DATA REPORT FOR SPECIAL STUDY: WHITE CROAKER FISH TRACKING STUDY PHASE 1

PORT OF LOS ANGELES AND PORT OF LONG BEACH LOS ANGELES COUNTY, CALIFORNIA

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ACRONYMS AND ABBREVIATIONS

AIC	Akaike Information Criterion
AMEC	AMEC Foster Wheeler
ANCOVA	Analysis of covariance
ANOVA	Analysis of variance
avg	average
°C	degrees Celsius
χ^2	Chi-square test
C. capitata	*Capitella capitata*
CAP	canonical analysis of principle coordinates
cm	centimeters
CSULB	California State University, Long Beach
D	Fractal dimension
dB	decibels
DDT	dichlorodiphenyltrichloroethane
df	degrees of freedom
diam.	diameter
DO	dissolved oxygen
EPA	United States Environmental Protection Agency
g	gram(s)
GAM	general additive model
GIS	geographic information system
GLM	general linear model
GPS	global positioning system
hr(s)	hour(s)
HSI	habitat selection index
IDW	inverse distance weighted interpolation
kHz	kilohertz

km^2	square kilometers
KUD	kernel utilization distribution
LA	Los Angeles, California
LA-LB	Los Angeles and Long Beach Harbor complex
LAIH	LA inner harbor
LAOH	LA outer harbor
LB	Long Beach, California
LBIH	LB inner harbor
LBOH	LB outer harbor
m	meter(s)
m/s	meters per second
m^2	square meters
MCMC	Markov Chain Monte Carlo
mg/L	milligrams per liter
min	minute(s)
MKDE	Movement based Kernel Density Estimator
mm	millimeters
ms	milliseconds
MS-222	Tricane Methanosulfate
µm	micrometers
OEHHA	California’s Office of Environmental Health Hazard Assessment
PCBs	polychlorinated biphenyls
PDS II	polydioxanone suture (Ethicon)
PERMANOVA	Permutational Multivariate Analysis of Variance
POLA	Port of Los Angeles
POLB	Port of Long Beach
PV shelf	Palos Verdes Shelf
PVS EPA	EPA Palos Verdes Shelf

ROM	rate of movement
± SD	standard deviation
SCB	Southern California Bight
SIMPER	similarity percentages
TMDL	total maximum daily load
TOC	total organic carbon
TSS	total suspended solids
WC	White Croaker

1.0 INTRODUCTION

The Port of Los Angeles and Port of Long Beach Harbor TMDL has presented the need to predict the most effective means to meet sediment quality objectives and total maximum daily load targets due to the size and feasibility associated with sediment remediation for such a large area. The Port of Los Angeles and Port of Long Beach are adjacent to the Palos Verdes Shelf (PV Shelf), an Environmental Protection Agency (EPA) Superfund site, which remains to be one of the largest historical dichlorodiphenyltrichloroethane (DDT) disposal sites worldwide (Schiff, 2000; Schiff et al., 2000). Prior to the ban in the 1970s, the former Montrose Chemical Corporation discharged DDT to the Palos Verdes Shelf via the wastewater treatment plant outfall at White Point (Schmidt et al., 1971). Contaminated surface water originating from the Montrose Chemical Corporation Plant also entered storm water drainage ditches, which eventually emptied into the Torrance Lateral that connects to the Dominguez Channel where the contaminants were carried into the Consolidated Slip (also an EPA Superfund site) in the northern reaches of Los Angeles Harbor (Innovative Technical Solutions, 2010; California Regional Water Quality Control Board Los Angeles Region 9 USEPAR, 2011). Apart from the historical legacy contaminants, other contaminants (including polychlorinated biphenyls [PCBs]), continue to enter the Los Angeles and Long Beach Harbor complex (LA-LB) through watersheds, storm water runoff, industrial outfalls, and atmospheric deposition from the greater Los Angeles area and from commercial and recreational activities within the Harbor (Port of Los Angeles and Port of Long Beach, 2009; California Regional Water Quality Control Board Los Angeles, 2011).

1.1 PROJECT RATIONALE

DDT and PCB contamination is of particular concern as these contaminants have low biodegradability and are lipophilic, which allows these contaminants to persist in sediments for decades and bioaccumulate trophically in marine organisms (Young et al. 1977). These contaminants have adverse effects on marine organisms and pose a human health risk if contaminated organisms are consumed (Colborn et al., 1993; Longnecker et al., 1997). Due to the negative effects associated with human consumption of organochlorines, a consumption advisory for many fish species within the Southern California Bight (SCB) has been established by California's Office of Environmental Health Hazard Assessment (OEHHA) (Klasing et al., 2009). Bioaccumulation models have been used to better understand the mobilization of contaminants through water and sediment into marine organisms in order to aid in remediation and management decisions. An in-depth linked hydrodynamic/bioaccumulation model is currently being developed for the LA-LB Harbor which aims to use "fate-and-transport" model predictions of sediment and water contaminant concentrations for various remedial scenarios to predict fish tissue contaminant concentrations over time. Additionally, the model aims to predict the time scale of which it will take fish tissue concentrations for each remedial scenario to decline below the total maximum daily load (TMDL) target (Anchor QEA, 2013).

One fish species of interest for the LA-LB Harbor bioaccumulation model is the white croaker (*Genyonemus lineatus*). White croaker are a sentinel fish species for contamination studies due to their direct interaction with contaminated sediments through benthic foraging (Ware, 1979; Love et al., 1984; Malins et al., 1987) and are a species monitored by the current Harbor TMDL. Presently, due to the high PCB and DDT concentrations in white croaker along the SCB, OEHHA has recommended that no white croaker from Santa Monica Pier to Seal Beach Pier should be consumed (Pollock et al., 1991; Klasing et al., 2009). Despite posted advisories for the species, subsistence fishers continue to catch and consume white croaker from local fishing piers within the LA-LB Harbor (Gossett et al., 1983; Allen et al., 1996; Jonick et al., 2010).

White croaker caught within the LA-LB Harbor have been shown to have highly variable levels of organochlorine contamination which do not reflect sediment contamination concentrations in the area in which the fish were caught (Gossett et al., 1983; Malins et al., 1987; Brown et al., 1998; Anderson et al., 2001). This discrepancy when used in bioaccumulation models complicates and potentially invalidates model estimates for fish contamination uptake. Although many bioaccumulation models have included white croaker (HydroQual, 1997; Connolly and Glaser, 2002; Glaser and Connolly, 2002; Gobas and Arnot, 2010), none of these models incorporated empirically derived movement data for this species. Thus, an accurate quantification of white croaker movements and habitat use is needed to determine where these fish may be foraging and subsequently acquiring contaminants. Additionally, quantifying white croaker habitat selection can be a useful tool to incorporate into predictive models to estimate the species' spatial response to changing environmental conditions in the Harbor (Rubec et al., 1997; Rubec et al., 1998; Guisan and Zimmermann, 2000).

Previous knowledge of white croaker movements has mostly been derived from catch data (e.g., recreational hook & line landings, and otter trawl surveys) which provides only static measures of habitats potentially utilized by white croaker. The overall focus of this special study was to quantify white croaker movement patterns, degree of site fidelity, activity space, habitat use, and migration patterns of white croaker to the two Superfund sites the PV Shelf and Consolidated Slip.

1.2 PROJECT GOALS AND OVERALL APPROACH

The specific goals of the project were to:

- Quantify the fine-scale movement patterns and habitat use of white croaker tagged in the Los Angeles and Long Beach Harbors.
- Characterize the longer-term movements and site fidelity of white croaker in the Long Beach Harbor over a one year period (addressed in Phase II report).
- Determine the degree to which fish tagged in the Long Beach and Los Angeles Harbor leave the outer Harbors and enter the Consolidated Slip or the Palos Verdes Shelf Area (addressed in Phase II report).
- Coordinate research and data analysis between the EPA funded study of fish movements and the POLA funded study (addressed in Phase II report).

To accomplish these goals, we used a combination of passive and active acoustic telemetry techniques to monitor and quantify movement patterns for white croaker over a 1-year period. Long-term, coarse-scale movements of white croaker were quantified for 99 fish using 12 omnidirectional acoustic receivers deployed throughout the Port of Los Angeles and Port of Long Beach for 1 year from August 2011- August 2012 (addressed in more detail in Phase II report). Short-term, fine-scale movements of fish were quantified using active tracking, which consisted of multiple non-consecutive continuous 24-hr fish tracks for a total of 20 individual white croaker within the Harbors.

1.3 PROJECT TEAM

Dr. Chris Lowe of the CSULB Shark Lab was the principle investigator and coordinator for the project. Dr. Lowe along with CSULB graduate students, Bonnie Ahr and Michael Farris were responsible for deployment and maintenance of the acoustic receiver array, active fish tracking, fish capture and tagging, data maintenance and analysis.

2.0 METHODS

2.1 STUDY LOCATION

The study was conducted within the Los Angeles and Long Beach Harbors (Figure 1), located in Los Angeles County, California (33°43′45″ N, 118°15′43″ W). The harbor complex includes 55 km^2 of subtidal habitat and subsequently is one of the busiest port complexes in the world. The Harbor is sheltered from wave energy by the surrounding Federal breakwater. The breakwater contains two wide entrances into the Harbor allowing some tidal exchange at Angel's Gate (700 m wide) (Port of Los Angeles [POLA]) and Queen's Gate (500 m wide) (Port of Long Beach [POLB]). The entire east side of the Long Beach Harbor opens directly to Eastern San Pedro Bay and this area as well as the harbor gates provides tidal flow into and out of the Harbor. The Harbor also contains several inputs from the greater LA and LB watershed, which can carry both nutrients and contaminants into the Harbor. These inputs include the Dominguez Channel which drains near the Consolidated Slip (POLA), the Terminal Island Treatment Plant which drains near Pier 400 (POLA), the Los Angeles River which connects to the San Pedro Basin (POLB), and numerous storm water drains throughout both ports.

The inner Harbor is composed of constrained shallow waterways whereas the outer Harbor includes open, deeper areas more affected by tidal movement. The habitat within the harbor also varies regionally in bathymetry, sediment contamination, amount of structure, shipping and boating traffic, and fishing pressure. To account for these differences which were expected to affect white croaker behavior, the study site was divided between the inner and outer harbor regions for POLA and POLB yielding four harbor regions among which data were compared.

2.2 TRACKING TECHNOLOGIES

2.2.1 CAPTURE AND TAGGING

Between March 2011 and April 2013, 119 white croaker were tagged for the purpose of this study. Fish were captured within the harbor using baited hook and line. Following capture, disposition of the fish was assessed, and if determined to be in good condition the fish was kept for tagging, otherwise it was released immediately. Fish kept for tagging were anesthetized in a bath of chilled seawater and Tricane Methanosulfate (MS-222, 100 mg/L) for 3-5 min. Fish were then weighed, measured, and surgically implanted with an acoustic transmitter (Vemco V9-1L; 21 mm x 9 mm, 2.9 g in air, power output 146 dB). Sex of fish was noted when either eggs or milt were observed, but could not be determined otherwise. A 2 cm incision was made on the ventral surface of the abdomen, through which the transmitter was inserted into the the peritoneal cavity. All transmitters were coated in a mixture of paraffin and beeswax (2.3:1) to reduce immunorejection by the fish (Lowe et al., 2003). The incision was then closed with two interrupted sutures (chromic gut or PDS II), and the fish was allowed to recover in a bath of fresh seawater. Following recovery, tagged fish were released at the site of capture.

The total tagging effort was divided as evenly as possible between the four designated regions of the harbor.

2.2.2 FINE-SCALE SHORT-TERM MOVEMENTS

In order to characterize the short-term movements of white croaker within the harbor, 20 of the 119 white croaker tagged for this study were fitted with a transmitter designed for active tracking, divided equally among the four harbor regions. These transmitters used a constant pulse interval (2000 ms) and had a manufacturer-estimated battery life of 35 days. Individual tagged white croaker were actively tracked for multiple, non-continuous 24 hr periods using a 5 m Boston Whaler Alert equipped with an onboard tracking receiver (Vemco VR100) and a gunwhale-mounted direction hydrophone (Vemco VH110) (Lowe, 2003; Mason & Lowe, 2010). Locations of white croaker during active tracking were manually recorded at 10 min intervals using a handheld GPS unit (Garmin GPSmap 76Cx) to determine coordinates. Signal strength and water depth were also recorded at 10 min intervals during active tracking. Only positions with signal strengths greater than 75 dB on gain of zero were used for data analysis in order to provide the most accurate position estimates for the fish. Active tracking was performed throughout the year during the course of this study.

2.2.3 TRANSMITTER DEPLOYMENT FOR LONG TERM MONITORING

White croaker were caught using hook and line throughout four regions of the LA and LB Harbor: LA outer harbor (LAOH), the LA inner harbor (LAIH), the LB inner harbor (LBIH), and the LB outer harbor (LBOH) (Figure 1). Equal numbers of white croaker were tagged within each region (25 per region except LBIH where n = 24) to examine fish movements within and among regions, especially among regions with high sediment contamination and regions with public fishing piers. Ninety-nine white croaker were surgically implanted with coded acoustic transmitters (Vemco, V9-1L, 24 mm long x 9 mm diam., 3.6 g in air, 2.2 g in water, pulse interval 30-90 sec, battery life 153 days, power output 145 dB, 69 kHz) during a summer (2011) and winter (2012) tagging event in all four regions of the LA-LB Harbor. Due to the battery life of the transmitters, two tagging events were used in order to capture an entire year of fish movement.

2.2.4 RECEIVER ARRAY AND RANGE TESTING

Twelve omnidirectional underwater acoustic receivers (Vemco VR2W receivers) were deployed throughout the Harbor in shipping channels and were designed to act as “gates,” which allow for determination of the direction of fish movement between receivers and harbor regions (Figure 1). The receivers were positioned approximately 1 m off the seafloor deployed on subsurface moorings or were suspended from existing dock structures. Two receivers (Harbor_12 and Harbor_13) were attached to existing moorings at 5 m depth. All receivers were deployed in August 2011 except for Harbor_13, which was deployed in January 2012. Each receiver also was equipped with a temperature data logger set to record seafloor temperatures every hour (Onset Computer Corporation, Pocasset, MA). Receivers recorded time, date, and unique ID code for each fish when within receiver range. Receivers and data loggers were deployed for one year and were downloaded monthly. Each receiver was range tested to determine detection range which varied based on observable obstructions and harbor location (Figure 2). Additional data were obtained from receivers deployed at the harbor gates for the concurrent EPA PV Shelf fish tracking study (Lowe, 2013; Wolfe, 2013).

2.3 DATA ANALYSIS

2.3.1 DAILY SPACE USE

Daily space use of white croaker was calculated in R v. 3.0.2 (R Foundation for Statistical Computing). The extent of space used during each 24 hr tracking period by white croakers were calculated using the Movement-based Kernel Density Estimator (MKDE)(Benhamou 2011). This analysis uses a biased random bridges approach to interpolate between successive animal relocations in order to quantify the size and characterize the shape of the area used by that animal during a specific tracking period. The 95% isopleth was chosen to represent space use for each tracking period. This analysis was selected as it is more accurate in tightly-bounded environments (such as the constraints of the Harbor) than a traditional Kernel Utilization Distribution (KUD). Any active tracking period lasting less than 24 hrs was not included in analysis of daily space use.

2.3.2 RATE OF MOVEMENT

Rate of movement of white croaker was also calculated in R v. 3.0.2 using the package adehabitatHR. The successive relocation points from each active tracking period were first converted into a trajectory file. These trajectory files were then deconstructed to give the distance traveled, time elapsed, and turning angle of each step length in the path recorded during the active track. Rate of movement was then calculated as the distance traveled (in meters) between each pair of relocations divided by the time elapsed (in seconds) between each pair of relocations.

2.3.3 TORTUOSITY

Tortuosity for day and night periods for each fish track was calculated using Fractal dimension (D). The fractal D value measures how tortuous a movement path is; a value of 1 indicates a straight movement path whereas a value of 2 indicates a movement path so tortuous that it completely covers a 2-dimensional plane (Nams, 1996; Papastamatiou et al., 2011). Areas of high tortuosity may represent times and location of benthic foraging or refuging, whereas periods of low tortuosity may be indicative of moving between foraging patches or refuging locations. Fractal D is calculated using the divider method where path length is described as $L(G) = kG^{1-D}$, where $L(G)$ is path length, k is a constant, and g is the divider size. Fractal analysis was performed using FRACTAL ver. 5.2 (V. Nams, Nova Scotia Agricultural College). Diel differences in tortuosity were determined using a paired t-test in R.

2.3.4 HABITAT SELECTION INDEX

A habitat selection index (HSI) was calculated based on white croaker active tracking data coupled with habitat maps for grain size, sediment TOC, substrata type, known dredged locations, benthic infauna density, polychaete/crustacean density, and polychaete density. The HSI calculation combined all data for all individuals to create a population-wide analysis. This was done by dividing the percent of each habitat category used by the percent of each habitat category available within the Harbor. The percent of habitat used was calculated as the proportion of fish positions within each habitat type divided by the total number of positions. Total harbor habitat available encompassed the northern reaches of the harbor south to the Federal Breakwater and extended from Cabrillo Beach to Queen’s Gate (the four harbor regions) (Figure 1). Harbor habitat area did not include the Eastern San Pedro Bay, east of Queen’s Gate. HSI values of 1 indicated no selection, a value > 1 indicated habitat selection, and values < 1 indicated assumed avoidance of habitat type (Manly et al., 2002; Lowe et al., 2003; Topping et al., 2005). Overall habitat selection as well as daytime and nighttime selection of habitat was examined. Diel differences in habitat selection were calculated for polychaete density with a paired t- test in R. The area of each habitat and number of fish positions inside each habitat was calculated in ArcMap. Ratios of habitat categories used/habitat categories available were compared using a Pearson's chi square test.

2.3.5 HABITAT MAPS

Bathymetry, grain size, sediment total organic carbon, and benthic polychaete density raster surfaces were created using ArcMap in ArcGIS 10.1. All maps were created using an inverse distance weighted (IDW) interpolation in order to account for the complex shape of the Harbor. The outline of the Harbor complex was used as a boundary for all IDW interpolations, preventing interpolated of values across land masses within the Harbor. All maps were created using natural breaks in the data for 5 categories except for the bathymetry surface which was binned according to the Ports Water Resource Action Plan (WRAP) model. All final maps were created using the California V State Plane meters projection. Maps including station locations are provided in Figures 3 - 5. Grain size and sediment total organic carbon (TOC) maps shared station locations (Figure 4 and 5). Habitat maps of known dredged locations and sediment substrata type were also created using ArcMap.

2.3.5.1 ENVIRONMENTAL AND BIOTIC DATA SOURCES/SETS:

Bathymetry. Bathymetry files were provided by Everest Consulting Inc. Data layers included USACE_Feb2001, USACE_Mar2001, USACE_Oct2002, NOAA 2004, USACE_May2005, USACE_Jul2006, POLA 2007, USACE_Jun2007, USACE_Jan2008, and POLB 2009.

Dredging locations. Dredging data spanned from 1995 to present. Data included Kaiser and San Pedro Boatworks, Southwest Slip Area 1-3, Berth 100 Wharf, 1995 MD, 1995 MD West Basin, 2001 Dredging, Channel Deepening 2003, 2004 MD, Shallow Fill 2004, 2006 MD, Dredge 2004-current, Pier 400 Phase 1 & 2 Channel Dredging, Dredge 9/2002-current, Land 2004-2005, and Land 2004-2006 files. Data files were provided by Anchor QEA, LLC.

Polychaete density. Draft Biological Regional Monitoring Program 2013 data (provided by AMEC) was the most recent benthic polychaete density data available near time of tracking and was used for analyses and interpolated maps. Comparisons of polychaete community composition between years included data from the POLA/POLB 2006 TMDL Sampling (TMDL 2006), Biological Regional Monitoring Program 2008 (Bight 2008), Biobaseline 2008, and draft Biological Regional Monitoring Program 2013 (Bight 2013) data. Benthic infauna community and abundance data was collected using a modified 0.1 m^2 Van Veen grab or box core sampler.

Sediment total organic carbon and grain size. The most recent data available for sediment TOC and grain size within the LA-LB Harbor included data from the Biological Regional Monitoring Program 2008 (Bight 2008) and Weston Solutions Inc. 2011 (Weston 2011) sampling. Sediment samples in both the Bight 2008 and Weston 2011 sampling were collected using a modified 0.1 m^2 Van Veen grab sampler for the top 5 cm of sediment. Bight 2008 grain sizes samples were presorted through 1000 and 2000 μm sieves and then analyzed using light scattering technology (Horiba LA920 instrument). Weston 2011 grain sizes samples were analyzed using sieve and pipette method (Plumb, 1981). Bight 2008 sediment TOC samples were analyzed using an Elemental Analyzer (samples combusted and then separated by gas chromatography) (Schiff et al., 2011). Weston 2011 sediment TOC samples were analyzed using the high temperature combustion method (standard method 5310 B) (Eaton and Franson, 2005).

Substratum type. Substratum type ArcGIS shapefiles (Thiessen polygons) were provided by Everest Consulting Inc. Substratum was quantified from point sediment sampling stations using a 0.1 m^2 modified Van Veen sampler. Substratum descriptions were classified according to the Wentworth Scale. Data included sampling from AMEC 2002, TMDL 2006, and Bight 2008.

POLB ambient water quality. Ambient water quality parameters used for sediment TOC comparisons included water column TOC, dissolved oxygen (DO), transmissivity, total suspended solids (TSS), nitrogen, and salinity. All water column data was from the dry weather water quality monitoring on 14 September 2010 as part of the ambient water quality characterization for the Port of Long Beach. Water quality parameters from the depth closest to the seafloor at each sampling location were used for data analysis. Data was provided by Port of Long Beach.

2.3.6 EUCLIDIAN DISTANCE ANALYSIS

White croaker association to dredged areas was examined using Euclidian distance analysis. The shortest distance of each fish position to the edge of the nearest dredged area was calculated in ArcMap (Mason and Lowe, 2010; Wolfe, 2013). The average distance from all fish positions to dredged areas was then calculated.

2.3.7 FREQUENCY DISTRIBUTION COMPARISONS OF FISH POSITIONS WITHIN EACH HABITAT

The frequency distributions of all observed and expected white croaker positions per habitat category were compared for depth, grain size, sediment TOC, and polychaete density. Expected fish positions were randomly generated in ArcMap using the same number of positions as the observed data (n = 4540), dispersed within areas available to the fish, and displayed over each habitat map. Observed and expected frequency distributions of white croaker positions per habitat type were then compared using a Pearson's chi square test (Mason and Lowe, 2010; Wolfe, 2013). Bin sizes varied for each parameter based on the range of values of the data and were as follows; depth (2 m bins), grain size (20 µm bins), sediment TOC (1% bins), and polychaete density (100 polychaetes per 0.1 m^2 bins). Frequency distributions (100 m bins) were also compared for the Euclidian distance of observed fish positions relative to dredged areas with expected fish positions randomly generated (Mason and Lowe, 2010; Wolfe, 2013). When necessary, bin sizes were increased in order to meet the requirements of the chi square test.

2.3.8 PREDICTIVE HABITAT MODELS

Two predictive habitat use models were created using the results of the habitat selection indexes in ArcMap (Rubec et al., 1997; Rubec et al., 1998; Guisan and Zimmermann, 2000). The first predictive model identified areas which white croaker select for based on sediment characteristics (dredged vs. non-dredged, preferred substrata type, and preferred grain size), sediment TOC, and prey density (polychaete density). A second predictive model was created indicating the likelihood of habitat use based on a combination of selection parameters. In this model, harbor areas which did not contain any of the four parameters white croaker selected for were deemed avoided areas. *Level 1* selection was identified as areas in which any one of the four parameters white croaker select for was present. *Level 2* selection included areas within the harbor that contained at least 2 out of the four selected for parameters, and *level 3* selection included harbor areas where 3 out of the 4 parameters were present.

2.3.9 MIXED EFFECTS MODELS/GENERAL ADDITIVE MODELS

Four sets of mixed effects models and one general additive model (GAM) was used to determine hierarchical habitat selection. The response variables for each set of models were depth, rate of movement (ROM), activity space, and fractal D. The GAM and all mixed effects models were performed using packages *lme4* and *mcgv* in R. Best candidate models were selected based on Akaike Information Criterion (AIC). Probability values and Markov Chain Monte Carlo (MCMC) confidence intervals for the best candidate models were calculated using the *language R* package in R.

Depth-Based Mixed Effects Model. Factors affecting white croaker depth selection were determined using mixed effects models and active tracking positions. Depth estimated from the bathymetry raster map for each fish position was used as the response for the model. Fish depth was assumed to be the same as seafloor depth due to white croaker association to the benthos (Allen and DeMartini 1983). Raster values were used due to only a subset of the active tracking data having corresponding seafloor depth for each fish position. Model factors included harbor location (inner or outer harbor), port (LA or LB), time of day (day or night), and harbor region (LAOH, LAIH, LBOH, and LBIH).

<u>ROM Model</u>. Factors likely affecting white croaker rate of movement (ROM) was determined using a mixed effects model and GAM. A GAM was used with ROM model parameters to determine which factors were likely to be valuable in the ROM model. ROM model parameters included harbor location, harbor region, time of day, polychaete density category (1-5), season, turning angle, grain size (μm), depth (m), sediment TOC (%), and temperature (°C). Each white croaker position was coupled with an estimation of seafloor depth, polychaete density, sediment TOC, and grain size from raster habitat map data. Seafloor water temperature of the data logger attached to the VR2W receiver closest to the location where the fish was actively tracked was aligned by date and hour to fish tracking positions. Temperature was only available for a subset of the active tracking data, thus an additional model containing only a subset of the ROM data was used for temperature models. The best candidate models describing ROM were determined using the results of the GAM model and stepwise elimination.

<u>Activity Space/Tortuosity Model</u>. Mixed effects models were used to determine which factors influenced activity space and tortuosity of white croaker. Two sets of models were generated; one set of models used fractal D as the response, and one set used activity space as the response. Average sediment TOC, depth, grain size, and polychaete density was calculated for each fish track in ArcMap 10.1 and used in both the activity space and tortuosity models. Other parameters included in both models included average ROM and temperature for each track, day length (hours), and season.

2.3.10 ASSOCIATIONS OF ENVIRONMENTAL AND BIOTIC FACTORS

To further understand white croaker habitat selection, associations solely between environmental and biotic factors were examined.

Dredging Area Comparison. To determine potential reasons for fish habitat selection in regards to dredging status (dredged vs. non-dredged); polychaete density, sediment TOC, and grain size were compared inside and outside of dredged areas using station sampling data from Bight 2013 (polychaete) and Bight 2008 and Weston 2011 (sediment TOC and grain size) data. Sediment TOC was compared inside and outside of dredged areas by harbor region using a general linear model (GLM) in Minitab 16. Sediment grain size data could not be normalized and was compared inside and outside of dredged areas using a Mann-Whitney test. Log-transformed polychaete density data was compared inside and outside of dredged areas using a Welch Two Sample T-test. Polychaete community composition was compared inside and outside of dredging areas using a Permutational Multivariate Analysis of Variance (PERMANOVA) in PRIMER 6. PERMANOVA uses permutation methods to simultaneously test the response of one or more variables to one or more factors in an analysis of variance (ANOVA) experimental design and was used to examine differences in polychaete community composition by region within the Harbor (Clarke, 1993). All t-tests and Mann-Whitney tests were performed in R.

Sediment Relationships. Sediment TOC (Bight 2008 and Weston 2011) was compared to interpolated polychaete density (Bight 2013 habitat map) values using a correlation (Figure 6). Interpolated sediment TOC data was compared to available water column data from 2010 POLB sampling using correlations. Available water column data included total organic carbon, dissolved oxygen (DO), transmissivity, total suspended solids (TSS), nitrogen, and salinity. Where applicable the minimum, maximum, average, and recorded value for the deepest depth for each water quality parameter was compared to sediment TOC. Sediment TOC was also compared to grain size using non-linear relationship curves in R. Curve slopes and intercepts were compared using an analysis of covariance (ANCOVA). Additionally, grain size data was compared to interpolated polychaete density values using a correlation. All analyses were performed in R.

Polychaete Associations and Community Analyses. Polychaete abundance (Bight 2013 data) was compared with water depth using a Pearson's correlation in R. Polychaete community composition was compared between harbor regions for Bight 2013 data using Canonical analysis of principal coordinates (CAP), Permutational Multivariate Analysis of Variance (PERMANOVA), and Similarity Percentages (SIMPER) analyses in PRIMER 6 and PERMANOVA+ (Clarke, 1993; Clarke and Gorley, 2006; Anderson et al., 2008). CAP determines axes through multivariate groups of points that have the strongest correlation with some other set of variables (polychaete community and Harbor region). SIMPER analysis calculates the contribution of each species (polychaetes) to the observed similarity (or dissimilarity) between samples (Harbor region). SIMPER applies only to Bray-Curtis similarities and compares two groups of samples at a time (Clarke, 1993; Clarke and Gorley, 2006; Anderson et al., 2008). The most abundant polychaete species per harbor region were compared between TMDL 2006, Bight and Biobaseline 2008, and Bight 2013 data using SIMPER analysis. Regional average abundance of polychaete species (from Bight 2013 data) likely to be current food items of white croaker in the LA-LB Harbor were identified based on previous analyses done by Ware

(1979). Prior to analysis all polychaete community data was transformed using a square root transformation.

3.0 RESULTS

Over the course of the study, a total of 20 white croaker were actively tracked for up to three 24 hr periods. These 20 white croaker were divided evenly among the four Harbor regions so that comparisons could be made regarding short-term behavior among different parts of the Harbor. Mean total length and age (± SD) of white croaker tagged for active tracking ($n = 20$) was 242 ± 21 mm (range: 214-298 mm) and 7.3 ± 3 years (range: 3.3-14.6 years) respectively (Figure 7; Table 1) (Love et al., 1984).

3.1 DAILY SPACE USE

Daily area use for all white croaker actively tracked in the harbor averaged 94,720 ± 78,720 m^2 and daily space use was not found to correlate with size of white croaker. Daily area use averaged 164,160 ± 85,960 m^2 in the outer Los Angeles Harbor (Figures 8-12), 41,820 ± 19,810 m^2 in the inner Los Angeles Harbor (Figures 13 -17) 102,950 ± 64,670 m^2 in the inner Long Beach Harbor (Figures 18-22), and 90,800 ± 91,310 m^2 in the outer Long Beach Harbor (Figures 23 - 27), and was found to differ significantly among harbor regions (ANOVA with Tukey's HSD, $F_3 = 4.982$, $p < 0.01$), with area use being significantly smaller in the inner LA region than the outer LA region ($p < 0.01$) (Figure 28). The size of the areas used was significantly greater during the daytime periods than during the nighttime periods (Paired t-test, $t = 2.99$, $p < 0.01$).

