Site Fidelity and Movement Patterns of Groundfish Associated with Offshore Petroleum Platforms in the Santa Barbara Channel

Authors: Lowe, Christopher G., Anthony, Kim M., Jarvis, Erica T., Bellquist, Lyall F., and Love, Milton S.

Source: Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science, 2009(2009) : 71-89

Published By: American Fisheries Society

URL: https://doi.org/10.1577/C08-047.1

Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 1:71–89, 2009

DOI: 10.1577/C08-047.1

[Article]

Site Fidelity and Movement Patterns of Groundfish Associated with Offshore Petroleum Platforms in the Santa Barbara Channel

CHRISTOPHER G. LOWE,* KIM M. ANTHONY, ERICA T. JARVIS, AND LYALL F. BELLQUIST

Department of Biological Sciences, California State University–Long Beach, 1250 Bellflower Boulevard, Long Beach, California 90840, USA

MILTON S. LOVE

Marine Science Institute, University of California–Santa Barbara, Santa Barbara, California 93106, USA

Abstract.—In order to better assess the ecological importance of offshore petroleum platforms for economically important groundfishes, we quantified the degree of site fidelity of 100 platform-associated individuals representing 15 species at three offshore platforms in the Santa Barbara Channel by means of acoustic telemetry monitoring. Thirty percent of the fish tagged were not detected after the first 6 d following release and were assumed to have died or to have immediately emigrated away from platforms. Degrees of site fidelity varied widely among individuals, among species, and between platforms. Of the most abundant species tagged (cabezon *Scorpaenichthys marmoratus*, vermilion rockfish *Sebastes miniatus*, widow rockfish *Sebastes entomelas*, copper rockfish *Sebastes caurinus*, and greenspotted rockfish *Sebastes chlorostictus*), widow rockfish showed a high probability of being detected at platforms over a 2-year period. Vermilion rockfish emigrated away from the shallower Platform Gilda (64 m) faster than vermilion rockfish tagged at the deeper Platform Grace (93 m). Ten tagged individuals (eight vermilion rockfish, one copper rockfish, and one lingcod *Ophiodon elongatus*) moved between platforms (range = 5–15 km) and/or natural habitat, although a majority moved from a shallower platform to a deeper one. These movements further support evidence that (1) many reef-associated rockfishes make ontogenetic shifts to deeper water and (2) shallower platforms export fishes faster than deeper platforms. There was no indication of seasonal emigration, but there was evidence for seasonal differences in activity for vermilion rockfish, widow rockfish, and greenspotted rockfish. Observed movements of fishes between platforms and natural reef habitat indicate that they can navigate between these habitats and that platform habitat, despite having higher densities of conspecifics, may be of higher quality to some individuals than natural reefs.

Twenty-seven oil and gas platforms are located in state and federal waters off the coast of southern California. These platforms have been in place an average of 28 years (range = 17–43 years) and, as a result, many have developed unique assemblages of marine organisms associated with the structures that vary with platform depth and location within the Southern California Bight. Many of these platforms are projected to be obsolete within the next decade, and in accordance with current state and federal regulations they will need to be fully decommissioned (Helvey 2002; Schroeder and Love 2004). Complete removal of platforms, their associated pipelines, and accumulated biogenic debris would result in destruction or dispersal of all platform-associated organisms (Bull and Kendall 1994; Schroeder and Love 2004). Various decommissioning alternatives, such as reefing (i.e., toppling or partial removal), have been implemented in the Gulf of Mexico, where over 5,000 offshore oil platforms have created substantial amounts of artificial habitat used by many sport and food fishes (Dugas et al. 1979). These artificial habitats have provided economically important fishing opportunities for sport- and commercial fishers in areas where they previously had not existed (Schroeder and Love 2004). However, the utility of this approach in California has been under considerable debate due to the lack of information supporting the ecological importance of these platforms (Helvey 2002; Schroeder and Love 2004). Unlike the platform fields in the Gulf of Mexico, the benthic habitat off the southern California coastline consists of more complex substrata (e.g., rocky reefs, slope habitat, and offshore island) that has historically supported large sport and commercial fisheries and is readily accessible to sport fishers due to their relatively close proximity to ports and marinas (<45 km). However, intensive fishing pressure over the last 50 years has led to systematic over-exploitation of many rocky reef fish assemblages and has significantly changed species composition and the demography of fishes in these areas (Lea et al.

Subject editor: Michelle Heupel, James Cook University, Australia

* Corresponding author: clowe@csulb.edu

Received November 30, 2008; accepted February 7, 2009
Published online May 7, 2009

1999; Love et al. 2006a). California platforms, despite their relatively close proximity to shore and major recreational fishing ports, are not as heavily fished as those in the Gulf of Mexico (Dugas et al. 1979; Stanley and Wilson 1989; Frumkes 2002; Schroeder and Love 2002; Love et al. 2006b; Peabody and Wilson 2006).

Over the last few years, a number of studies have examined aspects of the ecological function of oil platforms off the coast of California, particularly those in the northern portion of the Southern California Bight. Love et al. (2000, 2003, 2006b) conducted diver and manned submersible fish surveys of the platforms and natural reefs throughout the Southern California Bight and found significantly higher densities and larger individuals of rockfishes on platforms than natural reefs. The northern platforms (west Santa Barbara Channel and off Point Conception) were dominated by rockfishes and possessed significantly higher densities of over-exploited fishes, such as the cowcod *Sebastes levis*, bocaccio *Sebastes paucispinis*, and lingcod *Ophiodon elongatus*. In addition, surveys indicated high abundances of young-of-the-year (age-0) rockfishes in the midwater portions of some platforms, whereas juveniles and adults were found in higher abundances at the base of the platforms. It is hypothesized that age-0 fish recruit to the upper reaches of the platforms or shallow-water habitats and migrate to the base of platforms as they get larger (Love and Schroeder 2006).

Much of the debate regarding the ecological importance of these platforms revolves around whether they act as "sources" or "sinks." Love et al. (2006b) concluded that several Santa Barbara Channel platforms were important for age-0 bocaccio recruitment in 2003 and provided evidence that some platforms resulted in the production of bocaccio larvae. While data indicating that some platforms possess higher abundances of economically important fish species than natural reefs and may show enhanced recruitment (Love et al. 2003, 2006b), it is still unclear whether fish that recruit or emigrate to these platforms remain there, and if so, for how long.

Quantifying the degree of site fidelity of platform-associated fishes is essential in determining how they value platform habitat. It has been proposed that fishes that show high affinity for complex substrata typically exhibit small home ranges and high site fidelity. These complex habitats provide shelter from predation, sources of food, access to mates, and spawning substrata. In addition, the value of this habitat in meeting these needs may change as individuals mature or as density increases, which may lead to shifts or expansions in space requirements or site fidelity (Lowe and Bray 2006). Many epibenthic species of fishes associated with California platforms are thought to be highly residential when found on natural habitat. Tag and recapture studies of nearshore and shelf rockfishes have shown that a majority of individuals are recaptured within relatively close proximity of their site of release (<100 m), but some individuals are capable of movements in excess of 200 km (Miller and Geibel 1973; Hartmann 1987, Lea et al. 1999). Unfortunately, standard tag and recapture methods are problematic in quantifying site fidelity because they are fishing dependent, and therefore fishing effort may not be consistent in all locations, and recapture rates are typically low (<10%; Lowe and Bray 2006). Moreover, tag and recapture methods typically provide poor temporal and spatial resolution of site fidelity and degree of movement. However, acoustic telemetry tracking and monitoring have been used more successfully to quantify space use and site fidelity of individuals of a variety of reef-associated species (Lowe et al. 2003; Lowe and Bray 2006; Topping et al. 2006; Bellquist et al. 2008). Starr et al. (2002) used acoustic telemetry monitoring to quantify the movements and site fidelity of bocaccio and greenspotted rockfish *Sebastes chlorostictus* in the Monterey Bay canyon and found that greenspotted rockfish were more site specific than bocaccio (0.5–1.6 km^2 and >12 km^2, respectively). The use of acoustic telemetry allowed for continuous monitoring of the presence or absence of tagged fishes over periods spanning several years.

There is also growing evidence that habitat quality and conspecific density may affect space requirements and site fidelity of reef-associated fishes (Matthews 1990b; Lowe and Bray 2006; Bellquist et al. 2008). Miller and Geibel (1973) found that juvenile blue rockfish *Sebastes mystinus* exhibited less movement from shallow kelp bed habitats (~60 m) than individuals tagged on deeper reefs (~1.3 km). Similar observations were made by Matthews (1990a, 1990b), who found that tagged copper rockfish *Sebastes caurinus* and quillback rockfish *Sebastes maliger* had smaller home ranges when occupying high-relief habitats (<10 m^2) than when they were associated with low-relief habitat (~4,000 m^2). Consequently, if offshore petroleum platforms provide high vertical structure and high rugosity due to encrusting organisms, platform debris, and exposed bottom horizontal beams, and a majority of the fish species surveyed on platforms have been observed to be closely associated with the structure or surrounding debris field (Caselle et al. 2002; Love and York 2006; Love et al. 2006a), then individuals associated with platforms may prefer platform habitat over natural reefs. In addition, fidelity to this habitat may be even greater due to the isolation of these platforms from natural reef habitat.

