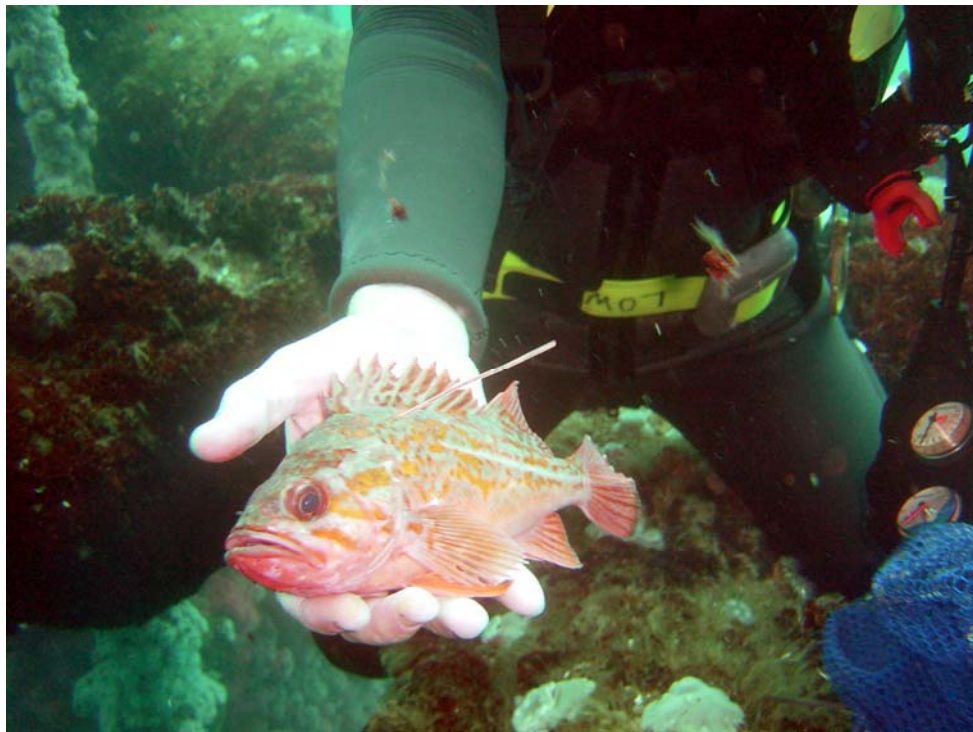


SITE FIDELITY OF CHARACTERISTIC FISH SPECIES AT OFFSHORE OIL PLATFORMS IN THE SANTA BARBARA CHANNEL

Final Report



**OCS Study
MMS 2007-006**

**SITE FIDELITY OF CHARACTERISTIC FISH
SPECIES AT OFFSHORE OIL PLATFORMS IN
THE SANTA BARBARA CHANNEL**

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Cover Photo: A research diver releasing a vermilion rockfish (*Sebastes miniatus*) that had been surgically fitted with an acoustic transmitter at Platform Gilda. Photo by Kim Anthony.

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TECHNICAL SUMMARY

Study Title: Site fidelity of characteristic fish species at offshore oil platforms in the Santa Barbara Channel

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Background and Objectives:

Recent debates regarding offshore oil platform decommissioning have raised questions about how these structures may function in replenishing local fish stocks. Populations of many deepwater reef-associated rockfishes, particularly bocaccio and cowcod, have been shown to be severely depleted due to overfishing. Recent submersible studies conducted by Love et al. (2003) at Pacific Outer Continental Shelf (POCS) platforms and natural reefs throughout the Southern California Bight have indicated that there are distinct differences in fish size and abundance, with some platforms having significantly higher densities of adult rockfishes (e.g., bocaccio, vermilion, greenspotted, greenblotched, shortbelly, and cowcod) than natural reefs. These platforms not only provide complex structure for these fishes, but also reduce fishing effectiveness due to difficulties fishing within and around the structure, thereby allowing the platforms to function like de facto reserves (Schroeder and Love 2002).

While it is thought that some fishes associated with these platforms recruit near the surface as larvae or young-of-the-year (YOY) and slowly move their way down to the base, it is unclear how site specific juveniles and adults may be to each platform and how this may vary with the depth of platform. In addition, it has been proposed that fish species with a strong affinity for complex substrata should have smaller home ranges and exhibit higher site fidelity than species that show lower affinity for complex substrata (Lowe & Bray 2006). Because some oil platforms in the east Santa Barbara Channel are located in areas relatively depauperate of suitable natural rock reef habitat (G. Cochrane, pers. comm.),

it is hypothesized that fishes associated with platforms may exhibit high site fidelity. To test this hypothesis, we tagged 100 fishes (including representatives of several deepwater reef associated species) with long-life acoustic transmitters at each of three neighboring (5-6 km apart) oil platforms in the east Santa Barbara Channel (Gail, Gilda, and Grace). Automated acoustic receivers were strategically placed in and around the platforms to continuously listen for tagged fish in order to quantify site fidelity over a 2-year period. In 2002 a pilot acoustic telemetry monitoring study was conducted at Platform Gail in the east Santa Barbara Channel where several greenspotted and a Mexican rockfish (potential surrogates for bocaccio and cowcod) were captured, tagged and released. Preliminary data indicated that fishes successfully survived the surgical implantation of acoustic transmitters and were detected moving in and amongst the structure of the platform. Therefore, expansion of that pilot study would provide critical knowledge of the residence time and degree of site fidelity of these fishes and would allow for a more accurate assessment of the importance of offshore oil platforms as reserves for impacted species.

The overall goal of this study was to quantify the site fidelity of fishes characteristic to offshore oil platforms located in the Santa Barbara Channel. To accomplish this goal, we 1) captured and surgically implanted individual coded acoustic transmitters in representative platform-associated fishes, 2) strategically placed automated acoustic receivers with overlapping areas of acoustic detection around each platform, 3) retrieved, downloaded, and maintained automated acoustic receivers quarterly, and 4) quantified the residence time, site fidelity, and movement patterns of fishes fitted with acoustic transmitters.

Significant Results:

In this study we used acoustic telemetry to monitor presence and absence of 100 platform-associated fishes of 15 species on three Pacific OCS platforms ranging in depth from 63 to 225 m in the east Santa Barbara Channel from 2004 to 2006. Platform-associated fishes were caught via hook and line, brought to the surface, and surgically fitted with uniquely coded acoustic transmitters between June and August 2004. A total of eight fish were tagged at Platform Gail (225 m), 50 fish were tagged at Platform Gilda (63 m), and 42 at Platform Grace (96 m). Detection efficiency and rates of detection of individuals varied with platform, and were considered to be moderate, but effective over the duration of the study period.

Thirty fish were not detected by any acoustic receivers six days following tagging and release and were assumed to have died or immediately emigrated away from the platforms. After this six-day period, the emigration rate of tagged fishes at all platforms was highest during the first winter and slowed significantly during the second year of monitoring. Of the fish present after the first six days following tagging, 60% were detected regularly at the platforms.

Degree of site fidelity varied greatly among individuals, among species, and between platforms. Lingcod (n=2), treefish (n=1), widow (n=4) and flag rockfishes (n=1) showed high site fidelity and were detected, on average, over 61% of the days they were at liberty. Cabezon (n=5), greenstriped (n=1), brown (n=3) and rosy rockfishes (n=3) showed moderate levels of site fidelity and were detected between 31% and 60% of their days at liberty, while bocaccio (n=1), blue (n=1), greenspotted (n=4), starry (n=1), vermilion (n=54), copper (n=7), and Mexican rockfishes (n=2) all showed a low degree of site fidelity, having been detected fewer than 30% of their days at liberty. Of the five most abundant species tagged (cabezon, widow, copper, greenspotted, and vermilion rockfishes), widow rockfish showed the highest probability of presence at platforms throughout the duration of the study.

Ten fish moved to other monitored platforms or locations. One mature lingcod moved from platform Gail to Santa Cruz Island—into the Scorpion State Marine Reserve (a total distance of 18 km following a straight line)—and back in just a four-day period. Eight vermilion rockfish moved between Platforms Gilda and Grace (~ 6 km apart), with a majority of the individuals moving from the shallower platform, Gilda, to the deeper platform, Grace. Vermilion rockfish tagged at Platform Gilda emigrated

faster than those monitored on the deeper platform, Grace. In addition, vermilion rockfish tagged at Platform Gilda were significantly smaller than those tagged on Platform Grace. One copper rockfish moved from Platform Gilda to Platform Grace.

Cabezon, copper, vermilion, and widow rockfish showed evidence of diel periodicity, whereas greenspotted rockfish that were tagged deeper (225 m) did not. Vermilion and widow rockfishes also showed evidence of tidal related periodicity that was not evident in the detection patterns of cabezon, greenspotted, and copper rockfishes.

STUDY PRODUCTS

MASTERS THESIS

2007 Jarvis, E.T. The effects of barotrauma on the catch & release survival of southern California nearshore and shelf rockfishes (Scorpaenidae, *Sebastes* spp.).

PAPERS

In press. Jarvis, E.T. and C.G. Lowe. 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.

Lowe, C.G., K.M. Anthony, E.T. Jarvis, L.F. Bellquist, and M.S. Love. Site fidelity of characteristic fish species at offshore oil platforms in the Santa Barbara Channel. ICES Journal of Marine Sciences *Manuscript in prep.*

PAPERS PRESENTED

Anthony, K.M., C.G. Lowe, E.T. Jarvis, L.F. Bellquist, M.S. Love. Site fidelity and movements of oil platform-associated fishes in the Santa Barbara Channel. American Fisheries Society. San Francisco, CA. September 2007.

Jarvis, E.T. and C.G. Lowe. The effects of angling-induced barotrauma on post-release survival of southern California nearshore and shelf rockfishes. Ann. Mtg. American Fisheries Society, San Francisco, CA. September 2007.

Lowe, C.G., L. Bellquist, D. Topping, E. Jarvis, K.M. Anthony, B. Ziegler, M. McCrea, Y. Papastamatiou, M. Love, and A. Scarborough-Bull. Using acoustic telemetry monitoring to assess catch & release survivorship and site fidelity of rockfishes on offshore oil platforms off southern California. Invited symposium: Influence of offshore platforms on marine fish ecology. Annual Meeting of the American Fisheries Society. Anchorage, AK. September 2005.