3.2 RATE OF MOVEMENT

Rate of movement was highly variable, both within and among tracking periods, averaging 0.067 ± 0.074 m/s across all active tracking periods. Rate of movement varied significantly among regions (Kruskal-Wallis $\chi^2 = 156.9456$, df = 3, $p < 0.001$), with average rate of movement recorded in the inner LA harbor (0.052 ± 0.062 m/s) significantly lower than all other harbor regions. Rate of movement in the other three regions averaged 0.081 ± 0.074 m/s for the outer LA harbor, 0.078 ± 0.074 m/s for the inner LB harbor, and 0.064 ± 0.068 m/s for the outer LB harbor. Significantly higher rates of movement were recorded during day time (0.071 ± 0.071 m/s) than during night time (0.061 ± 0.062 m/s) (Mann-Whitney test, $p < 0.01$).

3.3 TORTUOSITY

White croaker tortuosity per track between night and day periods did not significantly differ (Paired t-test, $t = -0.0712$, $p = 0.9438$). Mean white croaker tortuosity per track (± SD) during the day was 1.45 ± 0.16 (range: 1.15-1.96) and was 1.45 ± 0.2 (range: 1.09-1.94) at night.

3.4 HABITAT SELECTION

Sediment Selection. White croaker selected for sediment grain sizes < 23.5 µm and avoided larger grain size sediments ($\chi^2 = 161$, df = 4, $p < 2.2 \times 10^{-16}$) (Figure 29). White croaker selected grain sizes ≤ 20 µm disproportionally more often than would be expected based on random movements ($\chi^2 = 523$, df = 4, $p < 0.005$). These grain sizes correspond to medium silt and finer (silt and clay) on the Wentworth substrate scale. HSI of available substrata indicated white croaker select for areas of fine silt and very fine silt which constitutes most of the harbor apart from LA main channel, Sea Plane Lagoon, LB west basin, and a portion of outer LB Harbor. Significant selection was also observed for coarse clay, which was only available in LAOH ($\chi^2 = 1093$, df =7, $p < 2.2 \times 10^{-16}$) (Figure 30). White croaker also selected for non-dredged areas and were on average 329 m away from dredged areas ($\chi^2 = 663$, df = 1, $p < 2.2 \times 10^{-6}$) (Figure 31). White croaker selection of areas at least 100 m away from dredged areas differed significantly than expected selection based on a random distribution of fish positions ($\chi^2 = 1063$, df =11, $p < 0.005$). Apart from the Cabrillo Marina, Cabrillo Pier, and other shallow water habitat, dredged areas were the only areas where sand was present in the top 5 cm of substrata in the harbor (Figure 29).

Sediment total organic carbon selection. White croaker selected for sediment TOC of 4.8% to the highest available in the harbor (8.1%), which occurs in the LA Consolidated Slip and Cabrillo area ($\chi^2 = 41007$, df = 4, $p < 2.2 \times 10^{-16}$) (Figure 29). White croaker selected areas of sediment TOC of 5% and greater disproportionally more often than would be expected based on random movements ($\chi^2 = 42179$, df =11, $p < 0.005$).

Prey Availability Selection. The best predictor of white croaker habitat selection based on prey availability was polychaete density. Total benthic infauna density and polychaete/crustacean density was also compared to white croaker active tracking data but were weaker predictors of white croaker habitat selection. Thus, only polychaete density was used in all further analyses. White croaker selected for areas with estimated polychaete densities of 406-700 polychaetes/0.1 m^2 (category 4) overall and for day and night periods (Overall: $\chi^2 = 3201$, df = 4, $p < 2.2 \times 10^{-16}$; Day: $\chi^2 = 1541$, df = 4, $p < 2.2 \times 10^{-16}$; Night: $\chi^2 = 1733$, df = 4, $p < 2.2 \times 10^{-16}$) (Figure 29; Figure 32). Areas within the harbor which include polychaete densities of 406-700 polychaetes/0.1 m^2 were found in LA Consolidated Slip, LA Fish Harbor, and inner Long Beach Harbor. White croaker selected areas with estimated polychaetes densities from 300-600 polychaetes/0.1 m^2 disproportionally more often than would be expected based on random movements ($\chi^2 = 2054$, df = 5, $p < 0.005$) (Figure 29). Sea Plane Lagoon in LAOH was identified as a possible outlier, as this was the only area in the LA-LB Harbor to have polychaete densities over 700 polychaetes/0.1 m^2 (identified by a single grab sample). To ensure white croaker habitat selection of areas with 406-700 polychaetes/0.1 m^2 was not affected by the interpolation of this possible outlier, Sea Plane Lagoon was removed from an additional HSI. The removal of Sea Plane Lagoon from analysis was not significantly different than the original HSI and indicated white croaker selected for the polychaete category from 406-700 polychaetes/0.1 m^2 ($\chi^2 = 2967$, df = 3, $p < 2.2 \times 10^{-16}$).

3.5 MIXED EFFECTS MODELS/GENERAL ADDITIVE MODELS

Depth Mixed effects model. No significant difference was observed between interpolated raster depths and depths recorded from active tracking, thus raster depths were used for all models as this allowed a larger subset of the data to be used. The best candidate model describing white croaker depth selection included individual actively tracked fish, fish track (first, second, third), and an interaction between time of day and harbor region (Table 2). White croaker exhibited a diel shift in depth selection and on average occupied shallower depths at night than during the day. The shallowest depths used by white croaker were within LAIH and the deepest depths used were in LAOH. This did not necessarily coincide with the average depth per region; however, there was high variability for depth within each region (Figure 33). Parameters in the best candidate depth model with MCMC estimates are provided in Table 3. Additionally, white croaker selection for depths 7-11 m and 13-15 m differed significantly than expected selection based on a random distribution of fish positions ($\chi^2 = 2314$, df =11, $p < 0.005$) (Figure 33).

ROM Model. Results of the GAM indicated that time of day, polychaete density category, season, turning angle, grain size, and an interaction between time of day and polychaete density category would be important factors influencing white croaker ROM (Table 4). Despite all of the parameters included in the model, a key element appeared to be absent since the deviance explained from the GAM was only 6.9%. Seafloor water temperature did not improve the performance of the ROM model nor was a significant factor in the GAM. Therefore, temperature was excluded from the final models to allow a larger subset of the tracking data to be incorporated into the model. Additionally, fish weight and length did not improve model performance and were also excluded from final models.

The three ROM models which were close competitors for the best candidate model included the same parameters except for harbor location (inner or outer harbor) and season. The GAM indicated season to be an important factor but did not identify harbor location as an important predictor of ROM. Thus, the best candidate model is assumed to be the model which excludes harbor region and includes season even though this model was not the most parsimonious out of the other candidate models (Table 5). The model best describing ROM included individual fish, turning angle, estimated depth of fish, season, with an interaction between time of day and polychaete density category (Table

6). The model estimated that rate of movement increased during the night (by an estimated 0.005 m/s) and increased as depth decreased (by an estimated 0.0026 m/s). The highest ROM was observed in fall and spring and was the lowest in the summer and winter. An interaction between ROM and time of day and polychaete density category was also observed (Table 6).

Activity space. Temperature did not improve model performance for either set of activity space or tortuosity models and was excluded from final models to allow a larger subset of the data to be used. Factors affecting white croaker activity space were not explicitly clear as many models were similar in AIC values. The best candidate model with the fewest parameters describing activity space included individual fish, time of day, grain size, sediment TOC, and depth (Table 7). In this model, activity space was larger during the day than at night. Activity space was increased with increasing grain size and sediment TOC, and increasing depth. Additionally, activity space increased with increasing ROM.

Tortuosity model. The best model describing tortuosity included time of day, individual fish, harbor location, depth, day length, an interaction between activity space and ROM, and an interaction between grain size and sediment TOC (Table 8). Tortuosity was higher during the day (versus night) and increased as day length increased. Higher tortuosity was observed with decreasing activity space and decreasing rate of movement. Tortuosity also increased with increasing grain size, increasing sediment TOC, and increasing depth and was higher in the outer harbor (versus inner harbor). Even though white croaker were found more often in areas with small sediment grain size (< 23.5 µm), individuals still transverse through areas with higher sediment grain sizes. The estimated probability values and MCMC confidence intervals are provided in (Table 9).

3.6 PREDICTIVE HABITAT USE MODELS

A predictive model was created identifying areas which white croaker are expected to select for based on sediment grain size, sediment TOC, and prey density. Characteristics used to determine areas of sediment selection included non-dredged areas, fine silt, very fine silt, coarse clay, and grain sizes < 23.5 µm. Sediment TOC selection consisted of areas within the harbor where sediment TOC was 4.8% or higher and prey density consisted of areas with polychaete densities between 406-700 polychaetes/0.1 m^2 (Figure 34).

A second predictive model was created indicating the likelihood of habitat use based on a combination of the four selection parameters; dredged areas, grain sizes of < 23.5 µm, sediment TOC between 4.8-8.1%, and polychaete densities between 406-700 polychaetes/0.1 m^2. Harbor areas of level 1, 2, and 3 selections including predicted areas avoided by white croaker are presented in Figure 34. No area within the harbor contained all four parameters. Areas of expected high white croaker habitat use include Consolidated Slip (LA), Fish Harbor (LA), and LB inner harbor. Areas avoided included the LA main channel and portions of LB's West Basin.

3.7 ASSOCIATIONS OF ENVIRONMENTAL AND BIOTIC FACTORS

Dredging Area Comparison. Polychaete density (Bight 2013 data) did not differ significantly inside and outside of known dredged areas (t-test, $t_{28} = -0.47$, $p = 0.64$). Polychaete densities ranged from 69-318 polychaetes per 0.1 m^2 within dredged areas and

37-1014 polychaetes per 0.1 m^2 within non-dredged areas. Polychaete densities within non-dredged areas corresponded to the range of polychaete densities in areas where white croaker most frequently selected (400-700 polychaetes per 0.1 m^2). Polychaete community composition was significantly different between dredged versus non-dredged areas, harbor region, and dredging condition x harbor region (PERMANOVA, Dredged vs. non dredged: Pseudo-F = 2.3, p = 0.01; Harbor Region: Pseudo-F = 1.8, p = 0.004; Harbor Region x Dredging condition: Pseudo-F = 1.7, p = 0.017).

Sediment TOC varied significantly inside and outside of dredged areas, by region, and by region x dredging condition. Sediment TOC was significantly higher in non-dredged areas vs. dredged areas and was highest in LAIH (GLM: Region: F = 6.37, p = 0.001; Dredging Condition: F = 15.64, p = 0.000; Region x Dredging Condition: F = 4.58, p = 0.005).

Sediment grain size did not differ significantly inside and outside of dredged areas (Mann-Whitney, W = 966, p = 0.14). The range of grain sizes available was larger in dredged areas (6.7-388.5 µm) versus non-dredged areas (2.26-168.47 µm), but was not significant.

<u>Sediment TOC Comparisons</u>. No significant correlations were found between sediment TOC (interpolation using Bight 2008 and Weston 2011 data) and water column parameters (POLB 2010) including total organic carbon, dissolved oxygen, transmissivity, total suspended solids, nitrogen, and salinity (Water column TOC: p = 0.86, r = 0.06; DO: p = 0.58, r = -0.21; Transmissivity: p = 0.15, r = -0.51; TSS: p = 0.12, r = -0.55; Nitrogen: p = 0.61, r = -0.20; Salinity: p = 0.62, r = 0.20). Additionally,

sediment TOC was not significantly correlated with polychaete density (Bight 2013 data) ($p = 0.73$, $r = -0.036$).

Grain size comparisons. Sediment TOC and grain size for Bight 2008 and Weston 2011 data were found to have a non-linear relationship (Figure 35). Sediment TOC was highest at areas with smaller grain sizes and decreased as grain size increased. The equation best describing this relationship was $y = 1/x$. Year and covariate differed significantly; however, the interaction between grain size and year was not significantly different (ANCOVA, Grain size: $F_1 = 8.7$, $p = 0.004$; Year: $F_1 = 6.175$, $p = 0.014$; Grain size x Year: $F_1 = 0$, $p = 0.99$). This indicates similar slopes between the two curves, but varying intercepts. The similarity in slope between years for grain size and sediment TOC supported combining these datasets to provide a more complete interpolated surface for grain size and sediment TOC. No significant correlation was found for polychaete density (2013 data) and grain size ($p = 0.63$, $r = -0.05$).

Polychaete Community Analysis. Benthic infauna and polychaete community composition was compared between 2006 and 2008 and indicated a shift in benthic community structure between years. Benthic infauna community composition significantly differed between years (2006 and 2008) and harbor region (PERMANOVA, Year: Pseudo-F = 11.6, $p = 0.001$; Region: Pseudo-F = 2.83, $p = 0.001$, Year x Region: Pseudo-F = 1.28, $p = 0.04$). Polychaete community composition also varied significantly between years (2006 and 2008) and harbor region (PERMANOVA, Year: Pseudo-F = 11.13, $p = 0.001$; Region: Pseudo-F = 3.32, $p = 0.001$, Year x Region: Pseudo-F = 1.33, $p = 0.04$). Thus only the most recent data (Bight 2013) was used for comparison with fish movement data.

Polychaete abundance and depth were significantly negatively correlated (t = -4.04, df = 28, r = -0.607, p = 0.0003) (Figure 36). Polychaete community composition for Bight 2013 data varied significantly between the LAOH and LBOH as well as LAIH and LBOH, but did not differ between other regions (PERMANOVA, T=1.41, p = 0.01; T=1.72, p = 0.00 respectively)(Table 10, Figure 37). Within regions, similarity of polychaete community composition between stations ranged from 30.4-43.9%. The highest similarity was within the same region (LBIH, 43.9%), whereas the lowest similarity was between LAIH and LBOH (27.7%) (Table 11). Polychaete community composition tables, listing species and average abundance of each were created for each region (Tables 12 – 15). Additionally, regional comparisons of species contributing to dissimilarity between regions were constructed (Tables 16 – 21). The top polychaete species of relative abundance and similarity within each region varied among regions and by year. The most abundant polychaete species in LAOH, LBOH, and LBIH in 2006 was *Cossura sp.*, while the most abundant species in LAIH was *Spiophanes berkeleyorum*. The polychaete species exhibiting the highest relative abundance and regional similarity shifted for each region between 2006, 2008, and 2013. In 2013, the most abundant polychaete species shifted back to *Cossura sp.* in the outer harbors (LAOH and LBOH) and shifted to *Euchone limnicola* in LAIH and *Mediomastus sp.* in LBIH (Table 22). The following polychaete species are most likely prey items of white croaker in the harbor based on previous diet analysis: *Cossura sp*, *Mediomastus sp*, *Prionospio multibranchiata*, and *Spiophanes berkeleyorum* (Ware, 1979). Relative abundance of *Cossura sp* and *Spiophanes berkeleyorum* were higher in the inner harbors, while *Prionospio multibranchiata* abundance was higher in the outer harbors (Table 23).

3.8 LONG TERM-COARSE SCALE MOVEMENT

Receiver Efficiency. Estimated total receiver range area on average was 44,268 m^2 and ranged from 32,350 m^2 (Harbor_06) to 70,700 m^2 (Harbor_13) depending on conditions (Table 24, Figure 1). Detection efficiency within a 350 m radius of each receiver ranged from 12-100%. Receiver stations Harbor_01 and Harbor_09 had the lowest detection efficiencies (12%), whereas Harbor_03, Harbor_06, Harbor_12, and Harbor_13 had the highest detection efficiencies (86-100%). Remaining receiver detection efficiency ranged from 27-61%.

3.9 LONG-TERM MOVEMENT DATA

Mean total length and age (± SD) of white croaker tagged for passive tracking (n = 99) was 252 ± 21 mm (range: 201-315 mm) and 8.6 ± 2.6 years (range: 3.4-16 years) respectively (Figure 7, Table 25) (Love et al., 1984). White croaker capture locations were spatially concentrated at the Consolidated Slip in LAIH and the San Pedro Bait Barge in LAOH, but were more dispersed in LBIH and LBOH (Figure 38). Only 93 of the 99 individuals tagged were detected by the receiver array, and the remaining six individuals were omitted from all further analyses due to the likelihood of transmitter malfunction. Based on comparisons between recorded movements and the known maximum sustained swimming speed of white croaker, it was determined that 7 individuals had likely been victims of predation. These 7 individuals were subsequently excluded from any further analyses.

All harbor VR2W receivers (not including EPA study receivers at Angel's and Queen's Gates) detected white croaker from other regions except for Harbor_12 located in Sea Plane Lagoon and Harbor_13 located at the San Pedro Bait Barge (Figure 1). The number of fish visiting each receiver ranged from 7 to 46 individuals over the course of the 1-year receiver deployment (Table 24; Figure 39). Receivers located in Consolidated Slip (POLA) and the San Pedro Bait Barge (POLA) had the highest average detections per fish (# detections/fish), whereas the receiver in Sea Plane Lagoon (Harbor_12) had the lowest number of detections (# detections/fish) and fish visiting the station (# fish/station) over the course of the study (Table 24; Figure 40). Only 19 of the 93 white croaker tagged for passive tracking (20.4%) were detected at Angel's Gate, and 10 of 93 fish (10.8%) were detected at Queen's Gate (Table 24) over the 1-year monitoring period. White croaker that were detected at the Angel's Gate entrance to Los Angeles Harbor had very few subsequent detections, indicating the fish did not remain within receiver range for an extended period of time. Further discussion of Phase 1 long-term movement results are provided in comparison to the Phase 2 white croaker movements in the Phase 2 Fish Tracking study report.

4.0 DISCUSSION

4.1 DISCUSSION OF RESULTS OF SPECIFIC GOALS

4.1.1 Goal 1: Quantify the fine-scale movement patterns and habitat use of white croaker tagged in the Los Angeles and Long Beach Harbors.

Similar to what was observed by Wolfe and Lowe (in review) for white croaker on the Palos Verdes Shelf, area use exhibited by white croaker within the Los Angeles and Long Beach Harbor is quite large relative to what has been observed in other demersal fishes tracked within the Southern California Bight. Area use by white croaker over a two to three day period on the Palos Verdes Shelf was found to average 145,530 ± 91,420 m^2

(±SD) (Wolfe and Lowe, in review), which was not significantly different from what was measured in the harbor, averaging 152,090 ± 124,410 m^2 on the same time scale ($t = 0.174$, $p = 0.863$). Short-term (2-3 day period) area use of white croaker is considerably higher than that measured for sand bass (10,003 ± 4773 m^2; Mason and Lowe, 2010), Kelp bass (3,349 ± 3,328 m^2; Lowe *et al*, 2003), California sheephead (5,134 ± 26,007 m^2; Topping *et al*, 2005), and ocean whitefish (20,439 ± 28,492 m^2; Bellquist et al., 2008). It is important to note that area use estimates for white croaker taken over two to three days never reached an asymptote, therefore these area use estimates are not intended to represent home ranges. Indeed, Wolfe & Lowe (in review) asserted that if white croaker are a home ranging species, their home range is likely to be larger than the 20 km^2 area covered by the acoustic telemetry array employed in their study on the Palos Verdes Shelf.

The considerable differences in area use between white croaker and other demersal fishes in the SCB can be explained primarily by life history and habitat association. Lowe and Bray (2006) described a model relating the amount of area used by marine fish both to the habitat with which they are associated and to the strength of that association, in which there is an inverse relationship between home range size and affinity to complex habitat such that species most strongly associated with the most complex habitat will use the smallest amount of area. Area use of demersal fishes in the SCB generally tends to follow this pattern. Kelp bass and sand bass are both ambush predators, with kelp bass being strongly associated with rocky seafloor and kelp, while sand bass show high affinity for sand seafloor near rock/sand ecotone. Sheephead and ocean whitefish are diurnal benthic foragers that hunt for invertebrates across a wider range of rocky and sandy habitats and therefore must venture farther from the rock/sand ecotone in order to find prey, resulting in larger daily activity spaces than either kelp bass or sand bass. White croaker exhibit by far the greatest daily area use among these species and also have the weakest association with complex habitat, and therefor may have to cover more area in search of benthic prey patches. In addition, they show a weak affinity for rock/sand ecotone (~200 m from structure) (Wolfe and Lowe, in review), which suggests that they are not using complex substrata as a refuge from predators. The ecological mechanism driving this relationship is most likely the fact that an animal's home range must be large enough to provide enough food to meet that animal's energetic requirements (McNab, 1963), more complex habitat generally tends to be more productive and yields higher prey density (Heck, Jr. & Wetstone, 1977; Crowder and Cooper, 1982). Therefore, more complex habitat not only potentially offers more prey available at any given time, but due to higher productivity is likely to replenish prey stocks more quickly, thus allowing predators to remain for longer periods of time without needing to shift foraging grounds. Due to the fact that white croaker are associated with less productive sand/mud habitat (Love et al., 1984) and feed primarily on benthic infauna (Ware 1979), they are likely subjected to localized prey depletion which necessitates a spatial shift in habitat in order to avoid recently depleted foraging grounds (Gow and Wiebe, 2015; Wolfe and Lowe, in review). If white croaker do maintain a true home range, it is likely they are large and shift over time to allow locally depleted populations of benthic invertebrate prey to replenish.

Within the harbor, movements of white croaker varied considerably among the different regions. In general, area use was smaller in the inner harbor than the outer harbor, and was smallest in the region of the inner LA harbor known as the Consolidated Slip. Predictably, variations in rate of movement followed the same pattern, also being lower in the inner harbor and lowest in the Consolidated Slip. These metrics of movement are consistent with more resident behavior and more intense habitat exploitation, particularly refuging or foraging behavior, and these patterns indicate that the habitat available in the inner harbor is likely more preferable than the habitat in the outer harbor.

Habitat within the harbor is variable, with sediment grain size tending to be smaller throughout most of the harbor, but larger in the LA main shipping channel and in parts of the outer LB harbor (Ahr et al., in press). Total organic carbon (TOC) in the sediments is also highly variable, tending to be found in elevated levels in non-dredged regions of the harbor, and is highest in the Consolidated Slip (Ahr et al., in press). Abundance of key prey taxa (polychaetes) differs greatly among regions; it is negatively correlated with depth, and tends to be higher in the Consolidated Slip and inner LB harbor than most other areas (Ahr et al., in press). Behaviors indicative of area-restricted searching, such as low area use and low rate of movement, tend to correlate closely with these variations in sediment grain size and TOC. Furthermore the polychaete species *Capitella capitata*, which is known to historically be an important prey species for white croaker (Ware, 1979), has only been found in the Consolidated Slip in recent environmental surveys (Ahr et al., in press). Therefore the tendency of white croaker to use smaller areas in this particular region may be a reflection of the relatively high quality of foraging habitat available within it, which not only allows for greater prey density but may also offer greater productivity, thereby allowing for more consistent foraging opportunities for white croaker.

Harbor white croaker selected for depths of 7-11 and 13-15 m and were less frequently found in depths deeper than 15 m in the harbor, which are also available within the harbor. LA-LB Harbor white croaker depth selection was within the range of depths recorded for the species on the PV Shelf and Dana Point, CA of 3-30 m (Moore, 1998); but selected shallower depths than white croaker tracked on the PV Shelf (avg. = 25-35 m) (Wolfe, 2013). Harbor white croaker also exhibited a diel shift in depth selection and were found in shallower areas at night than during the day, which corresponded to previous trawl data that found white croaker utilize shallower depths at night (Allen and DeMartini, 1983). The difference between Harbor white croaker depth selection and that of white croaker on the PV Shelf could be attributed to the variation in habitats available on the PV Shelf versus the LA-LB Harbor.

White croaker within the LA-LB Harbor selected for areas of the highest sediment organic carbon most likely due to elevated prey availability within these areas. Sediment TOC was highest in areas with smallest grain sizes and decreased rapidly as grain size increased greater than 50 µm. The association between grain size and sediment TOC has been well documented (Horowitz and Elrick, 1987; Bergamaschi et al. 1997) and similar results have also been found in areas highly impacted by anthropogenic activities such as Tokyo Bay and the Yangtze River where sediment TOC was highest in substrata of silt and clay which consist of small grain sizes (Lin et al., 2001; Kodama et al., 2012). Hence, white croaker selection of small grain sizes (and subsequently substratum of silt and clay) is likely a result of selecting for areas with high sediment TOC which often correlates to increase in benthic infauna (Pearson and Rosenberg, 1978). Likewise, white croaker avoidance of dredged areas may be expected to be due to unfavorable sediment grain sizes, which contain lower TOC levels and lower polychaete densities.

LA-LB Harbor white croaker were shown to select areas receiving organic enrichment and high polychaete density. The preference for high polychaete density is understandable in schooling fish species as a higher density of prey items would be necessary to sustain all fish within the school. Foraging in areas of high polychaete density would also possibly allow the schooling fish to use a smaller area and potentially decrease the probability of an encounter with a predator.

Polychaete community change has been apparent in the harbor over the last few decades as pollutant-tolerant polychaetes (*Capitella capitata*) once highly abundant in the 1970s, have since decreased in abundance and distribution (Ware, 1979). Pollutant intolerant polychaete species such as *Cossura sp* are now the predominant polychaete species in the outer harbors. Additionally, *C. capitata* has only been found in one region of the harbor recently, the Consolidated Slip in LAIH, but may be present in un-sampled sections of the other harbor regions. Ware described *C. capitata* as an important food item to large white croaker in the harbor in the 1970s (Ware, 1979). Since the 1970s, the benthic infaunal community in the Harbor has shifted in part due to port development, reduced nutrient loading, and dredging. It is likely that white croaker have shifted diet and potentially habitat selection as well to utilize the benthic infaunal species now present in the Harbor. Estimated prey abundance of polychaete species likely consumed by white croaker presently in the harbor indicate a higher abundance of these prey items in the inner than the outer harbors. This relationship may help explain the higher site fidelity of white croaker to the inner harbors and the more dispersed movements of white croaker in the outer harbors.

Anthropogenic disturbances commonly conducted in the LA-LB Harbor such as dredging, construction, and fishing pressure can also greatly impact and change the benthic community as seen by the difference in polychaete community composition and sediment TOC between these areas. Areas with higher polychaete densities selected by white croaker were not present in dredged areas, thus indicating the benthic community is impacted by dredging in the harbor. Polychaete density and depth were negatively correlated, where depths over 15 m did not contain areas of polychaete densities for which white croaker selected (406-700 polychaetes/0.1 m^2). Thus, polychaete density may also be one of the main drivers of white croaker depth selection since white croaker were seldom found to use depths deeper than 15 m in the harbor.

The degree of tortuous movement for white croaker may be indicative of patch foraging and/or refuging behavior. Average tortuosity of white croaker for each fish track were similar between day and nighttime periods; however, model results indicate tortuosity was slightly higher during the day than night when combined with the other model parameters which could suggest movements indicative of foraging or refuging. Tortuosity increased with increasing day length and depth, suggesting longer periods of foraging with increasing day length in deeper areas. Tortuosity also varied between regions which may be expected, particularly since predation pressure is most likely higher in open areas such as the outer harbor versus more constrained habitats found in the inner harbor. Multiple factors contributed to rate of movement. The model results estimated that rate of movement was higher during the night, indicating potential predator avoidance while slower rates of movement during the day may be indicative of foraging behavior. Rate of movement was also the slowest during winter and summer months, which may be attributed to longer foraging hours in summer and decreased rate of movement during the breeding season (winter) (Love et al., 1984). White croaker movements and habitat selection may differ between sexes; however, this factor could not be addressed in this study.

White croaker have been thought to be a nocturnal foraging species based on diet analysis where fish caught in the morning had food in their intestines, suggesting nocturnal feeding (Ware, 1979). If white croaker within the LA-LB Harbor were strictly nocturnal foragers, it is expected that the fish would select for higher polychaete densities at night than during the day. However, white croaker selection of areas of high polychaete densities did not differ between day and night time periods. It is likely that with the changing polychaete community composition, densities, and distribution in the harbor that white croaker are foraging during both day and night periods.

Seafloor water temperatures did not appear to effect white croaker movements significantly within the harbor. As a fish species associated with the benthos, white croaker may not be as susceptible to seasonal sea surface temperature changes as water column species. Other factors that were not incorporated into the models included tidal fluctuation, salinity, and predator abundance. Tidal flux is estimated to be highest around the gate entrances to the harbor (Angel’s and Queen’s Gates), which are not considered important habitat for white croaker. None of the white croaker actively tracked were observed to move towards or through the harbor gates. White croaker may avoid harbor gates due to higher concentration of predators found in these high flow areas. Thus, it is likely that white croaker may only be using or transiting these areas during slack tide. Salinity was not expected to influence white croaker movements as it is thought to remain fairly constant in the harbor. The largest sources of fresh/brackish water input exist from the Dominguez Channel and the Los Angeles River. White croaker selection of the Consolidated Slip area, which receives fresh water input from the Dominguez Channel is most likely due to the higher organic enrichment rather than salinity. Predator abundance is very likely to affect white croaker movement and behavior; however, accurate data on predator abundance during the time of fish tracking was not available.

4.1.1.1 PREDICTIVE HABITAT USE MODEL

White croaker avoided the main shipping channels in both LA and LB harbor. These areas are consistently dredged in order to maintain open waterways for the many large ships which enter the harbor. Additionally, ships may scour the benthos, displacing finer sediments and nutrients, eliminating habitat characteristics (such as sediment TOC and high polychaete density) sought by white croaker. The areas predicted to be most preferable to white croaker include the Consolidated Slip and Fish Harbor, both of which have high sediment contamination. White croaker habitat selection of the Consolidated Slip in the LA harbor is largely expected to be due to the additional influx of nutrients from the Dominguez Channel which is unique to the Consolidated Slip versus other areas within the LA-LB Harbor. White croaker are also predicted to highly utilized Channel 3 in the LB Harbor, which may obtain nutrients from the numerous storm drains which discharge into the area. Passively and actively tracked white croaker avoided the area in the harbor with the highest polychaete density, Sea Plane Lagoon (POLA). Despite having the highest polychaete densities, the lack of white croaker activity in Sea Plane

Lagoon may be attributed to the lack of other key habitat factors, as Sea Plane Lagoon only contained one of the four habitat selection qualities that white croaker may prefer. Avoidance of Sea Plane Lagoon may have also been attributed to a higher abundance of predators or that despite having the highest polychaete densities; the polychaete community is dominated by undesirable species. The San Pedro Bait barge which had a high number of detections per fish visiting the area contained 2 out of the four selection categories and is likely important habitat for outer harbor white croaker. Since dead and dying bait are deposited on the seafloor beneath the bait barges, it is likely these areas have higher benthic infaunal densities than many surrounding habitats.

Knowledge of white croaker habitat selection can further be incorporated into bioaccumulation models for the LA-LB Harbor and aid in remediation planning. It is important to note that even though fish age did not improve the models in this study, fish age may be an important factor for bioaccumulation modeling. Habitat selection may differ between juvenile and mature white croaker and therefore cause contamination exposure rates to also vary significantly between age classes. Mature harbor white croaker commonly use areas containing more highly contaminated sediments. Thus, sediment remediation in areas such as the Consolidated Slip may lower white croaker contamination if the fish were to continue to use the area post remediation. Important remediation decisions will need to be made with the results of the bioaccumulation model to determine which remediation technique is likely to be the most effective.

The integrative technique of incorporating multi-scale movement data into bioaccumulation modeling framework is applicable to bioaccumulation models used worldwide. The value and quality of incorporating fish movement into bioaccumulation models should improve model accuracy and hence, improve the predictability and validity of such models to determine the best remediation action plans.

