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Are Fishes Attracted to Piers? Movements and Association of Marine Fishes to a Public Fishing Pier within a Commercial Harbor

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Abstract.—Ocean fishing piers are ubiquitous along the world's coastline, yet little research has examined how these structures can attract and retain fishes. Fishers routinely use these human-made structures as a reliable way to catch fish for subsistence or recreation. California halibut (*Paralichthys californicus*) and white croaker (*Genyonemus lineatus*) are commonly caught from fishing piers in southern California; however, some individuals have been found to contain high concentrations of hazardous contaminants. Thus, human health hazard warnings are posted throughout the Los Angeles area to limit fish consumption. To document attraction, residency, and association to fishing piers, 42 California halibut and 198 white croaker were tagged with acoustic transmitters in regions of the Los Angeles and Long Beach Harbors, including a local fishing pier, and the movements of these fish were tracked throughout a 1.5 year period. Average (±SD) fish residency near piers was 90.5 ± 104.8 days for California halibut and 31.9 ± 25.7 days for white croaker. Only 18% of white croaker and 6% California halibut were detected migrating to the pier from other locations of the LA-LB Harbors, and most spent < 10 min within 300 m of the public fish pier. Only 14% of California halibut and 0.35% of white croaker geo-positions were within casting range (approximately 30 m) of the pier, thus California halibut show the greatest potential affinity for pier habitat. Due to their movement patterns and habitat associations California halibut are much more likely to be attracted to fishing piers than white croaker.

Piers are common structures found throughout coastlines and embayments of the world; surprisingly, little research has examined how fish utilize these structures, even though they have the potential to function similarly to artificial reefs. Artificial reefs are human-made structures often designed to simulate reef structure to support fishes and other marine life, thus have been implemented for remediation of damaged reefs or to increase fish stocks (Alevras and Edwards 1985; Baine 2001; Bohnsack 1989; Deysher et al. 2002; Schroeter et al. 2015). Most are constructed to provide complex habitat often including vertical relief, hard substrata, high rugosity, etc., which are thought to be attractive features for a variety of fishes (Baine 2001). Though mainly constructed to support industrial, commercial, or recreational purposes, pier pilings and support beams provide complex habitat, which can serve to unintentionally attract fishes to these structures. The pier pilings provide hard substrata, which fosters invertebrate and algae recruitment (Butler and Connolly 1999; Keough 1983), and provide both food and protection for a variety of fishes. They also offer vertical relief and shade which has been correlated with an increase of abundance of forage fish at piers (Able et al. 2013). Vertical habitat relief in other marine systems has been linked

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with increased abundances, recruitment, and diversity of fishes (Carr 1991; Caselle et al. 2002; Kellison and Sedberry 1998; Martin and Lowe 2010; Rilov and Benayahu 1998). Piers in southern California are generally located in areas containing a homogenous flat seascape of mud/slit or sand, offering increased foraging opportunities for fishes that utilize ecotone environments. The ecotone between a rocky reef and sand has been found to contain greater diversity and abundance of epi and infaunal species than the communities found in the sediments further from the reef (Alongi 1989; Ambrose and Anderson 1990; Barros et al. 2001).

Public ocean and bay fishing piers have been a part of California's history for over a century and have attracted both recreational and subsistence fishers due to their ease of access, low cost, no required fishing license[1], and relatively consistent fish productivity (Jones 2004). Unfortunately, the majority of public piers in southern California (San Clemente to Ventura) lie within a region where fish consumption warnings have been enacted to limit the consumption of many potentially contaminated coastal fish species[2]. Cabrillo Pier is located in the center of this consumption warning zone, and is the closest pier to the EPA superfund site on the Palos Verdes Shelf (PV) as well as contaminated regions of the Los Angeles and Long Beach Harbors (henceforth referred to as LA-LB Harbors) (Fig. 1). Two contaminants of particular concern are types of organochlorines, dichlorodiphenyltrichloroethane (DDT) and polychlorinated biphenyls (PCBs). DDT was once a heavily used pesticide, and PCBs were an industrial chemical used in many applications; both are known carcinogens, and endocrine and reproductive disruptors (Longnecker et al. 1997). From the 1940's through early 1970's these chemicals were discharged into the local wastewater treatment system and watersheds. Since DDT and PCBs are resistant to degradation, they have persisted in the environment where they are bioaccumulated in the tissues of organisms and biomagnified through the food web due to their lipophilic properties (Brown et al. 1998; Malins et al. 1987; Zeng and Venkatesan 1999). Through these processes, many of the top marine predators within the Southern California Bight have been found to contain high tissue levels of organochlorines (Blasius and Goodmanlowe 2008; Mull et al. 2013).

Due to the proximity of the public Cabrillo Fishing Pier in LA Harbor to areas of relatively high sediment contamination, there is a concern that fish caught from the pier may contain harmful amounts of contaminants. Indeed, some fish caught and sampled near the pier have been found to contain high concentrations of organochlorines in their tissues; however, these concentrations vary widely and are likely attributed to the degree to which some individuals move and the habitats in which they feed (Anderson et al. 2001). Two species of fish that are commonly caught and consumed from coastal piers are white croaker (*Genyonemus lineatus*) and California halibut (*Paralichthys californicus*). They were chosen for this study because while they are benthic soft-substrata associating species, they have differences in habitat use, foraging ecology, and trophic position. In addition, in California white croaker is considered a "sentinel species" for contaminant exposure (Love et al. 1984; Malins et al. 1987). Both are known to obtain high concentrations of organic contaminants (84.9-2520 ppb DDT and 58.5-279 ppb PCBs for white croaker, 35.4-171

[1] California Fish and Game Code, section 7153.