Lowe, C.G., E. Jarvis, K.M. Anthony, L. Bellquist, B. Hight, M. McCrea, M. Love, and A. Scarborough-Bull. Site fidelity and emigration of fishes tagged at offshore oil platforms off southern California. Annual Meeting of the Western Society of Naturalist. Monterey, CA. November 2005.

Lowe, C.G., K.M. Anthony, L. Bellquist, E. Jarvis, T. Mason, D. Topping, J. Vaudo, and J. Caselle. Effectiveness of VR receivers in monitoring movements of fishes in different marine habitats. International Congress on the Biology of Fish, St. John's, Newfoundland. July 2006.

Jarvis, E.T. and C.G. Lowe. Post-release survivorship of southern California nearshore and shelf rockfishes caught on hook & line. Annual Meeting of the Western Society of Naturalists. Seattle, WA. November 2006.

Anthony, K.M., C.G. Lowe, L. Bellquist, T. Mason, D. Topping, J. Vaudo, and J. Caselle. Effectiveness of VR receivers in monitoring movements of fishes in different marine habitats. Annual Meeting of the Western Society of Naturalists. Seattle, WA. November 2006.

SITE FIDELITY OF CHARACTERISTIC FISH SPECIES AT OFFSHORE OIL PLATFORMS IN THE SANTA BARBARA CHANNEL

EXECUTIVE SUMMARY

Information Needed

Debates regarding offshore oil platform decommissioning have raised questions about how these structures function in replenishing local fish stocks. Populations of many deepwater reef-associated species of rockfishes, particularly bocaccio and cowcod, have been shown to be severely depleted due to overfishing. Recent submersible surveys conducted by Love et al. (2003) at Pacific Outer Continental Shelf (POCS) platforms and natural reefs throughout the Southern California Bight has indicated that there are distinct differences in fish size and abundances, with some platforms having significantly higher densities of larger rockfishes (e.g., bocaccio, vermilion, greenspotted, greenblotched, shortbelly, and cowcod) than natural reefs. These platforms not only provide complex structure for these fishes to associate with, but also reduce fishing effectiveness due to difficulties fishing within and around the structure, thereby allowing the platforms to function like de facto reserves (Schroeder and Love 2002).

There is also mounting evidence that POCS platforms may be identical to or better than natural reefs in regard to rockfish inhabitants. Love et al. (2006) measured higher densities of economically important adult bocaccio and cowcod on platforms than on natural reefs. They reported no differences in growth rates of YOY rockfish on platforms and natural reefs. In some cases, they even found that young rockfishes living around platforms showed lower mortality rates than those on natural reefs. All of these findings suggest that platforms may perform better ecologically than natural reefs. Another important metric for comparing the ecological performance of platforms is determining how long fish remain at platforms (degree of site fidelity) and to what extent platforms may export fish (rate of emigration).

Previous studies have hypothesized that some fishes associated with POCS platforms recruit to the midwater portions of platforms as larvae or young-of-the-year (YOY) and gradually move their way down to the base as they grow. However, it is unclear how site specific juveniles and adults may be to each platform and how this may vary with the depth of platform. Moreover, it has been proposed that fish species with a strong affinity for complex substrata should have smaller home ranges and exhibit higher site fidelity than species that show lower affinity for complex substrata (Lowe and Bray 2006). Because some oil platforms in the east Santa Barbara Channel are located in areas relatively depauperate of suitable natural rock reef habitat, fishes associated with platforms may exhibit a high degree of site fidelity to them.

Historically, techniques used to estimate site fidelity and movements have been limited to standard tag and recapture; however, the success of standard tag and recapture methods are strongly dependent on fishing effort. The evolution of acoustic telemetry techniques provides a means to continuously monitor tagged individuals at a particular location for up to seven years. In 2002, an acoustic telemetry monitoring pilot study was conducted at platform Gail in the east Santa Barbara Channel where several greenspotted and a Mexican rockfish (potential surrogates for bocaccio and cowcod) were captured, tagged and released. Data indicated that fish survived the surgical implantation of acoustic transmitters and were detected moving in and amongst the structure of the platform over time. Expansion of that pilot study would provide critical knowledge of the residence time and degree of site fidelity of these fishes and would allow for a more accurate assessment of the importance of offshore oil platforms for impacted species.

The overall goal of this study was to quantify the site fidelity of fishes characteristic to offshore oil platforms located in the Santa Barbara Channel. To accomplish this goal, we 1) captured and surgically implanted individual coded acoustic transmitters in representative platform-associated fishes, 2) strategically placed automated acoustic receivers with overlapping areas of acoustic detection around each platform, 3) retrieved, downloaded, and maintained automated acoustic receivers quarterly, and 4) quantified the residence time, site fidelity, and movement patterns of fishes fitted with acoustic transmitters.

Research Summary

In this study, we quantified the degree of site fidelity of platform-associated fishes on three Pacific Outer Continental Shelf (POCS) platforms in the east Santa Barbara Channel (Gail, Gilda, and Grace) from August 2004 to June 2006. One hundred fishes representing 15 different species were caught using hook and line, brought to the surface and surgically fitted with uniquely coded acoustic transmitters. Two automated acoustic receivers were deployed at each of the three platforms at locations that would provide the greatest probability of detecting tagged fish within the platform jacket. Despite the complex and noisy structure, detection efficiencies of receivers and detection rates of individuals were moderate, but adequate, considering the duration of the monitoring period.

Thirty fish were not detected by any acoustic receivers six days following tagging and release and were assumed to have died or immediately emigrated from the platforms. Emigration rate of tagged fish at all platforms was highest during the first winter and slowed significantly in the second year of monitoring. Over 60% of the fish present after the first 6 d following tagging eventually left monitored platforms.

Degree of site fidelity varied greatly among individuals, among species, and between platforms. Lingcod (n=2), treefish (n=1), widow (n=4) and flag rockfishes (n=1) showed high site fidelity and were detected, on average, over 61% of the days they were at liberty. Cabezon (n=5), greenstriped (n=1), brown (n=3) and rosy rockfishes (n=3) showed moderate levels of site fidelity and were detected between 31% and 60% of their days at liberty, while bocaccio (n=1), blue (n=1), greenspotted (n=4), starry (n=1), vermilion (n=54), copper (n=7), and Mexican rockfishes (n=2) all showed a low degree of site fidelity, having been detected less than 30% of their days at liberty. Of the five most abundant species tagged (cabezon, widow, copper, greenspotted, and vermilion rockfish), widow rockfish, showed the highest probability of presence at platforms. Since the probability of not detecting tagged fish at each platform was relatively low over the two-year monitoring period, it was assumed that fish not detected at a platform for over 1 month had left the area. Many of the individuals that were detected less than 30% of their days at liberty left the platform and returned at a later date.

Movements away from platforms were confirmed for ten fish that moved to other monitored platforms or natural reef locations. One mature lingcod moved from Platform Gail to Santa Cruz Island into the Scorpion State Marine Reserve and back in just a four-day period, indicative of a spawning migration. Eight vermilion rockfish moved between Platforms Gilda and Grace (~ 5 km apart), with a majority of the individuals moving from the shallower Platform Gilda to the deeper Platform Grace. Vermilion rockfish tagged at platform Gilda emigrated faster over time than those monitored on the deeper platform Grace. In addition, vermilion rockfish tagged at Platform Gilda were significantly smaller than those tagged on Platform Grace. There is now some evidence that there may be two subspecies of vermilion rockfish (a shallow and deeper water form), which may explain much of the variation in movement behavior. One copper rockfish moved from Platform Gilda to Platform Grace. These movements from the shallower platform to a deeper platform correlate with previously described ontogenetic movements of maturing fish to deeper habitats.

Greenspotted, widow, and vermilion rockfish showed seasonal peaks in the number of detections per fish per month, with greenspotted and widow rockfishes being detected more during winter than summer months. Vermilion rockfish showed the opposite pattern. These differences in the number of detections per fish per month probably represent seasonal differences in activity and corresponding changes in water temperature and productivity. Cabezon, copper, vermilion, and widow rockfish showed evidence of diel periodicity, whereas greenspotted rockfish tagged in significantly deeper water (225 m) did not. These diel patterns in detection likely correspond to changes in activity related to feeding behavior. Vermilion and widow rockfish also showed evidence of tidal-related periodicity that was not evident in detection patterns of cabezon, greenspotted, and copper rockfish. It is unclear why these fish showed tidal related activity.

This study provides strong evidence that POCS platforms constitute important habitat for many species of reef fishes and, at certain life stages, a proportion of individuals emigrate to deeper water habitats. Moreover, the observed movements of fish between POCS platforms and natural reef habitats indicate that they have the ability to navigate between these habitats and that platform habitat may be of higher quality than natural reefs.

Site fidelity of characteristic fish species at offshore oil platforms in the Santa Barbara Channel

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

Abstract

In order to determine the ecological importance of California oil platforms for many economically important fishes, knowledge of their site fidelity and movements around platforms is essential. We determined the degree of site fidelity of 100 platform-associated fishes, across 15 species at three POCS platforms in the east Santa Barbara Channel using acoustic telemetry monitoring. Thirty percent of the fish tagged were not detected after the first six days following release and were assumed to have died or 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, vermilion, widow, copper, and greenspotted rockfish), 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 fishes (8 vermilion, 1 copper, and 1 lingcod) moved between platforms (~ 5 km) and/or natural habitat; a majority moved from a shallower platform to a deeper one. These movements provide further support that many reef-associated fishes make ontogenetic shifts to deeper water, and therefore, 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, widow, and greenspotted rockfish. Observed movements of fishes between platforms and natural reef habitat indicate that they can navigate and that platform habitat may be of higher quality than natural reefs.

Introduction

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. Many of these platforms are projected to be obsolete within the next decade, and in accordance with current state and federal regulations, 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 5000 offshore oil platforms have created substantial amounts of artificial habitat used by many sport and food fishes (Dugas

et al. 1979). Therefore, these artificial habitats have provided economically important fishing opportunities for sport- and commercial fishers in areas where they otherwise do not exist (Schroeder and Love 2004). However, the utility of this approach in California has been under considerable debate due to political pressures and 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, offshore island) that has historically supported large sport and commercial fisheries and is readily accessible to sport fishers relatively close to shore (< 45 km). Intensive fishing pressure has led to systematic over-fishing and has significantly changed species composition and the demography of fishes in these areas (Lea et al. 1999). California POCS platforms, despite their relatively close proximity to shore and to major recreational fishing ports, are not fished as heavily as those in the Gulf of Mexico (Dugas et al. 1979, Stanley and Wilson 1989, Schroeder and Love 2002, Peabody and Wilson 2006, Love et al. 2006).