4.1.2 Goal 2: Characterize the longer-term movements and site fidelity of white croaker in the Los Angeles and Long Beach Harbors over a one year period.

While active tracking data only provide a short-term, but fine-scale measure of space use size, activity patterns and habitat use, passive tracking data provide a better measure of dispersal and shifts in habitat use of time scales of months. Most of the passive tracking data analysis will be provided in the Phase II final report so that interannual differences could be compared.

Twenty-five white croaker were tagged with coded acoustic transmitters in each of the four regions of the harbor were observed to disperse throughout the harbors over time; however, dispersal was disproportional. Fish tagged in the Consolidated Slip area tended to remain in that area for prolonged periods of time. This pattern of longer-term site fidelity is similar to what was observed from fish actively tracked in that part of the harbors. In addition, fish tagged in other locations of the harbor were observed to go into the inner harbor regions, including Consolidated Slip (Figure 39). Over the course of the study, more than 40 individual tagged white croaker were detected by receivers in the inner harbors. A cursory measure of site fidelity (avg number of detections per fish per receiver) showed interesting patterns of long term habitat use. Although few individuals visited the outer LA Harbor area (San Pedro bait barge), the few individuals that did used that area over prolonged periods of time. While the next greatest avg number of detections per fish were recorded from receivers in Consolidated Slip. This pattern is likely attributed to the habitat quality in these areas for white croaker (e.g. high nutrient loads, soft sediments). Very few individuals were observed entering the Seaplane Lagoon area (Figure 40). The lower number of average detections per fish at receivers in the inner LB harbor and main shipping channels indicate that white croaker may only transit through these areas while moving between better habitat and foraging areas. A more comprehensive analysis of movement pathways, high use areas, and dispersal models based on passive tracking data will be provided in the Phase II final report

5.0 CONCLUSIONS

This study represents one of the most comprehensive behavioral studies of white croaker in the field. This study also comprised of one of the largest sample sizes for any study of this type (active tracking) despite the unique challenge of active tracking in one of the largest and busiest commercial ports in the world. In addition to the white croaker high positional resolution data collected in this study, this study was also able to integrate a wide variety of biological and environmental data at a temporal and spatial resolution which is scarcely available in other systems. Passive tracking data (longer-term, coarse-scale) support areas use indicated from short-term active tracks of white croaker throughout the harbor, but indicate more harbor-wide dispersal over time.

The specific goals of the project were to:

1. Quantify the fine-scale movement patterns and habitat use of white croaker tagged in the Los Angeles and Long Beach Harbors.
2. Characterize the longer-term movements and site fidelity of white croaker in the Long Beach Harbor over a one year period.

3. Determine the degree to which fish tagged in the Long Beach and Los Angeles Harbor leave the outer Harbors and enter the Consolidated Slip or the Palos Verdes Shelf Area.

4. Coordinate research and data analysis between the EPA funded study of fish movements and the POLA funded study.

The results of goal 1 are presented in this report whereas the results of goals 2-4 are provided in conjunction with the results of the Phase 2 white croaker tracking study in the report "**Data Report for Fish Tracking Special Study: White Croaker and California Halibut Study Phase 2**". White croaker within the LA-LB Harbor exhibited hierarchical habitat selection: avoiding dredged areas while selecting for areas of high sediment total organic carbon (4.8-8.1%), high polychaete density (406-700 polychaetes/0.1 m^2), and small sediment grain size (< 23.5 µm). Model results suggest that these fish are moving into shallower waters at night, which presumably may be to forage and refuge more during the day presumably to avoid predation. The predictive model for white croaker habitat use indicated three important areas of use within the LA-LB Harbor: Consolidated Slip, Inner Long Beach Harbor, and Fish Harbor. Both active and passive tracking data indicate that areas containing the most frequently selected habitats by white croaker are also often areas of high sediment contamination, and thus are likely locations where these fish are acquiring contaminants. However, white croaker do dispersal throughout the harbor over periods of weeks to months, and a proportion of individuals likely completely emigrate from the harbor for extended periods of time (> 1 year).

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7.0 FIGURES AND TABLES

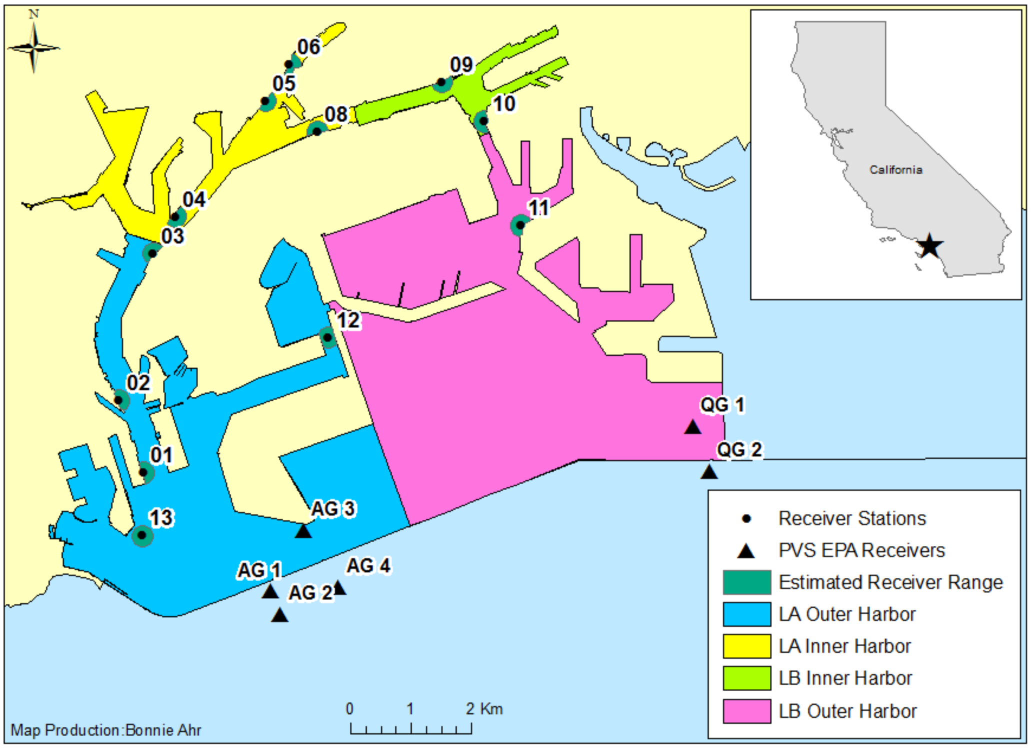

FIGURE 1. Location of the Los Angeles and Long Beach Harbors and receiver locations. The Los Angeles and Long Beach Harbor complex located in Southern California, USA. Black points represent each receiver station with the corresponding station number in black. The estimated receiver range is indicated by the dark green circles surrounding each receiver station. The harbor regions are indicated in blue and yellow for the Los Angeles outer (LAOH) and inner harbor (LAIH) respectively. Long Beach inner (LBIH) and outer harbor (LBOH) are shaded in green and pink respectively. Receivers from the EPA Palos Verdes Shelf study (PVS EPA) are indicated by the black triangles.

FIGURE 2. Map of locations of VR2W receivers within the Los Angeles and Long Beach harbors, represented by red dots. Buffer zones surrounding receiver locations represent the approximate detection range of that receiver as determined by on-site range testing.

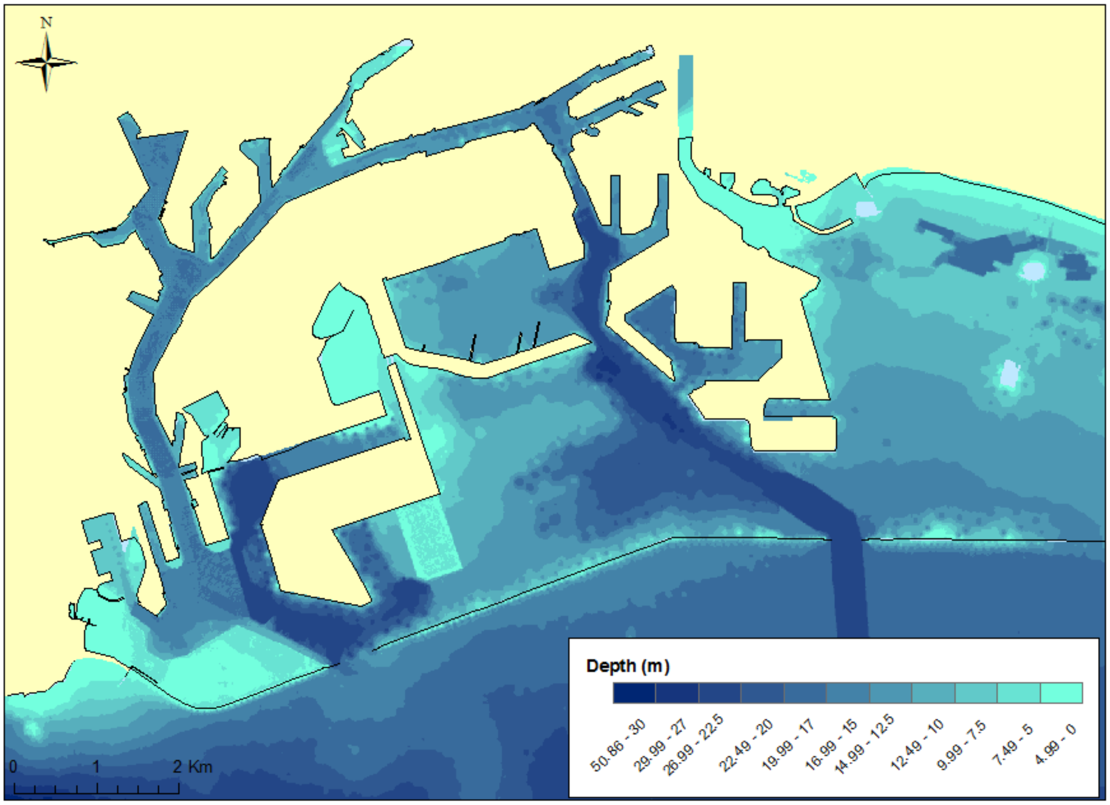

FIGURE 3. IDW interpolation map of bathymetry data from 2001 to 2009. Bathymetry data was provided by Anchor QEA, LLC.

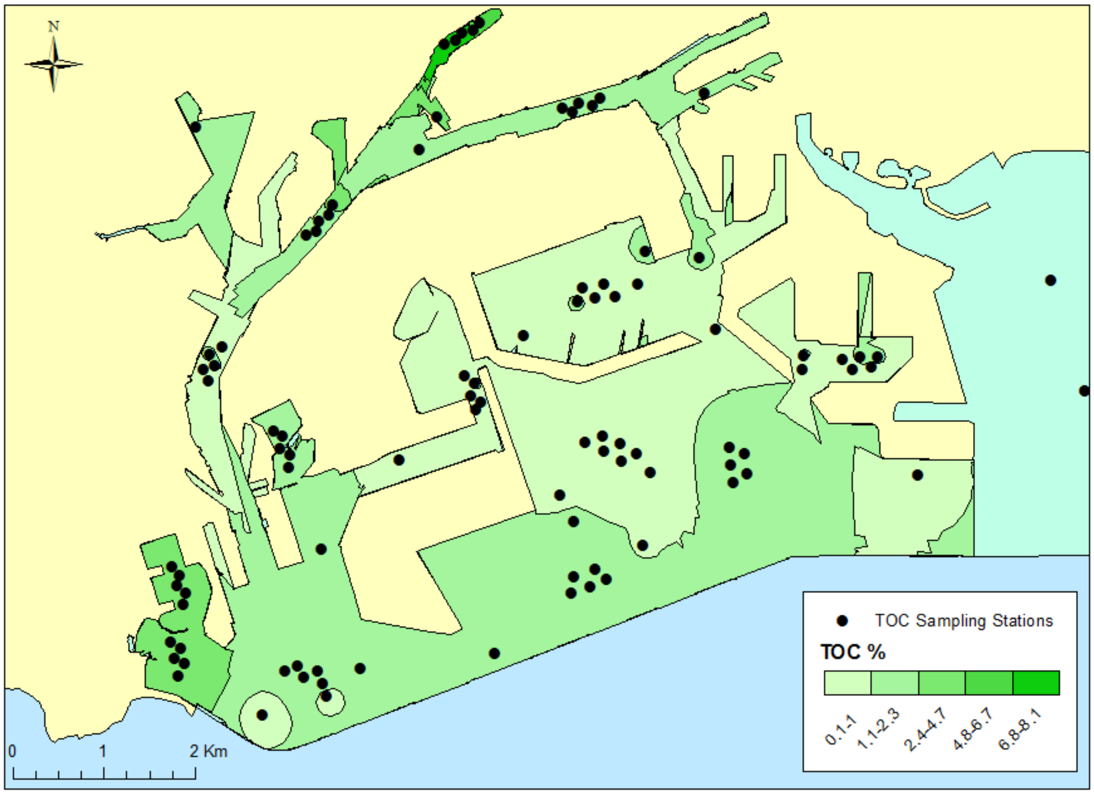

FIGURE 4. IDW interpolation map of sediment total organic carbon (%) from Bight 2008 and Weston 2011 sampling. Sampling locations are indicated by black points.

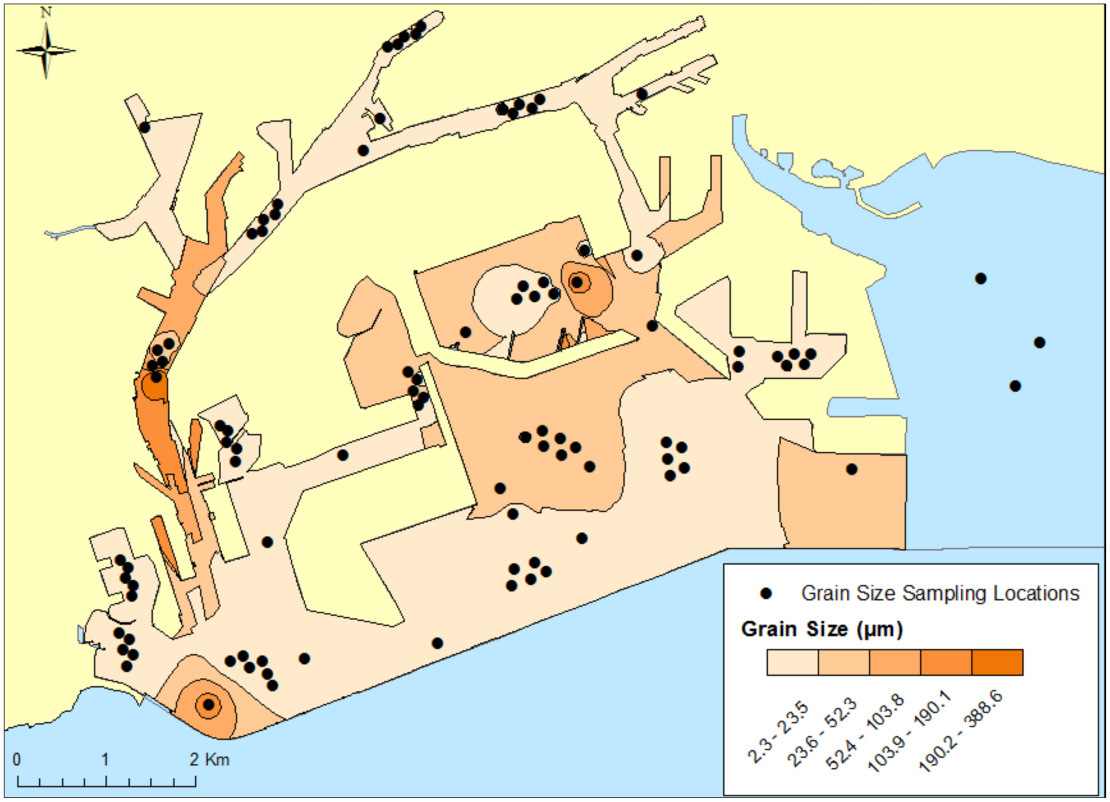

FIGURE 5. IDW interpolation map of grain size (µm) from Bight 2008 and Weston 2011 sampling. Sampling locations are indicated by the black points and are the same locations as the total organic carbon sampling locations.

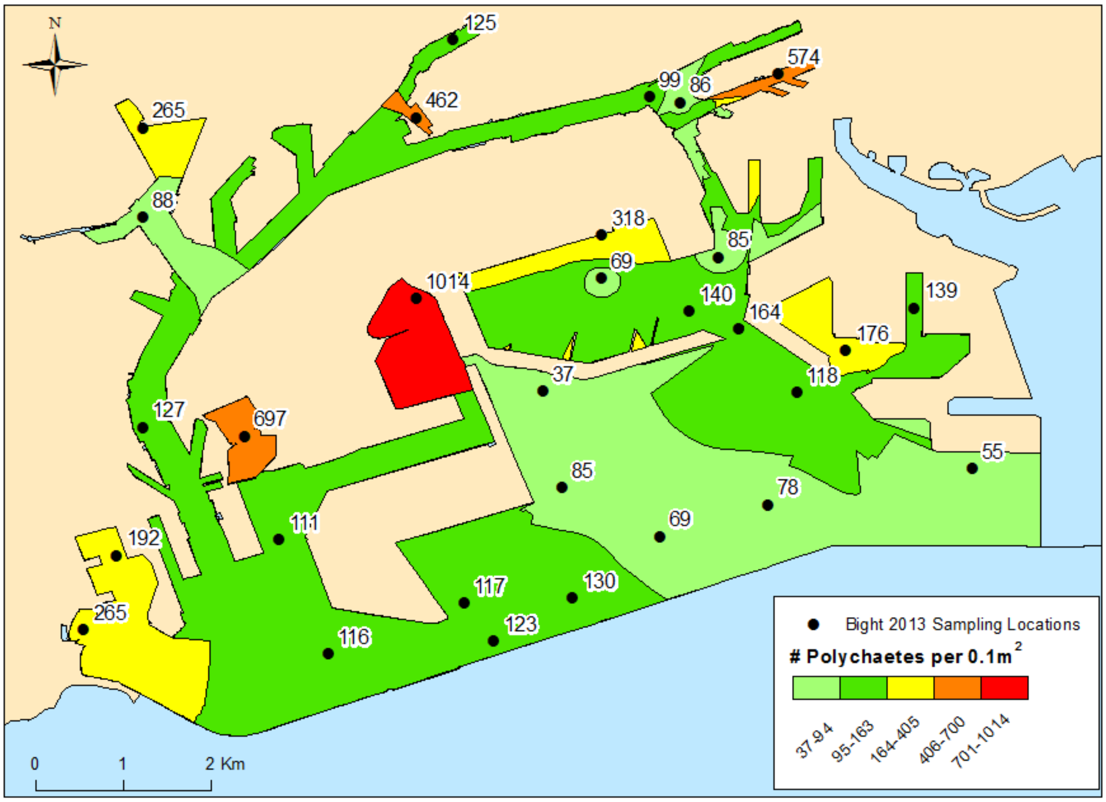

FIGURE 6. Inverse distance weighted (IDW) interpolation of draft polychaete density data from Bight Regional Monitoring program 2013. Black points indicate sampling locations with the associated number indicating the number of polychaetes recorded at each station via Van Veen grab (0.1 m^2). Light green areas indicate lower polychaete densities, whereas warmer colors indicate higher polychaete density.

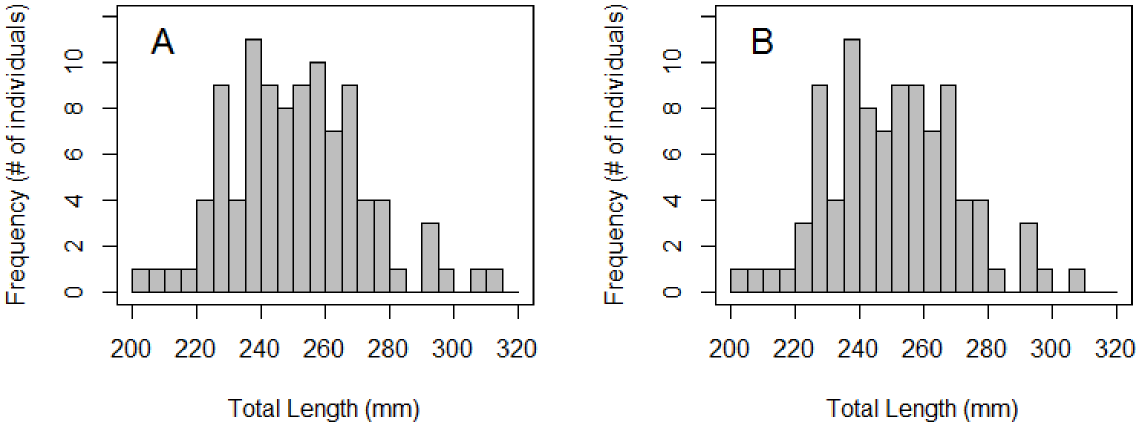

FIGURE 7. Histogram of the frequency of total length (mm) of white croakers tagged for passive tracking (**A**) (n = 99) and active tracking (**B**) (n = 20).

TABLE 1. White Croaker Tagged for Active Tracking and Tracking Dates

Fish #	**Region Tagged**	**Latitude Caught (DD)**	**Longitude Caught (DD)**	**TL (mm)**	**FL (mm)**	**SL (mm)**	**Age (years)**	**Weight (g)**	**Sex**	**Date Tagged (M/DD/YYYY)**	**Track 1 (M/DD/YYYY)**	**Track 2 (M/DD/YYYY)**	**Track 3 (M/DD/YYYY)**
1	LAOH	33.71294	-118.27217	230	220	194	7.7	190	U	5/7/2011	5/7-5/8/2011	ND	ND
2	LAIH	33.77314	-118.24812	238	234	205	4.8	185	F	6/23/2011	6/23-6/24/2011	6/25-6/26/2011	7/2-7/3/2011
3	LAOH	33.7135	-118.2701	237	228	200	4.8	185	F	6/27/2011	6/27-6/28/2011	7/8-7/9/2011	ND
4	LBOH	33.74568	-118.22133	235	231	203	8.2	165	U	10/26/2011	10/26-10/27/2011	11/3-11/4/2011	11/17-11/18/2011
5	LBIH	33.7725	-118.20925	236	232	209	8.3	175	U	12/3/2011	12/3-12/4/2011	12/7-12/8/2011	ND
6	LAIH	33.77325	-118.24802	228	225	191	7.5	220	U	2/24/2012	2/24/-2/25/2012	2/26-2/27/2012	ND
7	LBIH	33.77227	-118.20907	265	262	233	11.1	345	U	4/14/2012	4/14-4/15/2012	4/21-4/22/2012	ND
8	LBOH	33.74247	-118.22153	225	221	195	7.2	190	U	5/18/2012	5/22-5/23/2012	5/25-5/26/2012	ND
9	LAOH	33.71411	-118.27135	216	213	190	6.4	175	U	6/11/2012	6/11-6/12/2012	ND	ND
10	LAIH	33.77349	-118.24799	242	268	210	5.1	265	F	6/16/2012	6/18-6/19/2012	6/21-6/22/2012	ND
11	LBIH	33.76917	-118.22678	252	248	220	9.8	275	U	7/15/2012	7/16-7/17/2012	7/19-7/20/2012	ND
12	LBOH	33.74224	-118.22301	249	247	219	5.6	320	F	7/23/2012	7/23-7/24/2012	7/26-7/27/2012	ND
13	LAOH	33.71414	-118.27146	228	224	220	4.2	180	F	7/31/2012	7/31-8/2/2012	7/31-8/2/2012	ND
14	LAOH	33.77317	-118.24787	259	255	229	6.3	235	F	8/8/2012	8/9-8/10/2012	8/11-8/12/2012	ND
15	LBIH	33.7722	-118.20908	286	282	255	13.3	500	U	8/16/2012	8/17-8/18/2012	8/20-8/21/2012	ND

TABLE 1. Continued

Fish #	**Region Tagged**	**Latitude Caught (DD)**	**Longitude Caught (DD)**	**TL (mm)**	**FL (mm)**	**SL (mm)**	**Age (years)**	**Weight (g)**	**Sex**	**Date Tagged (M/DD/YYYY)**	**Track 1 (M/DD/YYYY)**	**Track 2 (M/DD/YYYY)**	**Track 3 (M/DD/YYYY)**
16	LBOH	33.74253	-118.22285	236	232	207	4.7	410	F	8/22/2012	8/22-8/23/2012	8/25-8/26/2012	ND
17	LAOH	33.71403	-118.27134	229	226	198	7.6	375	U	12/14/2012	12/14-12/16/2012	12/14-12/16/2012	ND
18	LAIH	33.77459	-118.24612	298	293	268	14.6	-	U	1/19/2013	1/21-1/22/2013	1/25-1/26/2013	ND
19	LBIH	33.76857	-118.21854	240	237	212	5.0	-	F	4/15/2013	4/16-4/17/2013	4/18-4/19/2013	ND
20	LBOH	33.75426	-118.21249	214	211	187	3.3	-	F	5/5/2013	5/5-5/6/2013	5/7-5/8/2013	ND

Note: ND = no data. Age was estimated using Von Bertalanffy curves from Love et al. 1984.