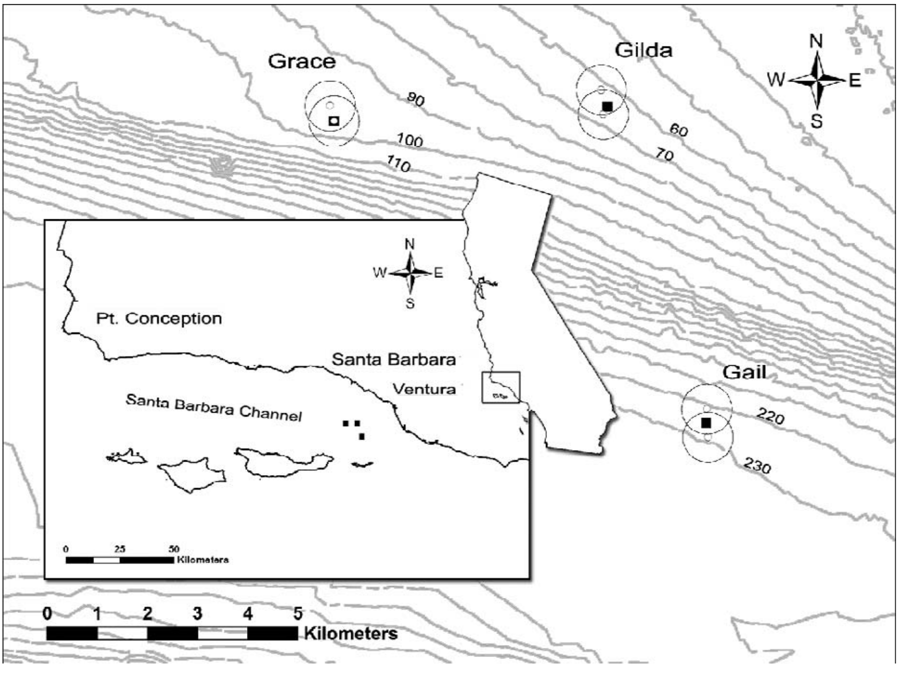

FIGURE 1.—Map of study site. Inset depicts the location along the southern California coast where the Pacific Outer Continental Shelf platforms Gail, Gilda, and Grace (solid squares) are located. Small open circles represent locations of VR2 receivers, around which 800-m detection zones are drawn. Numbers above bathymetry contours represent depths (m).

The goal of our study was to quantify the degree of site fidelity of characteristic platform-associated fishes on surveyed offshore petroleum platforms in the eastern Santa Barbara Channel using acoustic telemetry monitoring. It was assumed that the range of behavior exhibited by individuals monitored over a 655-d period would be representative of the variation across the population. Information on the degree of site fidelity and other aspects of behavior of characteristic platform fishes would be useful in further quantifying the ecological importance of California offshore platforms and would help managers assess the impacts of decommissioning on areas with Essential Fish Habitat status.

Methods

Study location.—Petroleum platform-associated fishes were monitored using acoustic telemetry at three platforms in the eastern Santa Barbara Channel. Fish were tagged on Platform Gilda (34°10′N, 119°25′W; 63-m depth), Grace (34°10′N, 119°28′W; 96-m depth) and to a lesser extent, Platform Gail (34°07′N, 119°24′W, 225-m depth), which proved to be difficult to fish at due to increased depth. These platforms are located on the edge of the Santa Barbara Basin between Ventura, California, and Anacapa Island (Figure 1). Benthic habitat beneath all three platforms consists of mussel shell mounds surrounded by sloping soft sediment substratum (Love et al. 1999, 2003).

Fish capture and tagging.—All fish were caught using standard hook-and-line techniques by fishing around the perimeter of each platform. To minimize barotrauma, we originally followed methods described by Starr et al. (2000), whereby fish were brought up to a depth of 20 m and met by a team of scuba divers for surgical implantation of acoustic transmitters underwater. However, preliminary trials showed that barotrauma signs exhibited by rockfishes at 20-m depth were similar to those of fish brought all the way to the surface. Thus, all fish tagged in this study were brought to the surface to increase tagging efficiency.

Once at the surface, fish were anesthetized by placing them in a bin of chilled seawater containing 20 ppm of clove oil. Once anesthetized, over-inflated fish were vented using an 18-gauge hypodermic needle and their total lengths (TLs) were measured. Fish were then inverted and a 1-cm incision was made at the ventral midline between the pelvic fins and anal vent through the abdominal wall; depending on the size of the fish, one of two sizes of acoustic transmitters (models V8SC-2 L-R04k and V13–1 L-R04k; Vemco, Halifax, Nova Scotia, Canada) was inserted into the peritoneal cavity. The V8SC-2 L-R04k transmitters (139-dB power output) were 9 mm in diameter × 30 mm long, and the V13–1 L-R04k (147-dB power output) were 13 mm in diameter × 35 mm long. Transmitters were coated with a combination of paraffin and beeswax (2.3:1.0) to prevent immunorejection (Lowe et al. 2003; Topping et al. 2006). Transmitters were programmed to produce a 69-kHz pulse train randomly within 150–300-s intervals, which yielded a nominal 3.5-year battery life for the V8SC-2 L transmitters and 5.5-year battery life for the V13–1 L transmitters. The incision was closed using 1–2 interrupted sutures (chromic gut), and an external plastic dart identification tag (Hallprint, Victor Harbor, Australia) was inserted into the dorsal musculature to allow individual identification if caught by a fisher or seen during submersible surveys. The entire tagging procedure took approximately 3–4 min/fish, after which individuals were placed in a large cooler containing fresh, chilled seawater pending release.

Initially, tagged fish were hand released ($n = 30$) by divers at a depth of 20 m at the platform of capture, so that their recovery from surgery and survival potential could be assessed. Good survival potential was determined by signs of regular opercular pumping, control of body orientation, and normal swimming motion. An additional experiment was conducted whereby tagged fish were placed in vinyl-coated wire mesh cages and lowered to the sea floor for a period of 1–2 d to confirm the detection of the transmitters and assess recovery times after exposure to barotrauma and postsurgical survival. After 1–2 d, the cage was retrieved to a depth of 20 m, where it was met by a team of divers who assessed the status of tagged fish using methods described by Jarvis and Lowe (2008). Divers released fish directly from the cage if signs of recovery were positive. Because we were able to confirm that fish held in cages survived capture and surgery, we terminated use of cages and released fish by assisting them to the bottom (forced recompression) using an inverted, weighted milk crate attached to a 40-m line (Jarvis and Lowe 2008). Because the fish were often still positively buoyant after the surgery, they were lowered to a depth of approximately 40 m, thereby recompressing the fish enough so they could swim to the bottom on their own.

Acoustic receivers.—Monitoring presence or absence of tagged individuals was accomplished using automated underwater acoustic receivers (Vemco Model VR2). The VR2 receivers were attached at 20-m depth to each of two support vessel moorings located approximately 250 m to the north and south of each platform (Figure 1). Platform Grace had no south mooring, so a VR2 was deployed inside the southeast quadrant of the platform jacket at a depth of 12 m. Detection zones around VR2 receivers were conservatively estimated to be 500 m for V8SC-2 L transmitters and 800 m for V13–1 L transmitters based on range test experiments. Zones of detection of each receiver were found to overlap the platform, providing detection coverage to areas at least 500 m beyond the base of the platform. The VR2 receivers recorded the date, time, and individual identification number when a transmitter emitted a pulse train within the detection range. Each receiver was downloaded every 2 months as weather permitted, and the data were processed and stored in a customized database.

At the completion of the study, we used a Vemco VR100 receiver and directional hydrophone on board the research vessel to locate tagged fish around each platform. Times of detections of tagged fish made using the mobile VR100 receiver were compared with records of stationary VR2 receivers to determine what percentage of tagged fish still located at the platforms were not being detected by stationary VR2 receivers.

Data analyses.—Because tagging was carried out over several months, the total number of fish detected per day was standardized to the number of days since each fish was tagged. The degree of platform site fidelity was determined for each species based on the proportion of days fish were detected at a platform relative to their time at liberty. A fish was defined as being present at a platform on a given day if it was detected at least three times on that day. We defined low, moderate, and high degrees of site fidelity as describing species that were detected an average of 0–30, 31–60, and 61–90%, respectively, of the days at liberty over the course of the study. Detection data for all fish were pooled over successive 2-week periods and logistic regression analyses were used to predict the probability of presence by species at a given platform over time. Odds ratios generated from logistic regression models with values less than one indicated decreasing odds of presence over time. Detection data for all fish by species were pooled over successive 2-week periods and Fourier time series analyses were conducted in Statistica (version 8.0; StatSoft, Tulsa, Oklahoma) to determine whether fish exhibited diel or tidal periodicity. Periodograms were generated to reveal cyclic patterns in detection rate. These analyses were only done for species with a sample size of four or more individuals.

Results

One-hundred platform-associated fishes comprising 15 species were tagged, released, and monitored over a 655-d period between June 2004 and June 2006 in order to assess their site fidelity to the platforms from which they were caught (Table 1). Fish were caught

TABLE 1.—Summary of all groundfish species tagged between 26 June and 28 August 2004 from petroleum platforms Gail, Gilda, and Grace, located off the coast of California.

Common name	Scientific name	Species code	Total tagged	Size range (TL, cm)	Platform		
					Gilda (63 m)	Gail (225 m)	Grace (96 m)
Blue rockfish	*Sebastes mystinus*	SMYS	1	29	—	—	1
Bocaccio	*Sebastes paucispinis*	SPAU	2	29, 30	—	—	2
Brown rockfish	*Sebastes auriculatus*	SAUR	3	24–27	3	—	—
Copper rockfish	*Sebastes caurinus*	SCAU	9	20–35	8	—	1
Flag rockfish	*Sebastes rubrivinctus*	SRUB	1	21	—	—	1
Greenspotted rockfish	*Sebastes chlorostictus*	SCHL	4	30–41	—	4	—
Greenstriped rockfish	*Sebastes elongatus*	SELO	1	25	—	1	—
Mexican rockfish	*Sebastes macdonaldi*	SMAC	2	52, 58	—	2	—
Rosy rockfish	*Sebastes rosaceus*	SROS	3	22–23	—	—	3
Starry rockfish	*Sebastes constellatus*	SCON	1	22	—	—	1
Treefish	*Sebastes serriceps*	STRE	1	24	—	—	1
Vermilion rockfish	*Sebastes miniatus*	SMIN	61	20–41	34	—	27
Widow rockfish	*Sebastes entomelas*	SENT	4	29–36	—	—	4
Lingcod	*Ophiodon elongatus*	OELO	2	39, 63	—	1	1
Cabezon	*Scorpaenichthys marmoratus*	SMAR	5	25–36	5	—	—
Total			100		50	8	42

and tagged relative to their availability and condition upon retrieval. Three individuals were eliminated from the data set due to believed transmitter failures. Initially, 11 tagged rockfish (nine vermilion rockfish and two copper rockfish) were placed in 1-m^3 cages and held at their depths of capture for a 48-h period to assess postsurgical survival. Two cages holding three fish each were incidentally cut from float lines and lost. Because these six fish were trapped and likely died, they were also removed from the data set. Of the five vermilion rockfish placed in the other cage, all five were recovered and released 2 d after cage deployment.