Over the last few years a number of studies have examined the ecological importance of oil platforms off the coast of California, particularly those in the northern portion of the Southern California Bight. Love et al. (2000, 2003, 2006) conducted diver and manned submersible fish surveys of POCS 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 cowcod (*Sebastes levis*), bocaccio (*S. paucispinis*), and lingcod (*Ophiodon elongatus*). In addition, surveys indicated high abundances of young-of-the-year (YOY) 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 YOY fish recruit to the upper reaches of the platforms and migrate to the base as they get larger (Love and Schroeder, 2006).

Because of the unique assemblages and higher densities of fishes at POCS platforms than natural reefs (Helvey 2002), 13 previously surveyed platforms (totaling only 0.04 km²) were proposed to be considered as “essential fish habitat” (EFH) in 2006. However, NOAA declined to designate these platforms as EFH due to lack of supporting scientific evidence of their

importance to sustaining fish stocks¹, though the National Artificial Reef Plan has determined that artificial reefs (such as oil platforms) could be designated as EFH (NOAA 2007, p. 34). Aside from the political aspects of this decision, much of the debate regarding the ecological importance of these platforms revolves around whether they act as “sources” or “sinks.” Love et al. (2006) concluded that several Santa Barbara Channel platforms were important for YOY 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, 2006), 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 residency of platform-associated fishes is essential in determining how these fishes 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 species of fishes associated with POCS 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, as they are fishing dependent, 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 has been used more successfully to quantify space use and site fidelity of individuals of a variety of reef associated species (Lowe and Bray 2006). Starr et al. (2002) used acoustic telemetry monitoring to quantify the movements and site fidelity of bocaccio and greenspotted rockfish (*S. chlorostictus*) in the Monterey Bay canyon and found that greenspotted rockfish were more site specific than

¹ <http://www.noaanews.noaa.gov/stories2006/s2590.htm>

bocaccio (0.5 – 1.6 km² and >12 km², 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 may affect space requirements and site fidelity of reef associated rockfishes (Matthews 1990b, Lowe and Bray 2006). Miller and Geibel (1973) found that juvenile blue rockfish (*S. 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 (*S. caurinus*) and quillback rockfish (*S. maliger*) had smaller home ranges when occupying high relief habitats (<10 m²) than when they were associated with low relief habitat (~ 4000 m²). Therefore, if POCS oil and gas 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 POCS 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. 2006), 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.

The goal of the present study was to quantify the degree of site fidelity (residency) of characteristic platform-associated fishes on surveyed POCS 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 POCS platforms and would help managers assess the impacts of decommissioning on areas with EFH status.

Materials and Methods

Study location

Characteristic platform-associated fishes were monitored using acoustic telemetry at three POCS platforms in the eastern Santa Barbara Channel. Fish were tagged on platforms

Gilda ($34^{\circ} 10' N$ $119^{\circ} 25' W$, 63 m depth), Grace ($34^{\circ} 10' N$ $119^{\circ} 28' W$, 96 m depth), and to a lesser extent, Gail ($34^{\circ} 07' N$ $119^{\circ} 24' W$, 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, CA and Anacapa Island (Figure 1). Benthic habitat beneath all three platforms consists of mussel shell mounds surrounded by sloping soft sediment bottom (Love et al. 1999, 2003).

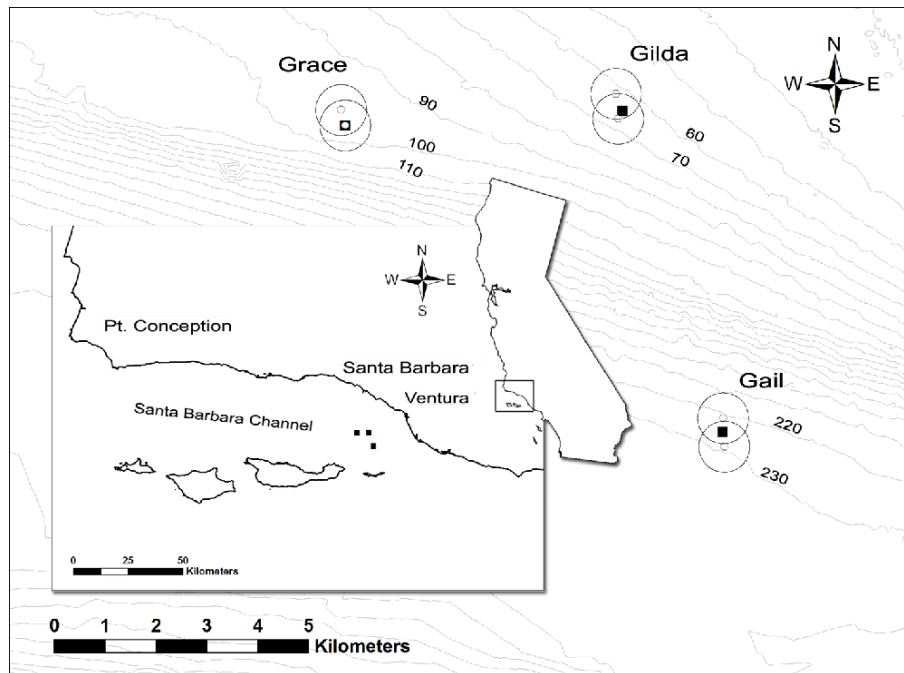


Figure 1. Map of study site. Inset depicts the location along the southern California coast where the POCS platforms Gail, Gilda, and Grace are located. Solid squares indicate locations of the platforms. Small open circles represent locations of VR2 receivers, around which 800 m detection zones have been drawn. Numbers above bathymetry contours represent depths (m).

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 rockfishes exhibited similar signs of barotrauma at 20 m depth to those 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 anaesthetized by placing them in a bin of chilled seawater containing 20 ppm of clove oil. Once anaesthetized, over-inflated fish were vented using an 18-gauge hypodermic needle and their total lengths were measured. Subsequently, fish were 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 (Vemco, Inc. models V8SC-R04k and V13-R04k) was inserted into the peritoneal cavity. The V8SC-R04k transmitters were 9 mm in diameter x 30 mm long and the V13-R04k were 13 mm in diameter x 35 mm long. Transmitters were coated with a combination of paraffin and beeswax (2.3:1) to prevent immuno-rejection. Transmitters were programmed to produce a 69 kHz pulse train consisting of seven discrete pulses that contain the individual ID code based on the timing between the pulses. Pulse trains were emitted randomly within pre-programmed 100-300 sec intervals, which yielded a nominal 3-yr battery life. The incision was closed using 1-2 interrupted sutures (Chromic Gut), and an external plastic dart ID tag (Hallprint) was inserted into the dorsal musculature to allow individual identification if caught by an angler or seen during submersible surveys. The entire tagging procedure took approximately 3-4 min per fish, after which individuals were placed in a large cooler containing fresh, chilled seawater pending release.

Initially, tagged fish were hand released ($n \sim 30$) 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-covered wire mesh cages and lowered to the sea floor for a period of one day to confirm the detection of the transmitters, assess recovery times after exposure to barotrauma, and post-surgical survival. After one day, 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. 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 using an inverted, weighted milk crate attached to a 40-m line. 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, Inc. model VR2). VR2 receivers were attached at 20 m depth to each of two support vessel moorings, one located to the north and the other to the 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 in at a depth of 12 m. The receivers had an approximate detection range of 800 m, which was based on preliminary range tests conducted before any fishes were tagged. VR2 receivers recorded the date, time, and individual ID number when a transmitter emitted a pulse train within the detection range. Each receiver was downloaded every two months as weather permitted, and the data were processed and stored in a customized database.

We used several methods to calibrate VR2 receivers and test their effectiveness in detecting tagged fish at each platform. Detection efficiency of VR2s at each platform was calculated as the proportion of registered code ID detections at a specific VR2 relative to the total number of pulses detected. This total value includes the detections that were counted but discarded by the VR2 because another transmitter emitted a pulse train at the same time. This detection efficiency is a measure of receivers' ability to detect different numbers of competing transmitters within the area, which can also be influenced by a number of biotic and abiotic factors. At the completion of the study, we used a Vemco VR100 receiver 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 days, the total number of fish detected per day was standardized to the number of days since each fish was tagged. The degree of site fidelity was determined for each species based on the proportion of days fish were detected relative to their time at liberty. We defined low, moderate, and high degrees of site fidelity for species that were detected an average of 0-30%, 31-60%, and 61-90% of the days at liberty over

the course of the study, respectively. Logistic regression analyses were used to predict the probability of presence by species at a given platform over time. This was only done for species with a sample size of 4 or more individuals. Detection data were pooled into successive 2-week periods (SAS Statistical Software v 9.1). Fourier time series analyses were conducted in Statistica (v 8.0) to determine whether fish exhibited diel and/or tidal periodicity; periodograms were generated to reveal cyclic patterns in detection rate. Finer scale patterns in movement around oil platforms were analyzed with date-time scatter plots, which show detections of individual fish on a temporal scale.

Results

Detection zones around VR2 receivers were conservatively estimated to be 500 m based on range test experiments using V8SC transmitters, which have a slightly lower power output than the V13 transmitters. Zones of detection of each receiver were found to overlap the platform, providing detection coverage to areas at least 800 m beyond the base of the platform. Detection efficiencies were calculated from recorded VR2 metadata for each receiver at the end of each deployment. Throughout the duration of the study period, VR2 receivers stationed at the three oil platforms had mean detection efficiencies as follows: Gail, 26.3 ± 16.7 % (\pm SD) (225 m depth, n = 8 fish tagged), Gilda, 43.3 ± 7.7 % (63 m, n = 40), and Grace, 32.8 ± 5.4 % (96 m, n = 48). Detection efficiencies varied considerably more at the deepest platform (Gail), where there was an increase in the number of fish detected without a decrease in detection efficiency as additional tags were deployed. Conversely, detection efficiencies were more consistent at the shallower platforms (Gilda and Grace) with increasing numbers of fish being detected (Figure 2).