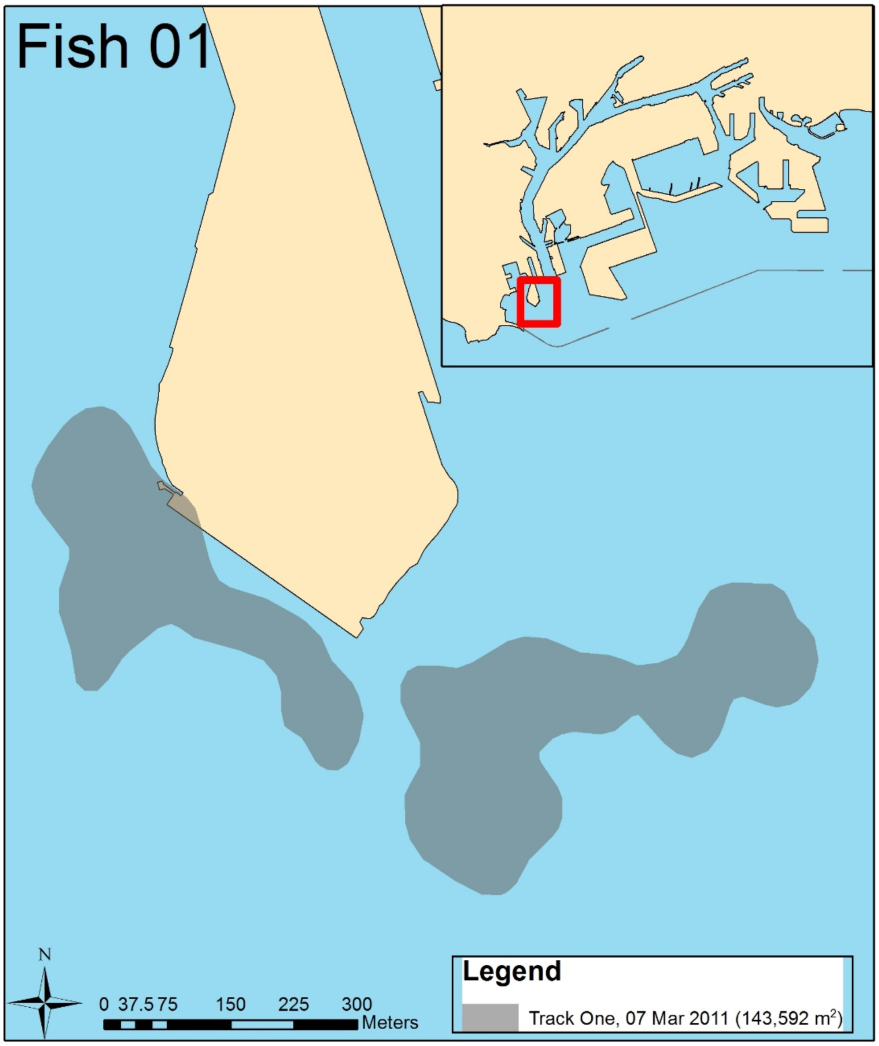

FIGURE 8. Map of area used by Fish 01, tracked in the outer LA Harbor

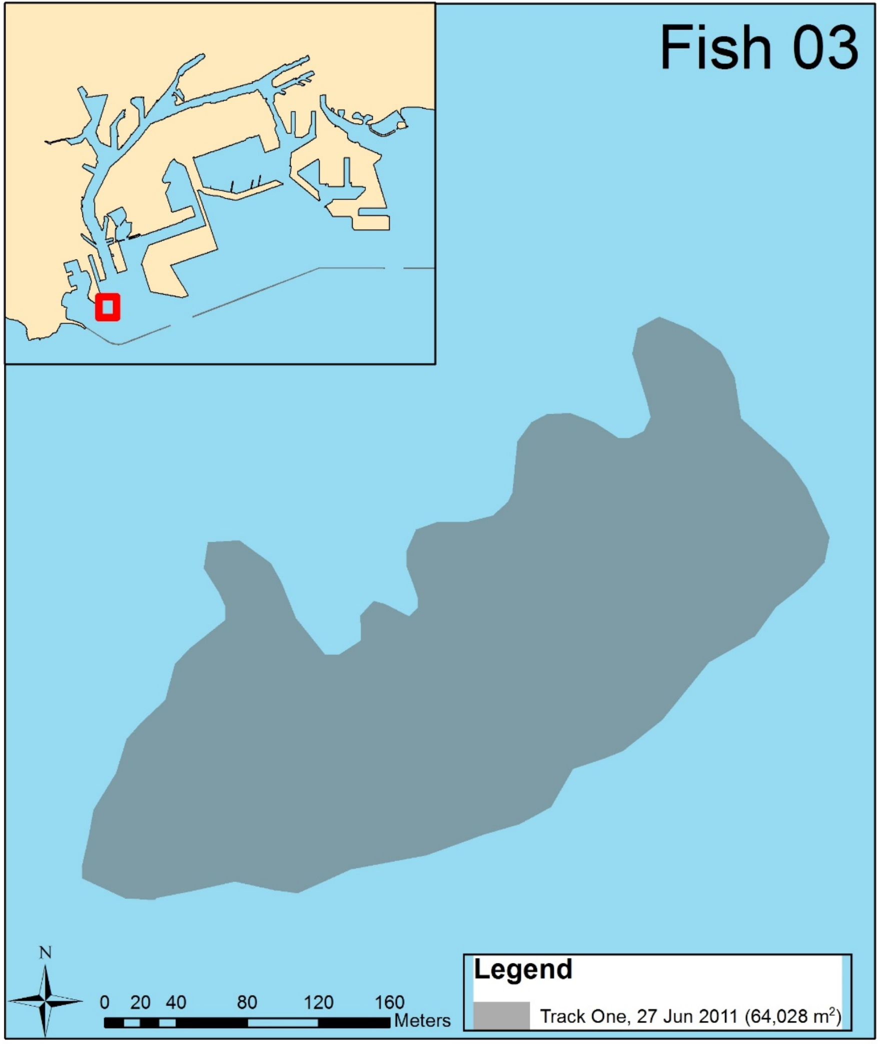

FIGURE 9. Map of area used by Fish 03, tracked in the outer LA Harbor

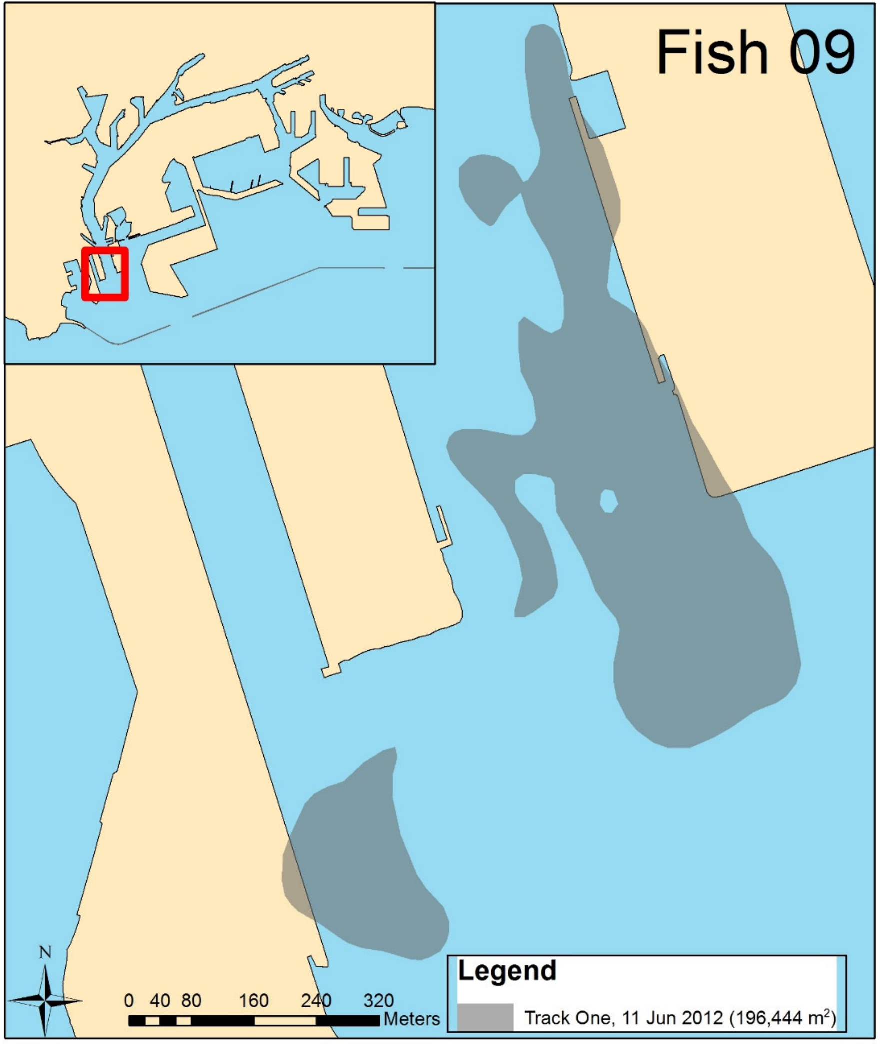

FIGURE 10. Map of area used by Fish 09, tracked in the outer LA Harbor

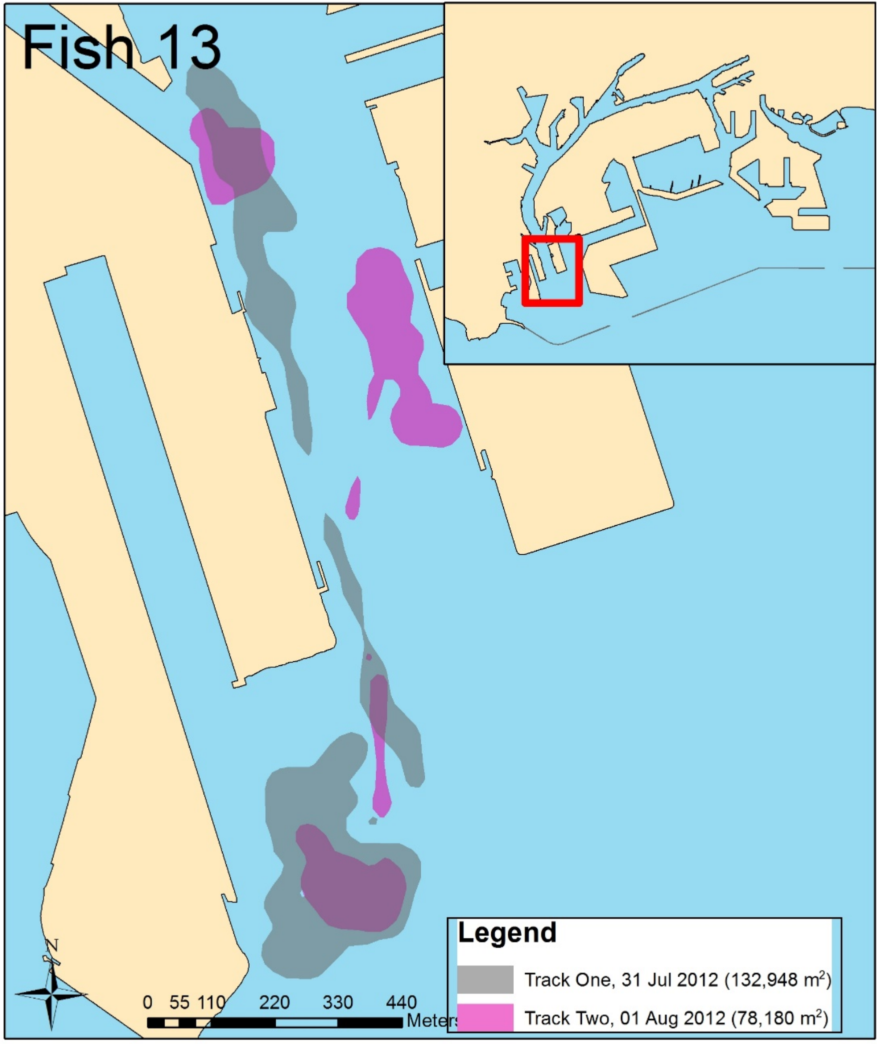

FIGURE 11. Map of area used by Fish 13, tracked in the outer LA Harbor

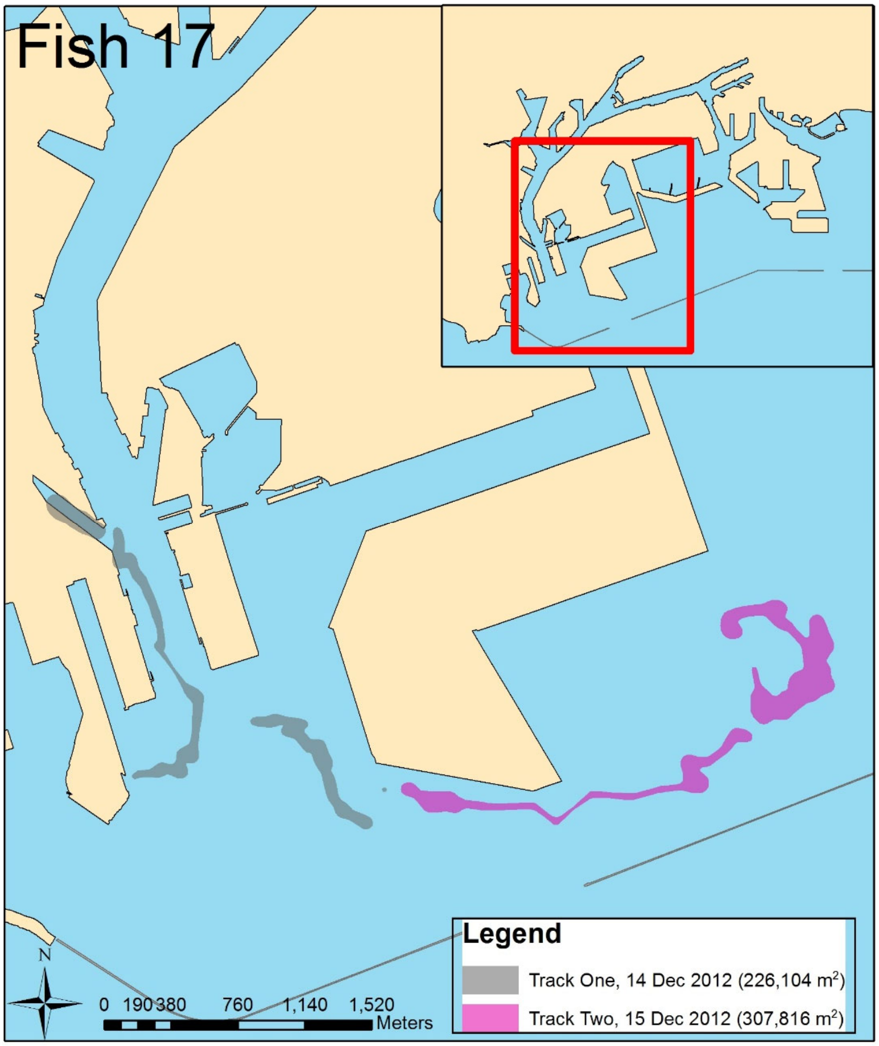

FIGURE 12. Map of area used by Fish 17, tracked in the outer LA Harbor

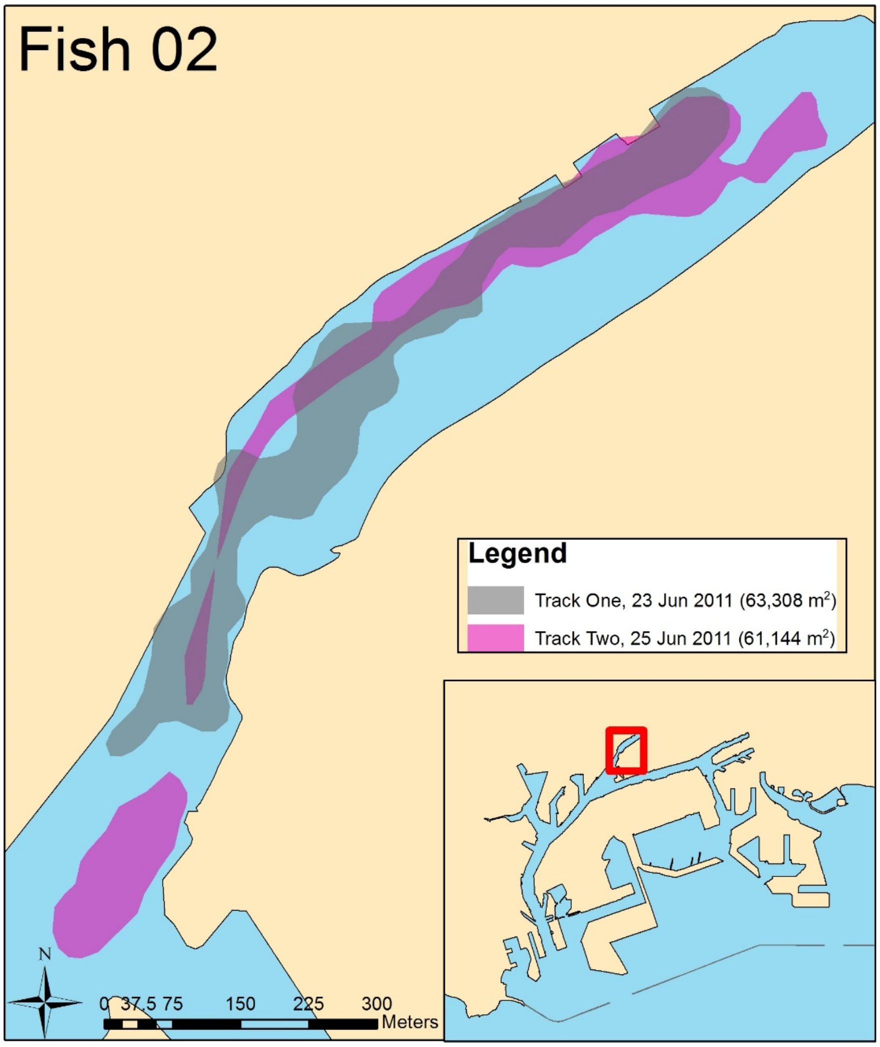

FIGURE 13. Map of area used by Fish 02, tracked in the inner LA Harbor

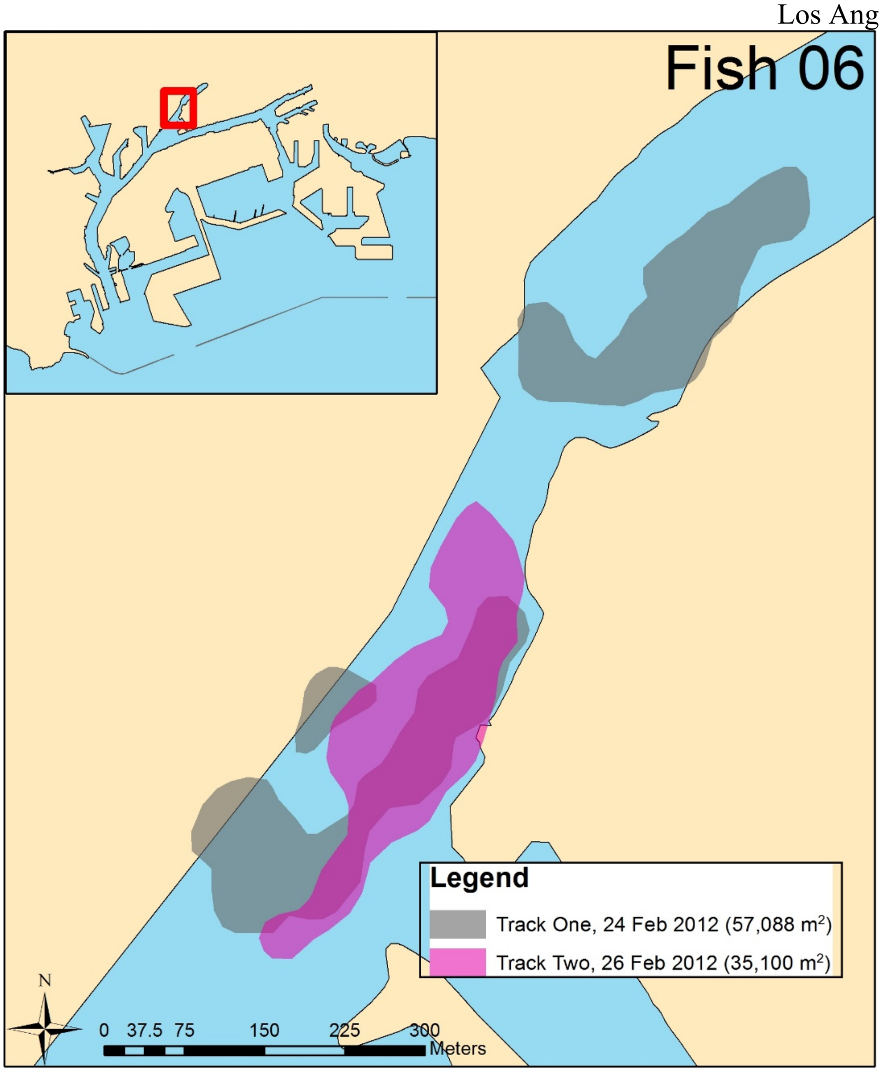

FIGURE 14. Map of area used by Fish 06, tracked in the inner LA Harbor

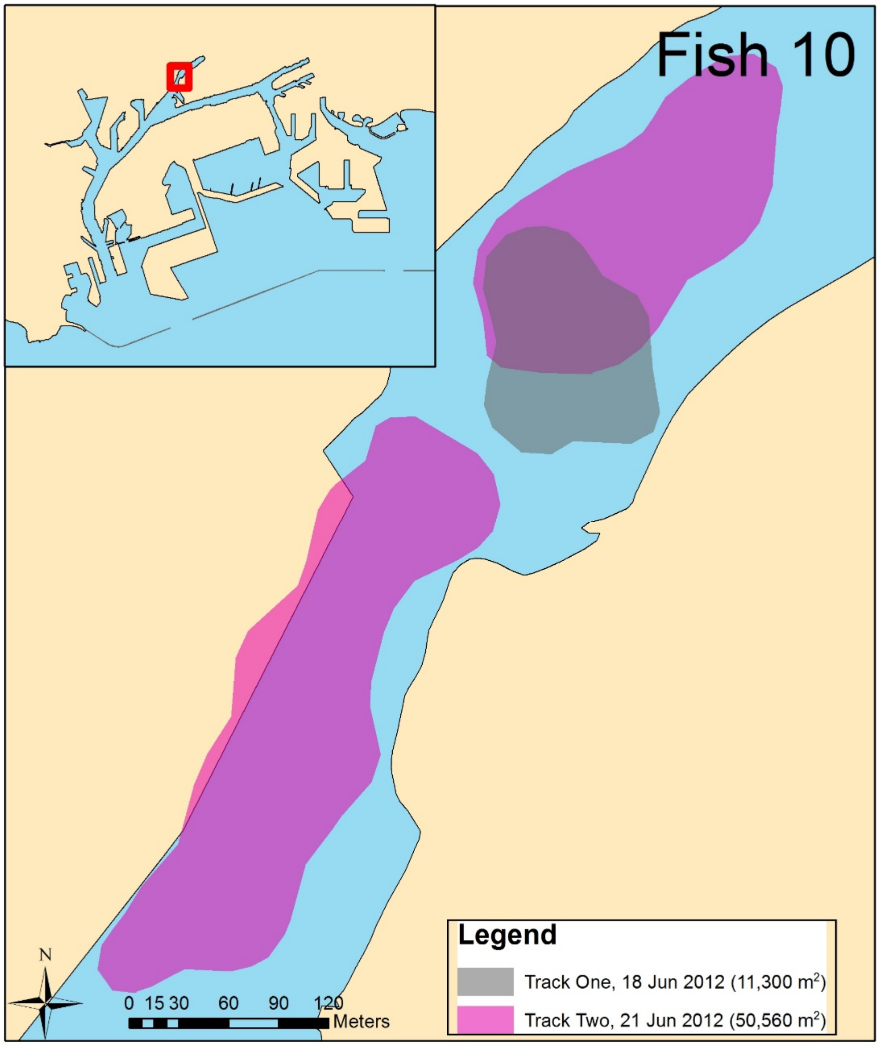

FIGURE 15. Map of area used by Fish 10, tracked in the inner LA Harbor

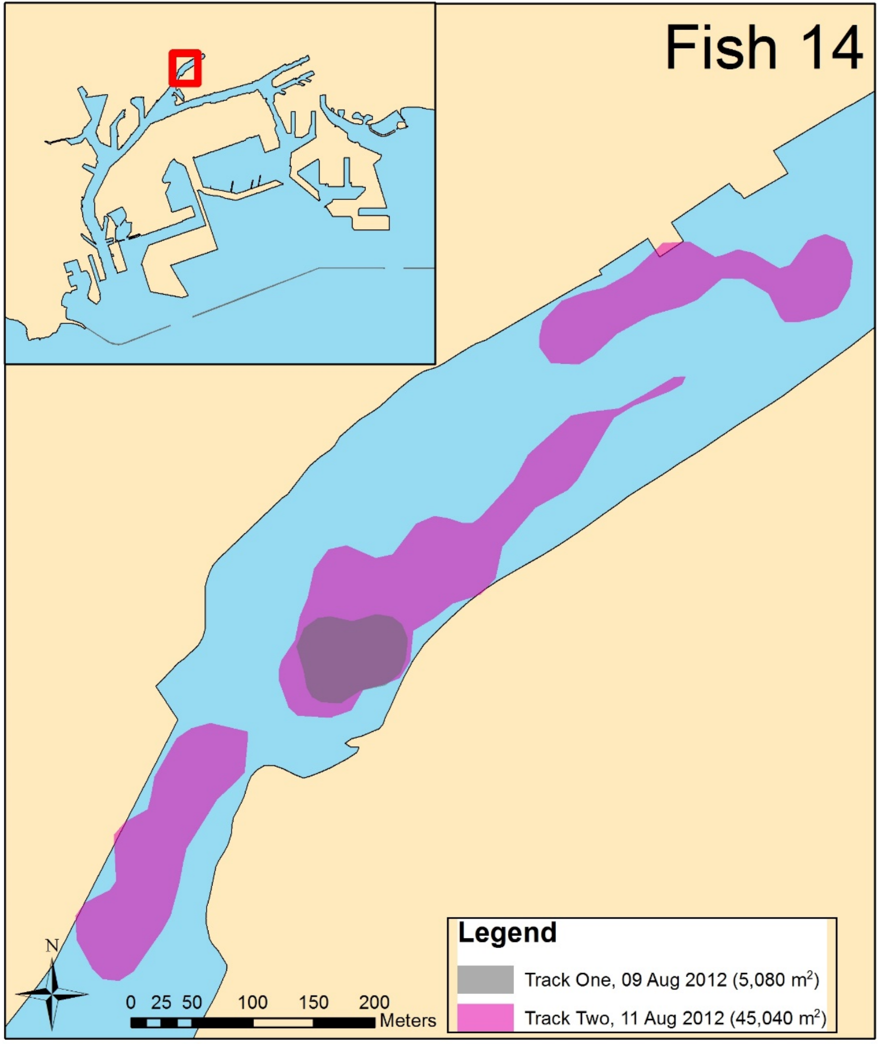

FIGURE 16. Map of area used by Fish 14, tracked in the inner LA Harbor

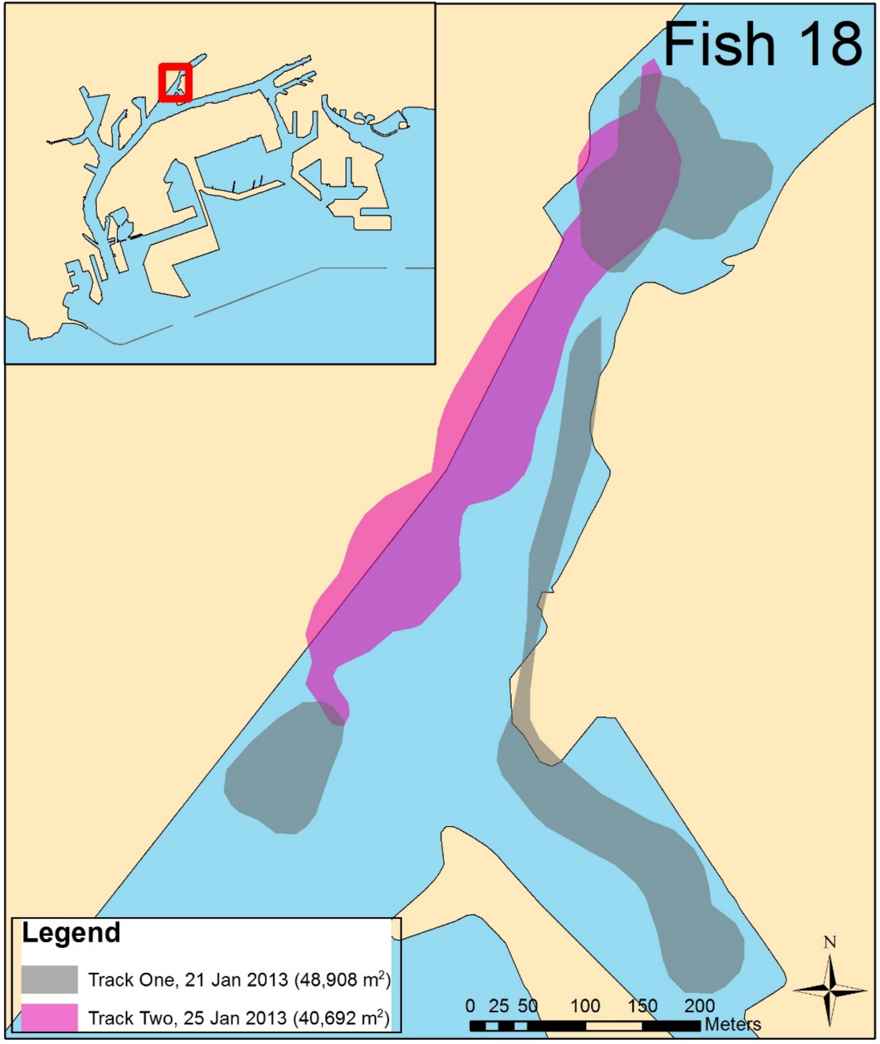

FIGURE 17. Map of area used by Fish 18, tracked in the inner LA Harbor

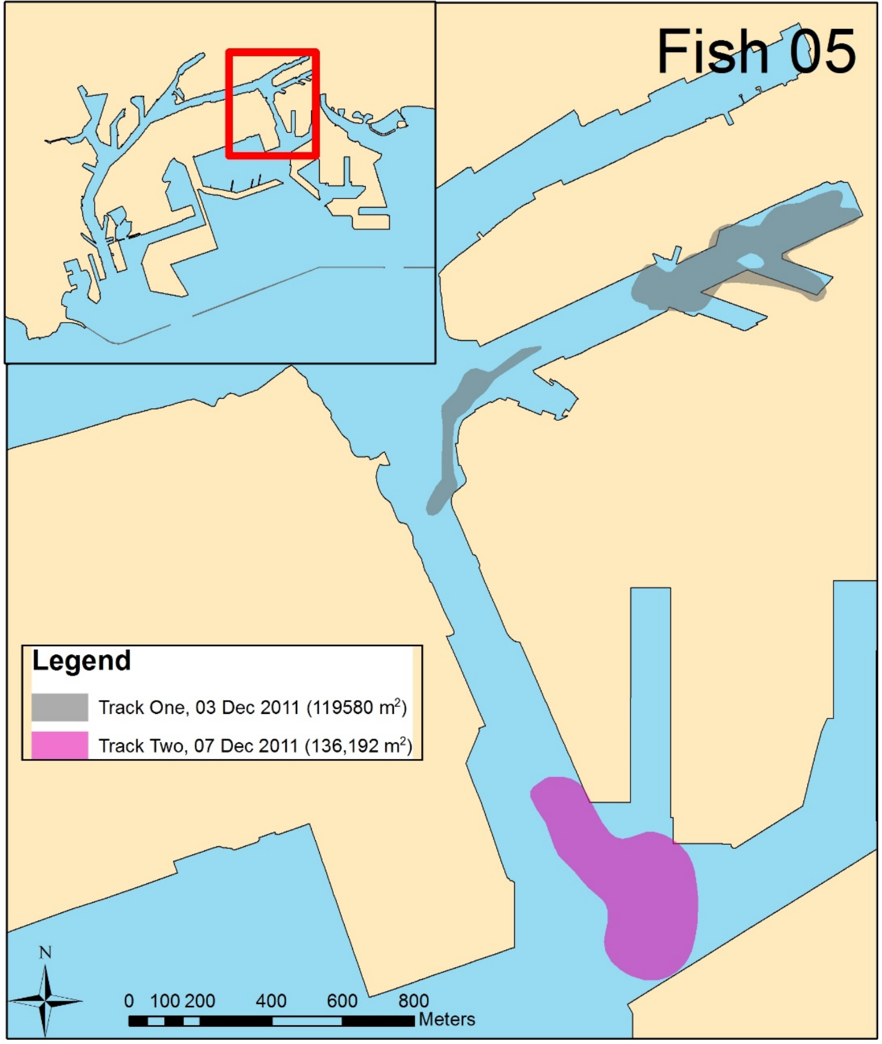

FIGURE 18. Map of area used by Fish 05, tracked in the inner LB Harbor

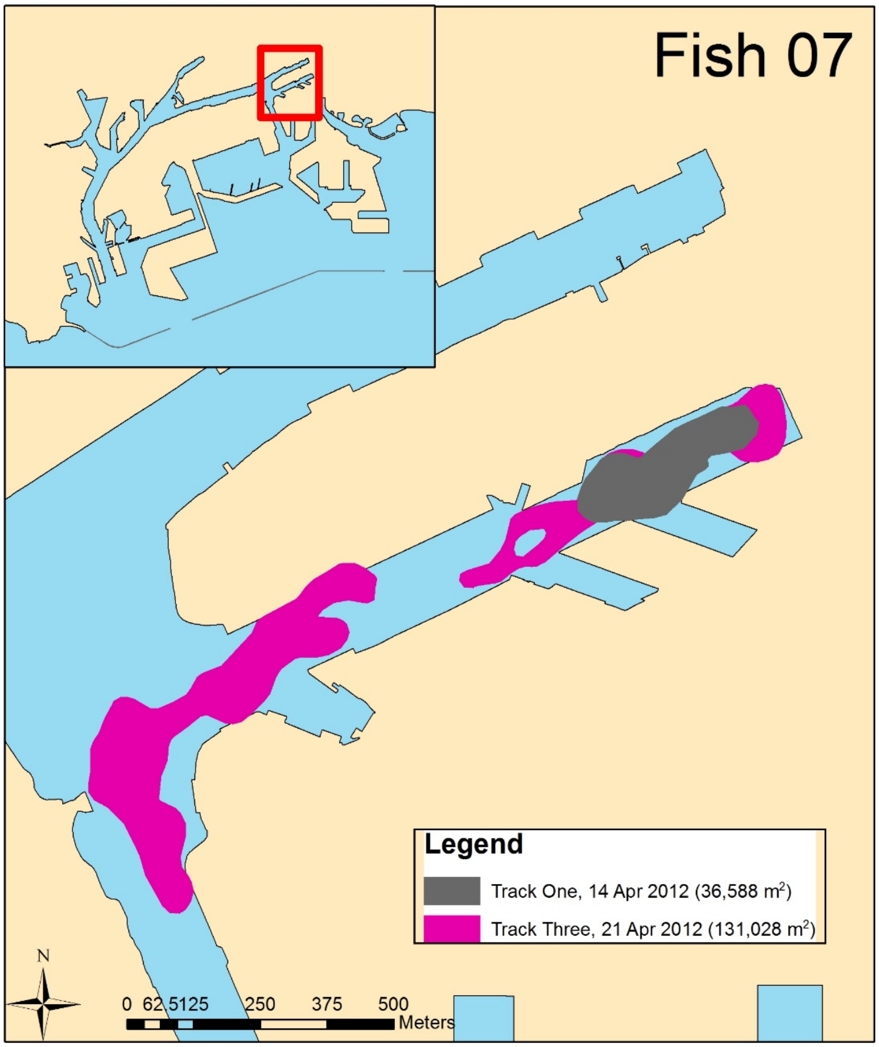

FIGURE 19: Map of area used by Fish 07, tracked in the inner LB Harbor

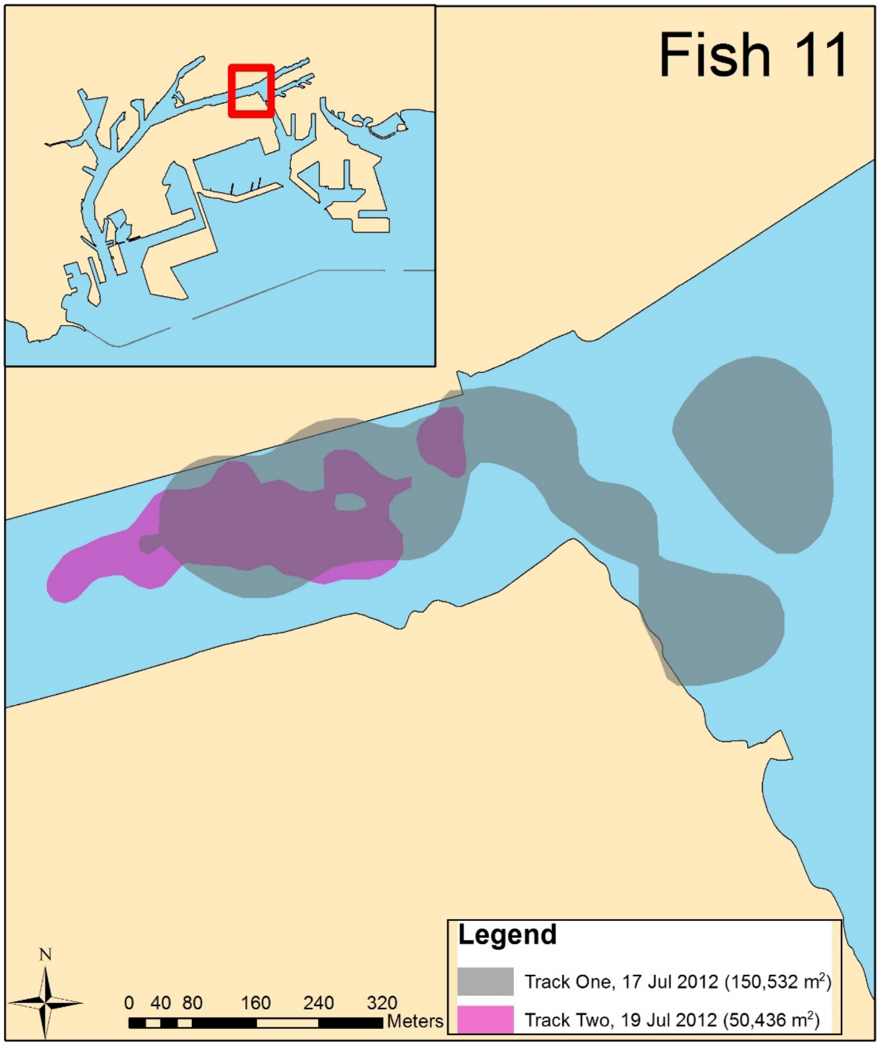

FIGURE 20: Map of area used by Fish 11, tracked in the inner LB Harbor

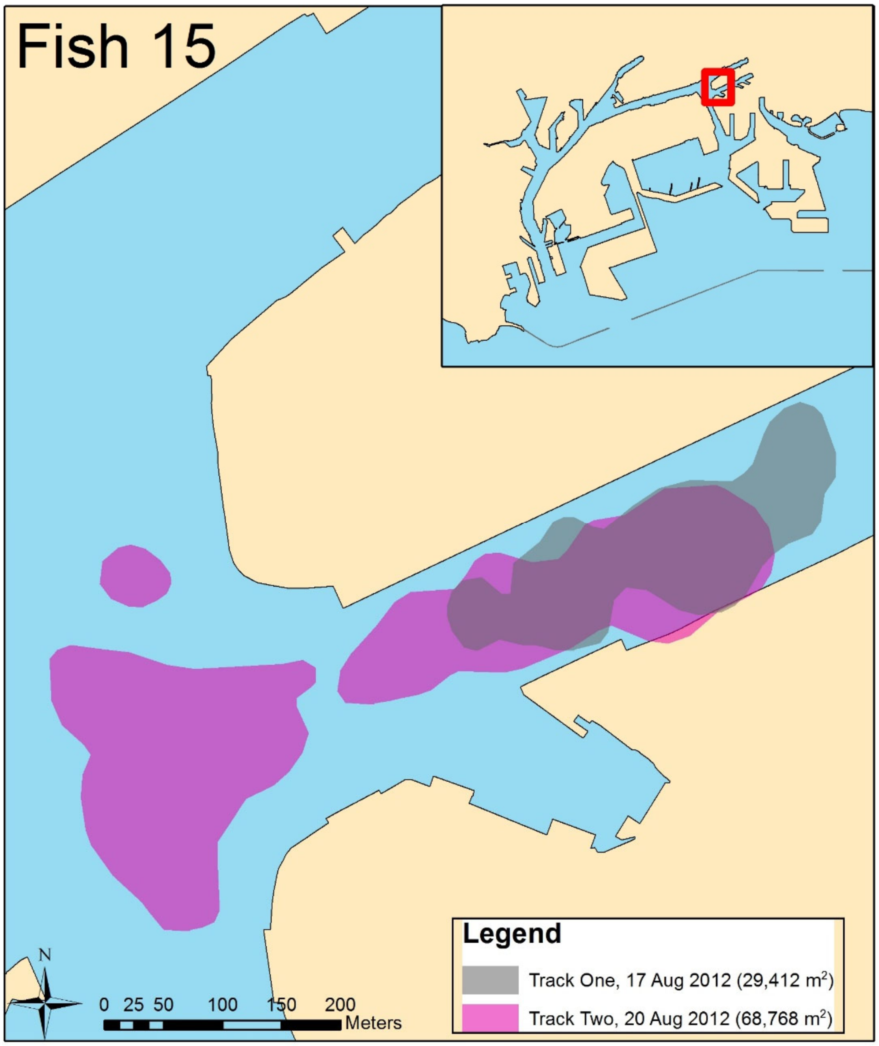

FIGURE 21. Map of area used by Fish 15, tracked in the inner LB Harbor

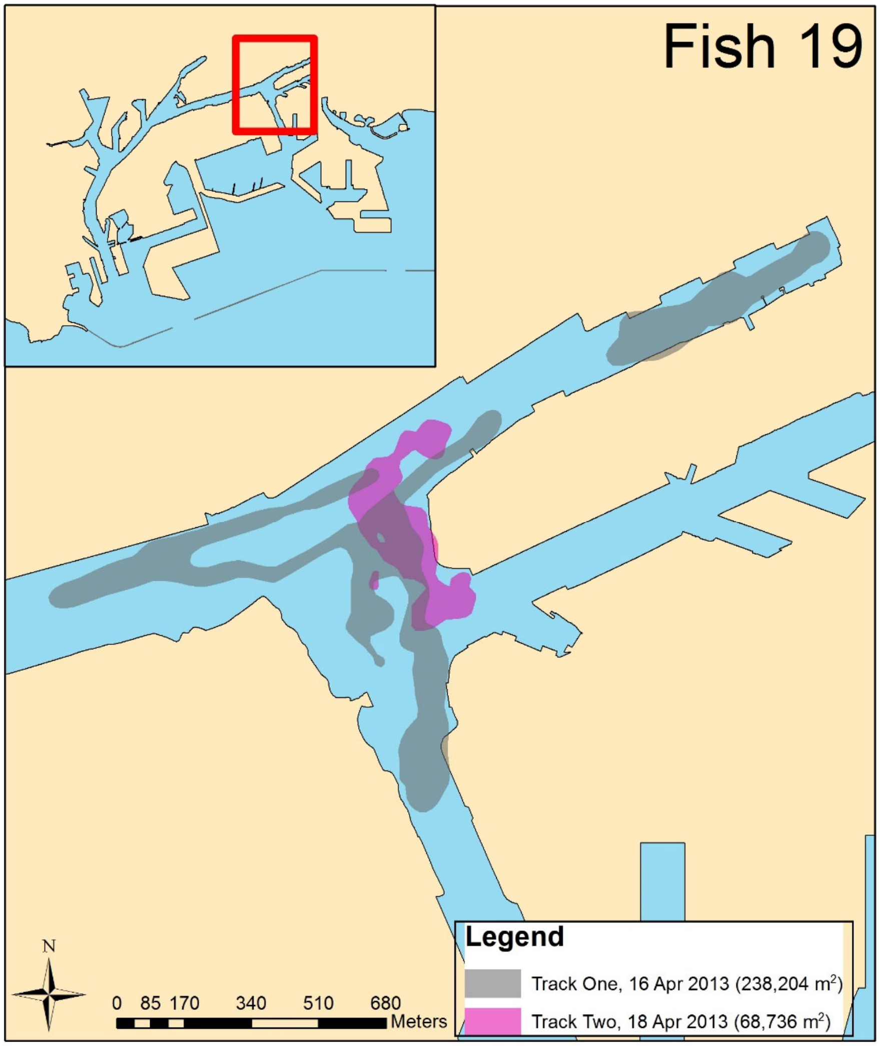

FIGURE 22. Map of area used by Fish 19, tracked in the inner LB Harbor

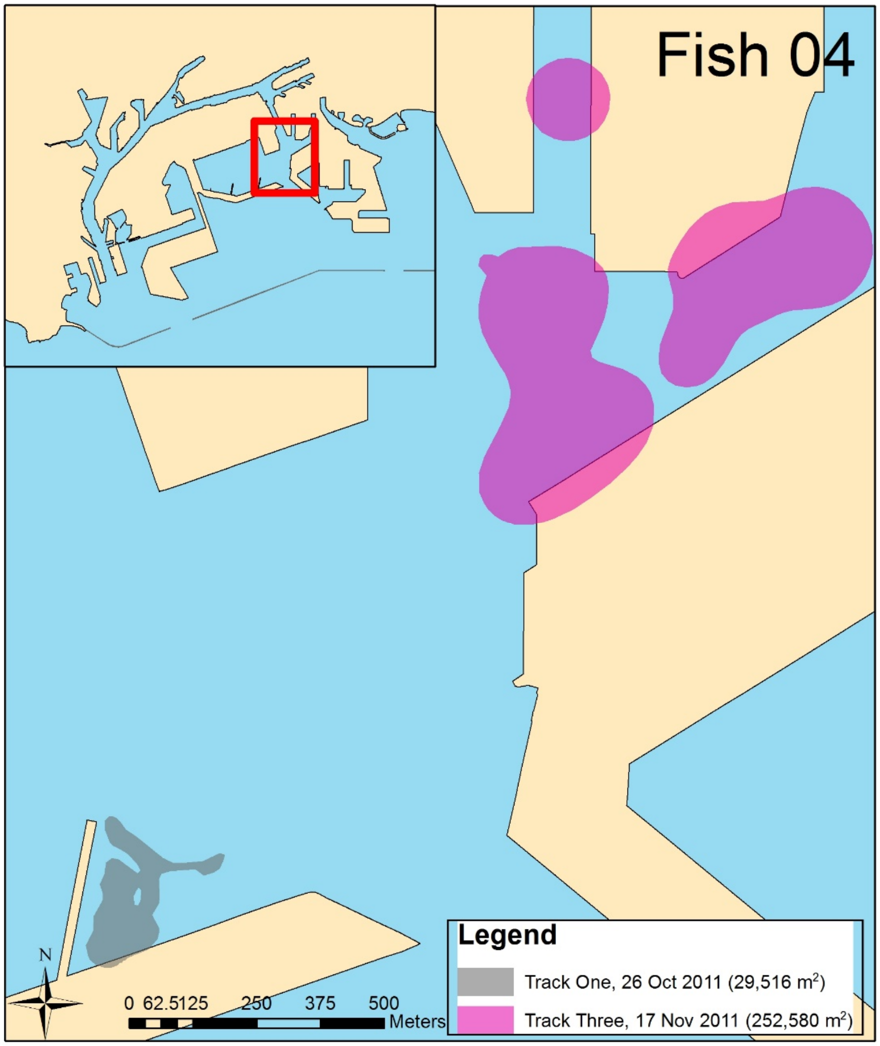

FIGURE 23. Map of area used by Fish 04, tracked in the outer LB Harbor

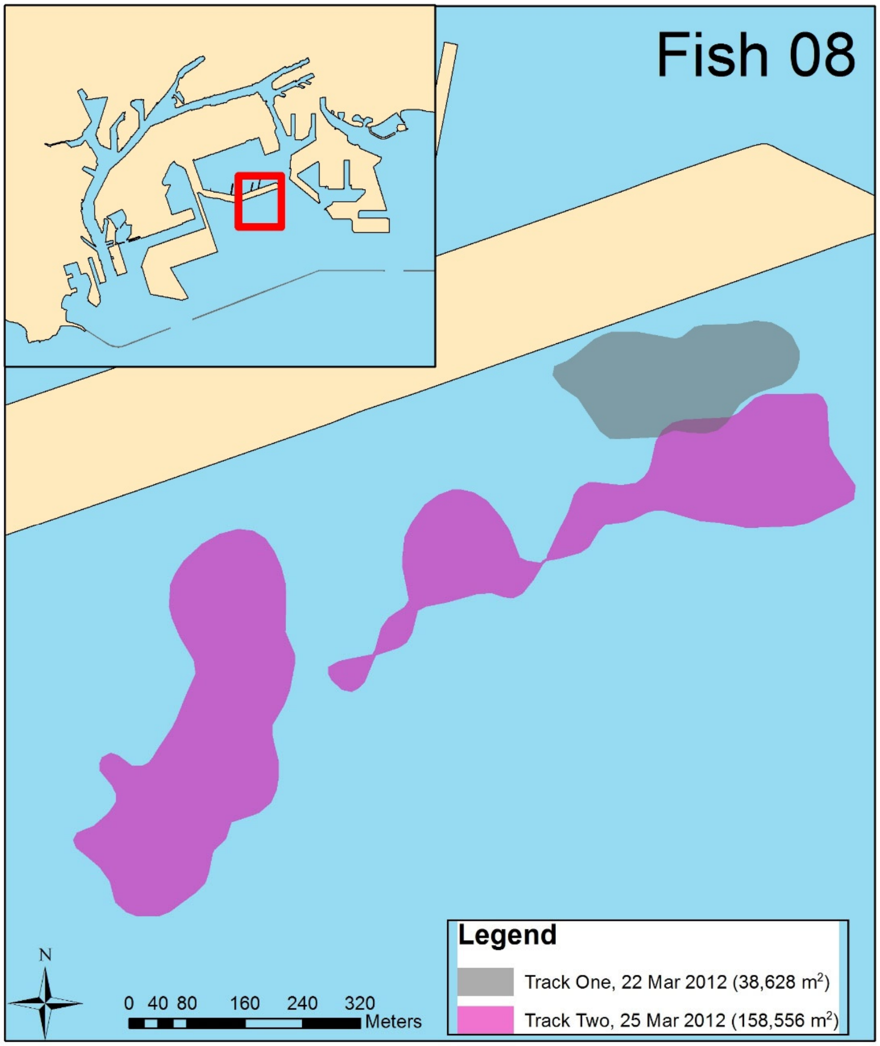

FIGURE 24. Map of area used by Fish 08, tracked in the outer LB Harbor

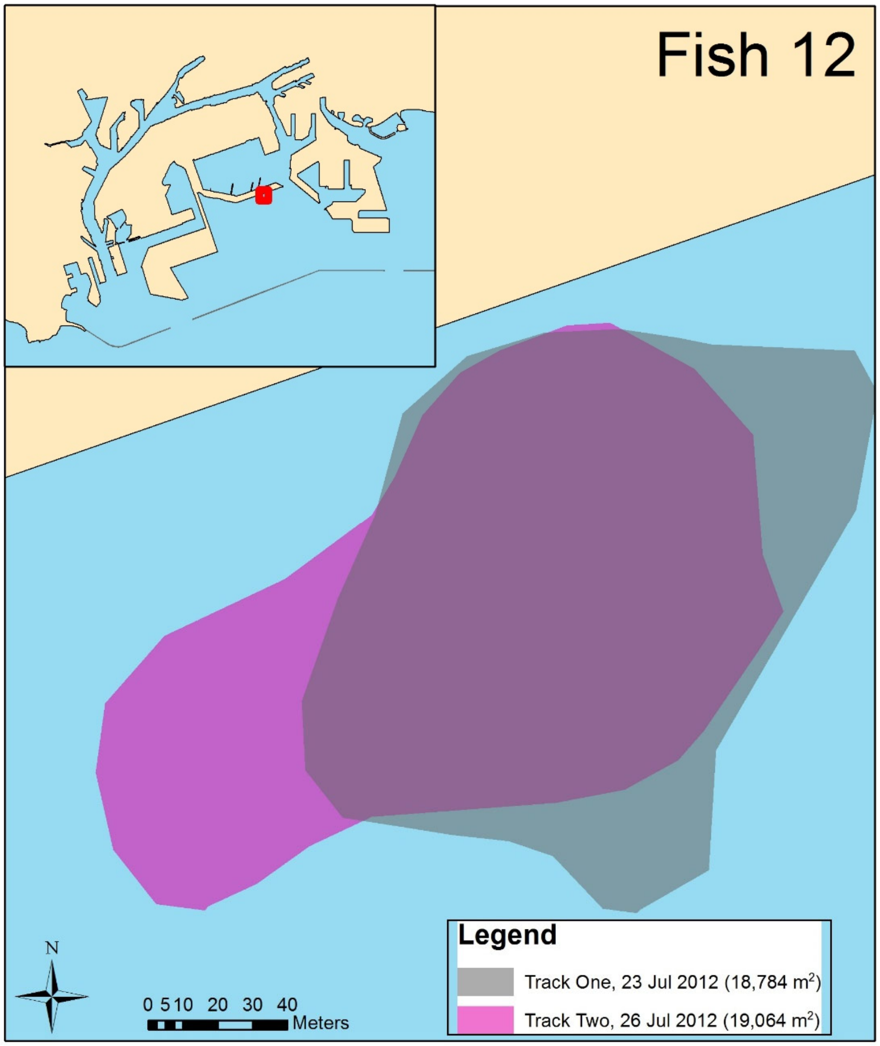

FIGURE 25. Map of area used by Fish 12, tracked in the outer LB Harbor

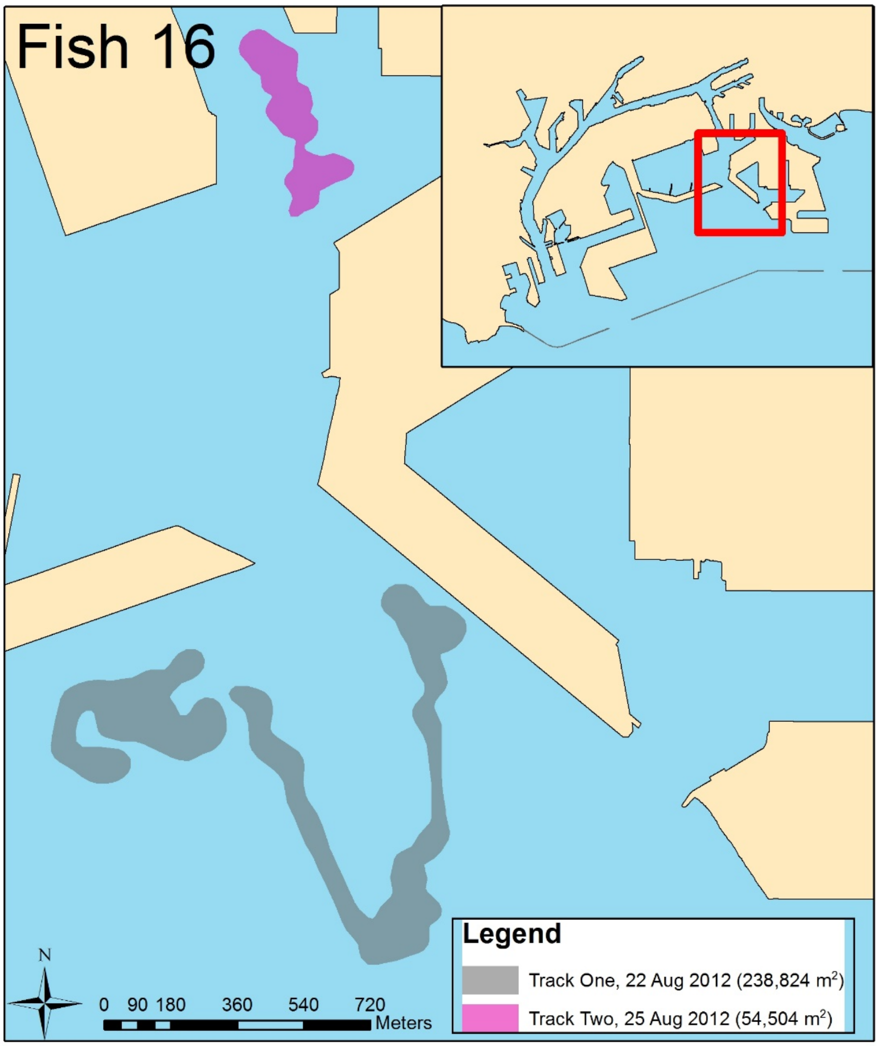

FIGURE 26. Map of area used by Fish 16, tracked in the outer LB Harbor

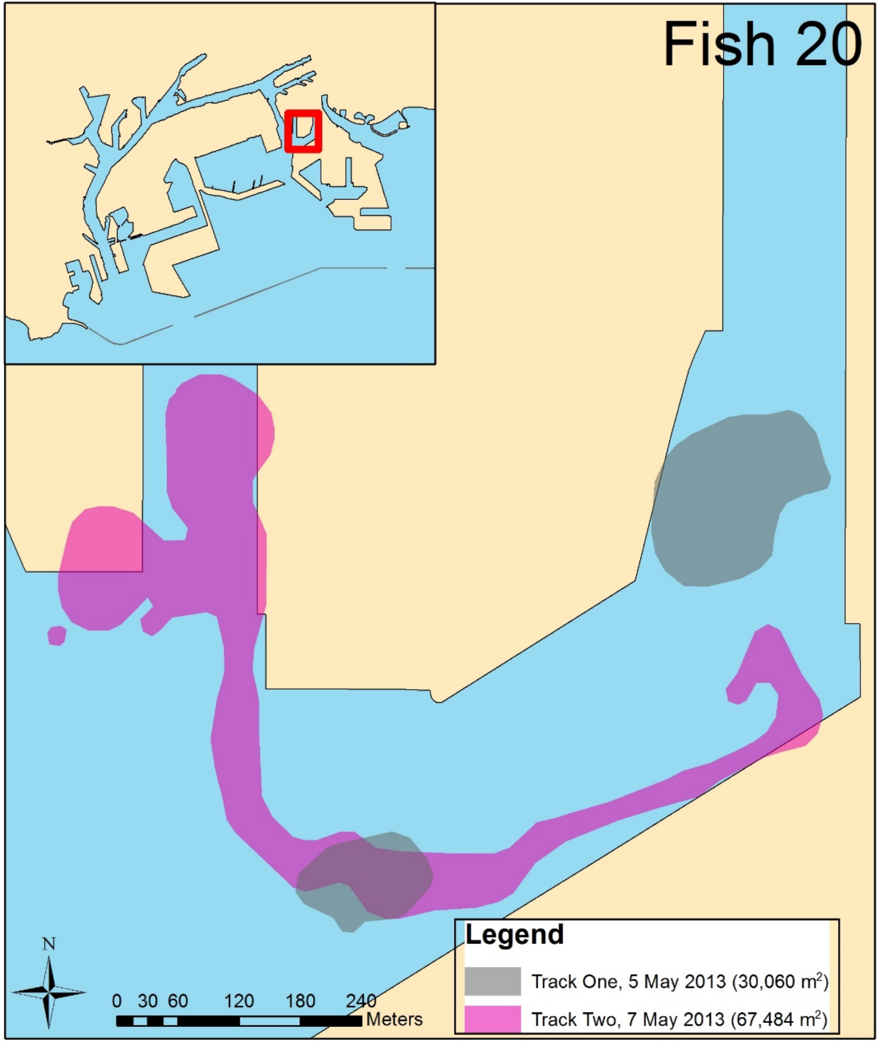

FIGURE 27. Map of area used by Fish 20, tracked in the outer LB Harbor