[2] Office of Environmental Health Hazard Assessment - https://oehha.ca.gov/media/downloads/advisories/socaladvisoryl61809.pdf

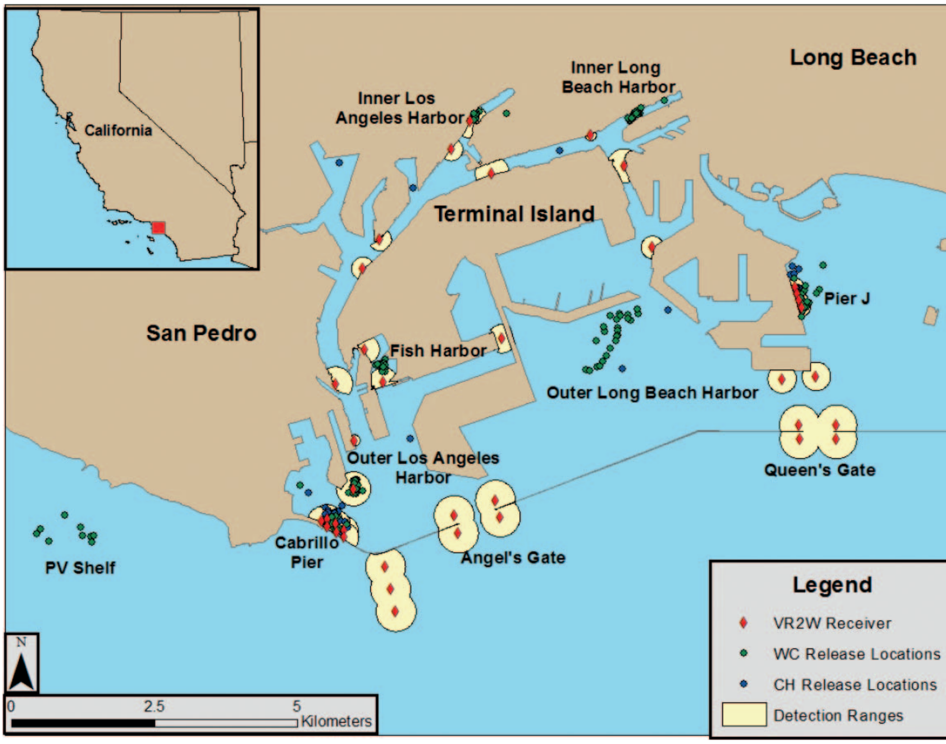

Fig. 1. Map of capture and release locations of passively tracked white croaker and halibut. Green dots indicate release locations of white croaker and blue dots represent locations of release for halibut. The red diamonds represent VR2W receiver locations and the beige circles around them are the nominal detection range of the receivers.

ppb DDT and 5.61-25 ppb PCBs for California halibut[3]). Since sediments from around Cabrillo Pier have been found to contain relatively low levels of organochlorine contaminants, it is likely some fish are being attracted to Cabrillo Pier from other more contaminated locations like the PV Shelf, Consolidated Slip (LA Harbor), Fish Harbor (LA Harbor), or inner LB Harbor (Anderson et al. 2001; Eganhouse and Pontolillo 2008). To identify the most important areas for sediment remediation, it is critical to determine which contaminated regions are the most connected to Cabrillo Pier.

Though both species are demersal soft substratum associated, they utilize these environments differently due to their foraging strategies, thus could be attracted to Cabrillo Pier based on different habitat attributes. White croaker are roving benthic foragers, selecting habitat that contains fine grain sized sediment with high levels of total organic carbon and high densities of benthic infauna, which describes the habitat surrounding Cabrillo Pier (Ahr et al. 2015; Love et al. 1984). Unlike white croaker, California halibut are lay-in-wait ambush predators of bait fish (e.g. *Engraulis mordax, Sardinops sagax, Leuresthes tenuis*) and epibenthic invertebrates, often associated with the ecotone between sand and reef or eelgrass (Freedman et al. 2015; Freedman et al. 2016; Haaker 1975). The ecotone, pier

[3] National Oceanic and Atmospheric Administration- https://19january2017snapshot.epa.gov/www3/region9/superfund/pvshelf/pdf/montrose_report.pdf

pilings, and vertical relief are attractive habitat features for bait fishes, thus the area near Cabrillo Pier could increase foraging opportunities for California halibut (Able et al. 2013; Johnson et al. 1994). Since Cabrillo Pier has potentially attractive habitat features for both species, the first goal of this study is to quantify the probability of both species moving to Cabrillo Pier from other areas of the LA-LB Harbors. In addition, test the hypotheses that 1) white croaker and California halibut exhibit selection for the habitat in close proximity to Cabrillo Pier; and 2) individuals visiting Cabrillo Pier from other regions of the LA-LB Harbors will display a similar degree of site fidelity to Cabrillo Pier as those tagged near Cabrillo Pier.

Materials and Methods

This study was conducted in the LA-LB Harbors complex located in southern California, USA (Fig. 1). White croaker and California halibut were caught and tagged throughout seven regions of the LA-LB Harbors. Regions were designated based on habitat differences and geospatial boundaries in order to compare fish movements across habitat types. These regions were Los Angeles outer harbor (LAOH), the Los Angeles inner harbor (LAIH), the Long Beach inner harbor (LBIH), the Long Beach outer harbor (LBOH), Fish Harbor, Cabrillo Pier, and Pier J, and the area off White Point, Palos Verdes (PV Shelf) (Fig. 1). They were chosen to examine fish movement within and among regions of the LA-LB Harbors, especially between regions with high sediment contamination and regions with public fishing piers.

Cabrillo Pier is located in the southwestern region of the LA-LB Harbors and is a public fishing pier that runs parallel to the Federal Breakwater and is 375 m long by 5-10 m wide. Water depth directly below the pier ranges from 1 m at northwestern end to 3 m at the southeastern end. The pier rests on the edge of a sand/mud shelf, which drops off from the pier to a seafloor depth of approximately 7 m. The substrata around Cabrillo Pier consists of mud, silt, and sand. There is a low-lying rock reef, partially buried under unconsolidated sediments at the eastern edge of the pier that runs perpendicular to the pier.