One-hundred platform-associated fishes comprising 17 species were tagged, released and monitored over a 655 d period between June 2004 and June 2006 in order to assess their affinity to the platforms from which they were caught (Table 1). Three individuals were eliminated from the dataset due to believed transmitter failures. Initially, eleven tagged rockfish (9 vermilion and 2 copper) were placed in 1 m³ cages and held at their depths of capture for a 48-hr period to assess post-surgical 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 removed from the dataset. Of the five vermilion rockfish placed in the other cage, all five were recovered and

released two days following cage deployment. There was no receiver coverage at Platform Gilda from 13 October to 23 October 2004, due to regularly scheduled mooring maintenance.

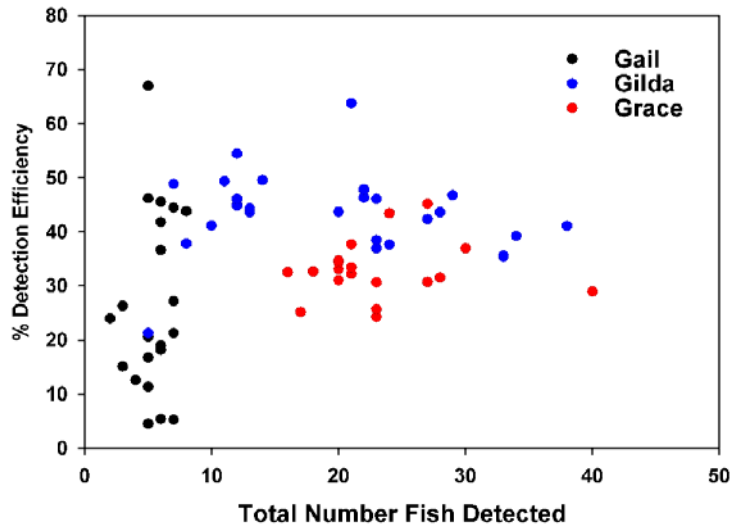


Figure 2. The relationship between the total number of fish detected during each VR2 receiver deployment versus the percent transmitter code detection efficiency for each receiver by platform.

Table 1. Summary of all species tagged between 26 June and 28 August 2004 from POCS platforms Gail, Gilda, and Grace.

Common Name	Scientific Name	Species Code	Total Tagged	Size Range (TL = cm)	Gilda (65 m)	Gail (225 m)	Grace (97 m)
Blue rockfish	<i>Sebastes mystinus</i>	SMYS	1	29	-	-	1
Bocaccio	<i>S. paucispinis</i>	SPAU	2	29, 30	-	-	2
Brown rockfish	<i>S. auriculatus</i>	SAUR	3	24-27	3	-	-
Copper rockfish	<i>S. caurinus</i>	SCAU	9	20-35	8	-	1
Flag rockfish	<i>S. rubrivinctus</i>	SRUB	1	21	-	-	1
Greenspotted rockfish	<i>S. chlorostictus</i>	SCHL	4	30-41	-	4	-
Greenstriped rockfish	<i>S. elongatus</i>	SELO	1	25	-	1	-
Mexican rockfish	<i>S. macdonaldi</i>	SMAC	2	52, 58	-	2	-
Rosy rockfish	<i>S. rosaceus</i>	SROS	3	22-23	-	-	3
Starry rockfish	<i>S. constellatus</i>	SCON	1	22	-	-	1
Treefish	<i>S. sericeus</i>	STRE	1	24	-	-	1
Vermilion rockfish	<i>S. miniatus</i>	SMIN	61	20-41	34	-	27
Widow rockfish	<i>S. entomelas</i>	SENT	4	29-36	-	-	4
Lingcod	<i>Ophiodon elongatus</i>	OELO	2	39, 63	-	1	1
Cabezon	<i>Scorpaenichthys marmoratus</i>	SMAR	5	25-36	5	-	-
Total			100		50	8	42

Data from trapped caged fish served as confirmation of post-release survival by comparison of patterns in their detections over time. As an example, a copper rockfish (SCAU 3664) confined to one of the cage sets that was lost inside the detection zone of a VR2 receiver

was continuously detected over time, showing no pattern of movement—representative of a dead fish (Figure 3a). Conversely, a flag rockfish (SRUB 3680) successfully released from a cage deployment showed a discrete pattern of detections 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 by Ann Bull on 24 September 2004, one month following its release, providing visual evidence that the fish had recovered from the tagging procedure (Figure 3b, c).

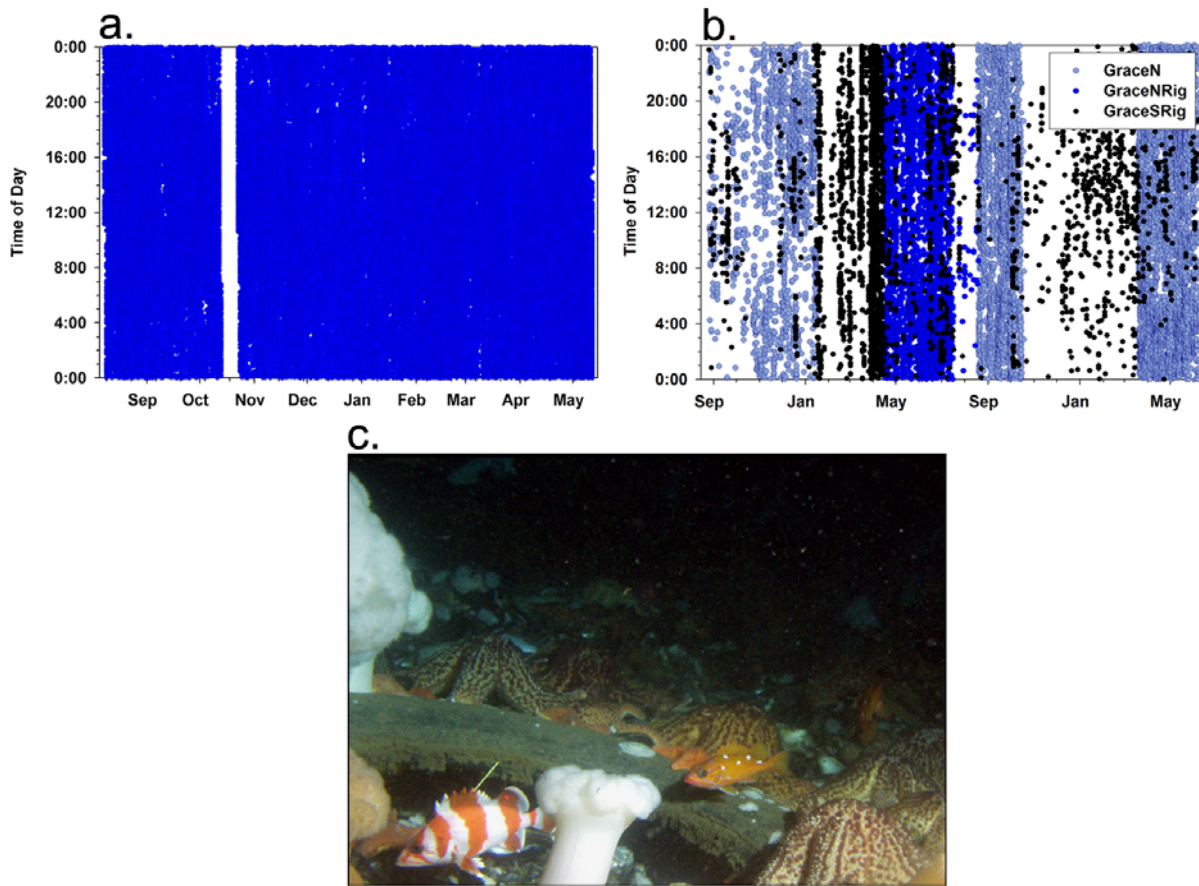


Figure 3. a) Date-time scatter plot of a caged copper rockfish (SCAU 3664) at Platform Gilda. Individual black marks, representing detections, are indistinguishable due to the inability of this fish to move out of detection range of VR2 receivers. The vertical blank space between 13 October - 23 October 2004 denotes a period of no VR2 receiver coverage. b) Date-time detections 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 represents detections at the north mooring receiver and gray represents detections at the south end of the platform. c) This flag rockfish (SRUB 3680) was photographed during a deepwater submersible survey as seen in the lower left hand corner.

The total days at liberty for tagged individuals ranged from 655 to 714, depending on when they were initially tagged. The total number of tagged fish detected at all platforms combined dropped sharply after the first six days following tagging and release (-3.8 fish per day) (Figure 4) and was attributed to mortalities, after which, detection rates declined more gradually from day 7 to 204 (-0.12 fish per day) and stabilized after day 233 to the end of the study (-0.038 fish per day).

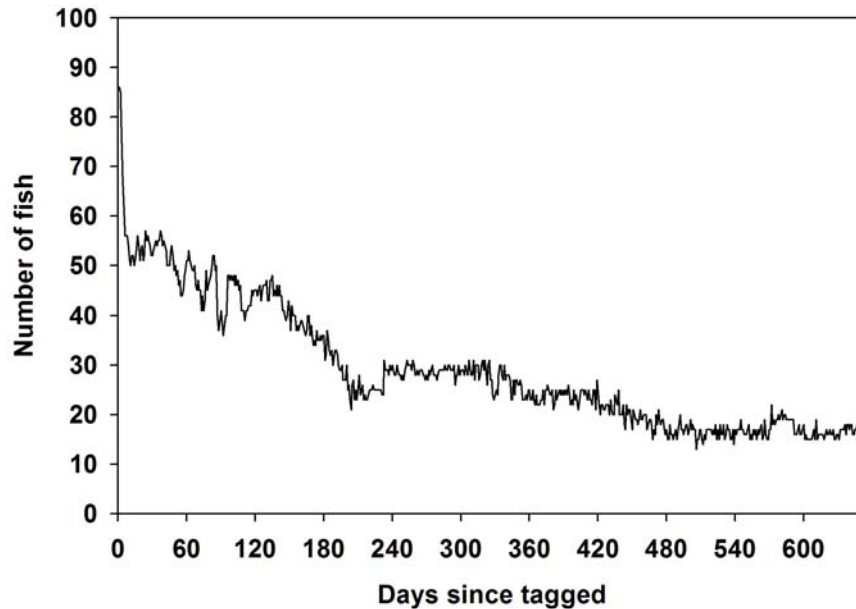


Figure 4. Total number of fish detected at all platforms since their day of release, from 0 to 655 d.