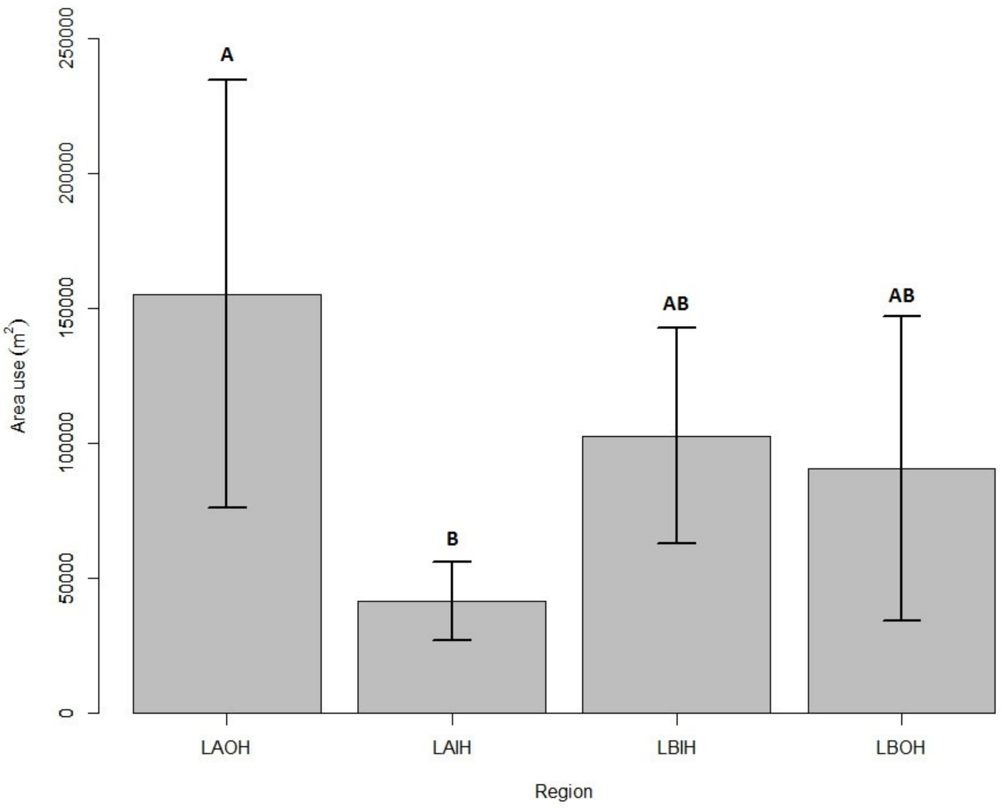

FIGURE 28. Area use (m^2) by harbor region. Significant differences existed between regions (F-value = 3.589, df = 3, p = 0.0298), however the only significant pairwise comparison existed between the inner LA and outer LA regions (p = 0.0179).

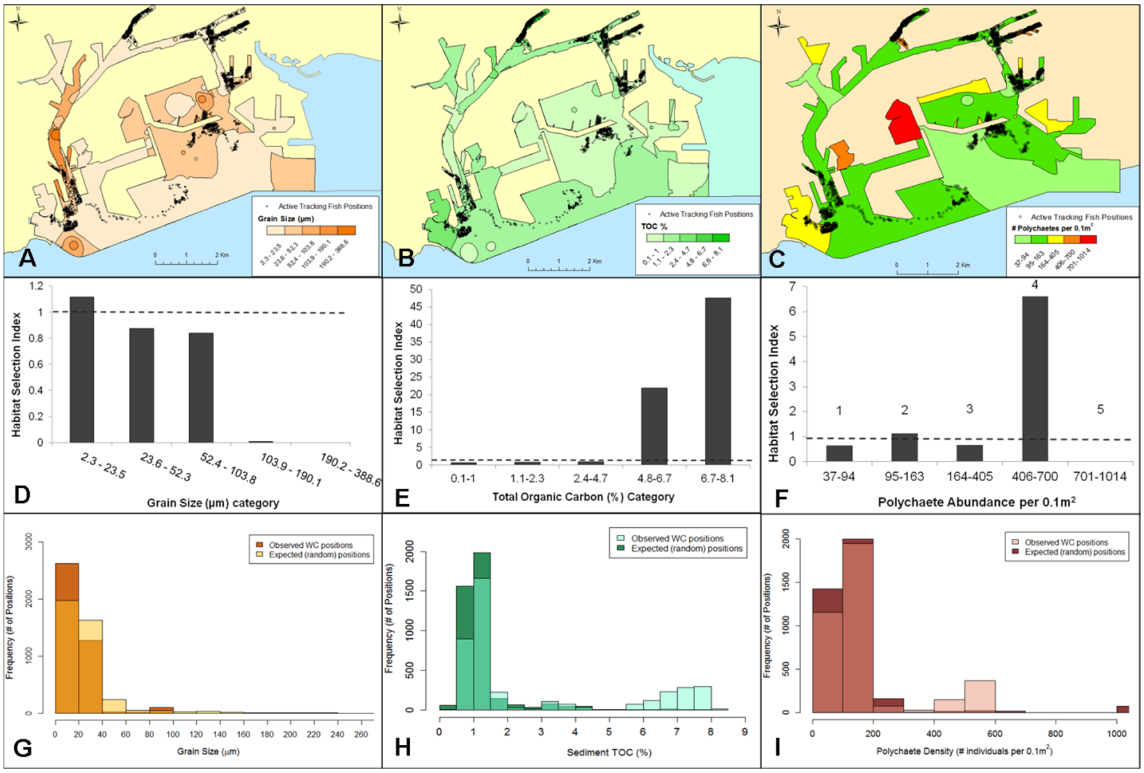

FIGURE 29. Habitat selection indexes and frequency distributions for sediment grain size, sediment total organic carbon, and polychaete density. **A**. IDW interpolation of grain size (µm) overlaid with all active tracking fish positions taken every 10 minutes during each 24 hour track (black points). **B**. IDW interpolation of sediment total organic carbon (%) overlaid with all active tracking fish positions (black points). **C**. IDW interpolation of draft polychaete density data from Bight 2013 overlaid with all active tracking fish positions (black points). **D**. White croaker habitat selection index (HSI) for grain size (µm). Dashed line indicates no selection at a HSI of 1. White croaker selected for grain sizes of < 23.5 µm ($\chi^2 = 161$, df = 4, $p < 2.2 \times 10^{-16}$). **E**. White croaker selection for sediment total organic carbon (TOC %). White croaker selected for TOC of 4.8% and above ($\chi^2 = 41007$, df = 4, $p < 2.2 \times 10^{-16}$). **F**. White croaker selection of polychaete abundance. Numbers above bars indicate polychaete density category (1-lowest, 5-highest). White croaker selected for areas of category 4 (406-700 polychaetes per 0.1 m^2) ($\chi^2 = 3201$, df = 4, $p < 2.2 \times 10^{-16}$). No white croaker was ever recorded in the highest polychaete category (5) even though the habitat was available. **G**. White croaker selected grain sizes ≤ 20 µm disproportionally more often than would be expected based on random movements ($\chi^2 = 523$, df = 4, $p < 0.005$). **H**. White croaker selected areas of sediment TOC of 5% and greater disproportionally more often than would be expected based on random movements ($\chi^2 = 42179$, df =11, $p < 0.005$). **I**. White croaker selected polychaetes densities from 300-600 polychaetes/0.1 m^2 disproportionally more often than would be expected based on random movements ($\chi^2 = 2054$, df = 5, $p < 0.005$).