To characterize the movements of white croaker and California halibut throughout the LA-LB Harbors and at fishing piers, 240 fish were caught and surgically fitted with acoustic transmitters and then passively tracked from July 2013 to January 2015. At least 25 white croaker and 2 halibut were tagged within each of the regions of the LA-LB Harbors, and 9 white croaker were tagged on the PV Shelf. All white croaker were caught using hook and line, and California halibut were caught using hook and line or a 3 m wide otter trawl. Fish were anesthetized in a bath of Tricaine methanesulfonate (MS222) (0.2 g/L of seawater) until reaching stage-4 level of anesthesia (Freedman et al. 2015; Wolfe and Lowe 2015). Weight (g), standard length (mm), fork length (mm), and total length (mm) were recorded (Summerfelt and Smith 1990). All fish were surgically fitted with a Vemco V9-1X acoustic transmitter (24 mm x 9 mm, nominal pulse interval 120-250 s, power output 145 dB, battery life 363 d) coated with a 1:2.3 mixture of beeswax and paraffin to reduce an immune response (Lowe et al. 2003). A 2 cm incision was made through the abdominal wall and the acoustic transmitter was inserted into the peritoneal cavity of the fish and closed with 2 sutures of dissolvable monofilament suture (Ethicon, 5-0 PDS*II). Once the fish recovered from surgery (minimum of 5 min) it was released near its capture location. California halibut were also externally tagged with a numbered spaghetti tag in the dorsal fin musculature. All capture, handling, and surgical procedures complied with the California State University Long Beach's IACUC #325.

To document fish movement throughout the LA-LB Harbors, 38 VR2W (Vemco, Ltd.) omni-directional underwater acoustic receivers were positioned at key locations around the LA-LB Harbors and surrounding areas from July 2013 through January 2015 (Fig. 1). Receivers were placed approximately 1-2 m off the seafloor at choke point areas to function as gates to monitor fish movement from different areas of the LA-LB Harbors. All receivers were deployed in July 2013, except for the two receivers placed in Fish Harbor (deployed August 2013 and November 2013), and the four additional receivers deployed at Cabrillo Pier in December 2013 to construct the Vemco Positioning System (VPS) array (Fig. 1). The VPS array was used to obtain fine-scale geo-position estimates of tagged fishes based on trilateration when a transmission was detected by three or more acoustic receivers (Espinoza et al. 2011; Wolfe and Lowe 2015). VPS receivers were paired with a synchronization transmitter (V16-5x, 69 kHz, 300 s pulse interval, power output of 150 dB) to correct for clock drift and improve positional accuracy (Espinoza et al. 2011). Receiver maintenance and downloads were conducted bimonthly. Mean maximum detection range for receivers at Cabrillo Pier was determined to be 401 ± 19 m (mean ± SD) (Fig. 1). Detection range of other receivers was used from previous studies (Farris et al. 2016; Wolfe and Lowe 2015). Fish detections from VR2W receivers were downloaded and managed using VUE v 2.2.2 (Vemco). Data analyses were carried out using R 3.0.2 (R Foundation for Statistical Computing) and PRIMER-E v.6 (Plymouth, UK) and maps were created using ArcGIS 10.2 (ESRI).

The acoustic receiver detection dataset was filtered to remove false detections and detections from individuals that were thought to have died. If a transmitter was detected continuously by the receiver closest to the fish's release location for the entire battery life of the transmitter, the fish was classified as a mortality from tagging stress. To determine potential predation of tagged fish, the displacement speed of movements between two receiver locations were calculated. White croakers have been estimated to have a maximum sustained swimming speed of 0.61 m/s (Dorn et al. 1979), therefore any tagged white croaker that were observed to travel faster than 0.61 m/s between receivers were considered predation events. Maximum sustained swimming speeds of California halibut are unknown so this test could not be performed for the halibut detection data; however, no erratic or excessively rapid (> 1 m s^{-1}) movements were documented for California halibut that would be characteristic of a predation event.

Several receivers had overlapping detection ranges allowing an individual to be simultaneously detected at multiple receivers. All receivers within each one of these groups were aggregated and treated as a single station (PV curtain, Angel's Gate, Queen's Gate, Pier J, Consolidated Slip, Fish Harbor and Cabrillo Pier). Furthermore, within each of these receiver groups, any detection from an individual that occurred less than 120 s (minimum pulse interval) after a previous detection was removed, as these represented simultaneous detections on multiple neighboring receivers. Removing these duplicated detections prevented artificially inflating the number of detections within a region.

Two methods were used to determine the likelihood of white croaker and California halibut moving from other regions of the LA-LB Harbors to Cabrillo Pier. First, was calculating the proportion of individuals tagged in each region of the LA-LB Harbors that were detected at Cabrillo Pier. Second, a one-way analysis of similarity (ANOSIM) was used to compare patterns of receiver presence across individuals that were tagged in different regions of the LA-LB Harbors (Garcia et al. 2015; Meyer et al. 2010; Papastamatiou et al. 2015). Similarities were based on daily receiver presence, which was calculated as the cumulative number of days an individual was present (> 1 detection within a day) for each receiver. A dispersion weighting transformation was used to normalize for high variability in daily receiver presence among individuals from each region of the LA-LB Harbors (Clarke 2014). The degree of overlap (R-value: < 0.25 = high overlap, > 0.75 = low overlap) was used to evaluate receiver usage between groups tagged in different regions of the harbor (Garcia et al. 2015; Meyer et al. 2010). Pair-wise comparison significance ($p < 0.05$) was interpreted as fish tagged in different regions primarily using a different core cluster of receivers. Non-metric multidimensional-scaling ordination (nMDS) plots were used to visualize the relative similarities of receiver presence among individuals from regions of the LA-LB Harbors.

Euclidean Distance-based Analysis (EDA) was used to quantify the pattern in spatial association between individuals and the pier. For each individual, the distance between each VPS rendered position and the closest edge of the pier was measured (Conner and Plowman 2001). These values were then compared to the available habitat, which was calculated as an equal number of randomized positions distributed within the detection range (approx. 250 m) of the Cabrillo Pier array. Distances from the pier to the randomized and VPS rendered geo-position of tagged fish were placed into 10 m bins for white croaker and 5 m bins for California halibut, as they had a larger number of VPS detections. To determine if the pier was influencing the species distributions within the Cabrillo Pier VPS array, the counts of the VPS and randomized positions were compared using a Pearson's chi-square test. Individual's pier selection index was calculated as the ratio of number of observed positions to randomized positions in each distance bin. The pier selection index was interpreted as values > 1 representing selection/association, values < 1 representing non-selection. Pier selection indices were averaged across individuals to create a species-wide pier selection index. Pier association for either species was defined as having a pier selection index > 1 within 50 m of Cabrillo Pier. In addition, there is a low-relief rocky reef that runs perpendicular to the southeast corner of the Pier, to determine if tagged individuals additionally used ecotone provided by this reef an EDA analysis was conducted to compare distances used to this reef.