On several occasions, VR2 receivers were lost or temporarily removed from platforms and their support moorings due to platform maintenance. Therefore, there were periods of reduced or absent VR2 receiver coverage. There was no receiver coverage at Platform Gilda from 13 to 23 October 2004, due to regularly scheduled mooring maintenance.

Data from caged fish served as confirmation of postrelease survival by comparison of patterns in their detections over time. As an example, a copper rockfish (SCAU 3664; four-letter species codes are defined in Table 1) confined to one of the cages that was lost inside the detection zone of a VR2 receiver was continuously detected over time, showing a pattern of no movement, which was representative of a dead fish (Figure 2a). Conversely, a flag rockfish (SRUB 3680) successfully released from a cage deployment showed a discrete pattern of detection at two different VR2 receivers, indicative of movement around the platform after release from the cage. A photograph of this individual was taken during a submersible survey of Platform Grace on 24 September 2004, 1 month following its release, providing visual evidence that the fish had recovered from the tagging procedure (A. Bull, MMS, personal communication; Figure 2b, c).

The period at liberty for tagged individuals ranged from 655 to 714 d, depending on when individuals were initially tagged. Fish tagged with the lower powered V8SC-2 L transmitters were not detected less frequently than those tagged with higher powered V13–1 L transmitters. The total number of tagged fish detected at all platforms combined dropped sharply during the first 6 d following tagging and release (–3.8 fish/d; Figure 3), and this decline was attributed to mortality or immediate emigration, after which detection rates declined more gradually from day 7 to day 204 (–0.12 fish/d) and stabilized after day 233 to the end of the study (–0.038 fish/d).

The degree of platform site fidelity, described as the percentage of days detected over the total number of days at liberty, varied considerably among individuals and greatly among species (Figure 4). Seven of the species tagged showed low platform site fidelity (detected <30% of the days at liberty), which included blue rockfish, bocaccio, greenspotted rockfish, starry rockfish, vermilion rockfish, copper rockfish, and Mexican rockfish. Four species exhibited moderate degrees of platform site fidelity (31–60%), including the cabezon, greenstriped rockfish, brown rockfish, and rosy rockfish, while four species (lingcod, treefish, widow rockfish, and flag rockfish) showed high platform site fidelity (>61%; Figure 4). In many cases, species with only 1–2 fish tagged showed either the lowest or highest degree of site fidelity. The single blue rockfish tagged was detected only 0.8% of the days at liberty, while treefish ($n = 1$; 91%) and flag rockfish ($n = 1$; 88%; shown in Figure 2c) were detected over 80% of their days at liberty (Figure 4). Vermilion rockfish (n

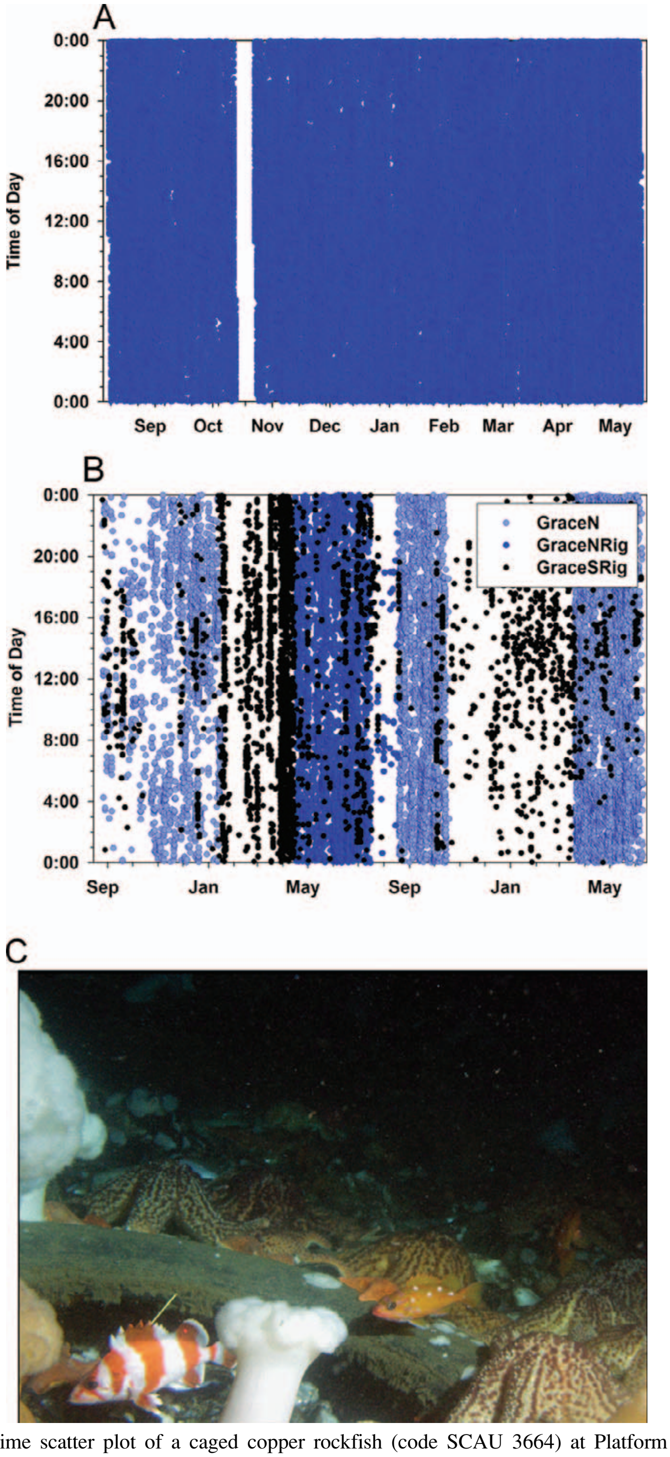

FIGURE 2.—**(a)** Date–time scatter plot of a caged copper rockfish (code SCAU 3664) at Platform Gilda off the coast of California. Blue dots representing detections are indistinguishable due to the inability of this fish to move out of detection range of VR2 receivers. The gap between 13 and 23 October 2004 denotes a period of no VR2 receiver coverage. **(b)** Date–time detections are depicted for a flag rockfish (SRUB 3680), which was able to move in and out of detection range of two different VR2 receivers stationed at Platform Grace. Black dots represent detections at the south end of the platform, blue dots represent detections at the north end of the platform, and light blue dots represent detections on the north mooring receiver. **(c)** Photograph of a tagged flag rockfish (SRUB 3680) taken during a deepwater submersible survey (photo by Ann Bull, MMS) is shown.

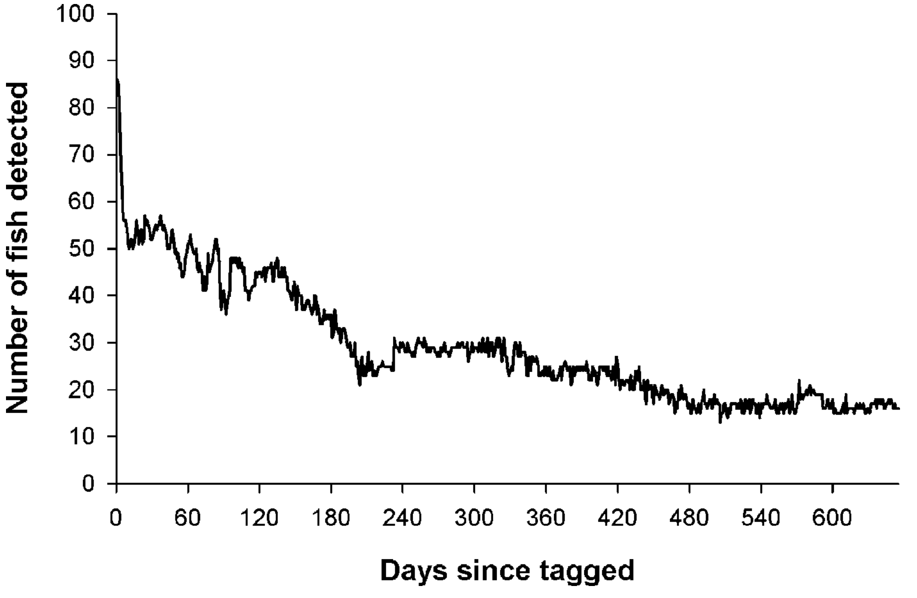

FIGURE 3.—Total number of groundfish detected at all three oil platforms monitored since their date of tagging and release.

= 54) did not exhibit a high degree of site fidelity overall and were detected on average 25 ± 30% of the days at liberty; however, some individuals were detected on fewer than 1% of days at liberty, while others were detected every day (100%) over the course of the study.

Logistic regression analysis revealed species-specific differences in the probability of tagged fish present at platforms over time (Figure 5a–f). Predicted probabilities of presence for all species analyzed except widow rockfish significantly decreased over time (Table 2). The presence of vermilion rockfish over time significantly differed between those tagged at platforms Gilda and Grace. The odds of tagged

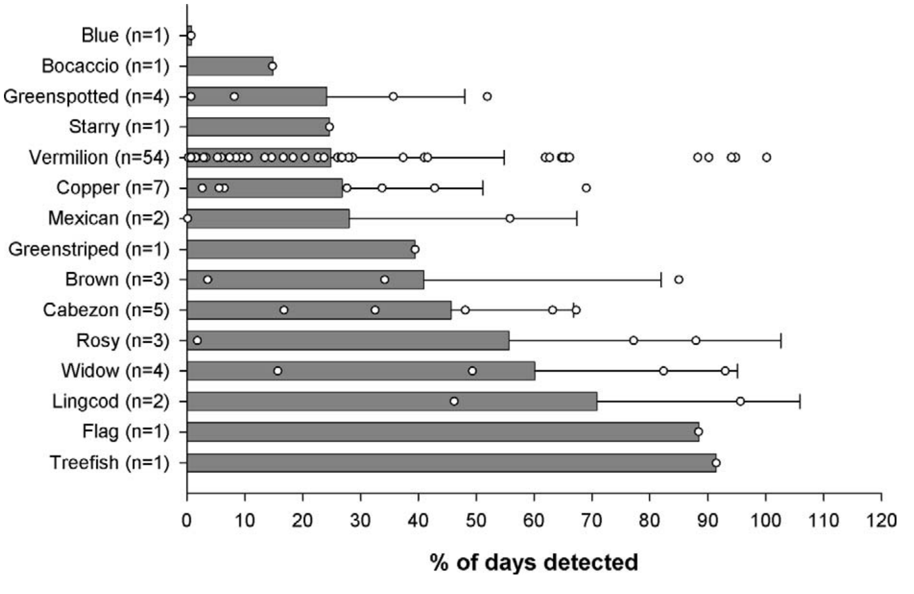

FIGURE 4.—Mean (±SD) proportion of the total number of days each groundfish species was detected (full species names are provided in Table 1). Each open circle represents the proportion of days on which an individual of each species was detected.

