal Beach National Wildlife Refuge and Anaheim Bay Home Range for Tag ID 182984

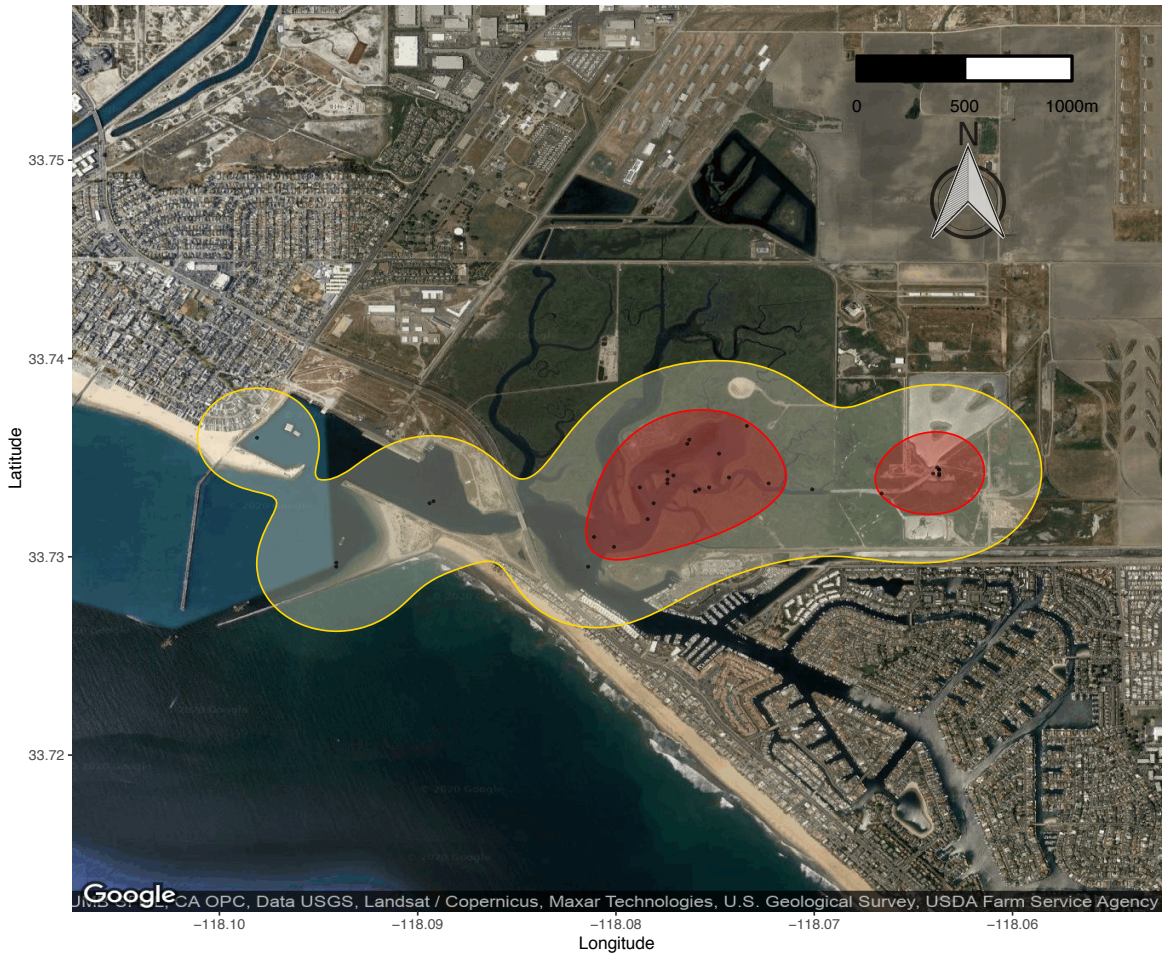


Figure S11. Seal Beach National Wildlife Refuge and Anaheim Bay Home Range for Tag ID 182985