Some California halibut had periods where they were detected consistently at a high frequency and some individuals had orders of magnitude more rendered VPS positions than others, allowing for temporal autocorrelation or a subset of individuals to drive results. To reduce effects of potential biases a bootstrapping procedure was used where 100 positions were randomly sampled from each individual with replacement and pooled across individuals (Teesdale et al. 2015). This process was repeated 1000 times and compared to the null model using a χ^2 test. This analysis was not used for white croaker due to low sample size and number of VPS rendered positions.

While the pier can impact what habitat individuals' use, it can also impact their fidelity to the area. The degree of site fidelity of fish caught and tagged in close proximity to Cabrillo Pier was compared with individuals tagged at other locations throughout the LA-LB Harbors that visited the pier, using two metrics: daily presence and duration at Cabrillo Pier. Daily presence was the sum of the days a fish was detected at Cabrillo Pier while the duration spent at Cabrillo Pier was determined by multiplying the average transmitter pulse interval (182 s) by the total number of detections at the pier for each fish. This time (duration) was then divided by an individual's daily presence, which yielded an average number of hours per day an individual was detected at the pier receivers.

A non-parametric randomization test was used to compare these site fidelity metrics between fish tagged at Cabrillo Pier and those visiting from other regions of the LA-LB Harbors. This method combined all individuals' fidelity data into one pool, and sampled

Table 1. Average total length (mm) and number (n) of white croaker (WC) and California halibut (CH) tagged by region. First two columns after Region are of white croaker and the last two columns are of California halibut.

Region	WC mean TL (mm) ± SE	n	CH mean TL (mm) ± SE	n
Cabrillo Pier	228 ± 4.2	29	455 ± 17.3	26
Fish Harbor	229 ± 2.1	30	NA	0
LAIH	252 ± 3.5	26	486 ± 64.3	4
LAOH	233 ± 1.9	29	492 ± 48.2	2
LBIH	237 ± 2.1	25	592 ± 20	2
LBOH	224 ± 2.1	25	416 ± 22.5	2
Pier J	231 ± 2.2	25	538 ± 72.5	6
PV Shelf	235 ± 3.4	9	NA	0

with replacement to generate two distributions that equaled the sample size of fish tagged at Cabrillo Pier and fish visiting from other regions. The difference in mean value of the two samples was calculated and repeated 10,000 times to create a distribution of expected differences between the means assuming all individuals of a species belonged to one population that utilized Cabrillo Pier equally. The observed difference to the created null distribution generated the probability of observing this outcome if all fish utilized Cabrillo Pier similarly. California halibut were not compared due to low sample size of individuals visiting from other regions of the LA-LB Harbors.

Results

A total of 42 California halibut and 198 white croaker were caught and tagged at locations throughout the LA-LB Harbors (Fig. 1, Table 1). White croaker averaged 234 ± 1.1 mm total length (TL), and all individuals tagged were larger than size at 100% maturity (190 mm TL) while California halibut averaged 472 ± 15 mm TL (mean ± SEM) (Love et al, 1984). Sex could not be determined for most individuals of either species due to the lack of sexual dimorphism. Only one California halibut (Transmitter ID 11392; 615 mm TL) was reported as being recaptured by a fisher, and it was released after being measured.

All 38 receivers recorded detections of tagged fish, and mean (±SEM) number of detections was highly variable among the two species (14,708 ± 31,869 for California halibut, 6,202 ± 8,073 white croaker). Twenty-seven white croaker and one California halibut were never detected on any receiver, and these individuals were excluded from all movement analyses. Many of these fish were not released in the vicinity of a receiver (> 300 m); however, most were released inside the LA-LB Harbor and therefore should have had a greater likelihood of detection. None of the nine white croaker tagged on the PV Shelf were detected by any of the 38 acoustic receivers used for this study. The proportion of white croaker identified as having died as the result of capture, handling, and surgery (tagging mortality) was 3.5% (7 individuals). Approximately 11.5% (23 individuals) of white croaker were estimated to have been eaten by a predator based on rate of movement between receivers (> 0.61 m s^{-1}). No California halibut were observed to exhibit rapid movements between receivers that could be considered a predation event. Four California halibut were detected making > 40 km movement from the LA-LB Harbors to receivers in Santa Monica Bay. A total of 163 white croaker and 41 California halibut were used for movement analyses after removing individuals that were never detected or were determined to die from tagging mortality.

Receivers in the Cabrillo Pier VPS array detected a total of 58 individual white croaker and 27 California halibut. 28 of the white croaker were tagged in the vicinity of Cabrillo Pier and the other 30 individuals were tagged in other regions of the LA-LB Harbors. Of the white croaker visiting Cabrillo Pier from other regions, most were from LAOH, but 12-17% of fish detected were tagged in Fish Harbor, LBIH, and LAIH (Table 2). Twenty-seven California halibut were detected by the Cabrillo Pier array, and of those, 26 were initially tagged at Cabrillo Pier (Table 2).

White croaker tagged in different regions of the LA-LB Harbors did not show similarity in daily receiver presence (ANOSIM, $R = 0.935$, $p = 0.001$, Table 3, Fig. 2A). Pair-wise comparisons revealed that white croaker tagged in different regions of the LA-LB Harbors showed low overlap in daily receiver presence, $R > 0.75$ for almost all regions, except between individuals from Cabrillo Pier and LAOH ($R = 0.646$), and LBIH and LBOH ($R = 0.69$), where there was a moderate amount of overlap between daily receiver presence. California halibut tagged in different regions of the LA-LB Harbors did not show similarity in daily receiver presence (ANOSIM, $R = 0.826$, $p = 0.001$, Fig. 2B).

A total of 563 fine-scale geo-positions were rendered for five white croaker within the Cabrillo Pier VPS array (Fig. 3). The distances of these positions from Cabrillo Pier was significantly different from a random distribution ($\chi^2 = 109.8$, df = 34, $p < 0.001$). The pier selection index of white croaker VPS-rendered positions to Cabrillo Pier exhibited one distinct peak between 50 to 120 m from Cabrillo Pier and two smaller peaks at approximately 220-230 m and 270-280 m from the pier (Fig. 3A). The distances of these positions from the adjacent low-lying reef was also significantly different from a random distribution ($\chi^2 = 194$, df = 66, $p < 0.001$). The reef selection index of white croaker positions to the reef had a peak from 0-20 m from the reef and multiple peaks 300-570 m from the reef (Fig. 3B).