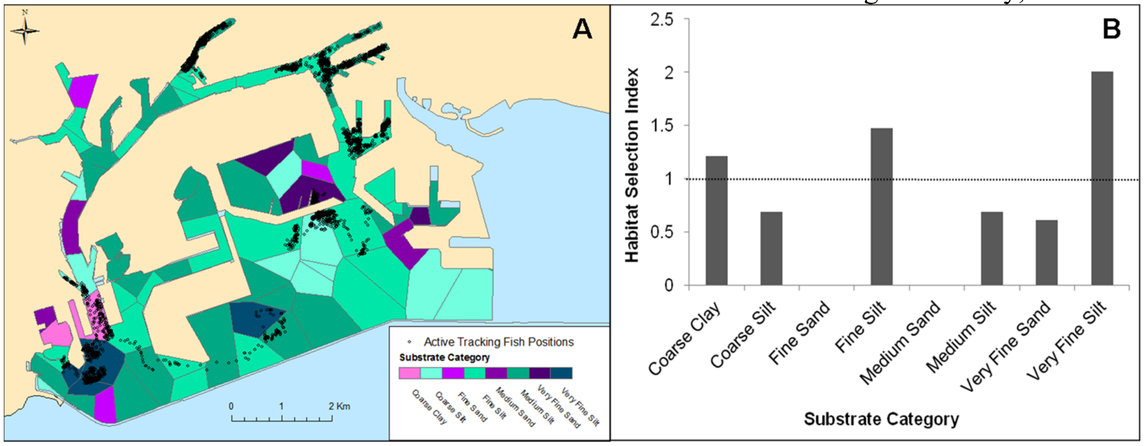

FIGURE 30. Habitat selection index for substratum type. **A**. Thiessen polygons indicating substratum category within the Los Angeles and Long Beach Harbor complex overlaid with all active tracking fish positions taken every 10 min during each 24 hr track (black points). Substratum data sources included AMEC 2002, POLA/POLB TMDL 2006, and the Bight 2008. **B**. White croaker selection for substratum type. Dashed line indicates no selection at a HSI of 1. White croaker selected for areas of coarse clay, fine silt, and very fine silt ($\chi^2 = 1093$, df =7, $p < 2.2 \times 10^{-16}$).

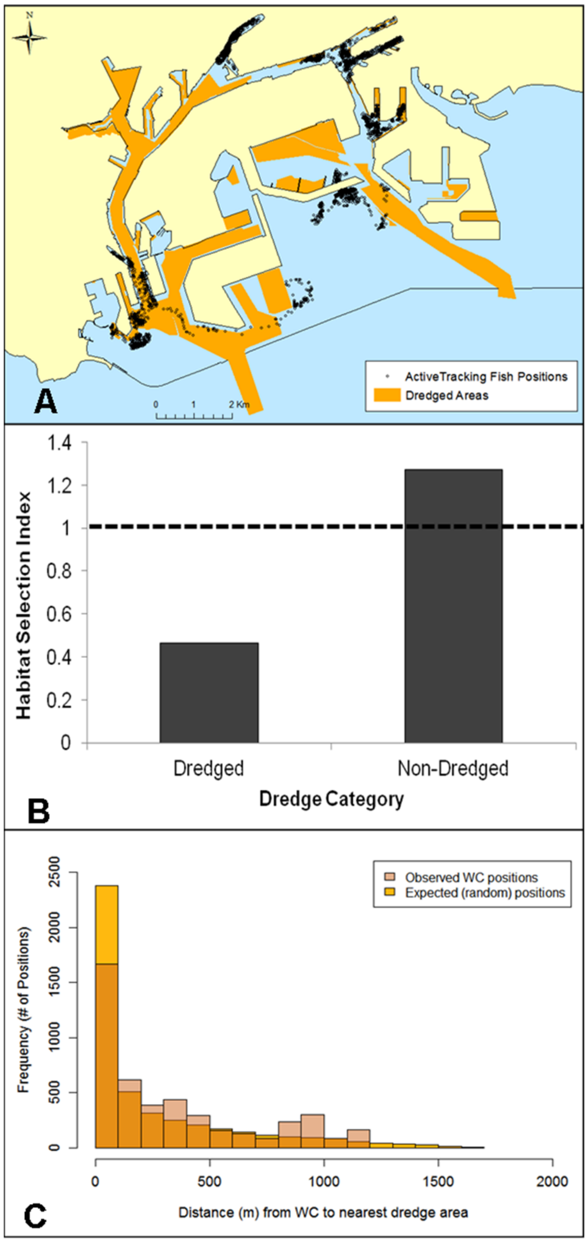

FIGURE 31. Habitat selection index and frequency distribution of fish positions for dredged vs. non-dredged areas. **A**. Known dredged areas (dark brown) overlaid with all active tracking fish positions (black points) taken every 10 min during each 24 hr track. White croaker selected were an average of 329 m away from dredged areas. **B**. White croaker selected for non-dredged areas ($\chi^2 = 663$, df = 1, $p < 2.2 \text{ x}10^{-6}$). **C**. White croaker selection of areas at least 100 m away from dredged areas differed significantly than expected selection based on a random distribution of fish positions ($\chi^2 = 1063$, df =11, $p < 0.005$).

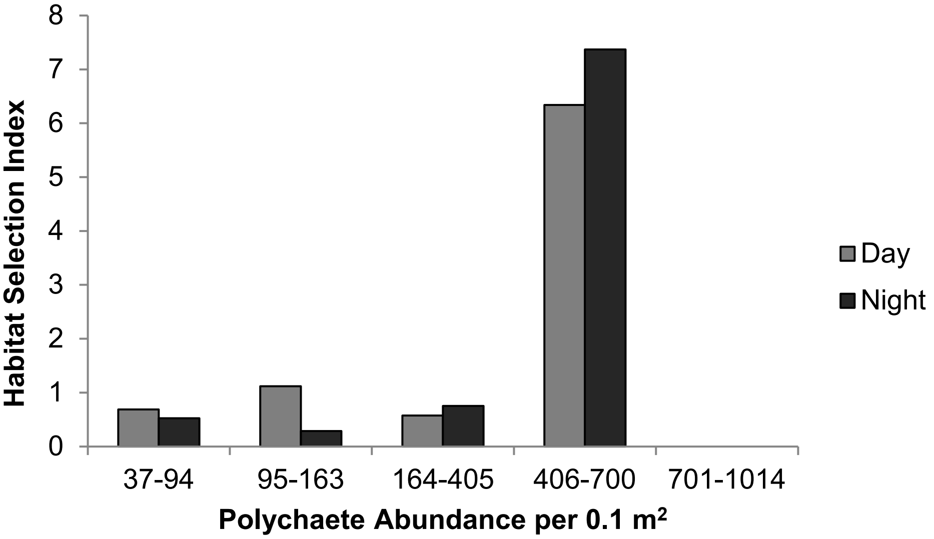

FIGURE 32. White croaker habitat selection of polychaete abundance for day and night periods. White croaker selected for areas of category 4 (406-700 polychaetes per 0.1 m^2) during both the day and night (Day: $\chi^2 = 1541$, df = 4, $p < 2.2 \times 10^{-16}$; Night: $\chi^2 = 1733$, df = 4, $p < 2.2 \times 10^{-16}$) however, selection did not differ between day and night periods (Paired t test, T=1.02, p = 0.366.). Data from draft Bight 2013 polychaete data. No white croaker was ever recorded in the highest polychaete category (5) even though the habitat was available.

TABLE 2. Example of Mixed Effects Model Equations used to Determine Factors Influencing Depth Selection of Actively Tracked White Croaker

Model #	Model for Raster Depth (m)	DF	AIC
0	1 + (1|individual fish)	3	42296.5
1	1 + (1|Fish Track #)	3	51085.2
2	Fish Track #+ (1|individual fish)	6	40944.2
3	Region + (1|individual fish)	6	42283.2
4	Time of day + (1|individual fish)	4	41721.1
5	Time of day + Region + (1|individual fish)	7	41707.8
6	Time of day + Port + (1|individual fish)	5	41720.6
7	Time of day + Inner or Outer Harbor + (1|individual fish)	5	41720.2
8	Time of day + Port * Inner or Outer Harbor + (1|individual fish)	7	41707.8
9	Time of day * Region + (1|individual fish)	10	41605.5
10	Time of day * Port * Inner or Outer Harbor + (1|individual fish)	10	41605.5
11	Time of day * Region + (1|Fish Track #) + (1|individual fish)	11	40136.3
12	Time of day + Region + (1|Fish Track #) + (1|individual fish)	8	40260.9

Note: Depth was estimated using raster values. Port jurisdiction (Port) was defined as either Los Angeles or Long Beach harbor; harbor location was defined as inner or outer harbor (combining both ports). Region was defined as described above as Los Angeles and Long Beach inner and outer harbors. The best candidate model with the lowest AIC value is highlighted in gray.

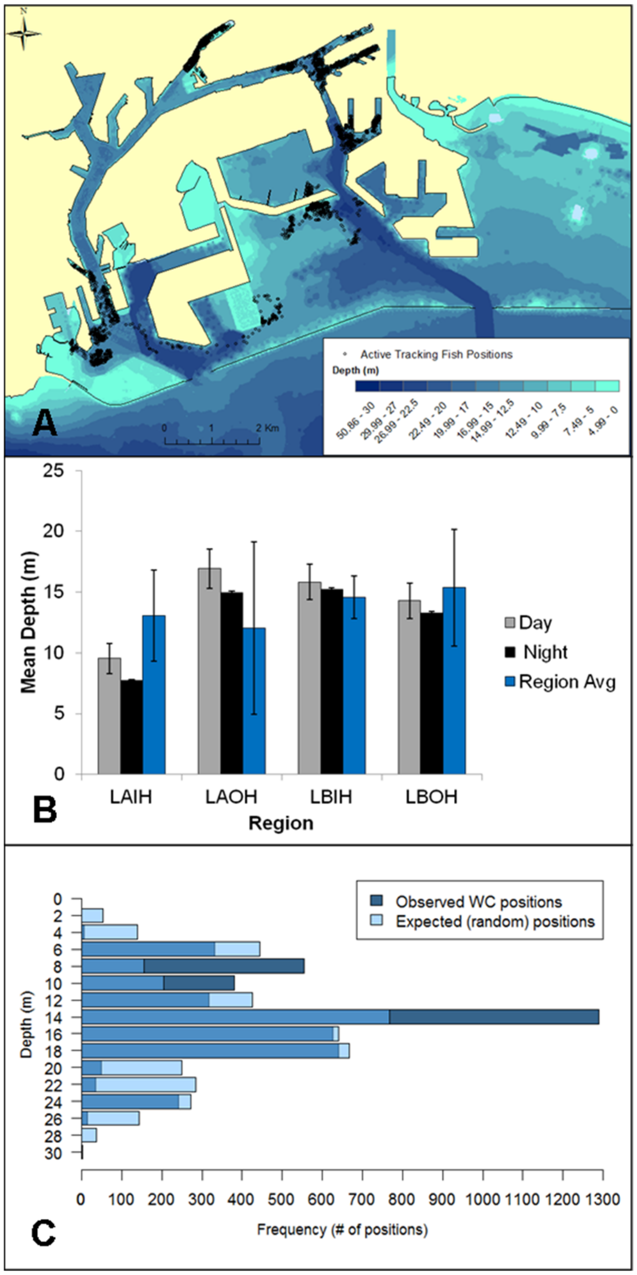

FIGURE 33. Bathymetry mixed effects model results and frequency distribution for fish positions in relation to bathymetry. **A**. IDW interpolation of bathymetry data from 2001 to 2009 overlaid with all active tracking fish position taken every 10 min during each 24 hr track (black points). **B**. Estimated depths (m) from mixed effects model for day (gray bars) and night (black bars) ± standard error. Regional average depth (blue bars ± standard error) was calculated from raster values in ArcMap. **C**. White croaker selection for depths 7-11 m and 13-15 m differed significantly than expected selection based on a random distribution of fish positions ($\chi^2 = 2314$, df =11, $p < 0.005$).

TABLE 3. Mixed Effects Model Results for the Best Candidate model (#11) for Actively Tracked White Croaker with Depth as the Response

Parameter	Δ Depth (m)	Std. Error	Lower MCMC confidence interval	Upper MCMC confidence level	P value
(Intercept)	9.55	1.23	6.78	11.91	0.0001
Time of day night	-1.84	0.09	-2.02	-1.65	0.0001
Region LAOH	7.38	1.62	5.04	10.19	0.0001
Region LBIH	6.27	1.46	4.14	8.46	0.0001
Region LBOH	4.74	1.46	2.61	6.96	0.0001
TOD (N) : Region LAOH	-0.16	0.15	-0.44	0.13	0.2716
TOD (N) : Region LBIH	1.22	0.13	0.97	1.49	0.0001
TOD (N) : Region LBOH	0.83	0.13	0.57	1.09	0.0001

Note: The best candidate model included Time of Day* Region, track number, and individual fish. Note: Depths were determined by extraction of raster depth values for position fixes taken during active tracking. Depth over which the boat was located every 10 minutes was assumed to be the depth of the fish. P value is the estimated value from the MCMC.

TABLE 4. Rate of Movement GAM Results

Parametric coefficients:	Estimate	Std. Error	T	P-value
(Intercept)	0.057	0.031	1.856	0.064
Harbor Location (OH)	-0.021	0.024	-0.863	0.388
Region LAOH	-0.002	0.013	-0.177	0.860
Region LBIH	0.003	0.036	0.076	0.939
Region LBOH	-0.019	0.016	-1.177	0.239
Time of Day (Night)	0.036	0.013	2.817	0.005
Polychaete Density Category	0.016	0.005	3.248	0.001
Season Summer	-0.020	0.009	-2.197	0.028
Season Winter	-0.009	0.015	-0.616	0.538
TOD (Night) : Polychaete Density Category	-0.018	0.006	-3.096	0.002
Approximate significance of smooth terms	**edf**	**Ref.df**	**F**	**P-value**
Turning Angle	6.812	7.906	2.937	0.003
Grain Size	5.465	6.667	3.135	0.003
Depth (m)	6.028	7.298	1.352	0.218
Sediment TOC (%)	1.303	1.546	0.216	0.748
Temperature (°C)	1.000	1.000	0.037	0.847

Note: Significant results are shaded in gray. $R^2 = 0.05$, deviance explained = 6.9%.

TABLE 5. Rate of Movement Mixed Effects Models and AIC Values

Model #	Models describing rate of movement (m per sec)	DF	AIC
0	(1|individual fish)	3	-6393.1
1	(1|individual fish) + Inner or Outer harbor	4	-6392.7
2	(1|individual fish) + Inner or Outer harbor + turning angle	5	-6394.4
3	(1|individual fish) + Inner or Outer harbor + turning angle + Depth	6	-6419.1
4	(1|individual fish) + Inner or Outer harbor + turning angle + Depth + Time of day	7	-6427.7
5	(1|individual fish) + Inner or Outer harbor + turning angle + Depth + Time of day*Polychaete Category	9	-6429
6	(1|individual fish) + Inner or Outer harbor + turning angle + Depth + Time of day + Grain Size	8	-6426.1
7	(1|individual fish) + Inner or Outer harbor + turning angle + Depth + Time of day + Grain Size + TOC	9	-6424.2
8	(1|individual fish) + Inner or Outer harbor + turning angle + Depth + Time of day + TOC	8	-6425.9
9	(1|individual fish) + Inner or Outer harbor + turning angle + Depth + Time of day*Polychaete Category + Grain Size	10	-6427.4
10	(1|individual fish) + Inner or Outer harbor + turning angle + Depth + Time of day*Polychaete Category + Grain Size + TOC	11	-6425.4
11	(1|individual fish) + Inner or Outer harbor + turning angle + Depth + Time of day*Polychaete Category + Grain Size*TOC	12	-6424.4
12	(1|individual fish) + Inner or Outer harbor + turning angle + Time of day*Polychaete Category	8	-6411
13	(1|individual fish) + Inner or Outer harbor + turning angle*Polychaete Category + Depth + Time of day*Polychaete Category	10	-6428
14	(1|individual fish) + turning angle + Depth + Time of day*Polychaete Category	8	-6430.6
15	(1|individual fish) + turning angle + Depth + Time of day*Polychaete Category + Season	11	-6431.8

Note: Example of mixed effects model equations used to determine factors influencing rate of movement for white croaker active tracking data. Depth was estimated using raster values. Harbor location was defined as inner or outer harbor (combining both ports), TOC = sediment TOC (%). The best candidate model with the lowest AIC value is highlighted in gray.

TABLE 6. Mixed Effects Model Results for the Best Candidate Model (# 15) for Tortuous Behavior (Fractal D value) of Actively Tracked White Croaker

Parameter	Estimate	Δ ROM (m/2)	Lower MCMC Confidence Level	Upper MCMC Confidence Level	P Value
(Intercept)	0.0397	0.039	0.0098	0.0687	0.012
Turning angle	-0.0017	-0.0017	-0.0033	0	0.0454
Depth (m)	-0.0026	-0.0026	-0.0037	-0.0015	0.0001
TOD Night	0.0055	0.0053	-0.0117	0.0239	0.5626
Polychaete Density Category	0.006	0.006	0.0002	0.0118	0.0424
Season Spring	-0.0041	-0.0037	-0.0263	0.0179	0.7274
Season Summer	-0.0202	-0.0199	-0.0407	0.0022	0.0724
Season Winter	-0.0171	-0.0167	-0.0456	0.0131	0.246
TOD Night : Polychaete Density Category	-0.0079	-0.0078	-0.0156	-0.0004	0.046

Note: The best candidate model included turning angle, depth, and time of day*polychaete category, and season. Note: Depths were determined by extraction of raster depth values for position fixes taken during active tracking. Depth over which the boat was located every 10 min was assumed to be the depth of the fish. Probability value is the estimated value from the MCMC. Polychaete density category was based off interpolated raster data.

TABLE 7. Activity Space Mixed Effects Models and AIC Values

Model #	Models describing activity space	DF	AIC
0	(1|Individual Fish)	3	1840.67
1	(1|Individual Fish) + Time of Day	4	1837.48
2	(1|Individual Fish) + Time of Day + Grain Size + TOC	6	1814.97
3	(1|Individual Fish) + Time of Day + Grain Size + TOC	6	1814.97
4	(1|Individual Fish) + Time of Day + Grain Size*TOC	7	1815.66
5	(1|Individual Fish) + Time of Day + Grain Size + TOC + Depth	7	1810.97
6	(1|Individual Fish) + Time of Day + Grain Size + TOC + Depth + ROM	8	1792.86
7	(1|Individual Fish) + Time of Day + Grain Size + TOC + Depth + ROM + Inner or Outer Harbor	9	1793.54
8	(1|Individual Fish) + Time of Day + Grain Size + TOC + Depth + ROM + Day Length	9	1792.35
9	(1|Individual Fish) + Time of Day + Grain Size + TOC + Depth + ROM + Day Length + Polychaete Density Category	10	1792.15
10	(1|Individual Fish) + Time of Day + Grain Size + TOC + Depth + ROM + Inner or Outer Harbor + Polychaete Density Category + Day Length	11	1791.08

Note: Example of mixed effects model equations used to determine factors influencing activity space for each active track for white croaker. Depth was estimated using raster values. Harbor location was defined as inner or outer harbor (combining both ports), TOC = sediment TOC (%), ROM = average rate of movement. Several models compete for the best candidate model and are highlighted in gray.

TABLE 8. Example of Mixed Effects Model Equations used to Determine Factors Influencing Fractal D for each Actively Tracked White Croaker

Model #	Models describing Fractal D	DF	AIC
0	(1|Individual Fish)	3	-41.1
1	(1|Individual Fish) + Day Length	4	-41.7
2	(1|Individual Fish) + Day Length + Season	7	-36.8
3	(1|Individual Fish) + Day Length + Season + Time of Day	8	-34.8
4	(1|Individual Fish) + Day Length + Time of Day	5	-39.8
5	(1|Individual Fish) + Day Length + Time of Day + Inner or Outer Harbor	6	-38.3
6	(1|Individual Fish) + Day Length + Time of Day + Inner or Outer Harbor + Activity Space	7	-53.1
7	(1|Individual Fish) + Day Length + Time of Day + Inner or Outer Harbor + Activity Space + ROM	8	-63.5
8	Time of Day + Activity Space*ROM +(1|Individual Fish)+ Inner or Outer Harbor + Depth + Day Length	10	-71.9
9	Time of Day + Activity Space*ROM +(1|Individual Fish)+ Inner or Outer Harbor + Depth + Day Length + Grain Size	11	-75.2
10	Time of Day + Activity Space*ROM +(1|Individual Fish)+ Inner or Outer Harbor + Depth + Day Length + Grain Size*TOC	13	-85.2
11	Time of Day + Activity Space*ROM +(1|Individual Fish)+ Inner or Outer Harbor + Depth + Day Length + Grain Size + TOC	12	-75.1
12	Time of Day + Activity Space*ROM +(1|Individual Fish)+ Inner or Outer Harbor + Depth + Day Length + Grain Size + TOC + Polychaete Category	13	-73.5
13	Time of Day + Activity Space*ROM +(1|Individual Fish)+ Inner or Outer Harbor + Depth + Day Length + Grain Size*TOC + Polychaete Category	14	-83.5
14	Time of Day + Activity Space*ROM +(1|Individual Fish)+ Inner or Outer Harbor + Depth + Day Length + Grain Size*TOC + Season	16	-80.1

Note: Depth was estimated using raster values. Harbor location was defined as inner or outer harbor (combining both ports), TOC = sediment TOC (%), ROM = average rate of movement. The best candidate model with the lowest AIC value is highlighted in gray. Temperature was used in a different set of models due to temperature only being available for a subset of the data.

TABLE 9. Mixed Effects Model Results for the Best Candidate Model (# 10) for Tortuous Behavior (Fractal D value) of Actively Tracked White Croaker

Parameter	Δ Fractal D Value	Lower MCMC Confidence Level	Upper MCMC Confidence Level	P Value
(Intercept)	1.4967	1.1106	1.8822	0.0001
Time of Day Night	-0.0678	-0.1312	-0.0095	0.0298
Activity Space	0	0	0	0.0024
Average ROM	-4.5028	-6.1294	-2.9129	0.0001
Harbor Location (OH)	0.0872	-0.0023	0.1825	0.0628
Average Depth (m)	0.0069	-0.0045	0.0185	0.2306
Day Length (hours)	0.0211	-0.0022	0.0435	0.0656
Grain size	0.0055	-0.001	0.0118	0.0876
Sediment TOC	0.0864	0.0238	0.1503	0.0076
Activity Space :Average ROM	0	0	0	0.0042
Grain size: sediment TOC	-0.0109	-0.0175	-0.0043	0.0012

Note: The best candidate model included time of day, activity space*average rate of movement, harbor location (inner or outer harbor), depth, day length, and grain size* sediment total organic carbon. Note: Depths were determined by extraction of raster depth values for position fixes taken during active tracking. Depth over which the boat was located every 10 min was assumed to be the depth of the fish. Probability value is the estimated value from the MCMC. Grain size, sediment TOC, and depth were averages based off interpolated raster data.

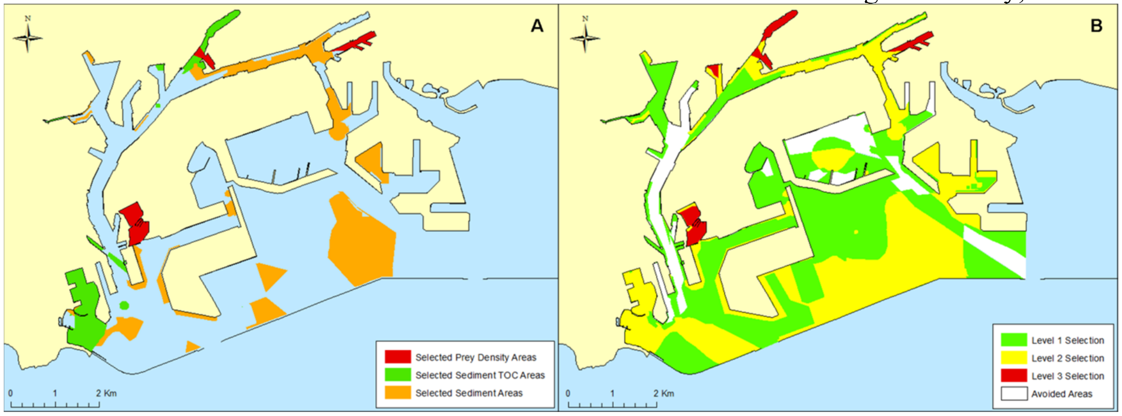

FIGURE 34. Predictive habitat use maps indicating areas of high habitat quality for white croaker. Analyses did not extend east of Queen's Gate into Eastern San Pedro Bay. **A.** Predictive model based on selection for sediment characterization, sediment TOC, and prey density. Selected sediment areas include non-dredged areas, sediment grain sizes < 23.5 µm, and preferred substratum types (coarse clay, fine silt, and very fine silt). Selected sediment TOC areas include areas with sediment total organic carbon of 4.8-8.1%. Selected prey density areas include areas with polychaete densities of 406-700 individual polychaetes. **B**. Predictive map based on environmental and biological factors indicating areas of high habitat quality for white croaker. Level selection corresponds to the number of selection parameters included in the spatial model. Level 1 selection (green) identifies areas which contain at least one of the four selection parameters, level 2 selection (yellow) identifies areas containing any combination of 2 out of the 4 selection parameters, and level 3 (red) identifies areas containing any combination of 3 out of the 4 selection parameters. White areas indicate areas that do not contain any of the selection parameters and are therefore avoided by white croaker. No location contained all four selection parameters.

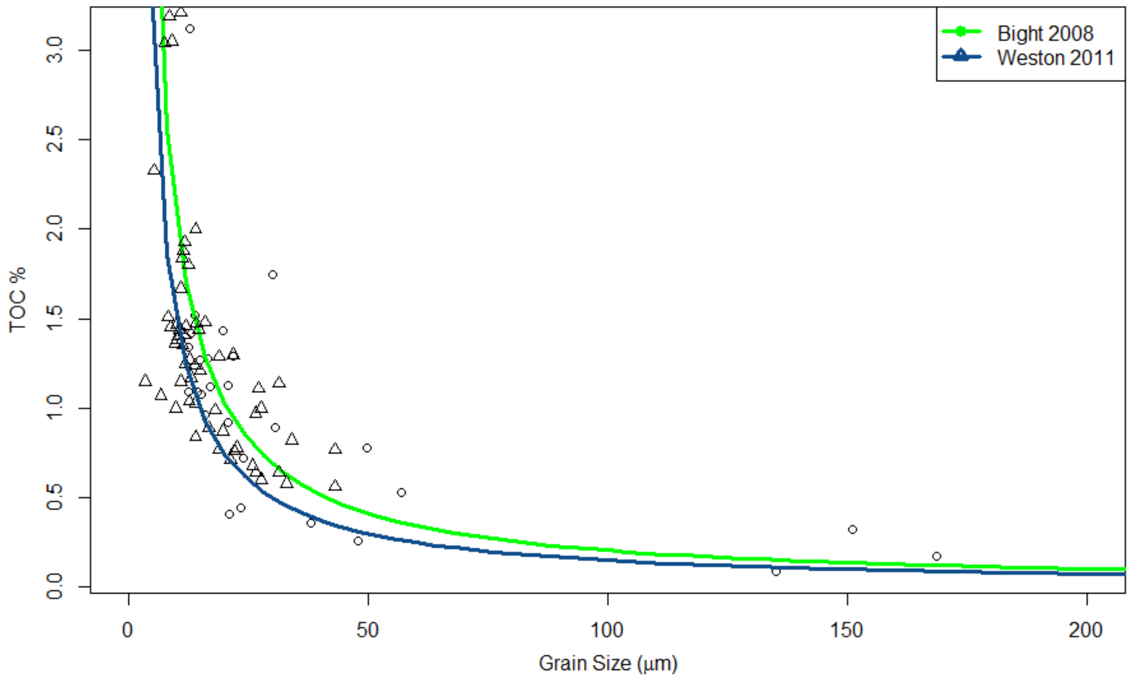

FIGURE 35. Non-linear model (y=1/x) between sediment TOC and grain size for Bight 2008 data (open circles with green curve) and Weston 2011 data (open triangles with blue curve). Year and covariate were significant however the interaction between grain size and year was not significant indicating similar slopes but varying intercepts (ANCOVA, Grain size: f = 8.7, df = 1, p = 0.004; Year: f = 6.175, df =1, p = 0.014; Grain size x year: f = 0, df = 1, p = 0.99).

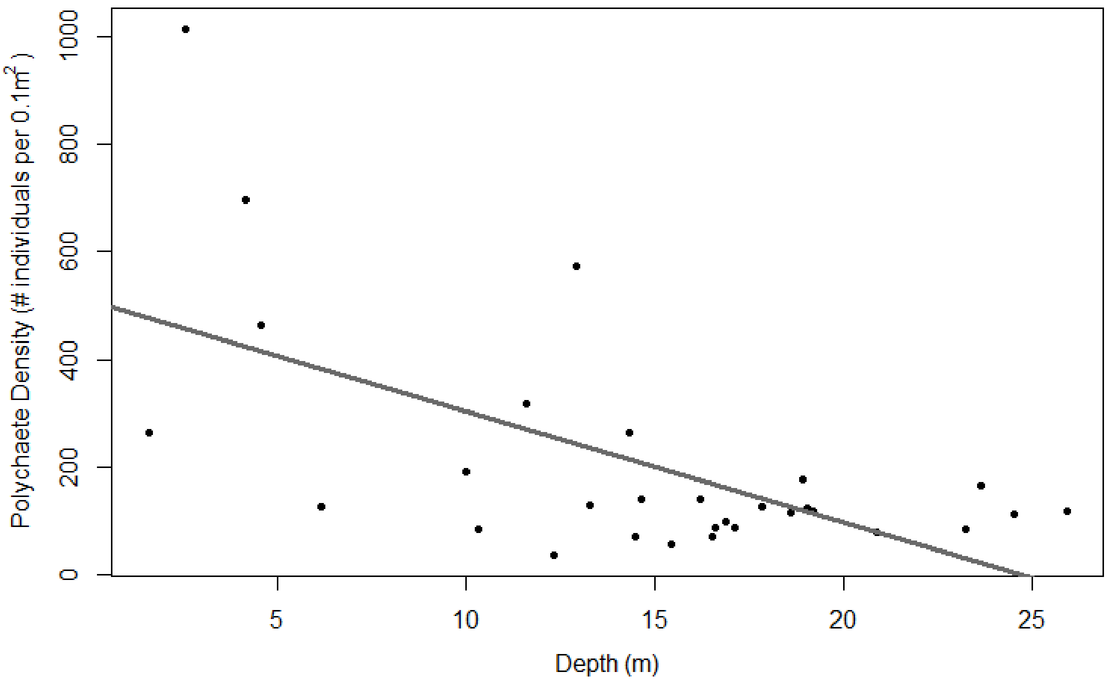

FIGURE 36. Negative correlation between polychaete density and depth (m) from draft Bight 2013 data (t = -4.04, df = 28, r = -0.607, p = 0.0003).