The degree of 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 5). Seven of the species tagged showed low site fidelity (detected < 30% of the days at liberty), which included blue, bocaccio, greenspotted, starry, vermilion, copper, and Mexican rockfishes. Four species exhibited moderate degrees of site fidelity (31% - 60%) including cabezon, greenstriped, brown, and rosy rockfishes, while four species (lingcod, treefish, widow, and flag rockfishes) showed high site fidelity (> 61%) (Figure 5). 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 (*S. serriceps*) (n = 1; 91%) and flag rockfish (n = 1; 88%) were detected over 80% of their days at liberty. Vermilion rockfish (n = 54) did not exhibit a high degree of site fidelity overall and were detected on

average $25 \pm 30\%$ of the days at liberty; however, some individuals were detected $< 1\%$ and as high as 100% of the days at liberty. Logistic regression analysis revealed species-specific differences in the probability of tagged fish presence at platforms over time. After a period of one year, the model predicted a wide range in the probability of individuals of a species being present at specific platforms (Figure 6). Predicted probabilities of presence for all species analyzed except widow rockfish significantly decreased over time (Table 2). 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 6). The probability of individual cabezon, copper, and vermilion rockfishes present at Platform Gilda decreased by 53%, 56%, and 57%, respectively. The probability of green-spotted rockfish presence at Platform Gail decreased by 14% after one year, and the probability of individual vermilion rockfish presence at Platform Grace decreased by 7%. Towards the end of the study (over 560 d), the probability of individual rockfish presence was 73% (widow rockfish at Grace), 36% (vermilion rockfish at Grace), 29% (green-spotted rockfish), 7% (cabezon), 5% (copper rockfish), and 1% (vermilion rockfish at Gilda). At any given time during the study, vermilion rockfish were 2-3 times more likely to be present at their platform of capture.

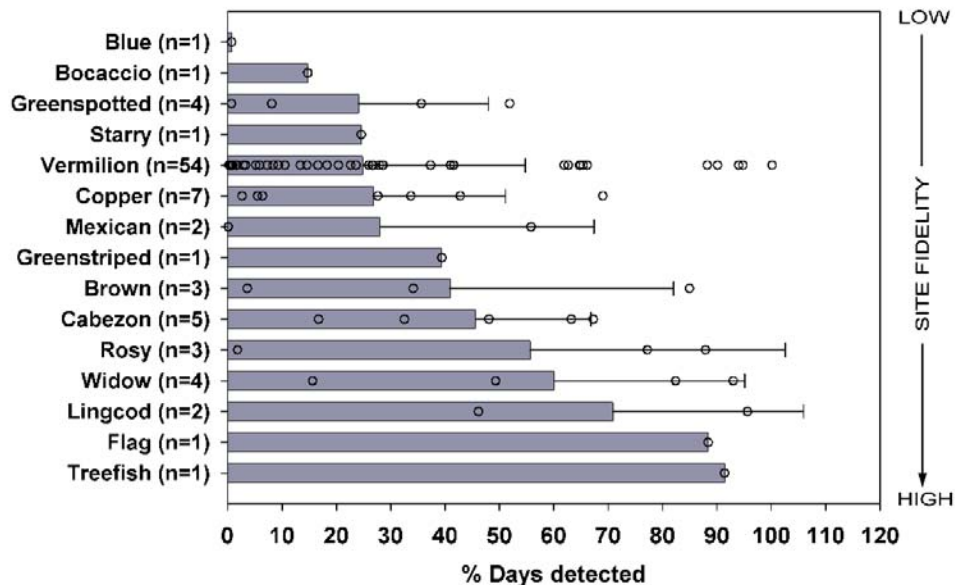


Figure 5. Mean (\pm SD) proportion of the total number of days each species was detected. Each open circle represents the proportion of days each individual of each species was detected.

Patterns of detection varied considerably among individuals and over time (Figure 7 and 8). Some individuals were not detected by any VR2 receivers for periods of several months and were detected again. For example, at least two of the four greenspotted rockfish went undetected for more than seven months (from 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 four months (15 February through 8 June 2005) before it was detected again. While it is not known where most individuals moved during periods of absence,

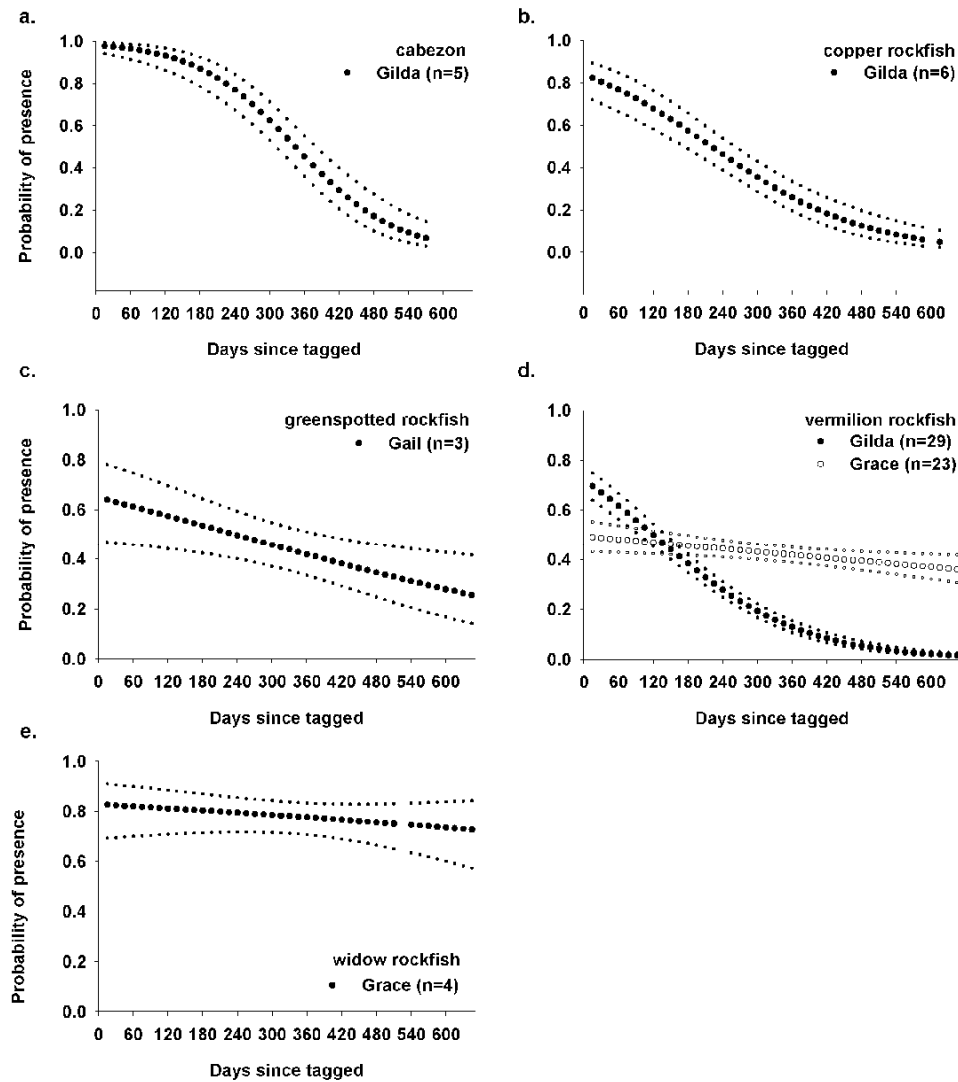


Figure 6. The predicted probability and 95% confidence intervals of tagged rockfish individuals being present over a 2-year period at Platforms Gilda, Grace, and Gail in southern California from June 2004 to June 2006 for a) cabezon, b) copper rockfish, c) greenspotted rockfish, d) vermilion rockfish, and e) widow rockfish.

a lingcod (OELO 3618) detected at platform Gail on 16 January 2006 was subsequently detected at Santa Cruz Island inside the Scorpion Anchorage Marine Reserve by several VR2 receivers maintained by the Pflieger Institute of Environmental Research (PIER) on 18 January 2006 (Figure 9). It was detected back at platform Gail on 20 January 2006, where it remained for the duration of the study.

Table 2. Logistic regression results of the effect of time (in 2 week bins) on individual rockfish presence (versus absence) at specific southern California oil platforms located in the Santa Barbara Channel, June 2004 to June 2006.

Model (presence = time period)	d.f.	Chi-Square	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

Mobile acoustic surveys conducted around the platforms using the VR100 receiver on 6 June 2006 and 11 June 2006 resulted in the location of a total of 32 (34%) tagged fishes, while 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 (Figure 7 and 8).

Eight vermilion rockfish (SMINs 3690, 3687, 3676, 3660, 3646, 3627, 3625, and 3612) ranging from 22.0-30.0 cm TL, and one copper rockfish (SCAU 3691), 26.5 cm TL, moved from their original platforms of capture to a neighboring platform (Figure 10). 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. These fish remained at Grace (Figure 9). However, three vermilion rockfish (SMINs 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 total length of vermilion

rockfish tagged at Gilda was significantly smaller (25.3 ± 3.1 cm [\pm SD]) than those tagged at Grace (29.8 ± 5.1 cm) (t-test, $t = -4.8$, $p = 0.00$).