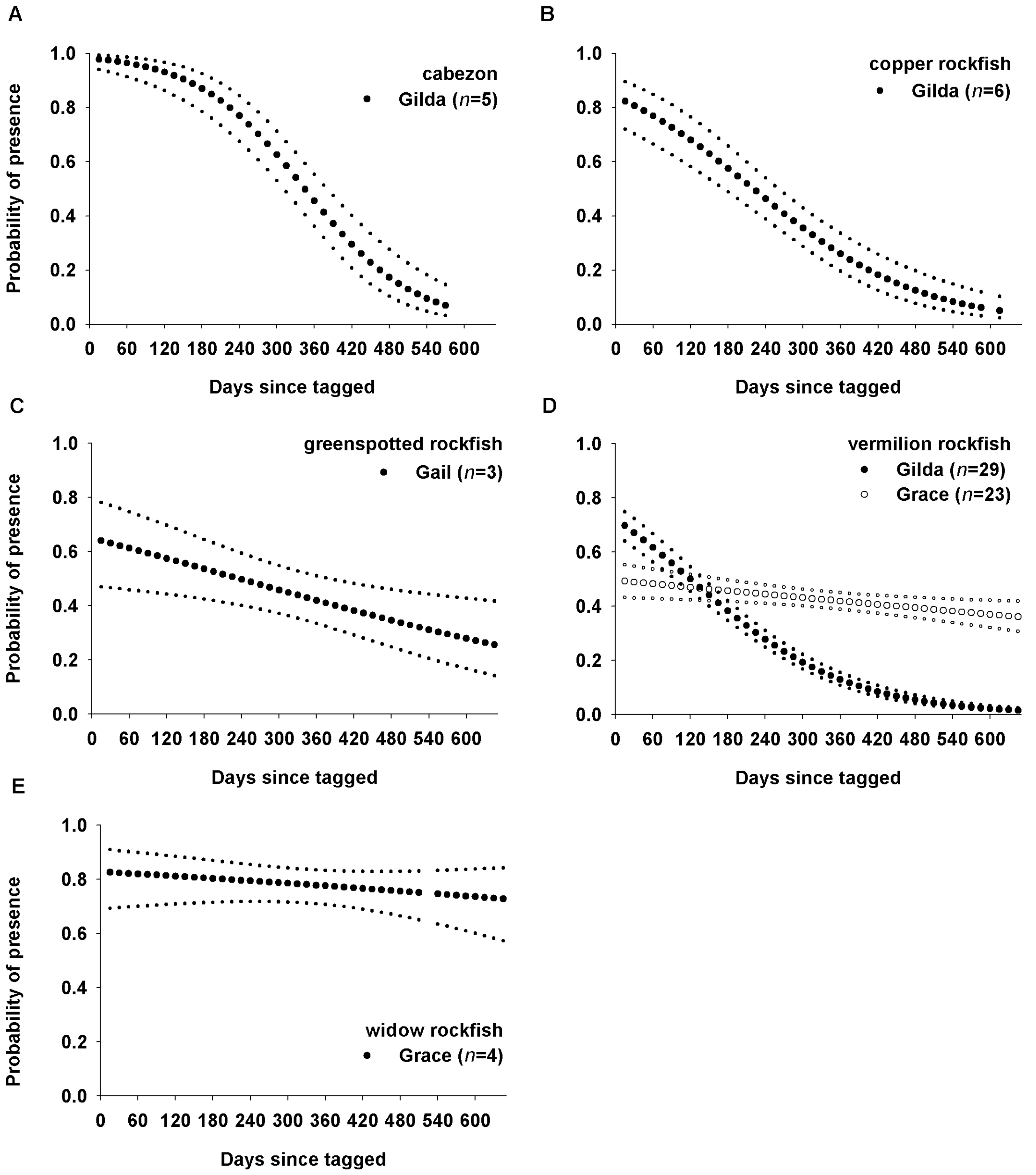

FIGURE 5.—Predicted probability (±95% confidence limits) of tagged groundfish being present over a 2-year period at platforms Gilda, Grace, and Gail in the Santa Barbara Channel, California, from June 2004 to June 2006: **(a)** cabezon, **(b)** copper rockfish, **(c)** greenspotted rockfish, **(d)** vermilion rockfish (platforms Gilda and Grace), and **(e)** widow rockfish.

vermilion rockfish remaining at Platform Gilda were lower than the odds of tagged vermilion rockfish remaining at Platform Grace over the study period (Table 2; Figure 5e, f). One year following release, the probability of presence of a tagged fish at any platform ranged from a low of 48% to a high of 78% depending on the species (Figure 5). The probability of individual cabezon, copper rockfish, and vermilion rockfish present at Platform Gilda decreased by 53, 56, and 57%, respectively. The probability of greenspotted rockfish presence at Platform Gail (225 m) decreased by 14% after 1 year, and the probability of individual vermilion rockfish presence at Platform Grace decreased by 7%. Towards the end of the study (over 560

TABLE 2.—Result of logistic regression analyses examining the effect of time (pooled over successive 2-week intervals) on the probability of detection (presence) for tagged fish at monitored oil platforms (Gilda, Gail, and Grace) in the Santa Barbara Channel, California, from June 2004 to June 2006.

Model (presence = time period)	df	χ^2	P	Odds ratio
Cabezon (Gilda)	1	38.6952	<0.0001	0.990
Copper rockfish (Gilda)	1	44.7428	<0.0001	0.993
Greenspotted rockfish (Gail)	1	6.7466	0.0094	0.997
Vermilion rockfish (all)	1	184.1409	<0.0001	0.996
Vermilion rockfish (Gilda vs. Grace)	1	102.6305	<0.0001	0.376
Widow rockfish (Grace)	1	0.8236	0.3641	0.999

d), the probability of individual rockfish presence was 73% (widow rockfish at Grace), 36% (vermilion rockfish at Grace), 29% (greenspotted rockfish), 7% (cabezon), 5% (copper rockfish), and 1% (vermilion rockfish at Gilda).

Patterns of detection varied considerably among individuals and over time (Figures 6, 7). Some individuals were not detected by any VR2 receivers for periods of several months, but were then detected again. For example, at least two of the four greenspotted rockfish went undetected for more than 7 months (February through July 2005) before reappearing in August and September of the same year. One copper rockfish (SCAU 3691) went undetected by any VR2 receiver for nearly 4 months (15 February through 8 June 2005) before it was detected again. While it is unknown where most individuals moved to during their absences from the platforms, a lingcod (OELO 3618) detected at Platform Gail on 16 January 2006 was subsequently detected at Santa Cruz Island inside the Scorpion State Marine Reserve by two VR2 receivers maintained by the Pfleger Institute of Environmental Research on 18 January 2006 (Figure 8). On 20 January 2006, it was detected back at Platform Gail, where it remained for the duration of the study.

Mobile acoustic surveys conducted around the platforms using the VR100 receiver on 6 and 11 June 2006 resulted in the location of 32 (34%) tagged fishes, while only 21 fishes (23%) were detected by all VR2 receivers during the time of the mobile surveys. Five of the 32 fish had not been detected by any VR2 receiver in over 5 months and one of these fish had not been detected by any VR2 receiver until the end of the study. Six of the 21 fish detected by VR2 receivers were not detected by the VR100 receiver (Figures 6, 7).

Eight vermilion rockfish (SMIN 3690, 3687, 3676, 3660, 3646, 3627, 3625, and 3612) ranging from 22.0 to 30.0 cm TL and one copper rockfish (SCAU 3691; 26.5 cm TL) moved from their original platforms of capture to a neighboring platform (Figure 9). Five of the eight vermilion rockfish tagged at the shallower Platform Gilda (63 m) moved to the deeper Platform Grace (96 m) 0–193 d after being tagged and released. However, three vermilion rockfish (SMIN 3690, 3676, and 3646) moved from the deeper Platform Grace to the shallower Platform Gilda within 2 d after being tagged and released, but each moved back to Platform Grace after less than 24 h (Table 3). The TL of vermilion rockfish tagged at Gilda was significantly smaller (25.3 ± 3.1 cm, mean ± SD) than those tagged at Grace (29.8 ± 5.1 cm; *t*-test, $t = -4.8$, $P = 0.00$).

Fourier time series analysis showed a sharp peak at 24 h/cycle for vermilion rockfish, copper rockfish, widow rockfish, and cabezon, indicating diel periodicity in activity (Figure 10a–c, e). Vermilion rockfish and widow rockfish also showed strong peaks at 12 h/cycle, representative of tidally related movements (Figure 10a, c). Greenspotted rockfish, all of which were caught at depths of 225 m, showed no diel or tidal periodicity (Figure 10d).