TABLE 10. PERMANOVA Pairwise Test Comparisons for Polychaete Community Composition between Regions for Draft Bight 2013 Data

Region	T Value	P Value
LAOH & LBOH	1.41	0.01
LAOH & LAIH	1.07	0.26
LAOH & LBIH	1.16	0.16
LBOH & LAIH	1.72	0.00
LBOH & LBIH	1.15	0.13
LAIH & LBIH	1.33	0.15

Note: Significant results are highlighted in gray.

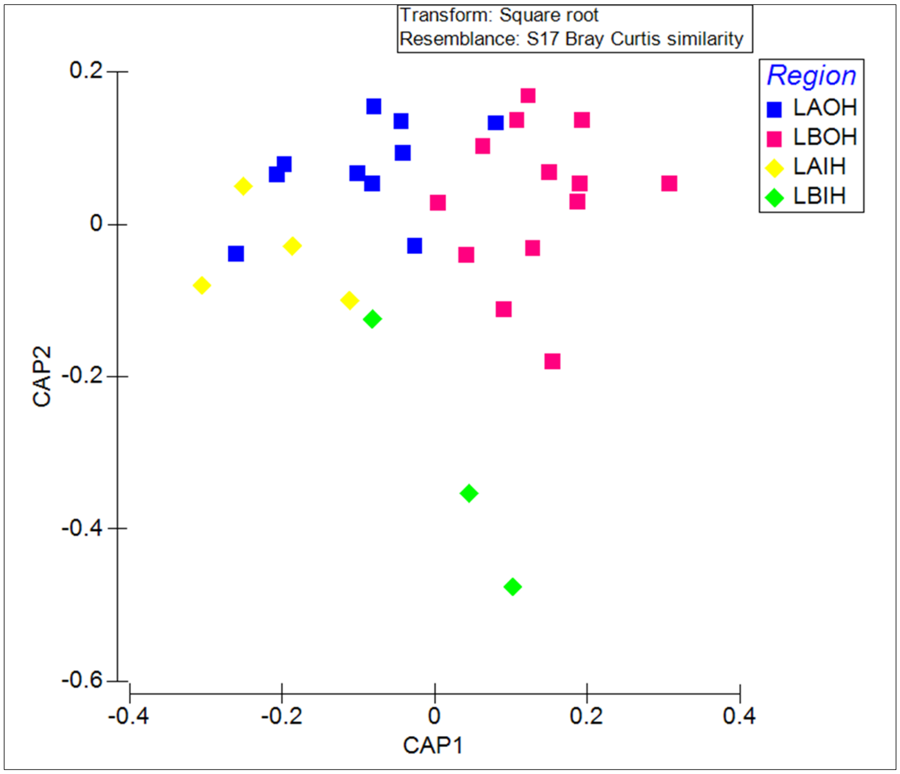

FIGURE 37. CAP analysis of polychaete community composition per region of the harbor based on station for draft Bight 2013 data. Data was square root transformed prior to analysis.

TABLE 11. Average Similarity (Percent) within and among Regions for Polychaete Community Composition for Draft Bight 2013 Data

Region	LAOH	LBOH	LAIH	LBIH
LAOH	30.40			
LBOH	31.72	37.61		
LAIH	31.84	27.68	35.17	
LBIH	32.82	37.98	32.84	43.86

TABLE 12. Polychaete Community Composition within LAOH for Draft Bight 2013 Data

Region: LAOH Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Cossura sp A	3.54	3.71	1.24	12.21	12.21
Euchone limnicola	2.43	2.21	0.73	7.28	19.49
Mediomastus sp	1.95	1.87	0.87	6.15	25.64
Pista wui	1.78	1.72	0.87	5.67	31.31
Pseudopolydora paucibranchiata	5.69	1.66	0.34	5.46	36.76
Pista brevibranchiata	1.44	1.5	1.11	4.94	41.7
Aphelochaeta monilaris	1.86	1.48	0.78	4.88	46.59
Prionospio (Minuspio) multibranchiata	1.54	1.47	1.14	4.85	51.44
Paramage scutata	1.41	1.33	0.85	4.37	55.81
Spiophanes duplex	1.38	1.05	0.8	3.45	59.26
Laonice cirrata	1.55	1.03	0.64	3.39	62.65
Notomastus hemipodus	0.89	0.83	0.92	2.74	65.39
Malmgreniella macginitiei	1.02	0.82	0.67	2.68	68.07
Paraprionospio alata	0.86	0.71	0.67	2.35	70.42
Spiophanes berkeleyorum	0.8	0.7	0.68	2.32	72.73
Cirratulidae	0.8	0.66	0.68	2.18	74.91
Scoletoma sp	0.96	0.62	0.5	2.05	76.96
Monticellina cryptica	0.87	0.51	0.51	1.69	78.65
Sigambra setosa	0.77	0.48	0.5	1.59	80.24
Leitoscoloplos sp A	0.69	0.46	0.52	1.5	81.74
Monticellina siblina	0.74	0.45	0.5	1.48	83.22
Pectinaria californiensis	0.62	0.44	0.52	1.46	84.68
Bipalponephtys cornuta	0.66	0.43	0.52	1.42	86.09
Glycera americana	0.66	0.43	0.52	1.42	87.51
Euclymeninae sp A	1.08	0.41	0.5	1.35	88.86
Cossura candida	0.67	0.39	0.52	1.29	90.15

Note: Average similarity between stations for polychaete composition within LAOH was 30.4% and had the lowest regional similarity.

TABLE 13. Polychaete Community Composition within LBOH for Draft Bight 2013 Data

Region: LBOH Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Cossura sp A	4.57	5.94	2.75	15.8	15.8
Aphelochaeta monilaris	2.11	3.15	1.88	8.37	24.16
Pista wui	1.96	2.3	1.01	6.1	30.27
Laonice cirrata	1.46	1.95	0.98	5.2	35.46
Paraprionospio alata	1.18	1.62	1.08	4.3	39.76
Leitoscoloplos sp A	1.36	1.59	1.08	4.22	43.98
Mediomastus sp	1.49	1.37	0.83	3.65	47.63
Glycera americana	1.03	1.3	1.05	3.46	51.09
Cossura candida	1.38	1.3	0.83	3.45	54.55
Prionospio (Minuspio) multibranchiata	0.98	1.15	0.88	3.07	57.62
Pista brevibranchiata	1.41	1.12	0.57	2.99	60.6
Petaloclymene pacifica	1	1.06	0.84	2.81	63.41
Paramage scutata	1.14	1.01	0.67	2.69	66.1
Monticellina cryptica	1.22	0.91	0.69	2.42	68.52
Scoletoma sp	1.03	0.84	0.7	2.22	70.75
Spiochaetopterus costarum Cmplx	0.87	0.83	0.58	2.21	72.96
Streblosoma sp B	0.98	0.77	0.7	2.05	75.01
Spiophanes berkeleyorum	0.84	0.75	0.58	2	77.01
Malmgreniella macginitiei	0.75	0.7	0.57	1.87	78.88
Amphicteis scaphobranchiata	0.7	0.59	0.59	1.58	80.46
Marphysa disjuncta	1.07	0.59	0.56	1.56	82.02
Monticellina siblina	0.98	0.56	0.47	1.48	83.5
Spiophanes duplex	0.7	0.54	0.59	1.44	84.94
Ninoe tridentata	0.61	0.41	0.47	1.1	86.04
Nereis sp A	0.49	0.41	0.47	1.08	87.12
Sigambra setosa	0.53	0.39	0.48	1.03	88.15
Poecilochaetus martini	0.49	0.39	0.48	1.02	89.17
Diopatra tridentata	0.45	0.28	0.38	0.74	89.91
Metasychis disparidentatus	0.38	0.26	0.38	0.7	90.61

Note: Average similarity between stations for polychaete composition within LBOH was 37.61%.

TABLE 14. Polychaete Community Composition within LAIH for Draft Bight 2013 Data

Region: LAIH Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Euchone limnicola	3.3	5.49	6.98	15.62	15.62
Cossura sp A	5.41	3.78	0.87	10.74	26.36
Cossura sp	2.27	3.39	4.35	9.64	36
Mediomastus sp	2.23	3.25	5.43	9.25	45.25
Pista brevibranchiata	2.06	3.18	3	9.04	54.3
Pista wui	2.52	2.43	0.9	6.9	61.19
Oligochaeta	5.02	2.18	0.41	6.19	67.38
Spiophanes berkeleyorum	1.35	1.13	0.89	3.22	70.6
Paraprionospio alata	1.1	1.13	0.9	3.21	73.81
Streblosoma sp B	1.83	1.03	0.41	2.91	76.72
Pseudopolydora paucibranchiata	3.47	0.99	0.41	2.82	79.54
Aphelochaeta sp	1.26	0.96	0.86	2.73	82.27
Dorvillea (Schistomeringos) longicornis	1.54	0.96	0.86	2.73	85
Exogone lourei	2.58	0.83	0.9	2.37	87.37
Sigambra setosa	1.25	0.59	0.41	1.68	89.06
Prionospio (Minuspio) multibranchiata	0.71	0.58	0.41	1.64	90.7

Note: Average similarity between stations for polychaete composition within LAIH was 35.17%.

TABLE 15. Polychaete Community Composition within LBIH for Draft Bight 2013 Data

Region: LBIH Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Mediomastus sp	3.99	5.99	3.62	13.66	13.66
Cossura sp A	6.83	4.25	3.53	9.68	23.34
Aphelochaeta monilaris	3.29	3.75	3.74	8.56	31.9
Monticellina siblina	3.15	3.51	3.23	8	39.9
Sigambra setosa	2.19	2.97	2.43	6.76	46.66
Leitoscoloplos sp A	1.96	2.61	4.09	5.96	52.62
Cossura candida	2.18	2.15	2.52	4.9	57.52
Monticellina cryptica	2.05	2.03	3.23	4.62	62.14
Cossura sp	2.33	1.78	3.86	4.07	66.21
Streblosoma sp B	1.47	1.78	4.16	4.05	70.26
Euchone limnicola	2.49	1.6	3.15	3.65	73.91
Lumbrineris japonica	1	1.6	3.15	3.65	77.56
Glycera americana	1.05	1.03	0.58	2.35	79.91
Pista wui	1.33	0.89	0.58	2.03	81.93
Aphelochaeta petersenae	4.38	0.85	0.58	1.94	83.88
Spiophanes berkeleyorum	1.24	0.77	0.58	1.76	85.63
Prionospio (Prionospio) jubata	0.8	0.73	0.58	1.66	87.3
Diopatra tridentata	0.67	0.73	0.58	1.66	88.96
Scalibregma californicum	0.91	0.73	0.58	1.66	90.62

Note: LBIH had the highest average similarity within region between stations for polychaete composition at 43.86%.

TABLE 16. Polychaete Community Composition Dissimilarity between LAOH and LBOH for Draft Bight 2013 Data

Groups LAOH & LBOH	LAOH	LBOH				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Pseudopolydora paucibranchiata	5.69	0	5.5	0.58	8.05	8.05
Cossura sp A	3.54	4.57	2.82	1.04	4.12	12.18
Oligochaeta	2.67	0.17	2.44	0.45	3.57	15.75
Euchone limnicola	2.43	0.54	2.36	1.15	3.45	19.2
Mediomastus sp	1.95	1.49	1.57	1.35	2.3	21.5
Aphelochaeta monilaris	1.86	2.11	1.54	1.46	2.25	23.76
Pista wui	1.78	1.96	1.49	1.32	2.18	25.94
Laonice cirrata	1.55	1.46	1.41	1.37	2.07	28.01
Pista brevibranchiata	1.44	1.41	1.36	1.4	1.99	30
Mediomastus spp	1.23	0	1.19	0.59	1.75	31.75
Paramage scutata	1.41	1.14	1.18	1.27	1.73	33.48
Spiophanes duplex	1.38	0.7	1.17	0.96	1.72	35.2
Cossura candida	0.67	1.38	1.15	1.17	1.69	36.88
Monticellina cryptica	0.87	1.22	1.11	1.24	1.62	38.51
Scoletoma sp	0.96	1.03	1.09	1.31	1.59	40.1
Prionospio (Minuspio) multibranchiata	1.54	0.98	1.09	1.03	1.59	41.69
Monticellina siblina	0.74	0.98	1.07	1	1.57	43.26
Euclymeninae sp A	1.08	0.15	1.06	0.6	1.55	44.81
Leitoscoloplos sp A	0.69	1.36	1.01	1.26	1.48	46.3
Streblosoma sp B	0.56	0.98	1	1.07	1.47	47.77
Marphysa disjuncta	0.37	1.07	0.95	0.95	1.39	49.16
Malmgreniella macginitiei	1.02	0.75	0.92	1.25	1.34	50.5
Petaloclymene pacifica	0.24	1	0.89	1.18	1.31	51.8
Notomastus hemipodus	0.89	0.48	0.84	1.28	1.22	53.03
Spiochaetopterus costarum Cmplx	0.34	0.87	0.82	1.12	1.2	54.23
Paraprionospio alata	0.86	1.18	0.82	1.27	1.2	55.43
Cossura sp	0.67	0.55	0.81	0.86	1.19	56.62
Glycera americana	0.66	1.03	0.8	1.19	1.18	57.79

TABLE 16. Continued

Groups LAOH & LBOH						
	LAOH	LBOH				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Spiophanes berkeleyorum	0.8	0.84	0.79	1.21	1.16	58.96
Amphicteis scaphobranchiata	0.64	0.7	0.79	1.13	1.16	60.11
Sigambra setosa	0.77	0.53	0.77	1.08	1.12	61.24
Poecilochaetus martini	0.59	0.49	0.75	0.91	1.1	62.34
Cirratulidae	0.8	0.08	0.74	1.12	1.08	63.42

Note: Contribution percent is equal to the percent each species contributed to the dissimilarity between regions.

TABLE 17. Polychaete Community Composition Dissimilarity between LAOH and LAIH for Draft Bight 2013 Data

Groups LAOH & LAIH	LAOH	LAIH				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Pseudopolydora paucibranchiata	5.69	3.47	6.1	0.77	8.95	8.95
Oligochaeta	2.67	5.02	5.31	1.04	7.79	16.75
Cossura sp A	3.54	5.41	3.61	1.49	5.3	22.04
Exogone lourei	0.4	2.58	2.09	0.84	3.07	25.11
Euchone limnicola	2.43	3.3	1.73	1.77	2.54	27.65
Aphelochaeta monilaris	1.86	1.41	1.7	1.22	2.5	30.15
Streblosoma sp B	0.56	1.83	1.67	1.11	2.45	32.6
Cossura sp	0.67	2.27	1.67	1.84	2.45	35.06
Pista wui	1.78	2.52	1.6	1.39	2.35	37.41
Dorvillea (Schistomeringos) longicornis	0.42	1.54	1.53	1.02	2.25	39.66
Laonice cirrata	1.55	0	1.37	0.98	2.02	41.67
Mediomastus sp	1.95	2.23	1.22	1.44	1.79	43.46
Mediomastus spp	1.23	0	1.13	0.59	1.65	45.12
Spiophanes duplex	1.38	0.68	1.13	1	1.65	46.77
Sigambra setosa	0.77	1.25	1.12	1.24	1.64	48.41
Paramage scutata	1.41	0.81	1.11	1.22	1.63	50.04
Aphelochaeta sp	0.24	1.26	1.1	1.37	1.62	51.66
Prionospio (Minuspio) multibranchiata	1.54	0.71	1.06	1.06	1.55	53.21
Euclymeninae sp A	1.08	0	1	0.57	1.46	54.67
Spiophanes berkeleyorum	0.8	1.35	0.91	1.27	1.34	56.01
Scoletoma sp	0.96	0.5	0.88	1.16	1.29	57.3
Pista brevibranchiata	1.44	2.06	0.88	1.28	1.29	58.59
Malmgreniella macginitiei	1.02	0.6	0.84	1.18	1.23	59.82
Capitella capitata Cmplx	0	0.96	0.81	0.88	1.19	61.02
Notomastus hemipodus	0.89	0	0.79	1.22	1.16	62.18
Leitoscoloplos sp A	0.69	0.85	0.79	1.21	1.16	63.34
Monticellina cryptica	0.87	0	0.78	0.89	1.14	64.48

TABLE 17. Continued

Groups LAOH & LAIH	LAOH	LAIH				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Paraprionospio alata	0.86	1.1	0.75	1.32	1.11	65.58
Monticellina siblina	0.74	0.6	0.73	1.1	1.07	66.65

Note: Contribution percent is equal to the percent each species contributed to the dissimilarity between regions.

TABLE 18. Polychaete Community Composition Dissimilarity between LBOH and LAIH for Draft Bight 2013 Data

Groups LBOH & LAIH						
	LBOH	LAIH				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Oligochaeta	0.17	5.02	4.75	0.98	6.57	6.57
Cossura sp A	4.57	5.41	4.09	1.39	5.66	12.23
Pseudopolydora paucibranchiata	0	3.47	3.16	0.85	4.36	16.59
Euchone limnicola	0.54	3.3	2.91	3.15	4.02	20.62
Exogone lourei	0.11	2.58	2.21	0.8	3.06	23.68
Streblosoma sp B	0.98	1.83	1.82	1.22	2.51	26.19
Cossura sp	0.55	2.27	1.8	1.55	2.49	28.68
Pista wui	1.96	2.52	1.77	1.47	2.45	31.14
Aphelochaeta monilaris	2.11	1.41	1.73	1.77	2.4	33.53
Dorvillea (Schistomeringos) longicornis	0	1.54	1.58	0.94	2.18	35.71
Laonice cirrata	1.46	0	1.49	1.36	2.06	37.77
Pista brevibranchiata	1.41	2.06	1.44	1.71	1.99	39.76
Mediomastus sp	1.49	2.23	1.33	1.56	1.83	41.6
Cossura candida	1.38	0	1.32	1.12	1.83	43.43
Sigambra setosa	0.53	1.25	1.19	1.25	1.65	45.08
Aphelochaeta sp	0.23	1.26	1.13	1.34	1.56	46.64
Paramage scutata	1.14	0.81	1.09	1.12	1.5	48.14
Monticellina cryptica	1.22	0	1.09	1.05	1.5	49.64
Spiophanes berkeleyorum	0.84	1.35	1.07	1.35	1.49	51.12
Leitoscoloplos sp A	1.36	0.85	1.05	1.23	1.46	52.58
Monticellina siblina	0.98	0.6	1	0.92	1.38	53.96
Petaloclymene pacifica	1	0	0.97	1.17	1.34	55.3
Marphysa disjuncta	1.07	0.25	0.92	0.86	1.28	56.58
Capitella capitata Cmplx	0	0.96	0.88	0.88	1.21	57.79
Spiochaetopterus costarum Cmplx	0.87	0	0.87	1	1.21	59
Scoletoma sp	1.03	0.5	0.85	1.1	1.17	60.17
Glycera americana	1.03	0.71	0.83	1.22	1.15	61.32
Spiophanes duplex	0.7	0.68	0.77	1.07	1.07	62.39
Prionospio (Minuspio) multibranchiata	0.98	0.71	0.76	1.24	1.05	63.44
Paraprionospio alata	1.18	1.1	0.74	1.31	1.02	64.46
Malmgreniella macginitiei	0.75	0.6	0.73	1.09	1.01	65.47

Note: Contribution percent is equal to the percent each species contributed to the dissimilarity between regions.

TABLE 19. Polychaete Community Composition Dissimilarity between LAOH and LBIH for Draft Bight 2013 Data

Groups LAOH & LBIH	LAOH	LBIH				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Pseudopolydora paucibranchiata	5.69	1.63	5.16	0.62	7.68	7.68
Cossura sp A	3.54	6.83	3.59	1.32	5.34	13.02
Aphelochaeta petersenae	0	4.38	2.9	0.99	4.32	17.34
Oligochaeta	2.67	0	2.12	0.42	3.15	20.49
Euchone limnicola	2.43	2.49	1.99	1.38	2.95	23.44
Monticellina siblina	0.74	3.15	1.96	2.25	2.92	26.36
Mediomastus sp	1.95	3.99	1.75	1.39	2.61	28.97
Aphelochaeta monilaris	1.86	3.29	1.65	1.73	2.45	31.42
Cossura sp	0.67	2.33	1.47	1.57	2.18	33.61
Cossura candida	0.67	2.18	1.44	1.29	2.14	35.74
Sigambra setosa	0.77	2.19	1.3	1.46	1.93	37.68
Laonice cirrata	1.55	1	1.22	1.16	1.82	39.49
Pista brevibranchiata	1.44	0	1.22	1.45	1.81	41.31
Prionospio (Minuspio) multibranchiata	1.54	0.47	1.2	1	1.78	43.09
Monticellina cryptica	0.87	2.05	1.18	1.83	1.75	44.84
Pista wui	1.78	1.33	1.16	1.15	1.72	46.56
Scoletoma sp	0.96	1.49	1.14	1.4	1.7	48.26
Leitoscoloplos sp A	0.69	1.96	1.1	1.68	1.63	49.89
Aphelochaeta sp	0.24	1.41	1.07	1.35	1.6	51.49
Mediomastus spp	1.23	0	1.07	0.58	1.59	53.07
Spiophanes duplex	1.38	1	1.03	0.93	1.54	54.61
Streblosoma sp B	0.56	1.47	1.02	2.52	1.52	56.13
Paramage scutata	1.41	0.8	0.97	1.22	1.44	57.57
Euclymeninae sp A	1.08	0	0.94	0.56	1.4	58.98
Scalibregma californicum	0	0.91	0.89	1.28	1.32	60.3
Cirratulidae	0.8	0.82	0.85	1.35	1.27	61.56
Spiophanes berkeleyorum	0.8	1.24	0.85	1.28	1.26	62.83
Malmgreniella macginitiei	1.02	0.33	0.84	1.03	1.25	64.08
Lumbrineris japonica	0.1	1	0.77	2.43	1.15	65.23
Glycera americana	0.66	1.05	0.76	1.14	1.14	66.36
Notomastus hemipodus	0.89	0	0.75	1.18	1.12	67.48
Prionospio (Prionospio) jubata	0.1	0.8	0.74	1.28	1.11	68.59
Chaetozone corona	0.28	0.91	0.73	1.1	1.09	69.68
Lumbrineris sp E	0.1	0.75	0.73	0.75	1.09	70.77
Paraprionospio alata	0.86	1	0.73	1.27	1.09	71.86

TABLE 19. Continued

Groups LAOH & LBIH	LAOH	LBIH				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Drilonereis sp	0.24	0.91	0.73	1.09	1.08	72.94
Amphicteis scaphobranchiata	0.64	0.47	0.67	0.98	1	73.94

Note: Contribution percent is equal to the percent each species contributed to the dissimilarity between regions.

TABLE 20. Polychaete Community Composition Dissimilarity between LBOH and LBIH for Draft Bight 2013 Data

	LBOH	LBIH				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Cossura sp A	4.57	6.83	3.69	1.09	5.94	5.94
Aphelochaeta petersenae	0.08	4.38	3.05	1	4.92	10.87
Mediomastus sp	1.49	3.99	2.35	1.68	3.79	14.66
Monticellina siblina	0.98	3.15	2.11	1.83	3.41	18.07
Euchone limnicola	0.54	2.49	1.92	1.62	3.09	21.16
Sigambra setosa	0.53	2.19	1.62	1.7	2.61	23.77
Cossura sp	0.55	2.33	1.53	1.55	2.47	26.24
Cossura candida	1.38	2.18	1.39	1.25	2.23	28.47
Pista wui	1.96	1.33	1.33	1.11	2.14	30.61
Pista brevibranchiata	1.41	0	1.3	0.91	2.09	32.71
Monticellina cryptica	1.22	2.05	1.24	1.59	1.99	34.7
Aphelochaeta monilaris	2.11	3.29	1.19	1.4	1.92	36.62
Scoletoma sp	1.03	1.49	1.14	1.34	1.84	38.46
Aphelochaeta sp	0.23	1.41	1.1	1.39	1.78	40.24
Pseudopolydora paucibranchiata	0	1.63	1.05	0.69	1.69	41.93
Laonice cirrata	1.46	1	1.03	1.14	1.65	43.58
Scalibregma californicum	0.2	0.91	1	1.32	1.61	45.19
Marphysa disjuncta	1.07	0.67	1	0.99	1.61	46.81
Paramage scutata	1.14	0.8	0.94	1.25	1.52	48.32
Spiophanes berkeleyorum	0.84	1.24	0.93	1.09	1.49	49.82
Leitoscoloplos sp A	1.36	1.96	0.88	1.2	1.42	51.23
Streblosoma sp B	0.98	1.47	0.88	1.32	1.41	52.65
Chaetozone corona	0.27	0.91	0.84	1.08	1.36	54.01
Prionospio (Minuspio) multibranchiata	0.98	0.47	0.83	1.13	1.34	55.34
Spiochaetopterus costarum Cmplx	0.87	0	0.82	0.97	1.32	56.67
Paraprionospio alata	1.18	1	0.81	1.29	1.31	57.97
Drilonereis sp	0.24	0.91	0.8	1.05	1.29	59.27
Petaloclymene pacifica	1	0.33	0.8	1.11	1.28	60.55
Lumbrineris sp E	0	0.75	0.77	0.69	1.24	61.79
Glycera americana	1.03	1.05	0.75	1.32	1.2	62.99
Spiophanes duplex	0.7	1	0.74	1.27	1.19	64.19
Lumbrineris japonica	0.57	1	0.74	1.72	1.19	65.37
Amphicteis scaphobranchiata	0.7	0.47	0.71	1.07	1.14	66.51
Malmgreniella macginitiei	0.75	0.33	0.7	0.93	1.12	67.63
Prionospio (Prionospio) jubata	0.42	0.8	0.69	1.11	1.11	68.74

TABLE 20. Continued

	LBOH	LBIH				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Streblosoma crassibranchia	0.62	0.58	0.67	0.94	1.09	69.83
Aphelochaeta glandaria	0.43	0.67	0.63	0.92	1.01	70.84

Note: Contribution percent is equal to the percent each species contributed to the dissimilarity between regions.

TABLE 21. Polychaete Community Composition Dissimilarity between LAIH and LBIH for Draft Bight 2013 Data

	LAIH	LBIH				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Cossura sp A	5.41	6.83	4.39	1.55	6.54	6.54
Oligochaeta	5.02	0	4.25	0.9	6.33	12.86
Pseudopolydora paucibranchiata	3.47	1.63	3.01	0.93	4.48	17.34
Aphelochaeta petersenae	0	4.38	2.94	0.96	4.38	21.72
Monticellina siblina	0.6	3.15	2.08	2.13	3.1	24.82
Aphelochaeta monilaris	1.41	3.29	2.03	2.28	3.02	27.83
Exogone lourei	2.58	0.58	2	0.78	2.97	30.8
Euchone limnicola	3.3	2.49	1.96	3.76	2.92	33.73
Cossura candida	0	2.18	1.93	1.63	2.88	36.61
Pista brevibranchiata	2.06	0	1.8	2.95	2.68	39.29
Monticellina cryptica	0	2.05	1.65	3.29	2.45	41.74
Streblosoma sp B	1.83	1.47	1.62	2.07	2.41	44.15
Pista wui	2.52	1.33	1.58	1.21	2.36	46.51
Mediomastus sp	2.23	3.99	1.55	1.92	2.31	48.81
Dorvillea longicornis	1.54	0	1.4	0.9	2.08	50.9
Sigambra setosa	1.25	2.19	1.22	1.22	1.82	52.72
Cossura sp	2.27	2.33	1.2	1.74	1.79	54.51
Leitoscoloplos sp A	0.85	1.96	1.03	1.32	1.54	56.05
Spiophanes berkeleyorum	1.35	1.24	1.01	1.46	1.5	57.55
Aphelochaeta sp	1.26	1.41	0.98	1.29	1.46	59.01
Scoletoma sp	0.5	1.49	0.95	1.16	1.41	60.42
Scalibregma californicum	0	0.91	0.91	1.22	1.35	61.77
Laonice cirrata	0	1	0.9	0.96	1.34	63.11
Lumbrineris japonica	0	1	0.88	3.72	1.31	64.41
Paramage scutata	0.81	0.8	0.81	1.09	1.2	65.61
Capitella capitata Cmplx	0.96	0	0.79	0.83	1.17	66.78
Drilonereis sp	0	0.91	0.77	1.03	1.14	67.92
Spiophanes duplex	0.68	1	0.75	1.16	1.11	69.03
Cirratulidae	0.6	0.82	0.74	1.17	1.1	70.13
Paraprionospio alata	1.1	1	0.73	1.27	1.09	71.22
Glycera americana	0.71	1.05	0.73	0.99	1.09	72.31
Lumbrineris sp E	0	0.75	0.72	0.67	1.08	73.39
Chaetozone corona	0.25	0.91	0.72	1.02	1.08	74.47
Prionospio (Prionospio) jubata	0.25	0.8	0.71	1.12	1.06	75.52
Prionospio (Minuspio) multibranchiata	0.71	0.47	0.68	0.88	1.01	76.53
Diopatra tridentata	0	0.67	0.67	1.31	1	77.53

Note: Contribution percent is equal to the percent each species contributed to the dissimilarity between region

TABLE 22. Most Abundant Polychaete Species for each Harbor Region based on Year

Region	Similarity 2013	Polychaete Species 2006	Polychaete Species 2008	Polychaete Species 2013
LAOH	30.40%	*Cossura sp.*	*Pista wui*	*Cossura sp A*
LBOH	37.61%	*Cossura sp.*	*Spiophanes berkeleyorum*	*Cossura sp A*
LAIH	35.17%	*Spiophanes berkeleyorum*	*Pseudopolydora paucibranchiata*	*Euchone limnicola*
LBIH	43.86%	*Cossura sp.*	*Monticellina siblina*	*Mediomastus sp*

Note: Similarity indicates the percent similarity of polychaete community composition with regions between sampling stations. Data was from: POLA/POLB TMDL (2006), draft Bight (2013), and Bight (2008).

TABLE 23. Potential Polychaete Prey Items of White Croaker in the LA-LB Harbor

Polychaete Species Regional Average Abundance (# individuals per 0.1 m^2)

Region	*Cossura sp*	*Mediomastus sp*	*Prionospio (Minuspio) multibranchiata*	*Spiophanes berkeleyorum*	*Sum*
LAOH	4.21	3.18	1.54	0.8	9.73
LBOH	5.95	1.49	0.98	0.84	9.26
LAIH	7.68	2.23	0.71	1.35	11.97
LBIH	13.52	3.99	0	1.24	18.75

Note: Prey items are based on Ware (1979) results. Relative abundance of each species within harbor region as well as the sum of these abundances per region are provided.