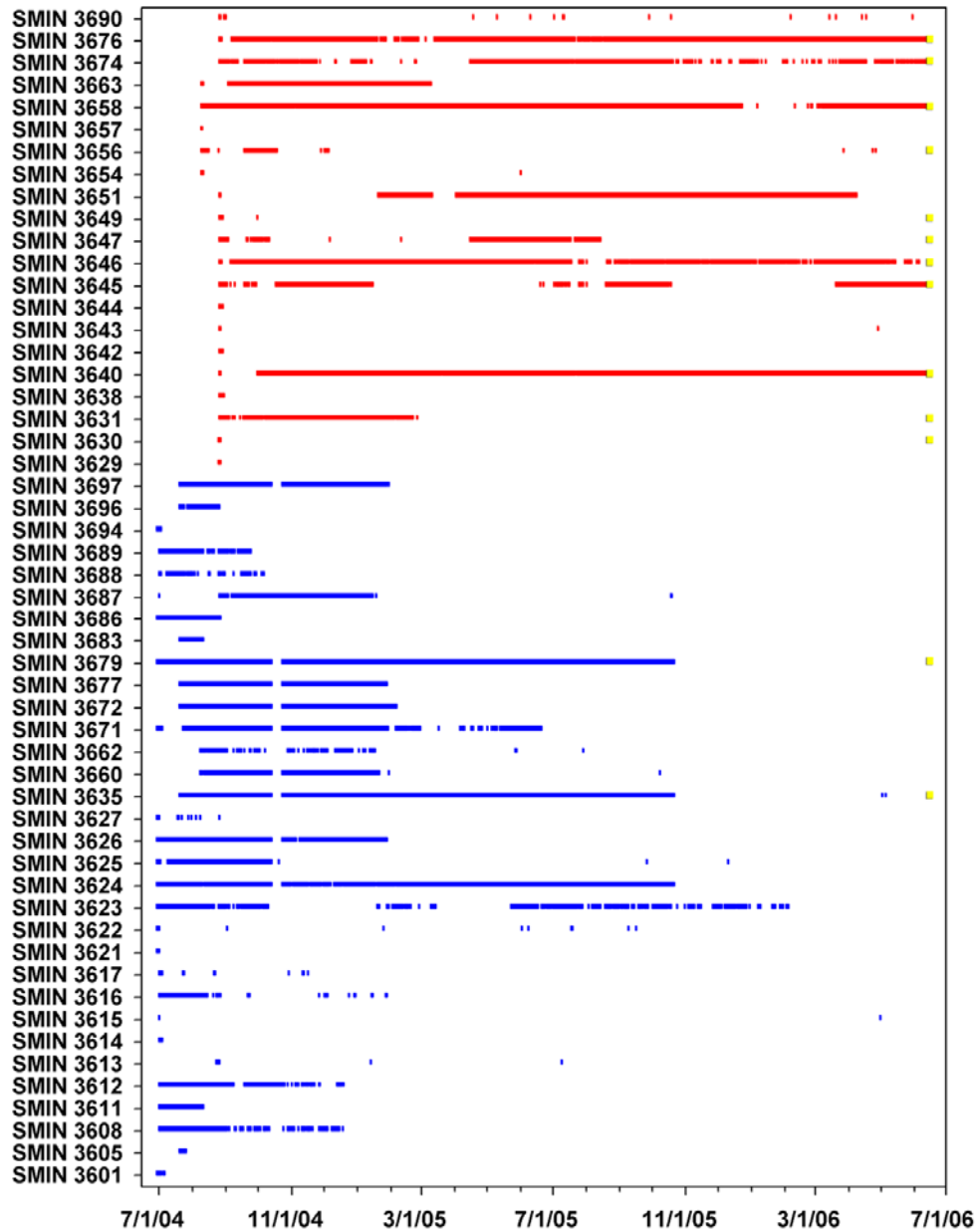


Figure 7. Detection plots of all vermilion rockfish tagged illustrating long-term periods of presence (colored bars) for the entire study period. Red bars represent fish detected at Platform Grace and blue bars represent fish detected at Platform Gilda. Yellow boxes on the right side of the plots represent detections when fish were relocated using the vessel borne VR100 receiver. Gaps in detections for some fish from 13 October – 23 October 2004 were due to lack of VR2 receiver coverage on platform Gilda.

Fourier time series analysis showed a sharp peak at 24 h/cycle for cabezon, vermilion, copper, and widow rockfishes indicating diel periodicity in activity (Figure 11a, b, c, e). This behavior is clearly illustrated in date-time scatter plots, where a distinct band of detections is apparent at different receivers during either daytime or nighttime hours (Figure 12a, b, c).

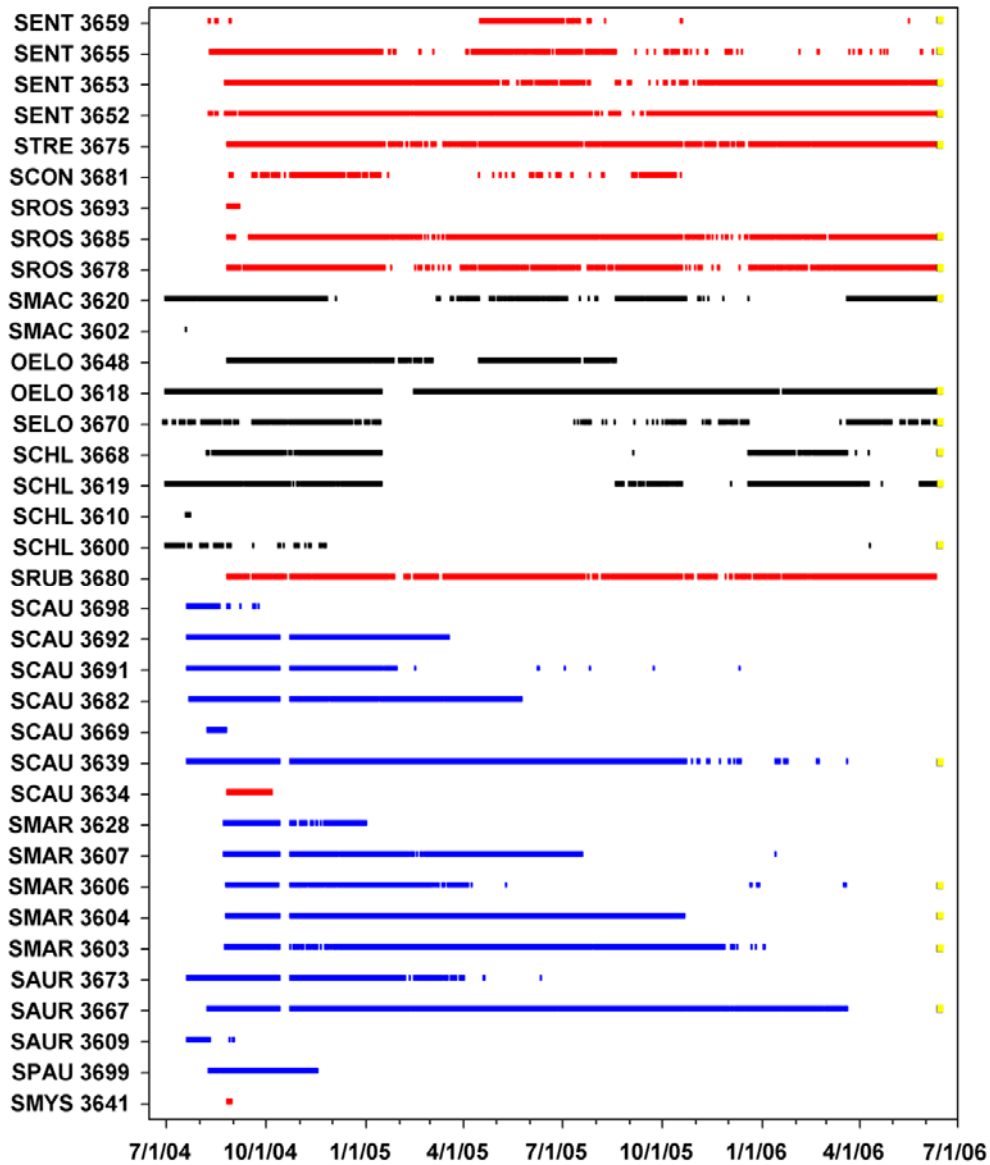


Figure 8. Detection plots of all species tagged other than vermilion rockfish illustrating long-term periods of presence (colored bars) for the entire study period. Red bars represent fish detected at Platform Grace, blue bars represent fish detected at Platform Gilda, and black represent fish detected at Platform Gail. Yellow boxes on the right side of the plots represent detections when fish were relocated using the vessel borne VR100 receiver. Gaps in detections for some fish from 13 October – 23 October 2004 were due to lack of VR2 receiver coverage on platform Gilda.

Some individuals of the same species showed opposite patterns in periodicity (Figure 12a & b vs. c). Vermilion and widow rockfishes also showed strong peaks at the 12 hr/cycle, representative of tidal cycles (Figure 11a, c and 12d). Greenspotted rockfish, all of which were caught at depths of 225 m, showed no diel or tidal periodicity (Figure 11).

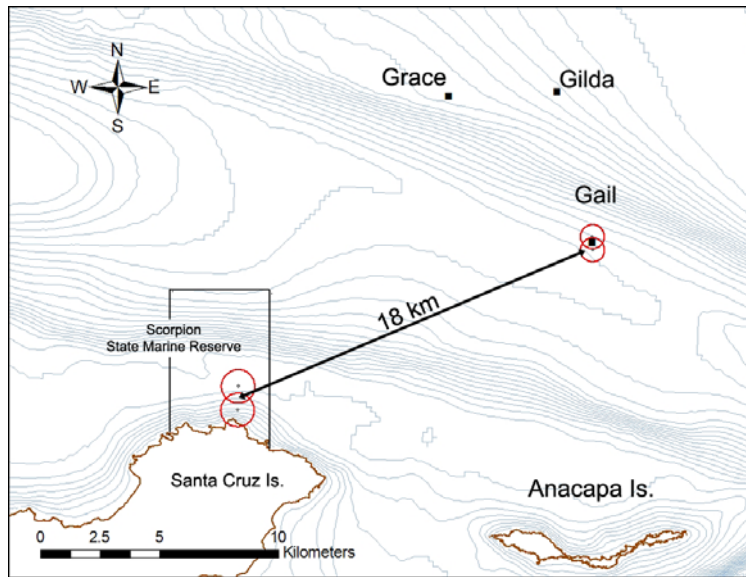


Figure 9. Movement of a lingcod, OELO 3618, tagged at platform Gail and detected on 16 January 2006 was detected on the north side of Santa Cruz Island (inside the Scorpion State Marine Reserve) by VR2 receivers maintained by the Pflieger Institute of Environmental Studies (PIER) on 18 January 2006 for several hours. This fish was then detected back at platform Gail on 20 January 2006, where it was detected for the rest of the study.