A total of 46,615 fine-scale geo-positions were rendered for 11 California halibut within the Cabrillo Pier VPS array (Fig. 4). The distribution of distances of these points from Cabrillo Pier was significantly different from random distribution ($\chi^2 = 170146.1$, df = 71, $p < 0.001$). The pier selection index suggests that California halibut mostly selected for habitats approximately 25-130 m from Cabrillo Pier when within 300 m of the pier (Fig. 4A). The distances of these positions from the low-lying reef was also significantly different from random distribution ($\chi^2 = 11120$, df = 127, $p < 0.001$). The distribution of reef selection index shows that California halibut selected for areas within 25 m from the reef, and sporadically > 45 m from the reef (Fig. 4B). California halibut pier and reef selection indices were robust against unbalanced sample size and temporal autocorrelation ($p < 0.001$) for all 1000 bootstrapped permutations.

White croaker caught and tagged in the vicinity of Cabrillo Pier spent an average of 31.9 $\pm$ 25.7 (mean $\pm$ SD) days at Cabrillo Pier, which was significantly greater than the total number of days spent at the pier by fish tagged in other regions (4.6 $\pm$ 10.8 d) ($p < 0.001$, Figs. 5A, 5C). The duration of each individual visit into the Cabrillo Pier array was also significantly longer for fish tagged in the vicinity of the pier (11.9 $\pm$ 5.2 hrs) than for fish tagged in other regions of the harbor (0.5 $\pm$ 1.7 hrs) ($p < 0.001$, Figs. 5B, 5D). California halibut spent an average of 95.9 $\pm$ 104.8 total days in the Cabrillo Pier area, with individual duration to the Pier area averaging 6.6 $\pm$ 5.3 hrs (Figs. 5E, 5F).

Table 2. Proportion of unique white croaker (WC) and California halibut (CH) detected by regions. Columns indicate region where fish were originally tagged and released, rows indicate regions where fish were subsequently detected. NA equates to no fish tagged in that region.

	Cabrillo Pier		LAOH		Fish Harbor		LAIH		LBIH		LBOH		Pier J		PV Shelf	
Region detected	WC	CH	WC	CH	WC	CH	WC	CH	WC	CH	WC	CH	WC	CH	WC	CH
LAOH	0.62	0.69	1	0.5	0.31	NA	0.13	0.25	0.08	0	0.04	0.5	0	0	0	0
Fish Harbor	0.1	0.58	0.07	0.5	1	NA	0	0.25	0.08	0	0.04	0.5	0	0.33	0	0
Angel's Gate	0.17	0.35	0.3	0.5	0.24	NA	0.13	0	0.08	0	0.04	0.5	0.08	0.17	0	0
Cabrillo Pier	0.97	1	0.74	0	0.17	NA	0.13	0	0.12	0	0	0	0	0.17	0	0
Queen's Gate	0.1	0.08	0.07	0.5	0	NA	0.04	0	0.16	0	0.04	0.5	0.16	0	0	0
PV Gate	0.03	0	0.11	0	0.1	NA	0.13	0.75	0.04	0	0.08	0	0	0	0	0
LBOH	0	0	0	0	0.07	NA	0.04	0.25	0.56	0.5	0.12	0.5	0	0.33	0	0
Pier J	0	0	0	0	0.03	NA	0	0.25	0.08	1	0	0	1	0	0	0
LAIH	0	0	0.15	0	0.03	NA	1	0	0.32	0	0	0	0.04	1	0	0
LBIH	0	0	0	0	0.03	NA	0.38	0	1	1	0.08	1	0	0	0	0

Table 3. LA-LB Harbors regional pairwise comparison of white croaker daily receiver presence from an ANOSIM test. CAB is short for Cabrillo Pier and Fish is short for Fish Harbor.

Regional comparison	Global R	P-value
LAOH v. Fish	0.883	0.001
LAOH v. CAB	0.646	0.001
LAOH v. LAIH	0.96	0.001
LAOH v. LBOH	0.944	0.001
LAOH v. LAIH	0.975	0.001
LAOH v. Pier J	0.998	0.001
Fish v. CAB	0.925	0.001
Fish v. LAIH	0.987	0.001
Fish v. LBOH	0.867	0.001
Fish v. LBIH	0.956	0.001
Fish v. Pier J	0.996	0.001
CAB v. LAIH	0.993	0.001
CAB v. LBOH	0.971	0.001
CAB v. LBIH	0.992	0.001
CAB v. Pier J	0.999	0.001
LAIH v. LBOH	0.914	0.001
LAIH v. LBIH	0.829	0.001
LAIH v. Pier J	1	0.001
LBOH v. LBIH	0.69	0.001
LBOH v. Pier J	0.975	0.001
LBIH v. Pier J	0.986	0.001

Discussion and Conclusions

Foraging strategies and habitat preferences likely influence the association of white croaker and California halibut to Cabrillo Pier. Both California halibut and white croaker showed an association to Cabrillo Pier; however, California halibut were in closer association to Cabrillo Pier and the ecotone of the low-lying reef. Most likely, white croaker were associating with the deeper habitat at the base of shelf that extends away from the Pier. In addition, California halibut showed a higher mean residency time (~ 96 d) compared to white croaker (~ 32 d) to the Cabrillo Pier area. These high mean residency times and closer association to ecotone (pier and reef) indicate that California halibut select these ecotone environments, most likely for increased foraging success due to the known higher prey densities compared to areas further from structure or reef (Ambrose and Anderson 1990; Anderson et al. 1989; Barros et al. 2001; Haaker 1975). In the temperate marine environment some reef-associated fishes acquire up to 25% of their diet from ecotone-associated prey (Johnson et al. 1994). Previous active tracking studies of juvenile California halibut in southern California estuaries found similar ecotone selection, where 54% of halibut position locations were within 2 m of eelgrass (*Zostera pacifica*) beds (Freedman et al. 2016). It is unclear if California halibut are associating to the ecotone provided by Cabrillo Pier or the sandy slope running parallel to the pier; however, it is clear they select for ecotone habitat, which puts them in closer proximity to Cabrillo Pier, resulting in a higher likelihood of being caught by fishers from the pier.