Discussion

Quantifying abundance and site fidelity of fishes on active offshore platforms presents several challenges not found around complex natural habitat. Although platforms may be structurally analogous to offshore seamounts or pinnacles in that they span from the seafloor to the surface, in many ways they are more structurally complex by providing extensive internal habitat (e.g., horizontal, diagonal, and vertical crossmembers, associated debris, and biogenic rugosity) as well as considerable shade. Acoustically, platforms are very noisy, more so than natural reefs, and the crossmembers of the platform jacket significantly occlude acoustic signals from transmitters. Most demersal reef-associated fishes are known to be closely associated with the substratum and seek shelter under ledges and in crevices (Caselle et al. 2002; Love and York 2005, 2006; Love et al. 2006a), and some are also known to be territorial (Larson 1980a, 1980b; Love 1996). If these fish move away from their shelters, depending on the location of these shelters relative to stationary VR2 acoustic receivers, it is possible that some tagged fish may go undetected for periods of time. Acoustic signal occlusions from fish moving within the platform structure likely explain much of the short-period variance in the total number of fish being detected over the days since tagging (Figure 3). It is unclear whether fish that had not been detected by VR2 receivers over extended periods of time had left the platform or if they died and their transmitters had fallen into locations where they could no longer be detected by a VR2 receiver. While it is possible that the six fish

FIGURE 6.—Detection plots of all vermilion rockfish (species code SMIN) tagged, illustrating periods of presence (colored bars) and absence over the duration of the study period at oil platforms Gilda (blue bars) and Grace (red bars) off the coast of California. Yellow boxes on the right side of the plots represent detections when fish were relocated using the vesselborne VR100 receiver. Gaps in detections for some fish from 13 to 23 October 2004 were due to lack of VR2 receiver coverage on Platform Gilda.

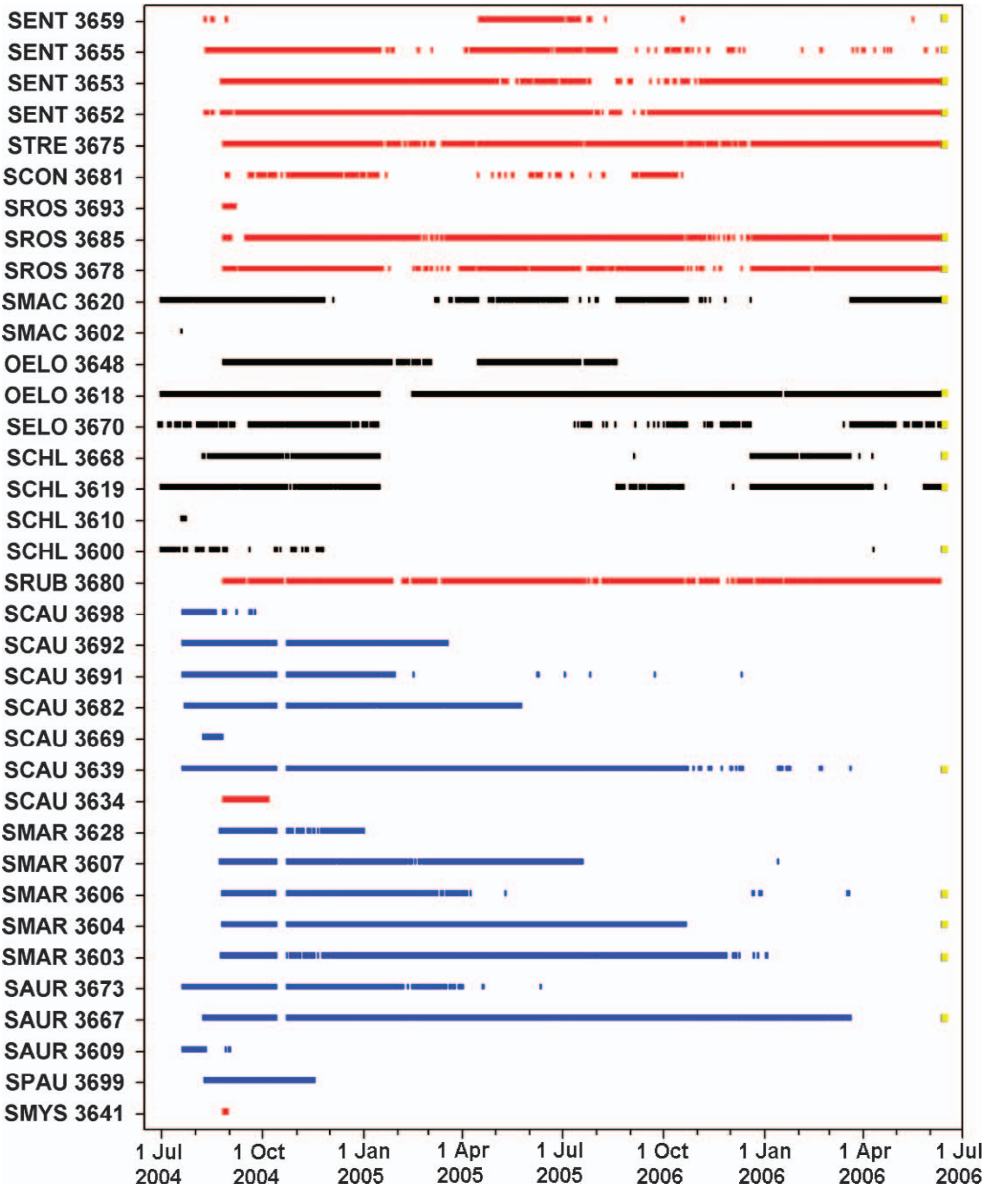

FIGURE 7.—Detection plots of all tagged groundfish species (codes defined in Table 1) other than vermilion rockfish, illustrating periods of presence (colored bars) and absence over the duration of the study period at oil platforms Gail (black bars), Gilda (blue bars), and Grace (red bars) off the coast of California. Yellow boxes on the right side of the plots represent detections when fish were relocated using the vesselborne VR100 receiver. Gaps in detections for some fish from 13 to 23 October 2004 were due to lack of VR2 receiver coverage on Platform Gilda.

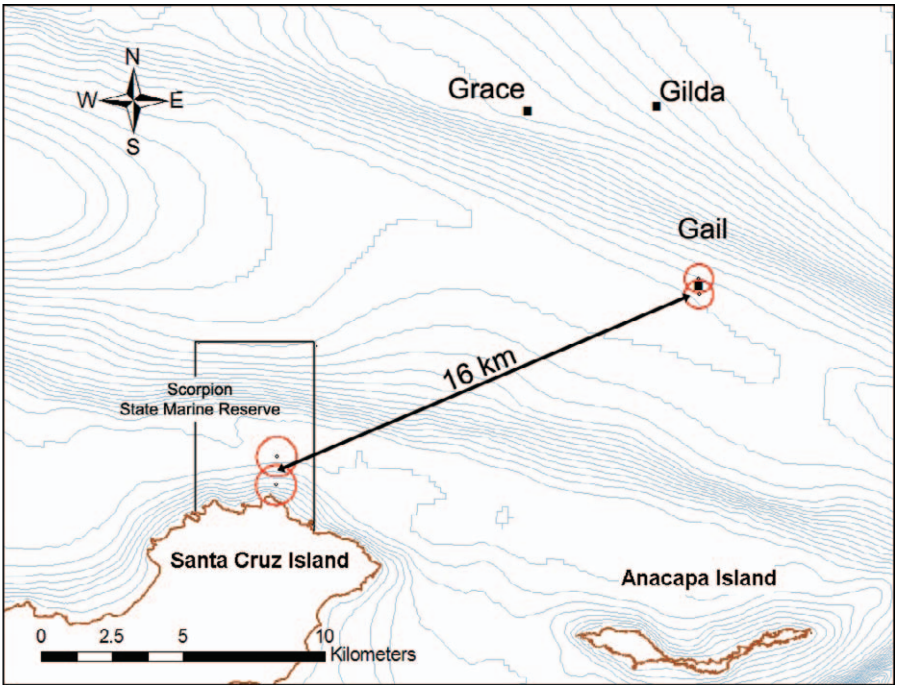

FIGURE 8.—Movement of a lingcod (code OELO 3618) tagged at Platform Gail off the coast of California; this fish was detected on 16 January 2006, was later detected for several hours (18 January 2006) on the north side of Santa Cruz Island (inside the Scorpion State Marine Reserve) by VR2 receivers maintained by the Pfleger Institute of Environmental Studies, and was then detected back at Platform Gail on 20 January 2006, where it was detected for the rest of the study.

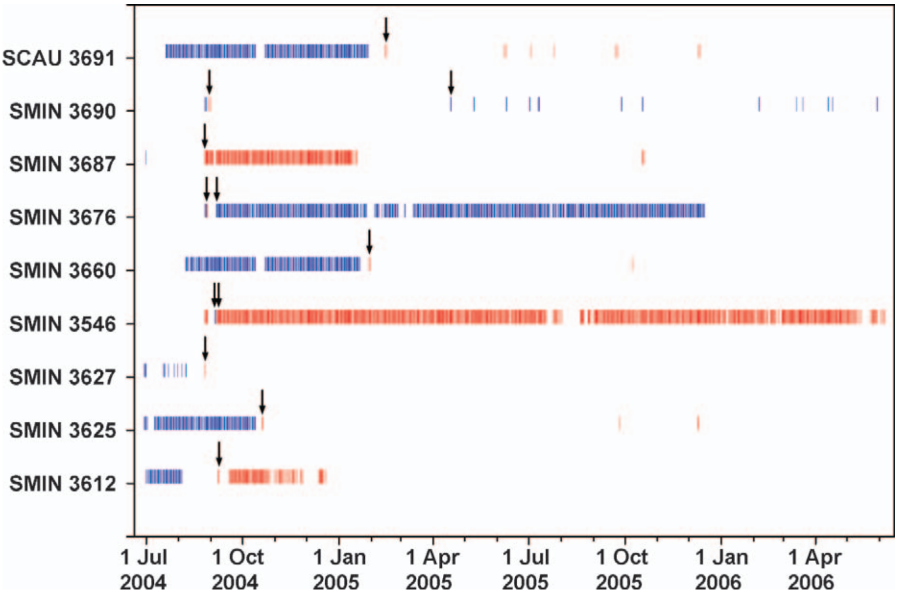

FIGURE 9.—Dates of detections of copper rockfish (species code SCAU) and vermilion rockfish (SMIN) that moved between oil platforms off the coast of California. Blue bars represent detections at Platform Gilda, and red bars represent detections at Platform Grace. Black arrows indicate interplatform movement events.

TABLE 3.—Summary description of rockfish that moved between oil platforms Gilda and Grace off the coast of California (TL = total length, cm).