TABLE 24. Receiver Station Coordinates, Deployment Date, Estimated Receiver Range, Relative Habitat, and Fish Detections per Receiver

Station	**Latitude (DD)**	**Longitude (DD)**	**Date of Deployment**	**Relative depth of receiver (m)**	**Receiver Range Area (m^2)**	**Total # fish**	**Total detections**	**Average # detections per fish**	**Average Depth (m) ± SD**	**Average TOC (%) ± SD**	**Average Grain Size (µm) ± SD**
Harbor_01	33.72164	-118.27141	8/16/2011	11	39900	30	7432	248	13.63 ± 4.27	1.13 ± 0.09	44.1 ± 25.62
Harbor_02	33.73060	-118.27500	8/13/2011	9	42225	30	127396	4247	14.03 ± 4.32	0.9 ± 0.06	113.95 ± 14.21
Harbor_03	33.74885	-118.26988	8/13/2011	12	41425	37	63834	1725	16.04 ± 1.74	1.28 ± 0.15	46.96 ± 13.22
Harbor_04	33.75343	-118.26664	8/13/2011	12	42950	43	45564	1060	14.12 ± 3.56	1.6 ± 0.03	13.38 ± 3.52
Harbor_05	33.76772	-118.25323	8/13/2011	11	35300	36	376250	10451	12.29 ± 1.90	2.83 ± 0.48	11.75 ± 0.45
Harbor_06	33.77223	-118.24959	8/16/2011	16	32350	38	668877	17602	7.54 ± 2.98	7.32 ± 0.20	9.06 ± 0.53
Harbor_09	33.77006	-118.22690	8/12/2011	16	39200	38	15272	402	15.85 ± 0.68	1.36 ± 0.01	11.55 ± 0.39
Harbor_10	33.76519	-118.22054	8/12/2011	11	42600	39	23016	590	14.91 ± 1.88	1.06 ± 0.30	18.06 ± 4.38
Harbor_11	33.75230	-118.21513	8/12/2011	18	49075	46	112522	2446	19.97 ± 3.96	1 ± 0.03	21.85 ± 2.38
Harbor_12	33.73841	-118.24385	8/13/2011	6	53875	7	163	23	5.95 ± 2.53	0.84 ± 0.03	24.59 ± 3.77
Harbor_13	33.71397	-118.27155	1/28/2012	4	70700	10	312024	31202	16.13 ± 0.54	1.7 ± 0.28	21.31 ± 1.92
AG 1	33.70900	-118.25400	6/1/2010	12	NA	8	29	4	NA	NA	NA
AG 2	33.70411	-118.25086	6/1/2010	15	NA	0	0	0	NA	NA	NA
AG 3	33.71459	-118.24740	6/1/2010	23	NA	5	20	4	NA	NA	NA
AG 4	33.70750	118.24223-	6/1/2010	17	NA	3	25	8	NA	NA	NA
QG 1	33.72600	-118.18400	6/1/2010	16	NA	0	0	0	NA	NA	NA
QG 2	33.72187	-118.18694	6/1/2010	17	NA	0	0	0	NA	NA	NA

Note: Number of fish detected and total detections are summed for the one year tracking period. Average depth (m), total organic carbon (%), and grain size (µm) within each receiver range were estimated from interpolated habitat maps. Polychaete density within each receiver range was not estimated due to insufficient coverage by the interpolation for polychaete density.

TABLE 25. White Croaker Tagged for Passive Tracking

Transmitter ID	**Date**	**Estimated Tag Die Date**	**Region Landed**	**Time of Day Landed**	**Latitude Landed (DD)**	**Longitude Landed (DD)**	**Time of Day Released**	**Latitude Released (DD)**	**Longitude Released (DD)**	**TL (mm)**	**FL (mm)**	**SL (mm)**	**Age (years)**	**Weight (g)**	**Sex**
41727	8/24/2011	2/14/2012	LAOH	12:49	33.71444	-118.27107	13:06	33.71250	-118.26732	259	253	216	10.5	210	U
41728	8/24/2011	2/14/2012	LAOH	11:07	33.71377	-118.27125	11:48	33.71252	-118.26771	255	251	216	10.1	190	U
41733	8/24/2011	2/14/2012	LAOH	12:20	33.71421	-118.27069	12:37	33.71252	-118.26734	257	253	211	10.3	230	U
41734	8/24/2011	2/14/2012	LAOH	11:05	33.71377	-118.27125	-	33.71252	-118.26771	252	250	214	9.8	185*	U
41729	8/25/2011	2/15/2012	LAOH	12:26	33.71413	-118.27094	13:12	33.71013	-118.25839	238	237	199	4.8	175	F
41731	8/25/2011	2/15/2012	LAOH	9:43	33.71420	-118.27280	10:04	33.71218	-118.26992	238	238	201	4.8	150	F
41732	8/25/2011	2/15/2012	LAOH	11:35	33.71401	-118.27122	11:55	33.70980	-118.26825	276	274	236	7.6	275	F
41730	8/25/2011	2/15/2012	LAOH	11:32	33.71400	-118.27089	12:08	33.71211	-118.26689	258	254	216	10.4	220	M
41737	8/25/2011	2/15/2012	LAOH	10:13	33.71422	-118.27307	10:26	33.71114	-118.26789	251	250	214	9.7	225	M
41736	8/25/2011	2/15/2012	LAOH	11:07	33.71408	-118.27200	11:24	33.71281	-118.26784	240	239	206	8.6	165	U
41738	8/25/2011	2/15/2012	LAOH	9:20	33.71423	-118.27176	9:38	33.71206	-118.26805	246	245	211	9.2	215	U
41697	8/30/2011	2/20/2012	LAIH	10:36	33.77340	-118.24820	10:51	33.77334	-118.24824	270	261	234	11.6	290	U
41698	8/30/2011	2/20/2012	LAIH	11:06	33.77341	-118.24824	11:21	33.77338	-118.24825	267	259	234	11.3	250	U

TABLE 25. Continued

Transmitter ID	Date	Estimated Tag Die Date	Region Landed	Time of Day Landed	Latitude Landed (DD)	Longitude Landed (DD)	Time of Day Released	Latitude Released (DD)	Longitude Released (DD)	TL (mm)	FL (mm)	SL (mm)	Age (years)	Weight (g)	Sex
41699	8/30/2011	2/20/2012	LAIH	11:31	33.77336	-118.24828	11:56	33.77339	-118.24828	245	240	214	9.1	200	U
41707	8/30/2011	2/20/2012	LAIH	12:34	33.77341	-118.24824	12:55	33.77340	-118.24819	280	270	241	12.7	270	U
41735	8/30/2011	2/20/2012	LAOH	9:18	33.71279	-118.27153	9:33	33.71218	-118.27232	246	239	215	9.2	220	U
41700	9/1/2011	2/22/2012	LAIH	12:04	33.77327	-118.24812	12:20	33.77326	-118.24810	258	253	226	6.2	-	F
41701	9/1/2011	2/22/2012	LAIH	8:25	33.77324	-118.24818	8:40	33.77320	-118.24815	253	246	220	5.9	-	F
41702	9/1/2011	2/22/2012	LAIH	11:42	33.77328	-118.24809	11:55	33.77328	-118.24811	247	240	214	5.5	-	F
41706	9/1/2011	2/22/2012	LAIH	11:31	33.77326	-118.24812	11:43	33.77328	-118.24809	239	234	208	4.9	-	F
41705	9/1/2011	2/22/2012	LAIH	10:49	33.77326	-118.24814	11:01	33.77327	-118.24813	315	310*	270	10.7	-	F
41703	9/1/2011	2/22/2012	LAIH	8:54	33.77322	-118.24818	9:08	33.77326	-118.24812	269	264	240	11.5	-	U
41704	9/1/2011	2/22/2012	LAIH	9:11	33.77327	-118.24816	9:24	33.77329	-118.24817	245	233	213	9.1	-	U
41708	9/1/2011	2/22/2012	LAIH	10:35	33.77330	-118.24818	10:47	33.77326	-118.24813	235	230	205	8.2	-	U
41709	9/1/2011	2/22/2012	LAIH	10:04	33.77328	-118.24816	10:17	33.77327	-118.24815	259	253	221	10.5	-	U
41720	9/5/2011	2/26/2012	LBIH	11:18	33.77660	-118.21007	11:37	33.77678	-118.21013	275	268	242	7.5	300	F
41715	9/6/2011	2/27/2012	LBIH	9:52	33.76760	-118.23330	10:10	33.76710	-118.23344	228	224	200	4.2	165	F

41714	9/8/2011	2/29/2012	LBIH	10:50	33.76551	-118.22218	11:18	33.76759	-118.22179	235	230	205	8.2	185	M

TABLE 25 Continued

Transmitter ID	**Date**	**Estimated Tag Die Date**	**Region Landed**	**Time of Day Landed**	**Latitude Landed (DD)**	**Longitude Landed (DD)**	**Time of Day Released**	**Latitude Released (DD)**	**Longitude Released (DD)**	**TL (mm)**	**FL (mm)**	**SL (mm)**	**Age (years)**	**Weight (g)**	**Sex**
41717	9/8/2011	2/29/2012	LBIH	9:05	33.76622	-118.22139	9:28	33.76783	-118.22325	249	244	215	9.5	220	U
41719	9/8/2011	2/29/2012	LBIH	10:02	33.76672	-118.22179	10:39	33.76988	-118.22412	241	237	213	8.7	200	U
41712	9/11/2011	3/3/2012	LBIH	14:58	33.77253	-118.22041	15:17	33.77093	-118.22154	279	272	240	7.8	330	F
41713	9/13/2011	3/5/2012	LBIH	14:03	33.76937	-118.22630	14:17	33.76795	-118.22924	224	220	192	7.1	160	M
41711	9/13/2011	3/5/2012	LBIH	13:29	33.76924	-118.22614	13:45	33.76904	-118.22730	249	245	215	9.5	240	U
41718	9/15/2011	3/7/2012	LBIH	13:45	33.77250	-118.20929	13:57	33.77251	-118.20934	263	257	223	6.6	270	F
41710	9/15/2011	3/7/2012	LBIH	15:09	33.77254	-118.20929	15:23	33.77255	-118.20934	240	235	205	8.6	200	U
41721	9/15/2011	3/7/2012	LBIH	15:29	33.77258	-118.20928	15:43	33.77254	-118.20931	269	264	232	11.5	295	U
41722	9/15/2011	3/7/2012	LBIH	9:25	33.76698	-118.22237	9:46	33.76832	-118.22170	310*	305	268	16.0	450	U
41740	9/20/2011	3/12/2012	LBOH	13:07	33.74723	-118.22005	13:22	33.74953	-118.21851	237	232	201	8.3	165	M
41743	9/20/2011	3/12/2012	LBOH	12:36	33.74623	-118.22010	12:50	33.74727	-118.22195	234	230	201	8.1	195	U
41726	9/21/2011	3/13/2012	LBOH	10:47	33.74704	-118.22277	11:12	33.75054	-118.22079	245	241	213	9.1	210	U
41744	9/21/2011	3/13/2012	LBOH	9:55	33.74946	-118.21936	10:17	33.74888	-118.22048	208	205	178	5.7	140	U

41723	9/25/2011	3/17/2012	LBOH	10:59	33.74612	-118.22305	11:18	33.74824	-118.22093	250	246	216	5.7	190	F
41746	9/25/2011	3/17/2012	LBOH	10:05	33.74615	-118.22251	10:23	33.74757	-118.22062	229	225	194	4.2	170	F

TABLE 25. Continued

Transmitter ID	**Date**	**Estimated Tag Die Date**	**Region Landed**	**Time of Day Landed**	**Latitude Landed (DD)**	**Longitude Landed (DD)**	**Time of Day Released**	**Latitude Released (DD)**	**Longitude Released (DD)**	**TL (mm)**	**FL (mm)**	**SL (mm)**	**Age (years)**	**Weight (g)**	**Sex**
41739	9/25/2011	3/17/2012	LBOH	11:35	33.75001	-118.21883	11:49	33.75172	-118.21719	228	224	196	7.5	180	M
41724	9/25/2011	3/17/2012	LBOH	10:59	33.74612	-118.22305	11:24	33.74892	-118.22016	229	225	196	7.6	190	U
41725	9/25/2011	3/17/2012	LBOH	11:21	33.74851	-118.22060	11:33	33.75001	-118.21883	225	222	194	7.2	155	U
41741	9/25/2011	3/17/2012	LBOH	9:00	33.74652	-118.21921	9:27	33.74628	-118.22218	229	226	185	7.6	165	U
41742	9/25/2011	3/17/2012	LBOH	9:39	33.74720	-118.22133	10:00	33.74566	-118.22301	214	209	185	6.3	150	U
41745	9/25/2011	3/17/2012	LBOH	10:32	33.74655	-118.22213	10:49	33.74799	-118.22078	240	235	206	8.6	230	U
2535	1/9/2012	7/1/2012	LAOH	10:59	33.71399	-118.27180	11:22	33.71399	-118.27180	240	236	209	5.0	175	F
2538	1/9/2012	7/1/2012	LAOH	12:27	33.71399	-118.27180	13:19	33.71399	-118.27180	294	289	256	9.0	410	F
2536	1/9/2012	7/1/2012	LAOH	11:39	33.71399	-118.27180	12:00	33.71399	-118.27180	248	244	215	9.4	215	M
2534	1/9/2012	7/1/2012	LAOH	10:59	33.71399	-118.27180	11:50	33.71399	-118.27180	260	250	221	10.6	215	U
2540	1/10/2012	7/2/2012	LAOH	14:02	33.71372	-118.27208	14:16	33.71372	-118.27208	239	234	208	4.9	190	F
2544	1/10/2012	7/2/2012	LAOH	12:32	33.71372	-118.27208	12:49	33.71372	-118.27208	262	258	225	6.5	230	F

2545	1/10/2012	7/2/2012	LAOH	14:17	33.71372	-118.27208	14:41	33.71372	-118.27208	276	270	242	7.6	270	F
2542	1/10/2012	7/2/2012	LAOH	11:04	33.71372	-118.27208	11:28	33.71372	-118.27208	243	238	207	8.9	180	M
2537	1/10/2012	7/2/2012	LAOH	10:27	33.71372	-118.27208	10:52	33.71372	-118.27208	241	237	209	8.7	210	U

TABLE 25. Continued

Transmitter ID	Date	Estimated Tag Die Date	Region Landed	Time of Day Landed	Latitude Landed (DD)	Longitude Landed (DD)	Time of Day Released	Latitude Released (DD)	Longitude Released (DD)	TL (mm)	FL (mm)	SL (mm)	Age (years)	Weight (g)	Sex
2541	1/10/2012	7/2/2012	LAOH	12:01	33.71372	-118.27208	12:22	33.71372	-118.27208	265	261	230	11.1	290	U
2543	1/10/2012	7/2/2012	LAOH	11:41	33.71372	-118.27208	11:58	33.71372	-118.27208	260	256	221	10.6	240	U
2539	1/10/2012	7/2/2012	LAOH	13:25	33.71372	-118.27208	13:50	33.71372	-118.27208	221	218	194	6.9	155	U
2553	1/12/2012	7/4/2012	LAIH	13:44	33.77316	-118.24821	14:11	33.77316	-118.24821	269	265	236	7.0	290	F
2546	1/12/2012	7/4/2012	LAOH	8:27	33.71376	-118.27221	8:52	33.71376	-118.27221	228	225	197	7.5	140	U
2547	1/12/2012	7/4/2012	LAIH	10:15	33.77336	-118.24815	10:40	33.77336	-118.24815	259	253	224	10.5	245	U
2548	1/12/2012	7/4/2012	LAIH	10:15	33.77336	-118.24815	10:54	33.77336	-118.24815	251	248	220	9.7	225	U
2549	1/12/2012	7/4/2012	LAIH	12:18	33.77311	-118.24821	12:34	33.77311	-118.24821	285	280	249	13.2	370	U
2550	1/12/2012	7/4/2012	LAIH	12:41	33.77315	-118.24816	12:56	33.77315	-118.24816	294	288	258	14.2	390	U
2551	1/12/2012	7/4/2012	LAIH	13:04	33.77319	-118.24821	13:18	33.77319	-118.24821	251	247	216	9.7	245	U
2552	1/12/2012	7/4/2012	LAIH	13:33	33.77314	-118.24826	13:45	33.77314	-118.24826	267	263	235	11.3	285	U

2554	1/13/2012	7/5/2012	LAIH	9:55	33.77328	-118.24807	10:34	33.77328	-118.24807	242	239	216	5.1	210	F
2556	1/13/2012	7/5/2012	LAIH	13:15	33.77335	-118.24815	13:37	33.77335	-118.24815	251	248	221	5.7	245	F
2555	1/13/2012	7/5/2012	LAIH	11:05	33.77331	-118.24807	11:27	33.77328	-118.24812	270	265	238	11.6	335	U
2565	1/14/2012	7/6/2012	LBIH	12:12	33.77234	-118.20905	12:51	33.77234	-118.20905	261	257	227	10.7	270	M

TABLE 25. Continued

Transmitter ID	Date	Estimated Tag Die Date	Region Landed	Time of Day Landed	Latitude Landed (DD)	Longitude Landed (DD)	Time of Day Released	Latitude Released (DD)	Longitude Released (DD)	TL (mm)	FL (mm)	SL (mm)	Age (years)	Weight (g)	Sex
2557	1/14/2012	7/6/2012	LAIH	9:56	33.77317	-118.24815	10:14	33.77316	-118.24816	275	271	241	12.1	310	U
2558	1/14/2012	7/6/2012	LAIH	10:22	33.77317	-118.24815	10:49	33.77317	-118.24815	295	286	254	14.3	360	U
2559	1/14/2012	7/6/2012	LBIH	12:09	33.77234	-118.20905	12:36	33.77234	-118.20905	271	261	236	11.7	300	U
2561	1/16/2012	7/8/2012	LBIH	13:18	33.77241	-118.20894	13:37	33.77241	-118.20902	274	270	239	12.0	350	M
2560	1/16/2012	7/8/2012	LBIH	9:18	33.77234	-118.20899	9:32	33.77234	-118.20899	270	265	237	11.6	320	U
2562	1/16/2012	7/8/2012	LBIH	13:23	33.77241	-118.20894	13:46	33.77241	-118.20894	269	265	233	11.5	260	U
2566	1/17/2012	7/9/2012	LBIH	11:55	33.77233	-118.20899	12:11	33.77237	-118.20905	299	292	262	9.4	415	F
2568	1/17/2012	7/9/2012	LBIH	12:09	33.77237	-118.20905	12:32	33.77240	-118.20892	250	246	222	5.7	245	F
2564	1/17/2012	7/9/2012	LBIH	11:33	33.77228	-118.20901	11:49	33.77233	-118.20904	261	258	229	10.7	265	M
2563	1/17/2012	7/9/2012	LBIH	9:49	33.77228	-118.20902	10:06	33.77228	-118.20903	265	262	231	11.1	265	U

2567	1/17/2012	7/9/2012	LBIH	12:09	33.77237	-118.20905	12:26	33.77235	-118.20900	262	258	232	10.8	270	U
2574	1/18/2012	7/10/2012	LBIH	11:39	33.77222	-118.20908	12:03	33.77224	-118.20907	259	255	224	10.5	260	U
2578	1/18/2012	7/10/2012	LBIH	11:29	33.77221	-118.20911	11:55	33.77221	-118.20911	254	250	223	10.0	260	U
2575	1/30/2012	7/22/2012	LBOH	9:34	33.75374	-118.21474	10:00	33.75406	-118.21368	227	225	201	4.1	175	F
2572	1/30/2012	7/22/2012	LBOH	13:37	33.74023	-118.22849	13:49	33.73982	-118.22906	243	239	215	8.9	225	U

TABLE 25. Continued

Transmitter ID	Date	Estimated Tag Die Date	Region Landed	Time of Day Landed	Latitude Landed (DD)	Longitude Landed (DD)	Time of Day Released	Latitude Released (DD)	Longitude Released (DD)	TL (mm)	FL (mm)	SL (mm)	Age (years)	Weight (g)	Sex
2576	2/3/2012	7/26/2012	LBOH	10:39	33.74074	-118.22461	10:54	33.73922	-118.22598	234	230	205	4.6	185	F
2577	2/3/2012	7/26/2012	LBOH	9:48	33.74056	-118.22512	10:03	33.73913	-118.22614	216	213	189	3.4	145	F
2579	2/5/2012	7/28/2012	LBOH	12:54	33.75454	-118.21291	13:14	33.75577	-118.21127	251	246	221	5.7	220	F
2571	2/5/2012	7/28/2012	LBOH	12:54	33.75454	-118.21291	13:29	33.75688	-118.20979	259	257	223	10.5	290	U
2582	2/5/2012	7/28/2012	LBOH	11:34	33.75350	-118.21415	11:49	33.75447	-118.21414	228	224	198	7.5	170	U
2573	2/6/2012	7/29/2012	LBOH	9:35	33.75239	-118.21510	10:18	33.75317	-118.21377	223	218	194	3.8	145	F
2581	2/6/2012	7/29/2012	LBOH	10:50	33.75300	-118.21410	11:12	33.75478	-118.21152	238	235	209	4.8	195	F
2580	2/6/2012	7/29/2012	LBOH	9:06	33.75251	-118.21487	9:21	33.75319	-118.21444	240	236	208	8.6	185	U
2569	2/10/2012	8/2/2012	LBOH	11:45	33.75512	-118.21159	12:00	33.75558	-118.21014	230	226	199	4.3	185	F

2570	2/10/2012	8/2/2012	LBOH	11:05	33.75618	-118.21020	11:17	33.75647	-118.20937	245	241	212	5.3	210	F
2583	2/10/2012	8/2/2012	LBOH	10:35	33.75354	-118.21532	10:59	33.75606	-118.21077	201	198	176	5.1	125	M

Note: TL= total length (mm), FL= fork length (mm), SL= standard length (mm). Age was calculated from Von Bertalanffy curve in Love et al. 1984. Sex was determined as being male (M), female (F), or unknown (U

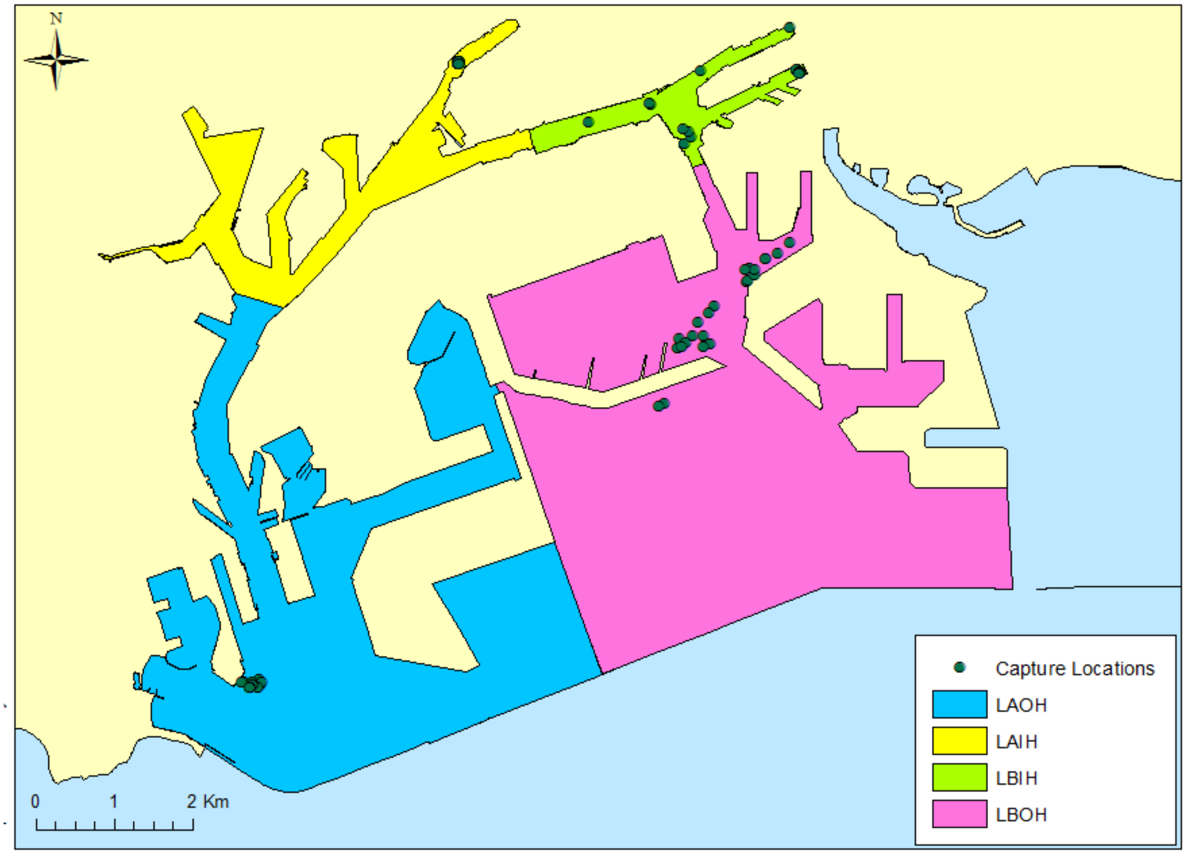

FIGURE 38. Capture location of passively tagged white croaker. Twenty-five white croaker were tagged in each of the four regions over a summer and winter tagging event. Regions are indicated by the shaded areas. Green circles represent capture locations of passively tracked white croaker.

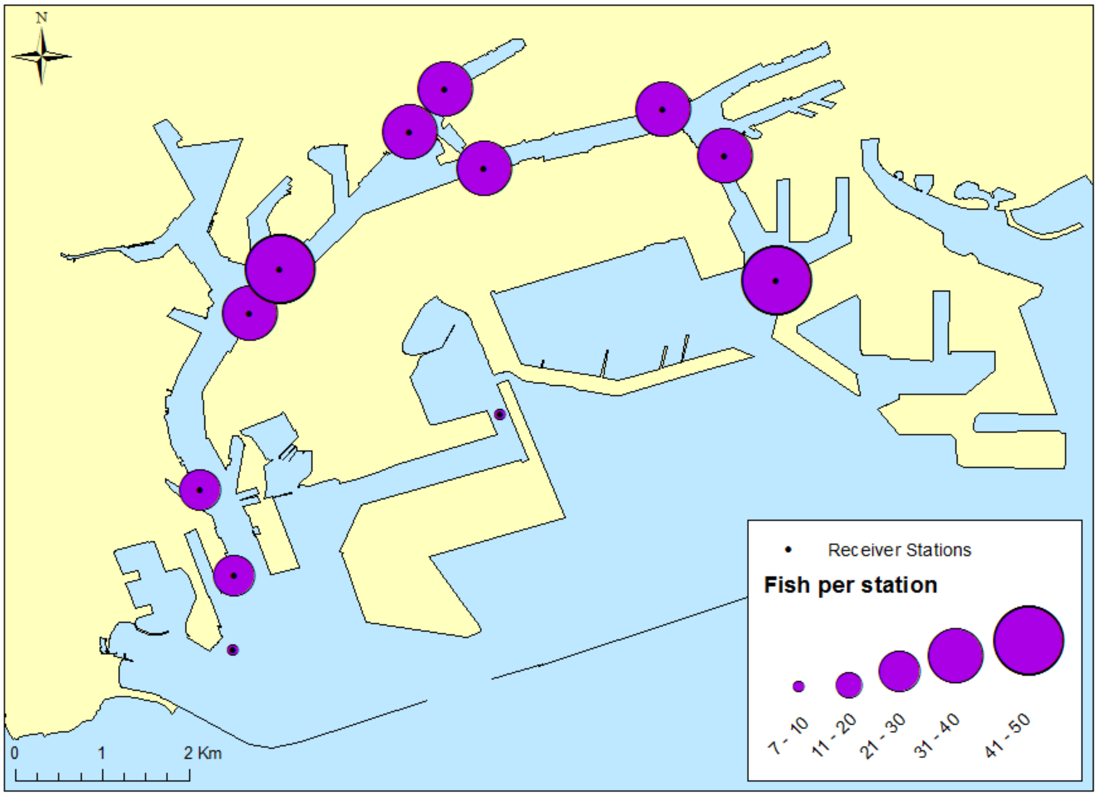

FIGURE 39. Number of passively tagged white croaker detected by each receiver station. The circumference of the purple circle surrounding each receiver station (black point) is proportional to the number of white croaker that was detected by the receiver.

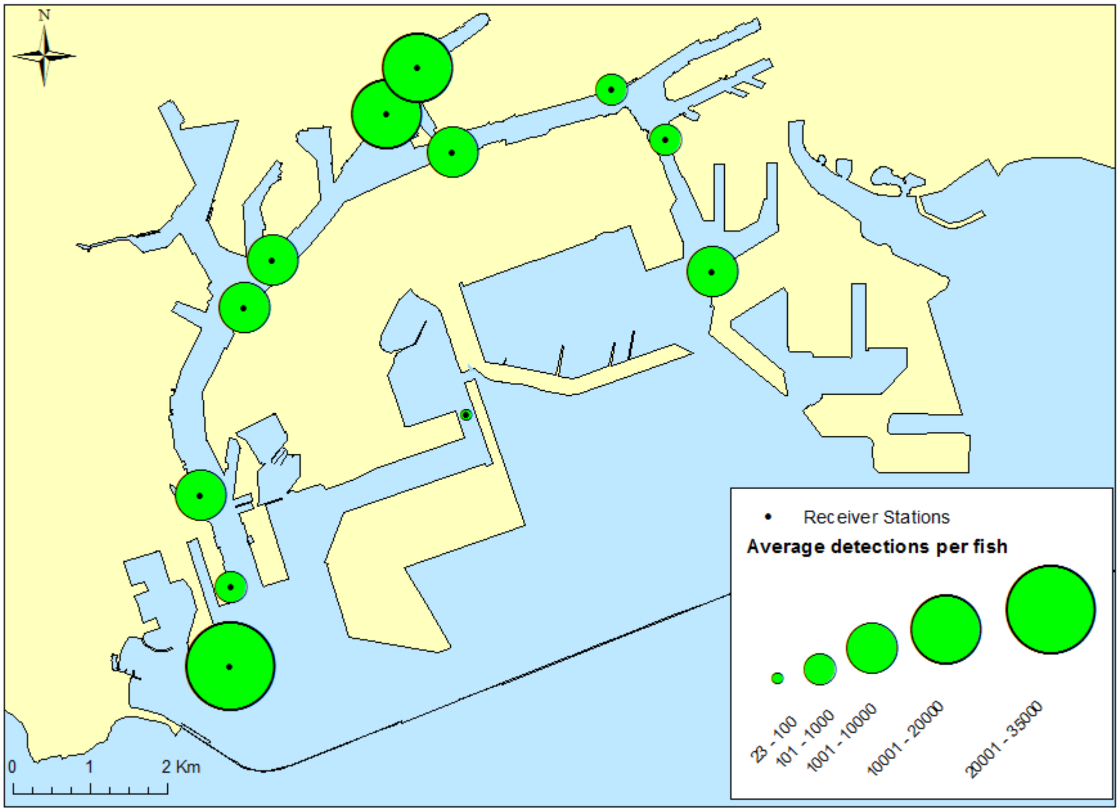

FIGURE 40. Average detections per passively tagged white croaker for each receiver station. Receivers were deployed for 1 year. The circumference of the green circle surrounding each receiver station (black point) is proportional to the average number of detections per fish