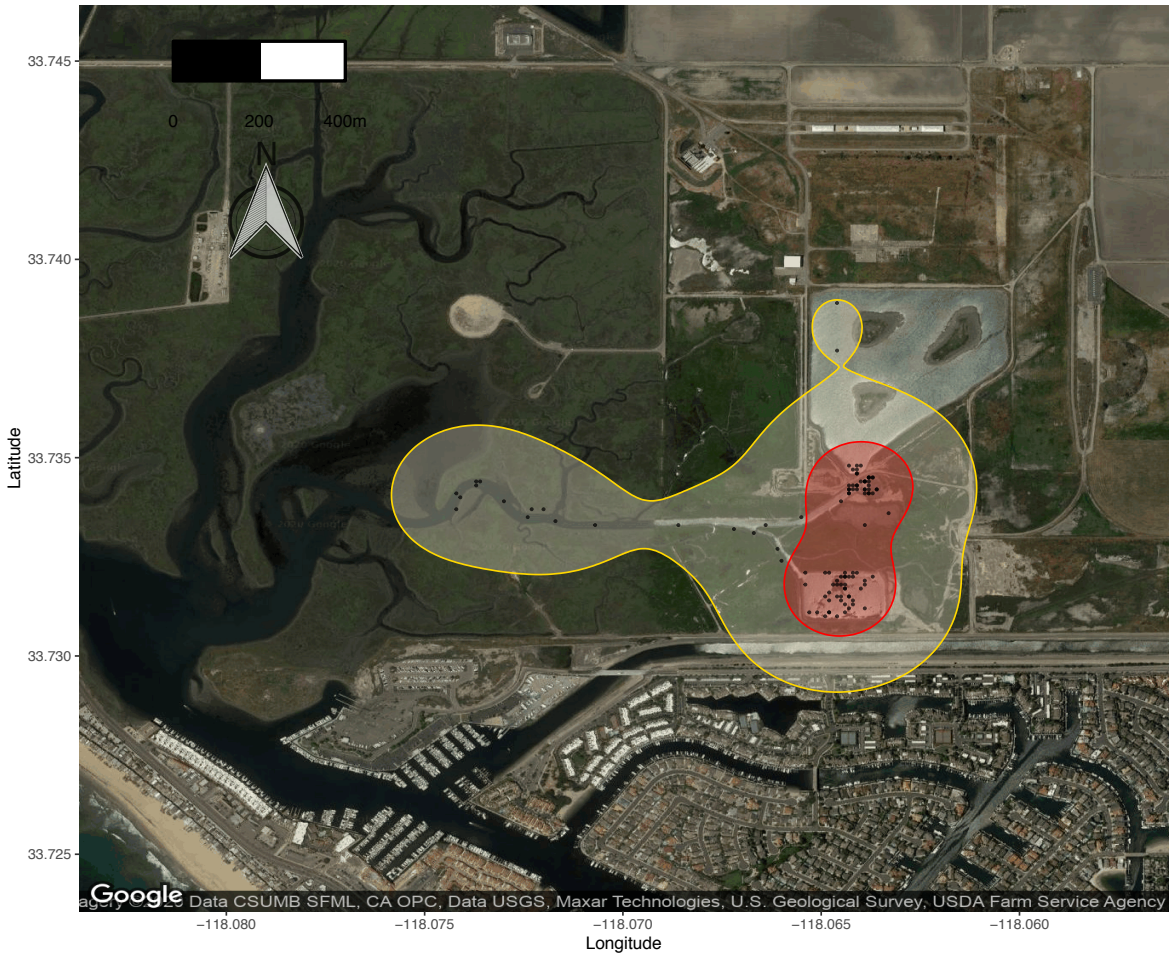
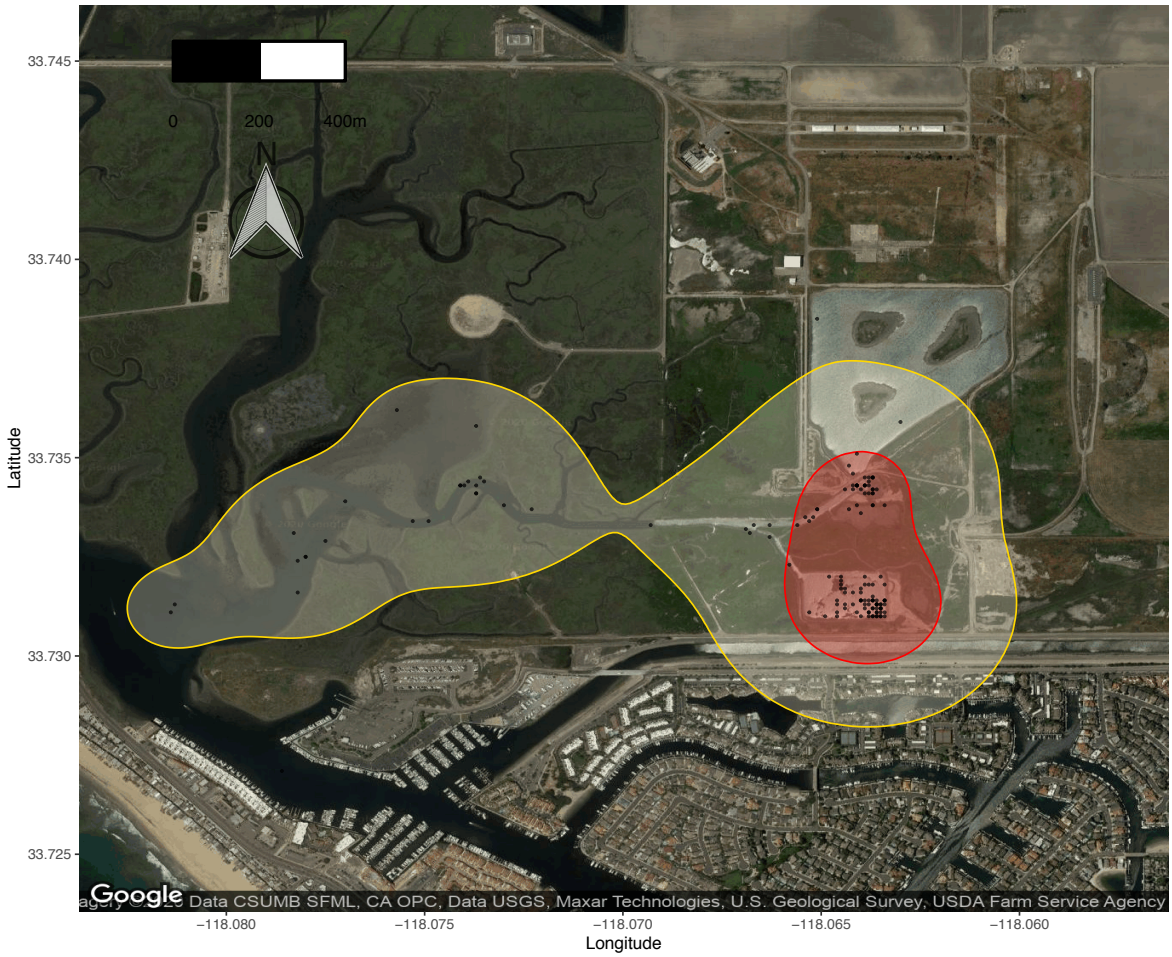