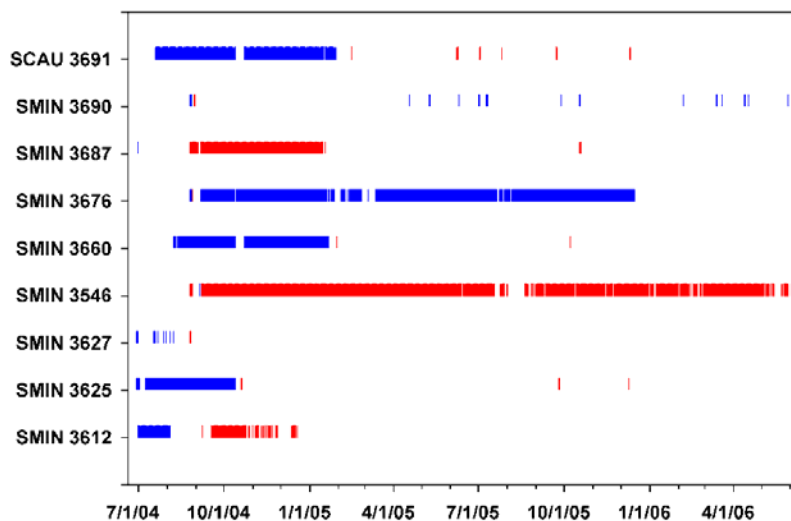


Figure 10. Dates of detections of copper (SCAU) and vermilion rockfish (SMIN) that moved between platforms. Blue bars represent detections at platform Gilda and red bars represent detections at platform Grace. Arrows point toward changes in the location of detections.

Table 3. Summary of rockfishes that moved between platforms Gilda and Grace.

Code	Species	TL (cm)	Tag Location	Tag Date	Last Detection Date	Last Detection Time	Moved To	First Detection Date	First Detection Time	Min. Distance Traveled (km)
SMIN 3625	vermilion	27.0	Gilda	29 Jun 2004	13 Oct 2004	06:44	Grace	20 Oct 2004	17:02	4.5
SMIN 3627	vermilion	27.5	Gilda	29 Jun 2004	8 Aug 2004	06:00	Grace	26 Aug 2004	21:01	4.5
SMIN 3687	vermilion	23.5	Gilda	1 Jul 2004	1 Jul 2004	14:28	Grace	26 Aug 2004	11:51	4.5
SMIN 3612	vermilion	26.5	Gilda	1 Jul 2004	8 Sep 2004	19:14	Grace	8 Sep 2004	21:20	4.5
SCAU 3691	copper	26.5	Gilda	20 Jul 2004	29 Jan 2005	01:29	Grace	15 Feb 2005	08:54	4.5
SMIN 3660	vermilion	26.2	Gilda	8 Aug 2004	21 Jan 2005	11:42	Grace	21 Jan 2005	16:12	4.5
SMIN 3676	vermilion	22.0	Grace	26 Aug 2004	27 Aug 2004 28 Aug 2004	02:49 18:31	Gilda Grace	28 Aug 2004 6 Sep 2004	03:42 11:20	9.0
SMIN 3690	vermilion	28.5	Grace	26 Aug 2004	27 Aug 2004 1 Sep 2004	22:04 14:40	Gilda Grace	30 Aug 2004 18 Apr 2005	06:11 23:57	9.0
SMIN 3646	vermilion	30.0	Grace	26 Aug 2004	28 Aug 2004 5 Sep 2004	00:56 04:22	Gilda Grace	5 Sep 2004 7 Sep 2004	04:06 15:49	9.0

Discussion

Site fidelity varied among platform-associated fishes and between individuals, suggesting that the utilization of oil platforms as habitat to these fishes varies between species and at different life history stages. Using acoustic telemetry monitoring to quantify site fidelity of fishes at offshore platforms can be particularly challenging due to the relatively small footprint, structurally complex (e.g. stanchions and cross members of jacket) and acoustically noisy nature of active platforms. Moreover, the high density of tagged fishes and their assumed fidelity to each platform should increase the probability of transmitter detection competition (code collisions), thereby reducing the number of daily detections per individual, as well as the number of individuals detected. Nevertheless, because stationary acoustic receivers are constantly listening for coded transmitters, this method is far superior to the traditional tag-recapture method, which is greatly dependent on fishing effort.

Analysis of detection efficiency based on the total number of pulses received from a pulse train relative to the number of codes detected at each VR2 receiver after each of 23 deployments indicated that environmental noise probably had the greatest effect on detection rates at the shallower platforms (Gilda and Grace). It is unlikely that code collisions from the high number of tagged fish at these platforms significantly reduced detection efficiency because detection efficiencies did not decrease with increasing numbers of tagged fish being detected at Platform Gilda ($43.3 \pm 7.7\%$) and Grace ($32.8 \pm 5.4\%$). In addition, detection efficiencies varied considerably more at the deeper platform Gail ($26.3 \pm 16.7\%$), where only 8 fishes were tagged in total. The greater variation in detection efficiencies at platform Gail are attributed to

the deeper depth of this platform (225 m) and the power output of transmitters used in this study. Because VR2 receivers at platform Gail were at greater distances from tagged fish near the base of the platform, it is likely that attenuating transmitter signals and environmental noise reduced detection efficiencies, particularly during certain environmental conditions (e.g. periods of high swell, current flow, and strong thermoclines).

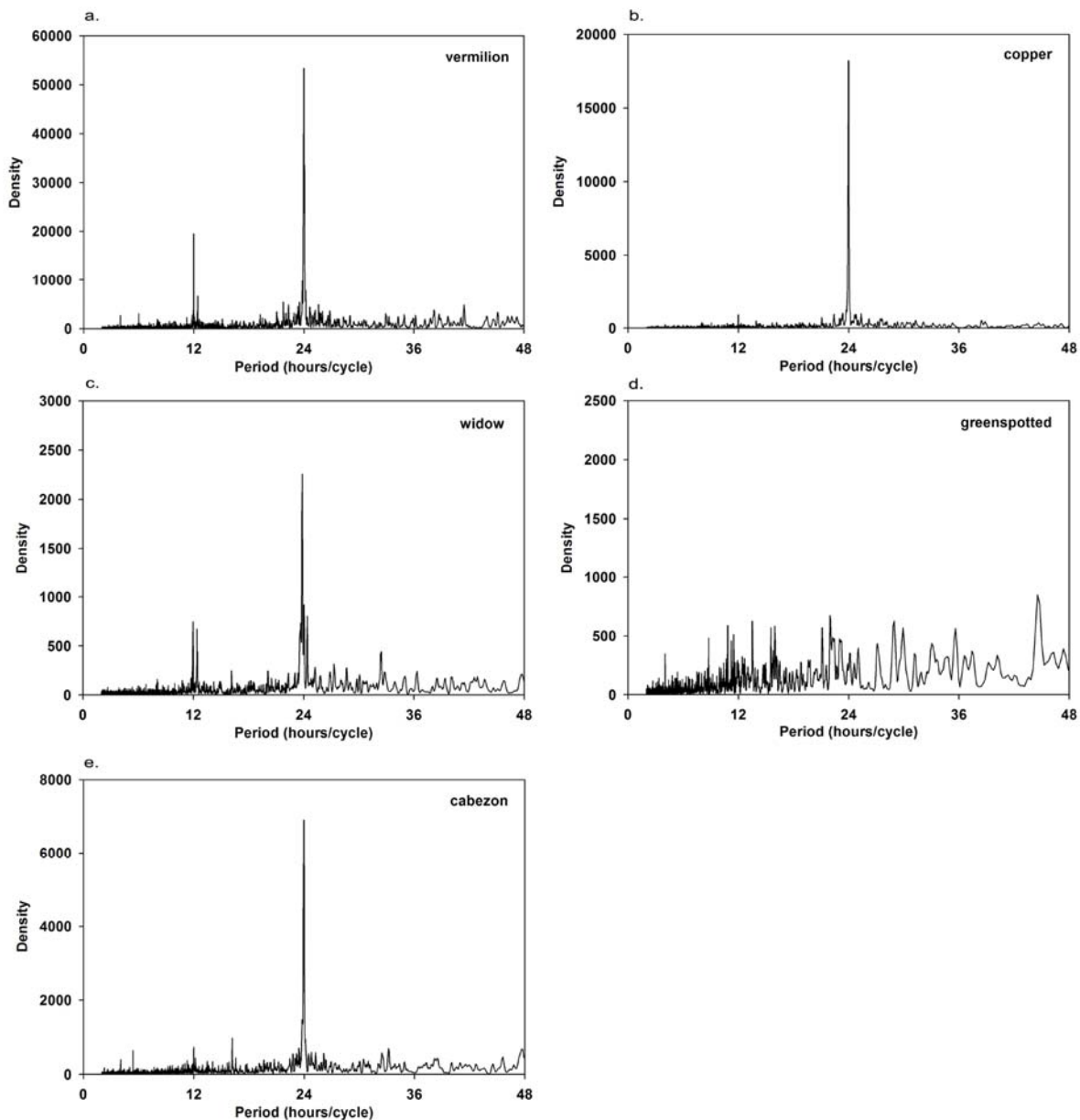


Figure 11. Fourier time series analysis periodograms for a) vermilion, b) copper, c) widow, d) greenspotted and e) cabezon. Detection data were pool across individuals for each species over 2-week intervals.

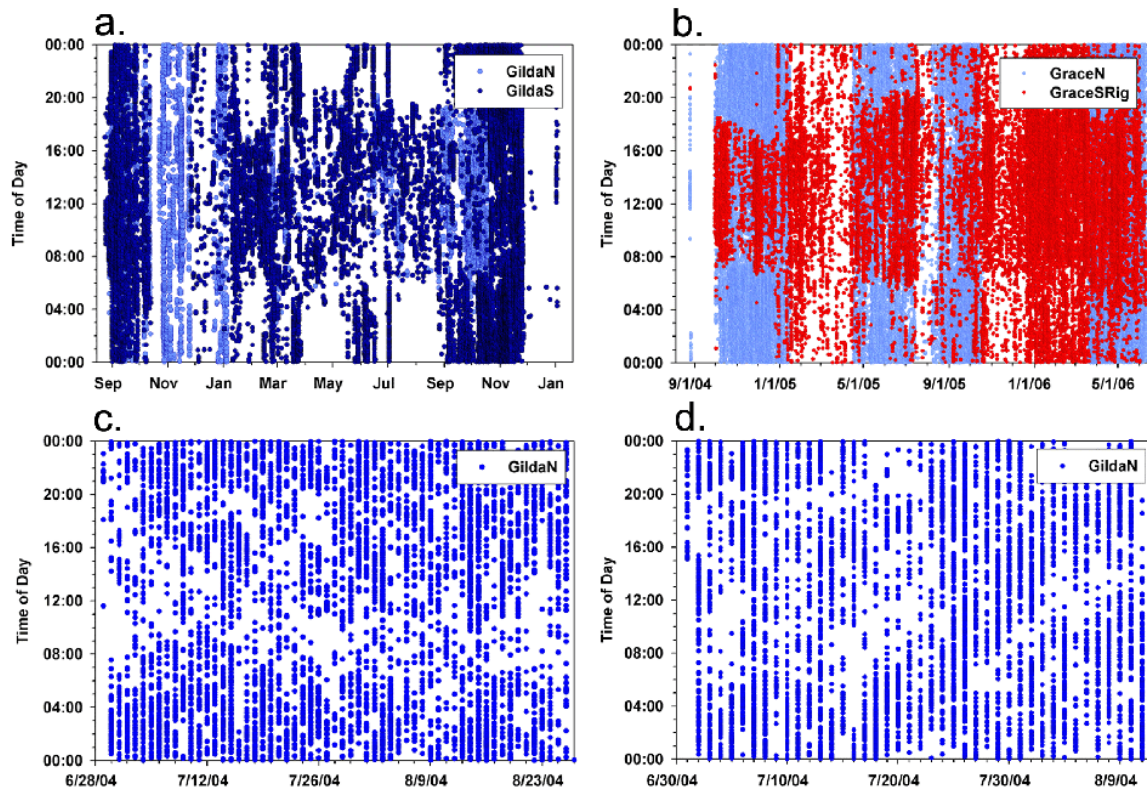


Figure 12. Representative date-time scatter plots of different fishes showing distinct patterns in detection. a) cabezon (SMAR 3603), b) vermilion rockfish (SMIN 3640), c) vermilion rockfish (SMIN 3686, and d) vermilion rockfish (SMIN 3611).