Code	Rockfish species	TL (cm)	Tagging location	Tagging date	Last date of detection	Last time (hours) of detection	Moved to platform	First date of detection	First time (hours) of detection	Minimum distance traveled (km)
SMIN 3625	Vermilion	27.0	Gilda	29 Jun 2004	13 Oct 2004	0644	Grace	20 Oct 2004	1702	4.5
SMIN 3627	Vermilion	27.5	Gilda	29 Jun 2004	8 Aug 2004	0600	Grace	26 Aug 2004	2101	4.5
SMIN 3687	Vermilion	23.5	Gilda	1 Jul 2004	1 Jul 2004	1428	Grace	26 Aug 2004	1151	4.5
SMIN 3612	Vermilion	26.5	Gilda	1 Jul 2004	8 Sep 2004	1914	Grace	8 Sep 2004	2120	4.5
SCAU 3691	Copper	26.5	Gilda	20 Jul 2004	29 Jan 2005	0129	Grace	15 Feb 2005	0854	4.5
SMIN 3660	Vermilion	26.2	Gilda	8 Aug 2004	21 Jan 2005	1142	Grace	21 Jan 2005	1612	4.5
SMIN 3676	Vermilion	22.0	Grace	26 Aug 2004	27 Aug 2004	0249	Gilda	28 Aug 2004	0342	9.0
					28 Aug 2004	1831	Grace	6 Sep 2004	1120	
SMIN 3690	Vermilion	28.5	Grace	26 Aug 2004	27 Aug 2004	2204	Gilda	30 Aug 2004	0611	9.0
					1 Sep 2004	1440	Grace	18 Apr 2005	2357	
SMIN 3646	Vermilion	30.0	Grace	26 Aug 2004	28 Aug 2004	0056	Gilda	5 Sep 2004	0406	9.0
					5 Sep 2004	0422	Grace	7 Sep 2004	1549	

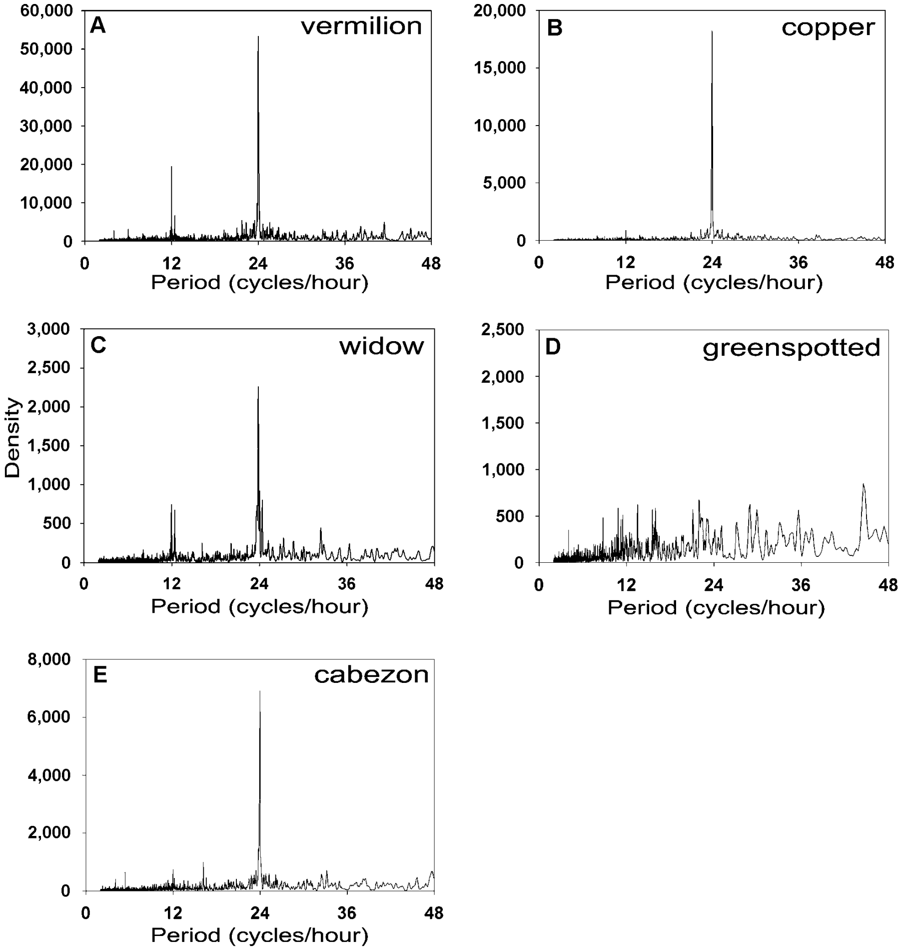

FIGURE 10.—Fourier time series analysis periodograms for **(a)** vermilion rockfish, **(b)** copper rockfish, **(c)** widow rockfish, **(d)** greenspotted rockfish, and **(e)** cabezon. Detection data were pooled across individuals for each species over 2-week intervals.

detected by the mobile VR100 receiver and not by stationary VR2 receivers over a 5-month period had emigrated and returned to the platform around the time of the survey, it is more likely these fish had died and the transmitters were more easily detected by the mobile VR100 as we surveyed around the platforms. Nevertheless, moderate detection rates per individual were expected for a study of this nature considering the complexity of the habitat and the behavior of the species being studied. Furthermore, the chance of a live tagged fish residing at a monitored platform over the 655-d study period and not being detected at all over the study period was considered to be quite low. Despite these limitations, acoustic telemetry monitoring methods provide a much better tool for quantifying degree of site fidelity and movement behavior than standard tag and recapture methods.

Throughout the study period, the numbers of tagged fishes being detected at all platforms changed, which likely reflected a combination of mortalities and emigration from platforms. There was a 30% reduction in the total number of fish being detected at all platforms during the first 6 d following release; this reduction was assumed to be primarily attributed to postrelease mortality. In an associated study examining the effects of barotrauma and postrelease survival of rockfishes, approximately 30% of the fish exposed to angling-induced barotrauma and recompressed in cages at depth died within 2 d following capture (Jarvis and Lowe 2008). However, Jarvis and Lowe (2008) also found strong species-specific differences in the post-release survival of rockfishes exposed to angling-related barotraumas. Strong currents that flow by platforms in the Santa Barbara Channel as well as roving scavengers could carry moribund tagged fish away from the platform and outside the detection range of the VR2 receivers. It is also likely that some of these individuals immediately emigrated from the platforms to other areas. For example, two vermilion rockfish caught at Platform Gilda were detected there for only 1–2 d after release and were then detected at Platform Grace a minimum of 1 d later (Table 3). It is also possible that these fish had died and were scavenged by a predator (e.g., sealion *Zalophus californianus* or shark) and the predator was detected moving between these platforms. However, a predator that has consumed a transmittered fish should regurgitate the transmitter after 5–10 d (Papastamatiou and Lowe 2004).

Comparisons of detection records between fish in lost cages and those detected after 6 d following release showed clear differences in detection patterns and behavior. Detection patterns of tagged fish in lost cages within detection range of a VR2 receiver show constant rates of detection by that receiver over time (Figure 2a); however, a majority of fish detected after 6 d following release showed signs of movement because they were detected by different VR2 receivers at different times of the day (Figure 2b). Additionally, many of these patterns changed over time and were used to confirm survival of individuals over time. Abrupt and continuous absences of detections from tagged fishes that previously exhibited these patterns were assumed to be emigrations away from the platforms. This probably describes the pattern of detection of tagged fish following the initial rapid decline in fish detections.

Although it is difficult to fully characterize the degree of site fidelity for many species where fewer than three fish were tagged, some interesting observations were obtained for species of low sample sizes. Based on our criteria for defining differing degrees of site fidelity, four species of platform-associated fish (lingcod, treefish, widow rockfish, and flag rockfish) were detected on greater than 61% of their days at liberty at any of the monitored platforms and are therefore believed to exhibit high site fidelity over a 655-d monitoring period. For example, a treefish and a flag rockfish tagged at Platform Grace showed the highest degree of site fidelity and were detected over 80% of their days at liberty. Both species are typically found in close association with the substratum, are solitary as adults, and may be territorial (Love et al. 2002); therefore, they would be expected to exhibit a higher degree of site fidelity due to their need to protect a territory. Obviously, more research is needed to support these observations, particularly in light of the high variability of site fidelity in species of much higher sample sizes.

The two lingcod acoustically monitored in our study exhibited the third highest level of site fidelity (71%). Previous tag and recapture studies conducted on lingcod in California have reported conflicting results, with some suggesting that lingcod exhibit high site fidelity, while others have indicated low levels of site fidelity. Lea et al. (1999) examined tag and recapture data for lingcod in California and found that some individuals were recaptured very close to their original tagging site, while others were recaptured up to 124 km away. Starr et al. (2004) reported high site fidelity of adult lingcod acoustically monitored in an Alaska marine reserve; although fish frequently left the reserve, they would return to their original tagging locations after various lengths of time. Lingcod in our study showed similar behavior and were regularly detected at platforms Grace and Gail; however, both individuals showed periods of absence from these platforms. The largest lingcod (OELO 3618; 63.2 cm TL) tagged at Platform Gail traveled to Santa Cruz

Island inside the Scorpion State Marine Reserve (~16 km away) over several days before returning back to Platform Gail (Figure 8). In southern California, lingcod are known to move into shallow water during winter months to spawn (Love 1996). This movement observed from the lingcod tagged at Platform Gail is believed to be spawning related based on the time of year, size of this fish, and its detection in shallower water (~50–80 m) at Santa Cruz Island. In addition, based on the short duration of absence from Platform Gail (~4 d) during that period it is likely that this was a female, as a successful mating male would have remained on the nest for 8–10 weeks (Love 1996). Also, large females are typically found in deeper water (Mathews and LaRiviere 1987; Love 1996) and the lingcod tagged at Platform Gail was caught in 225 m of water. The other lingcod was much smaller (39 cm TL, immature), and it is not known where this fish may have gone between September 2005 and June 2006. Nevertheless, the observed movement between natural habitat and Platform Gail indicates that platforms may offer better foraging opportunities due to the high density of prey (small rockfish), but some may not provide suitable habitat for spawning due to their depth (e.g., Platform Gail; Love et al. 2003).