Figure S12. Seal Beach National Wildlife Refuge and Anaheim Bay Home Range for Tag ID 182986



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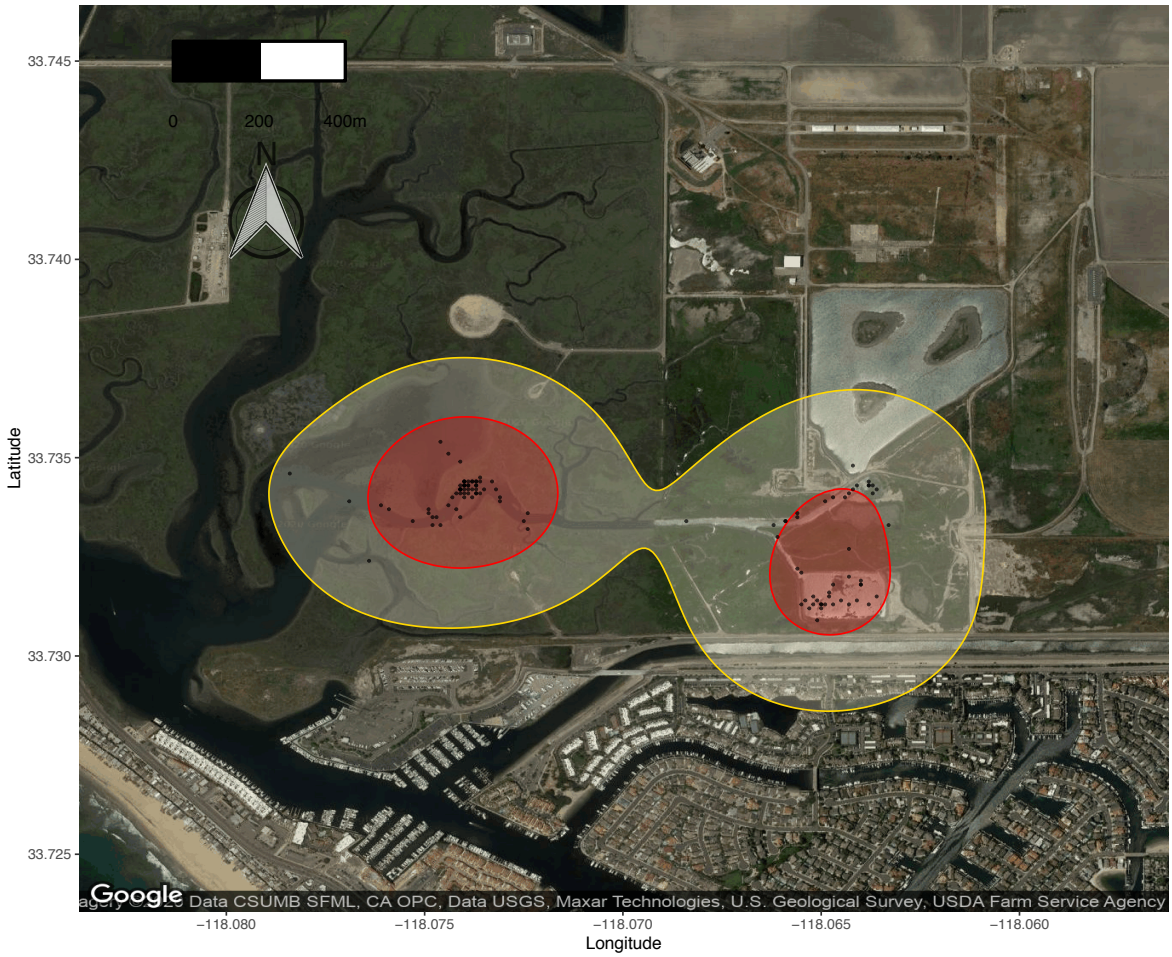