White croaker are commonly caught by anglers from fishing piers, including Cabrillo Pier, and were expected to have VPS rendered positions in close proximity to the Pier; however, the position data suggest that white croaker are not closely associating (<30 m) to Cabrillo Pier, but are selecting for the area slightly farther away (50-120 m). The sed-

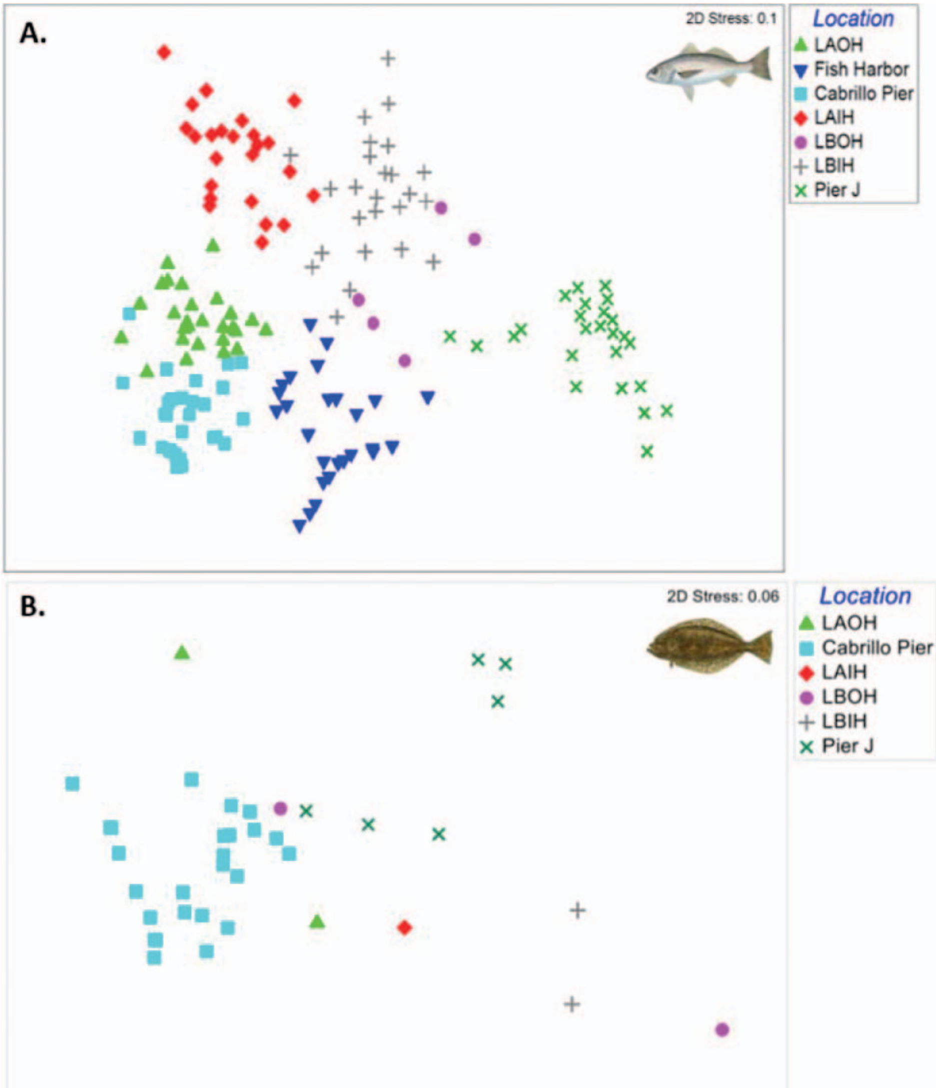

Fig. 2. Non-metric multidimensional scaling plot of receiver overlap of white croaker (A) and California halibut (B) from different tagging regions with the LA-LB Harbors after the dispersion weighting transformation. Tagging regions are as such: green triangles are LAOH, blue triangles are Fish Harbor, light blue squares are Cabrillo Pier, red diamonds are LAIH, pink circles are LBOH, grey crosses are LBIH, and dark green Xs are Pier J.

iment in the area 50-120 m from Cabrillo Pier consists of mud and silt, whereas in close proximity to Cabrillo Pier the sediment is primary comprised of sand (A. Barilotti, pers. obs.). Ahr et al. (2015) found that white croaker selected for areas of fine sediment grain size within the LA-LB Harbors, since it is correlated with higher sediment nutrient loads, high turbidity and increased densities of polychaete worms. This suggests that white croaker are not preferentially selecting areas in close proximity to Cabrillo Pier due to the lack of