Widow rockfish were detected more consistently over the duration of the study (Figure 5) and also exhibited a high degree of site fidelity (Figure 4). Although previous tag and recapture studies have indicated that widow rockfish are capable of moderate degrees of movement over short periods of time (Love 1980; Hartmann 1987), no individuals tagged in our study were detected at other platforms or other monitored locations (i.e., Anacapa or Santa Cruz Islands). Some of the widow rockfish tagged in this study were likely caught in the midwater portion of the platform and, like bocaccio, widow rockfish are known to move vertically throughout the water column (Love et al. 2002; Stanley et al. 2002). Love et al. (2003) observed widow rockfish in the midwater and base of several petroleum platforms in the Santa Barbara Channel. Because these fish are not as closely associated with the substratum as other more demersal species, it was thought that they may show a lower degree of site fidelity. However, the more extensive structure of the platforms may provide widow rockfish with additional feeding opportunities that are not as available around rocky pinnacles or outcrops. While the transmitters used in this study could not be used to determine depth, it is assumed that the higher degree of movement throughout the midwater portion of the platform increases their probability of being detected by VR2 receivers.

Cabezon, rosy rockfish, brown rockfish, and greenstriped rockfish were found to exhibit moderate degrees of site fidelity and were detected, on average, between 31% and 60% of their days at liberty. Previous tag and recapture studies have indicated that cabezon exhibit high site fidelity (Hartmann 1987; Lea et al. 1999), although recapture rates were typically low (~4%). All of the cabezon in our study were tagged at Platform Grace and were caught in the midwater portion of the platform. All five cabezon tagged were detected regularly from August 2004 through January 2005, after which individuals were detected much less frequently. It is not known whether several of these individuals left the platform; however, three of the five fish were detected by the VR100 at the completion of the study. It is possible that detection rates changed for cabezon as they moved toward the base of the platform or moved to locations in the structure where they were not as easily detected. Some rosy rockfish and brown rockfish showed high degrees of site fidelity, while some individuals showed very low site fidelity. Brown rockfish in Puget Sound are thought to have small home ranges (~30 m^2) and to exhibit high site fidelity but are also known to move in response to habitat quality (Matthews 1990b). Very little is known about the movement patterns of rosy rockfish, but it is assumed based on their affinity for complex substratum that they should also have small home ranges and show high site fidelity. Therefore, it is likely that some individuals may have left the platform in response to competition with other species or were lost to predation by larger species.

Seven of the 15 species tagged exhibited low degrees of platform site fidelity (detected on average <30% of their days at liberty), including the bocaccio, blue rockfish, greenspotted rockfish, starry rockfish, vermilion rockfish, copper rockfish, and Mexican rockfish. Copper rockfish and vermilion rockfish, two of the most abundant species tagged in our study ($n = 7$ and 54, respectively), showed high variation in the percentage of days on which individuals were detected (0.5–100%); however, on average, they exhibited low site fidelity. Previous standard tag and recapture studies of copper rockfish have reported low to moderate degrees of movement and site fidelity (Hartmann 1987; Matthews 1990b; Lea et al. 1999). The copper rockfish was the only other species found to move between monitored platforms (Table 3), providing further evidence for successful emigration. Conversely, vermilion rockfish are thought to be highly site specific (Hartmann 1987; Lea et al. 1999), but like many species of rockfishes they are known to exhibit ontogenetic movements to deeper water as they grow and mature (Love et al. 1991; Love 1996; Lea et al. 1999). Some of the variation in degree of site fidelity among vermilion rockfish was attributed to the depth of platforms where individuals were tagged. The vermilion rockfish tagged at Platform Gilda were on average significantly smaller than those tagged at the deeper Platform Grace, and they showed a steady decline in probability of presence over time. Larger individuals tagged on Platform Grace exhibited a higher probability of presence over time (Figure 5). Evidence of emigration of smaller vermilion rockfish tagged on the shallower Platform Gilda to deeper water was supported by interplatform movements exhibited by five vermilion rockfish that moved from Platform Gilda (63 m) to Platform Grace (96 m) shortly after they were tagged and released. Although three vermilion rockfish moved from the deeper Platform Grace to Platform Gilda, they quickly returned to Platform Grace. In addition, some of the variation in rates of emigration could be related to species-specific differences. There is growing evidence that there may be two different cryptic species of vermilion rockfish, a shallow-water species (vermilion rockfish) and a deeper water species (sunset rockfish *Sebastes crocotulus*; Hyde et al. 2008). If both species co-occur at the shallow platforms, it is possible that the sunset rockfish are the primary species emigrating to the deeper water as they grow, while the vermilion rockfish are remaining at the shallower platforms.

Rapid interplatform movements and the movements observed for the lingcod that moved between Platform Gail and Santa Cruz Island clearly indicate that fish are able to navigate between these platforms and natural habitat efficiently and may be cueing in on sounds or odors (e.g., Mitamura et al. 2005) specific to each platform. In addition, these observations provide strong evidence of homing ability, which is important for fish that leave their home ranges in pursuit of food or temporary shelter (e.g., seasonal changes in kelp canopy) or to reproduce. This behavior may be more common in adults with well-established home ranges, and thus, we expect that juveniles and immature fish would tend to exhibit shorter-term site fidelity and fewer instances of homing (Love et al. 2003; Lea et al. 1999).

Although the lack of site fidelity of some individuals tagged at platforms may be partially attributed to mortalities, low measures of site fidelity are more likely a result of emigration and in some cases discontinuous residence times of individuals over the 655 d. For example, individuals with continuous but short platform residency may show low site fidelity similar to individuals that leave a platform for extended periods of time and then return at a later date. Because the chance of not detecting a fish that is present at a platform is relatively low, it is likely that continuous periods of nondetection reflect actual absence of a fish from the platform rather than a prolonged inability of the VR2 to detect the fish (Figures 6, 7). It was assumed that continued absence of tagged individuals after a period of detection was the result of emigration. Overall emigration rates varied over time, with relatively higher rates of emigration during the first winter than in the subsequent year (Figure 3). It is unclear why the emigration rate was higher in the first winter than in the second winter, but this could be attributed to annual differences in production and food availability. In addition, this reduction in emigration rate over the duration of the study might be explained by individual propensities to move, particularly for younger fish. Some individuals within a population are more prone to move than others (e.g., Willis et al. 2003; Lowe and Bray 2006; Topping et al. 2006; Bellquist et al. 2008). Therefore, the stabilization of emigration rate over the final 200 d of monitoring could represent the fraction of more resident individuals within the tagged population. This portion of emigration could be attributed to density-dependent spillover of juveniles and subadult fish. Fish surveys by Love et al. (2003) indicated higher fish densities on platforms than nearby natural reefs and larger fish at platforms than natural reefs. Therefore, it is also possible that some fish, particularly smaller individuals, emigrated away from platforms due to inter- and intraspecific competition for space and food or increased predation risk from larger fish.

Diel trends in daily detections were discernable in a majority of the individuals monitored. Four of the five most abundant species tagged (cabezon, vermilion rockfish, widow rockfish, and copper rockfish) showed distinct evidence of diel periodicity. However, we could not determine the times of day different species might be most active (e.g., noctural, diurnal, or crepuscular); this was due to variability in the locations of VR2 receivers relative to refuges used by individuals of different species. These increased periods of activity observed through changes in hourly detections are most likely related to feeding and refuging behavior (Peabody and Wilson 2006). Interestingly, greenspotted rockfish tagged at Platform Gail (225 m) showed no signs of diel periodicity. Less light penetrates to that depth, so there is no cue to regulate a diel clock (Lowe and Bray 2006). Because this species is known to span a depth range from 30 to 300 m, it would be interesting to verify whether individuals in shallower water (juveniles) exhibit any diel periodicity and whether this ability is lost as they move to deeper water. Vermilion rockfish and widow rockfish also showed some tidal periodicity (~12 h/cycle). Current direction and strength at the platforms can be strongly influenced by tidal changes. Therefore, vermilion rockfish and widow rockfish may be responding to tidally related currents, which may enhance or reduce foraging opportunities in addition to diel influences.

Management Implications

Although there are no directly comparable studies to determine whether site fidelity of the species associated with platforms are any longer than individuals associated with natural habitat, fish appear to be using platforms in a manner similar to that of fish found on natural reefs. In fact, some species such as widow rockfish and lingcod may show higher site fidelity to platform habitat than natural habitat. Love et al. (2003, 2006b) suggested that some rockfishes recruit to platforms as larvae or age 0 and that size- and age-classes can be tracked on these platforms over time. While some juvenile and subadult fish emigrate away from platforms over time, a fraction (~30%) of similarly sized individuals remain for at least 2 years. This suggests that these platforms are not simply acting as sinks but are supplying larger, more mature individuals to other locations, thereby also acting as sources of export to the fishery. In addition, of the 93 fish tagged and successfully released, only two were reported as being recaptured by fishers. This further supports evidence that these platforms may be acting as de facto reserves due to their release from fishing pressure. Observed movements of lingcod, vermilion rockfish, and copper rockfish between platforms and natural habitat support the supposition that platform-associated fishes have the ability to navigate between structures and home back to a platform. This suggests that platform habitat for some individuals may be perceived as higher quality than encountered natural habitat and may enhance fitness.

Continued declines in groundfish populations throughout southern California resulting from high recreational and commercial fishing pressure, coupled with signs of growth overfishing of many rockfish species (Jarvis and Lowe 2008), constitute only one of the reasons the state of California is implementing Marine Protected Areas throughout the region. The degree of site fidelity and export of subadult fish associated with offshore petroleum platforms in the eastern Santa Barbara Channel, along with the higher abundances and reduced fishing pressure (Love et al. 2003), suggests that these platforms function like "protected" natural habitats. Therefore, removal of these platforms would result in a loss of essential habitat for many platform-associated fishes, and managers should consider the potential benefits of incorporating some platforms into reserves.