In addition, most demersal rockfishes 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. 2006), some are also known to be territorial (Larson 1980a,b, Love 1996). Depending on how often these fish move away from their shelters and 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 structures likely explain much of the short-period variance in the total number of fish being detected over the days since tagged (Figure 4). The VR2 receivers were detecting 65% of the tagged individuals found at the platforms on those days, some of which had not been detected by VR2 receivers for over 5 months. It is unclear whether fish that had not been detected by VR2 receivers over extended periods of time had left the platform or whether these fish had died and the transmitters had fallen into locations where they could no longer be detected by a VR2 receiver. Nevertheless, moderate detection efficiencies and 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 tagged fish residing at a monitored platform over the 655 d study period and not being detected was low, and acoustic telemetry monitoring methods provide a much better tool for quantifying degree of site fidelity and movement behavior than standard tag and recapture methods.

The numbers of tagged fish being detected at all platforms changed throughout the study period, 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 six days following release, which was assumed to be primarily attributed to post-release mortality. In an associated concurrent study examining the effects of barotrauma and post-release survival of rockfishes, 30% of the fish exposed to angling-induced barotrauma and recompressed in cages at depth died within 2 d following capture (Jarvis and Lowe in press). Strong currents that flow by platforms in the Santa Barbara Channel as well as roving scavengers could carry moribund fishes away from the platform and outside the detection range of the VR2 receivers. However, it is also possible that some of these individuals immediately emigrated away from the platforms to other areas. As an example, two vermilion rockfish caught at Platform Gilda were detected there for only one to two d after release and were then detected at Platform Grace a minimum of one d later (Table 3).

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 3a); however, a majority of fish detected after 6 days following release showed signs of movement because they were detected by different VR2 receivers at different times of the day (Figure 12). Additionally, many of these patterns changed over time. These detection patterns 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.

Although it is difficult to fully characterize the degree of site fidelity for many of the species where fewer than 3 fish were tagged, some interesting observations can be made from these 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 and flag rockfish)

were detected > 61% of their days at liberty at any of the monitored platforms and therefore are 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), and therefore, would be expected to exhibit a higher degree of site fidelity due to their need to protect a territory. 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 and others have indicated rather low levels of site fidelity. Lea et al. (1999) examined tag and recapture data for lingcod tagged 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 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 travel to Santa Cruz Island inside the Scorpion State Marine Reserve (~ 8 km away) over several days before returning back to Platform Gail (Figure 9). In southern California, lingcod are known to move into shallow water during winter months to spawn. 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 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 the platform indicates that the platform offers something not available in the natural habitat. It is likely that lingcod show high site

fidelity to platforms and return to the platforms after spawning due to higher densities of prey (small rockfishes) found around these sites (Love et al. 2003).

Widow rockfish were detected more consistently over the duration of the study (Figure 8) and also exhibited a high degree of site fidelity (Figure 6). 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, are known to move vertically throughout the water column (Stanley et al. 2002, Love et al. 2002). Love et al. (2003) observed widow rockfish in the midwater and base of several POCS platforms. Because these fish are not as closely associated with the substratum as other more demersal species, it was thought that widow rockfish may show a lower degree of site fidelity. However, the more extensive structure of the platforms may provide widow rockfish with additional feeding opportunities not as available around rocky pinnacles or outcrops. Unfortunately, the transmitters used in this study could not be used to determine depth, but 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.

Cabazon, rosy, brown, and greenstriped rockfishes 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 cabazon exhibit high site fidelity (Lea et al. 1999, Hartmann 1987, Mireles et al. unpubl. data), although recapture rates were typically low (~4%). All of the cabazon in our study were tagged at Platform Grace and were caught in the midwater portion of the platform. All five cabazon 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 cabazon as they moved down toward the base of the platform or moved to locations in the structure where they were not as easily detected. Both the rosy and brown rockfishes tagged showed high variability in the percentage of days detected among individuals. Several rosy and brown rockfish showed high degrees of site fidelity while some

individuals showed very low site fidelity. Individual differences could be attributed to mortalities, emigration, or inter-annual variation in platform residency.

Seven of the 15 species tagged exhibited low degrees of site fidelity (detected on average < 30% of their days at liberty), which included bocaccio, blue, greenspotted, starry, vermilion, copper, and Mexican rockfishes. Copper and vermilion rockfishes, two of the most abundant species tagged in our study (n = 7 and 54, respectively), showed great variation in the percentage of days individuals were detected (0.5% - 100%); however, on average, they exhibited low site fidelity. Earlier standard tag and recapture studies of copper rockfish have reported moderate degrees of movement and site fidelity (Hartmann 1987, Lea et al. 1999). One copper rockfish tagged in our study was recaptured by a crew boat operator fishing at the same platform where it was originally tagged and released; the remaining individuals either died or emigrated away from the platform. Vermilion rockfish, however, are thought to be highly site specific (Hartmann 1987, Lea et al. 1999), but also exhibit ontogenetic movements to deeper water as they grow and mature (Love et al. 1991, Lea et al. 1999, Love 1996). 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, which were significantly smaller (on average) than those tagged at the deeper Platform Grace, showed a steady decline in probability of presence over time, while those tagged on Platform Grace exhibited a higher probability of presence over time (Figure 6). Evidence of emigration of smaller vermilion rockfish tagged on the shallower Platform Gilda to deeper water was supported by inter-platform 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. Interestingly, three vermilion rockfish moved from the deeper Platform Grace to Platform Gilda, but quickly returned to the deeper Platform Grace. In addition, there is growing evidence that there may be two different species of vermilion rockfish, a shallow and deep water forms (Hyde et al. in press). Some of the variation in vermilion rockfish emigration away from platforms could be attributed to us catching both of these species or forms. Nevertheless, these rapid inter-platform movements, and the movements observed for the lingcod that moved between Platform Gail and Santa Cruz Island, indicate that fish may be 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. Homing is

important for fish that leave their home ranges in pursuit of food, 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). Copper rockfish was the only other species found to move between monitored platforms or natural habitat (Table 3), which provides further evidence for successful emigration away from a platform.

Although the lack of site fidelity of some individuals tagged at platforms may be partially attributed to mortalities, low measures of site fidelity may be 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 low, it is likely that continuous periods of non-detection reflect actual absence of a fish from the platform rather than a prolonged inability of the VR2 to detect the fish. 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 the subsequent year (Figure 4). Approximately 60% of the fishes tagged on platforms left and were no longer detected over the 655 d period. However, this reduction in emigration rate over the duration of the study might be explained by individual propensities to move. There is growing evidence that some individuals within a population are more prone to move than others (e.g., Willis et al. 2003, Bellquist et al. in press, Lowe and Bray 2006, Topping et al. 2006, Mason and Lowe, unpubl. data). Therefore, the stabilization of emigration rate over the final 200 d of monitoring could represent the fraction of more resident fish within the tagged population.

Diel trends in daily detections were more discernable. Four of the five most abundant species tagged (cabezon, vermilion, widow, and copper rockfishes) showed distinct signs of diel periodicity. The interspecific variation in diel patterns of detection (Figure 12b, c, d) suggests that a fish may be more or less frequently detected at a platform during the day or night depending on the degree of signal obstruction from distinct areas of refuge and foraging. Due to variability in the locations of VR2 receivers relative to refuges used by individuals, we could not determine the times of day different species might be most active (e.g., nocturnal, diurnal,

crepuscular). These increased periods of activity observed through changes in hourly detections are most likely related to feeding behavior (Peabody and Wilson 2006). Interestingly, greenspotted rockfish tagged at platform Gail (225m) 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 m to 300 m, it would be interesting to verify whether fish in shallower water (juveniles) exhibit any diel periodicity. Vermilion and widow rockfishes also showed some tidal periodicity (~12 hr/cycle). It is unclear why these species exhibit spikes in activity around tidal cycles; however, the peaks may likely be attributed to aspects of feeding behavior.

Results from this study indicate that fishes associated with OSC platforms show varying degrees of site fidelity and that residence varies among individuals, among species, and between platforms. Unfortunately, there are no comparable data to determine whether residence times of the species studied would be any higher on natural habitat. Nevertheless, some inferences can be made about the ecological performance of platforms in the eastern Santa Barbara Channel based on site fidelity and movements of platform-associated fishes. Love et al. (2003, 2006) have data which suggests that many individuals recruit to these platforms as larvae or YOYs and that size and age classes can be tracked on these platforms over time. Juvenile and young adult fish emigrate away from platforms over time although a fraction (40%) of similar sized individuals remain for at least two years. In our study, vermilion rockfish monitored on the shallower platform emigrated away faster than those monitored on the deeper water platform. These movements correlate with observations of larger fish being caught or sited in deeper water and are indicative of ontogenetic movements to deeper water habitats. This also suggests that these platforms are not simply acting as sinks, but are supplying larger, more mature individuals to other locations, thereby acting as sources. Observed movements of lingcod, vermilion and copper rockfishes 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 of higher value than encountered natural habitat.

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