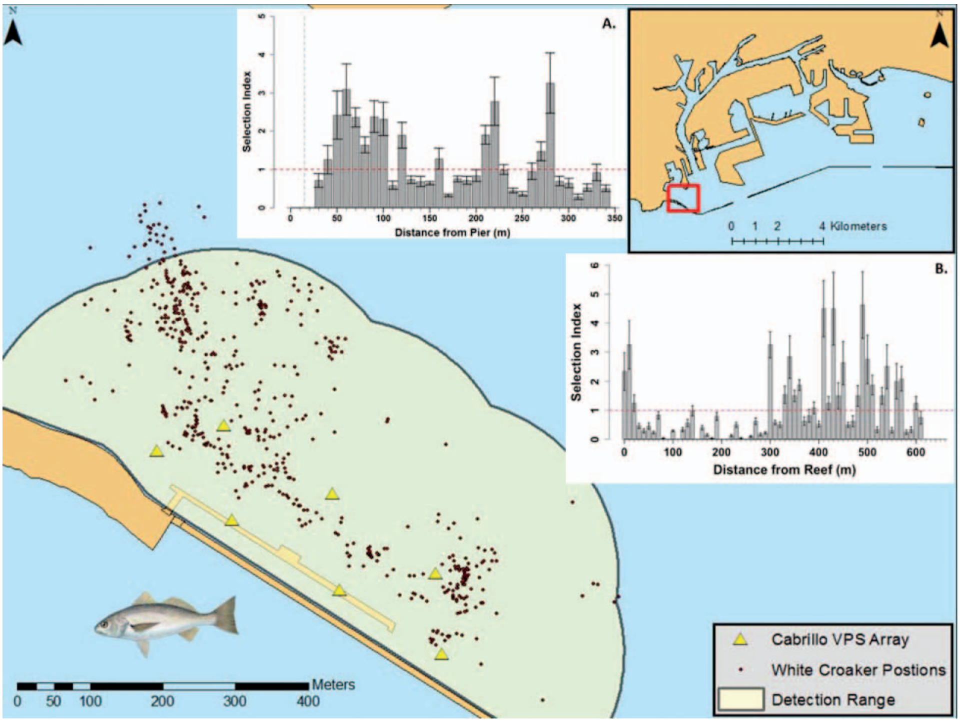

Fig. 3. Map of VPS-rendered positions of white croaker detected at Cabrillo Pier. Inset in upper right shows the Cabrillo Pier in the red box reference to the LA-LB Harbors. A.) Mean Pier selection index (±SEM) of white croaker by distance (10 m bins) using VPS rendered positions. B.) Mean reef selection index (±SEM) of white croaker by distance (10 m bins) using VPS rendered positions. Grey vertical line is the approximate distance of the bottom edge of the sand slope from Cabrillo Pier. The red line represents where fish randomly distributed would associate themselves; values above the red line equate to selection and value below the line indicate non-selection.

appropriate foraging habitat. Those individuals caught from Cabrillo Pier are most likely traveling nearer to the pier (50-100 m) and potentially lured towards the bait of fishers in an area they would not typically use.

Both white croaker and California halibut had virtually no VPS-rendered positions within 5 m of Cabrillo Pier, indicating neither species selects for close association for pier structure and the habitat directly under the pier. This was surprising since both species are caught frequently from Cabrillo Pier, and it was expected that some individuals would be detected underneath the pier. As an ambush predator, California halibut were expected to use shade provided by piers to strike at prey not in the shade (Able et al. 2013; Cermak 2002). One possibility why both species are avoiding the habitat directly associated with the pier is this habitat may have been too shallow as previous studies have found white croaker select for deeper areas within the LA-LB Harbors and coastal habitats (Ahr et al. 2015; Love et al. 1984). It is unlikely that California halibut are avoiding shallow water habitat as they are found in the surf-zone and in shallow estuaries (Haaker 1975), but their prey may be selecting deeper habitats to avoid aerial or surface predators such as plunge diving birds. However, another possibility for not detecting either species underneath or near the pier is that the pier pilings could be attenuating the acoustic signal and thereby reducing

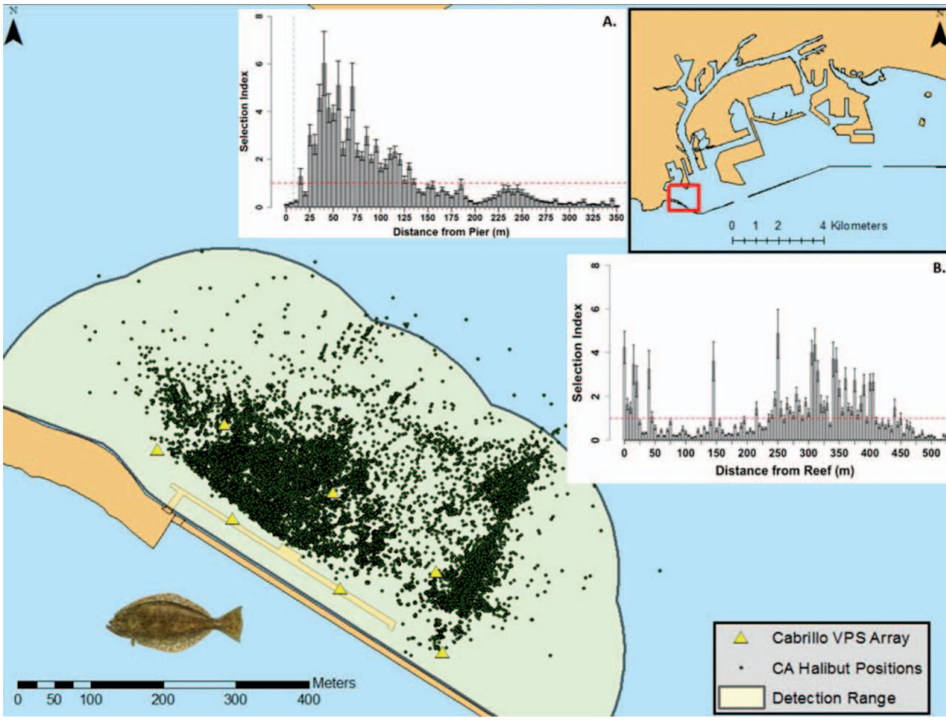

Fig. 4. Map of VPS-rendered positions of California halibut detected at Cabrillo Pier. Inset in upper right shows the Cabrillo Pier in the red box reference to the LA-LB Harbors. A.) Mean Pier selection index (±SEM) of California halibut by distance (5 m bins) using VPS rendered positions. B.) Mean reef selection index (±SEM) of California halibut by distance (5 m bins) using VPS rendered positions. Grey vertical line is the approximate distance of the bottom edge of the sand slope from Cabrillo Pier. The red line represents where fish randomly distributed would associate themselves; value above the red line equate to selection and value below the line indicate non-selection.

geo-position estimates for detections closer to the pier. Both receivers placed underneath Cabrillo Pier had reduced detection efficiency compared to the other five receivers in the Cabrillo Pier VPS array; however, it is unlikely all signals were blocked, since receivers in another study placed on offshore oil platform jackets did not experience large reductions in receiver performance (Anthony et al. 2012; Mireles et al. 2019). Overall, this indicates that both species are most likely not selecting this habitat, but anglers may be catching these species by fishing in the deeper water away from the pier.