Acknowledgments

We thank A. Bull and G. Steinbach for their support of this research. M. McCrea, D. Topping, Y. Papastamatiou, B. Hight, D. Cartamil, J. Barr, and J. Caselle provided assistance with fishing, tagging, and maintenance of the acoustic receivers. We thank A. Monge for his expertise with database management and the Ventura Harbor Master for providing us dock space for our vessel. This research was funded by the Minerals Management Service (Cooperative Agreement 1435-01-04-CA-34196 OCS/MMS 2007–006) based on an information need identified by the Minerals Management Service's Pacific Outer Continental Shelf Region and by the California Artificial Reef Enhancement Program. We also thank M. Edwards, V. Menapace, J. Hollis, and T. Martinez of Venoco and K. Moschetto, K. Orr, R. Pena, and F. Arsi from DCOR LLC for facilitating fishing and diving operations around platforms Gail, Grace, and Gilda.

References

Bellquist, L., J. E. Caselle, and C. G. Lowe. 2008. Fine-scale movement patterns, site fidelity, and habitat selection of ocean whitefish, *Caulolatilus princeps*. Fisheries Research 91:325–335.

Bull, A. S., and J. J. Kendall, Jr. 1994. An indication of the process: offshore platforms as artificial reefs in the Gulf of Mexico. Bulletin of Marine Science 55:1086–1098.

Caselle, J. E., M. S. Love, C. Fusaro, and D. Schroeder. 2002. Trash or habitat? Fish assemblages on offshore oilfield seafloor debris in the Santa Barbara Channel, California. ICES Journal of Marine Science 59:S258–S265.

Dugas, R., V. Guillory, and M. Fischer. 1979. Oil rigs and offshore sport fishing in Louisiana. Fisheries 4(6):2–10.

Frumkes, D. R. 2002. The status of the California Rigs-to-Reefs programme and the need to limit consumptive fishing activities. ICES Journal of Marine Science 59:S272–S276.

Hartmann, A. R. 1987. Movement of scorpionfishes (Scorpaenidae: *Sebastes* and *Scorpaena*) in the southern California Bight. California Department Fish and Game Fish Bulletin 73:68–79.

Helvey, M. 2002. Are southern California oil and gas platforms essential fish habitat? ICES Journal of Marine Science 59:S266–S271.

Hyde, J. R., C. A. Kimbrell, J. E. Budrick, E. A. Lynn, and R. D. Vetter. 2008. Cryptic speciation in the vermilion rockfish (*Sebastes miniatus*) and the role of bathymetry in the speciation process. Molecular Ecology 17:1122–1136.

Jarvis, E. T., and C. G. Lowe. 2008. The effects of barotrauma on the catch-and-release survival of southern California nearshore and shelf rockfish (Scorpaenidae, *Sebastes* spp.). Canadian Journal of Fisheries and Aquatic Sciences 65:1245–1249.

Larson, R. J. 1980a. Territorial behavior of the black and yellow rockfish and gopher rockfish (Scorpaenidae, *Sebastes*). Marine Biology 58:111–122.

Larson, R. J. 1980b. Influence of territoriality on adult density in two rockfishes of the genus *Sebastes*. Marine Biology 58:123–132.

Lea, R. N., R. D. McAllister, and D. A. VenTresca. 1999. Biological aspects of nearshore rockfishes of the genus *Sebastes* from central California. California Department of Fish and Game Fish Bulletin 177.

Love, M. S. 1980. Evidence of movements of some deepwater rockfishes (Scorpaenidae: genus *Sebastes*) off southern California. California Department Fish and Game Fish Bulletin 67:246–249.

Love, M. S. 1996. Probably more than you wanted to know about the fishes of the Pacific coast, 2nd edition. Really Big Press, Santa Barbara, California.

Love, M. S., M. H. Carr, and L. J. Haldorson. 1991. The ecology of substrate-associated juveniles of genus *Sebastes*. Environmental Biology of Fishes 30:225–243.

Love, M. S., J. Caselle, and L. Snook. 1999. Fish assemblages on mussel mounds surrounding seven oil platforms in the Santa Barbara Channel and Santa Maria Basin. Bulletin of Marine Science 65:497–513.

Love, M. S., J. E. Caselle, and L. Snook. 2000. Fish assemblages around seven oil platforms in the Santa Barbara Channel area. U.S. National Marine Fisheries Service Fishery Bulletin 98:96–117.

Love, M. S., and D. M. Schroeder. 2006. Ecological performance of OCS platforms as fish habitat off California. MMS OCS Study 2004-005. Marine Science Institute, University of California, Santa Barbara. MMS Cooperative Agreement Number 1435-01-03-CA-72694.

Love, M. S., D. M. Schroeder, W. Lenarz, and G. R. Cochrane. 2006a. Gimme shelter: the importance of crevices to some fish species inhabiting a deeper-water outcrop in southern California. California Cooperative Oceanic Fisheries Investigations Reports 47:119–126.

Love, M. S., D. M. Schroeder, W. Lenarz, A. MacCall, A. Scarborough Bull, and L. Thorsteinson. 2006b. Potential use of offshore marine structures in rebuilding an overfished rockfish species, bocaccio (*Sebastes paucispinis*). U.S. National Marine Fisheries Service Fishery Bulletin 104:383–390.

Love, M. S., D. M. Schroeder, and M. M. Nishimoto. 2003. The ecological role of oil and gas production platforms and natural outcrops on fishes in southern and central California: a synthesis of information. U.S. Geological Survey, Biological Resources Division, Seattle, Washington, OCS Study MMS 2003-032.

Love, M. S., M. Yoklavich, and L. Thorsteinson. 2002. The rockfishes of the northeast Pacific. University of California Press, Berkeley.

Love, M. S., and A. York. 2005. A comparison of the fish assemblages associated with an oil/gas pipeline and adjacent seafloor in the Santa Barbara Channel, southern California Bight. Bulletin of Marine Science 77:101–117.

Love, M. S., and A. York. 2006. The relationships between fish assemblages and the amount of bottom horizontal beam exposed at California oil platforms: fish habitat preferences at man-made platforms and (by inference) at natural reefs. U.S. National Marine Fisheries Service Fishery Bulletin 104:542–549.

Lowe, C. G., and R. N. Bray. 2006. Movement and activity patterns. Pages 524–553 *in* L. G. Allen, M. H. Horn, and D. J. Pondella, editors. The ecology of California marine fishes. University of California Press, Berkeley.

Lowe, C. G., D. T. Topping, D. P. Cartamil, and Y. P. Papastamatiou. 2003. Movement patterns, home range and habitat utilization of adult kelp bass (*Paralabrax clathratus*) in a temperate no-take marine reserve. Marine Ecology Progress Series 256:205–216.

Mathews, S. B., and M. LaRiviere. 1987. Movement of tagged lingcod, *Ophiodon elongatus*, in the Pacific Northwest. U.S. National Marine Fisheries Service Fishery Bulletin 85:153–159.

Matthews, K. R. 1990a. A telemetric study of the home ranges and homing routes of copper and quillback rockfishes on shallow rocky reefs. Canadian Journal of Zoology 68:2243–2250.

Matthews, K. R. 1990b. An experimental study of the habitat preferences and movement patterns of copper, quillback, and brown rockfishes (*Sebastes* spp.). Environmental Biology of Fishes 29:161–178.

Miller, D. J., and J. J. Geibel. 1973. Summary of blue rockfish and lingcod life histories; a reef ecology study; and giant kelp, *Macrocystis pyrifera*, experiments in Monterey Bay, California. U.S. National Marine Fisheries Service Fishery Bulletin 158.

Mitamura, H., A. Nobuaki, W. Sakamoto, Y. Mitsunaga, H. Tanaka, Y. Mukai, K. Nakamura, M. Sasaki, and Y. Yoneda. 2005. Role of olfaction and vision in homing behaviour of black rockfish *Sebastes inermis*. Journal of Experimental Marine Biology and Ecology 322:123–134.

Papastamatiou, Y. P., and C. G. Lowe. 2004. Postprandial response of gastric pH in leopard sharks (*Triakis semifasciata*) and its use to study foraging ecology. Journal of Experimental Biology 207:225–232.

Peabody, M. B., and C. A. Wilson. 2006. Fidelity of red snapper (*Lutjanus campechanus*) to petroleum platforms and artificial reefs in the northern Gulf of Mexico. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, Louisiana. OCS Study MMS 2006-005.

Schroeder, D. M., and M. S. Love. 2002. Recreational fishing and marine fish populations in California. California Cooperative Oceanic Fisheries Investigations Reports 43:182–189.

Schroeder, D. M., and M. S. Love. 2004. Ecological and political issues surrounding decommissioning of offshore oil facilities in the southern California Bight. Ocean and Coastal Management 47:21–48.

Stanley, D. R., and C. A. Wilson. 1989. Utilization of offshore platforms by recreational fishermen and scuba divers off the Louisiana coast. Bulletin of Marine Science 44:767–775.

Stanley, R. D., R. Kieser, and M. Hajirakar. 2002. Three-dimensional visualization of a widow rockfish (*Sebastes entomelas*) shoal over interpolated bathymetry. ICES Journal of Marine Science 59:151–155.

Starr, R. M., J. N. Heine, J. M. Felton, and G. M. Cailliet. 2002. Movements of bocaccio (*Sebastes paucispinis*) and greenspotted (*S. chlorostictus*) rockfishes in a Monterey submarine canyon: implications for the design of marine reserves. U.S. National Marine Fisheries Service Fishery Bulletin 100:324–337.

Starr, R. M., J. N. Heine, and K. A. Johnson. 2000. Techniques for tagging and tracking deepwater rockfishes. North American Journal of Fisheries Management 20:597–609.

Starr, R. M., V. O'Connell, and S. Ralston. 2004. Movements of lingcod (*Ophiodon elongatus*) in southeast Alaska: potential for increased conservation and yield from marine reserves. Canadian Journal of Fisheries and Aquatic Sciences 61:1083–1094.

Topping, D. T., C. G. Lowe, and J. E. Caselle. 2006. Site fidelity and seasonal movement patterns of adult California sheephead *Semicossyphus pulcher* (Labridae): an acoustic monitoring study. Marine Ecology Progress Series 326:257–267.

Willis, T. J., R. B. Millar, and R. C. Babcock. 2003. Protection of exploited fish in temperate regions: high density and biomass of snapper *Pagrus auratus* (Sparidae) in northern New Zealand marine reserves. Journal of Applied Ecology 40:214–227.