Figure S14. Seal Beach National Wildlife Refuge and Anaheim Bay Home Range for Tag ID 182988

Figure S15. Seal Beach National Wildlife Refuge and Anaheim Bay Home Range for Tag ID 182989

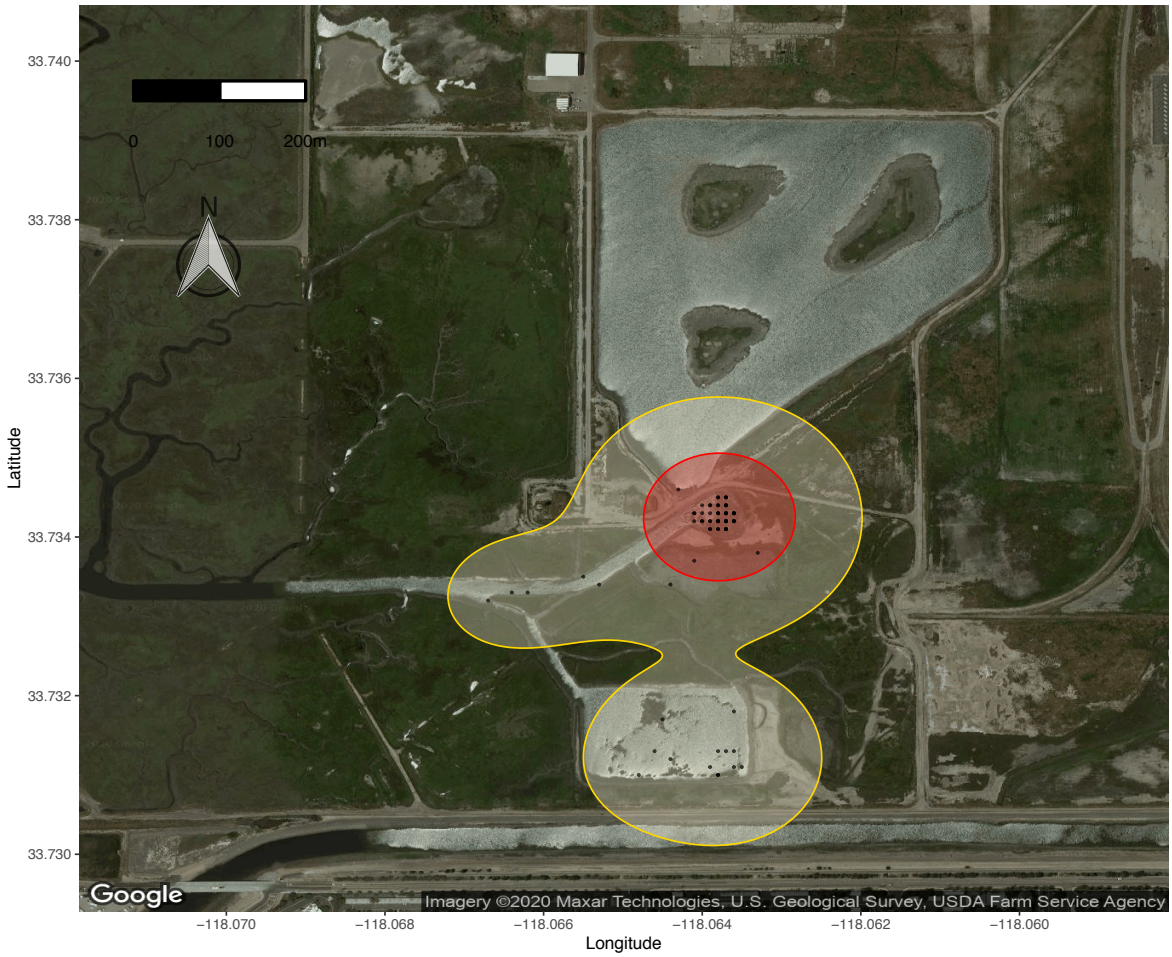

Figure S16. Seal Beach National Wildlife Refuge and Anaheim Bay Home Range for Tag ID 182990

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