Based on LA-LB Harbor-wide habitat characteristics, the area near Cabrillo Pier should provide suitable habitat for supporting white croaker (Ahr et al. 2015), and white croaker tagged at Cabrillo Pier were detected using the area for over a month. In addition, some white croaker with high levels of tissue contamination have been captured at Cabrillo Pier (Anderson et al. 2001), so it was expected to find individuals from other regions of the LA-LB Harbor using the areas around Cabrillo Pier. White croaker tagged in other areas of known sediment contamination within the LA-LB Harbors traveled to Cabrillo Pier; however, visitations were infrequent and those that were detected within the pier receiver array showed low affinity for the site. Previous movements studies have suggested that white croaker are nomadic (Farris et al. 2016; Wolfe and Lowe 2015), which is characterized by

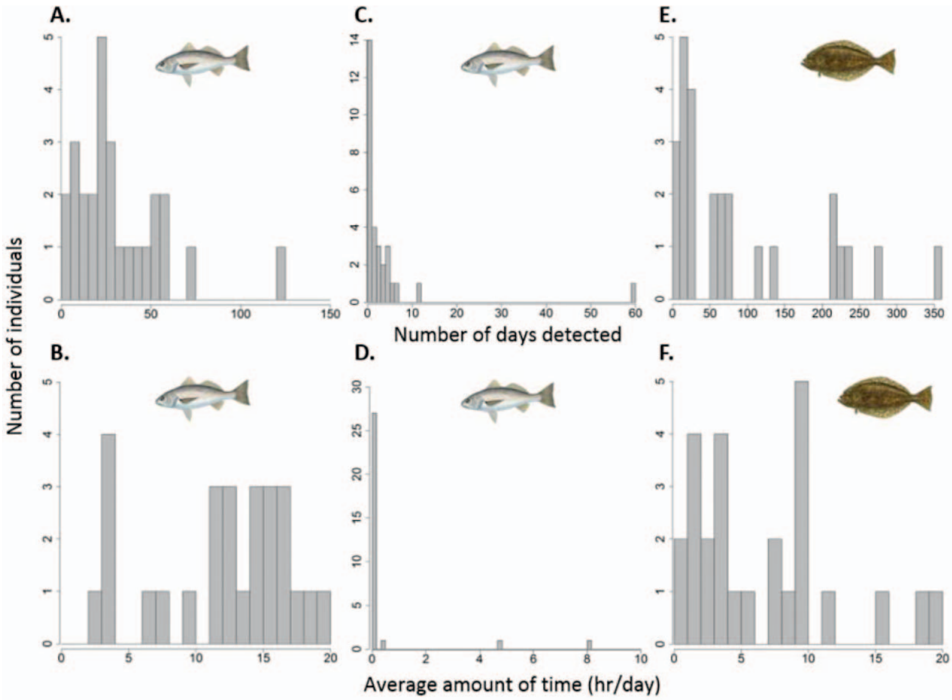

Fig. 5. The number of days individual white croaker tagged at Cabrillo Pier (A) and other regions (C) were detected within the Cabrillo Pier receiver array. The duration of time (hr/d) white croaker tagged at Cabrillo (B) and other regions (D) spent at the pier when detected. The number of days individual California halibut were detected at Cabrillo Pier (E) and the duration of time (hr/d) they spent at the pier when detected (F).

irregular movement behaviors that differ annually and are most likely the cause of inconsistent resource patches, periodic refuging from predators, or unsuitable environmental conditions (Berbert and Fagan 2012; Dean 1997; Lowe and Bray 2006). Thus, understanding and predicting white croaker movement patterns cannot only be a function of selecting for preferable habitat, but must incorporate individualistic patterns and unknown exogenous variables, which cause more movement variation. These unknown variables and nomadic behavior could explain why visiting white croaker moved on from Cabrillo Pier whereas those caught and tagged there remained for long periods of time.

Though many of the white croaker tagged from areas of higher known sediment contamination did not visit or stay at Cabrillo Pier for appreciable periods of time, white croaker found with the higher levels of tissue contamination are likely coming from these contaminated areas. Fish Harbor is the closest contaminated site to Cabrillo Pier and white croaker tagged in Fish Harbor had the highest probability of moving to Cabrillo Pier with five individuals visiting Cabrillo Pier and one staying for more than an hour. Though further away from Cabrillo Pier, LAIH has the highest levels of contaminants within the LA-LB Harbors (Anderson et al. 2001). White croaker tagged within LAIH displayed the highest degree of site fidelity of any area within the LA-LB Harbors, with some individuals detected for > 5 mos (Farris et al. 2016). However, when individuals did leave LAIH, they were found to move to all regions of the LA-LB Harbors (Farris et al. 2016). As a result, white croaker in the LAIH have the potential to accumulate unsafe levels of contaminants and then disperse these contaminants to other areas as well as up the food chain.

No California halibut initially tagged in a known contaminated region were observed moving to Cabrillo Pier, and the greatest connectivity was observed between the outer LA-LB Harbor receivers. The lack of connectivity between contaminated regions and Cabrillo Pier could be a result of a relatively small inner LA-LB Harbor sample size (n = 6). However, no California halibut (n = 36) tagged in outer LA-LB Harbor regions were detected moving into the inner harbor regions, suggesting that inner LA-LB Harbors could potentially have few resources for supporting an adult California halibut population. A translocation study of California halibut in southern Californian estuaries concluded that California halibut select for areas with higher prey delivery potential, where individuals were found to relocate from backwater areas of low flow to areas of high flow within 24 hrs of translocation (Freedman et al. 2015; Freedman et al. 2016). If California halibut do select for areas of high flow and greater prey delivery, then it would explain why none of the individuals tagged in the outer LA-LB Harbors were detected by the inner harbor receivers, and why half those tagged in the inner regions left. Those individuals caught in the inner LA-LB Harbors potentially recruited to the area as larval fish and used the area as a nursery. As California halibut grow they experience ontogenetic shifts in diet from more benthic associated invertebrates to more epibenthic and pelagic fishes. To sustain this diet of fish it is advantageous for California halibut to emigrate from the inner harbor and find areas that have increased prey delivery, resulting in a relatively small adult population within the inner LA-LB Harbors. Thus, the likelihood of catching individuals with potentially high levels of tissue contamination emigrating from the inner LA-LB Harbor regions may be relatively infrequent.

This is the first known study to examine the influence of California fishing piers on the association and movements of fishes. This study only examined one pier within a large harbor complex where other piers are available; pier habitat may be important to fish in areas where there is less vertical structure available or in non-protected habitats (e.g. piers on surf exposed beaches). Also, to understand the effectiveness of pier structure as habitat for fish, future research should use fish species that are known to associate with reef structure (e.g. *Paralabrax* spp., *Sebastes* spp.), since they should show a higher affinity for the structure provided by piers. Piers, both public and commercial, are integral parts of the waterfront, and understanding their influence as fish habitat should be included in future fish research.

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