Pacific Outer Continental Shelf Region **OCS Study**
MMS 2009-033

TRANSLOCATION, HOMING BEHAVIOR AND HABITAT UTILIZATION OF GROUNDFISHES AROUND OFFSHORE OIL PLATFORMS IN THE EAST SANTA BARBARA CHANNEL

Final Report

MMS U.S. Department of Interior
Minerals Management Service
Pacific OCS Region

OCS Study
MMS 2009-033

TRANSLOCATION, HOMING BEHAVIOR AND HABITAT UTILIZATION OF GROUNDFISHES AROUND OFFSHORE OIL PLATFORMS IN THE EAST SANTA BARBARA CHANNEL

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Prepared under:
MMS Cooperative Agreement No. 1435-01-06-CA-39796

U.S. Department of Interior
Mineral Management Service
Pacific OCS Region

Camarillo
November 2009

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Suggested citation

Anthony, K.M., C.G. Lowe, and M.S. Love. Translocation, homing behavior, and habitat utilization of groundfishes around offshore oil platforms in the East Santa Barbara Channel. MMS OCS Study 2009-033. California State University Long Beach, Long Beach, California. MMS Cooperative Agreement Number 1435-01-06-CA-39796.

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TECHNICAL SUMMARY

Study Title: Translocation, homing behavior and habitat utilization of groundfishes around offshore oil platforms in the East Santa Barbara Channel

Report Title: Translocation, homing behavior and habitat utilization of groundfishes around offshore oil platforms in the East Santa Barbara Channel

Contract Number: 1435-01-06-CA-39796

Sponsoring OCS Region: Pacific

Applicable Planning Area: Southern California

Fiscal Years of Project Funding: FY2006-FY2009

Completion Date of the Report: November 2009

Costs: $252,077.00

Cumulative Project Cost: $252,077.00

Principal Investigator: Christopher G. Lowe

Key Words: oil platforms, California, rockfishes, Sebastes, homing, translocation, acoustic telemetry, decommissioning, *Sebastes miniatus*, *Sebastes caurinus*, *Sebastes* c*hlorostictus*, *Sebastes auriculatus*, *Ophiodon elongatus*

Background and Objectives:

There are 27 oil platforms (23 Federal, 4 State) offshore of the southern California coast from Point Arguello to Huntington Beach. In the near future, several deepwater (>121 m) platforms may be slated for decommissioning. However, California's decommissioning policy currently requires full removal, which can have detrimental effects on the local populations of marine life associated with the underwater structure, as explosives are often used to separate the vertical stanchions below the seafloor. Using non-explosive methods, when technically feasible, still removes long-standing habitat and the entire biofouling community. Of particular concern are the rockfishes, whose populations have been depleted due to overfishing on natural reefs. However, submersible surveys conducted over the past 13 years by Love et al. (2003) have shown significantly higher densities of larger adult rockfishes residing around oil platforms compared to nearby natural reefs. Platforms provide complex structure spanning the depth of the water column, which provides habitat for recruits in shallower depths, and larger individuals toward the base. Furthermore, fishing within and around the structure is difficult and sometimes restricted. As a result, platforms function like *de facto* marine reserves.

Although there is growing evidence that platforms provide important habitat to rockfishes, decommissioning decisions on many aging California platforms is rapidly approaching. Therefore, finding suitable alternatives that mitigate the effects of platform removal may be an important measure to protect these overexploited stocks. Lowe et al. (2009) demonstrated that tagged rockfishes from three oil platforms in the Santa Barbara Channel had variable levels of site fidelity to the platforms, and that some individuals moved between platforms. By the end of the study, more than 60% of the tagged fishes had gone undetected, suggesting movement away from the platforms after a 2-yr period. If provided with suitable rockfish habitat of comparable depth, it may be possible that fishes removed from an oil platform and released on a natural reef would remain there. Moreover, translocating fishes inside a marine reserve offers protection from recreational and commercial fishing, where fish could be monitored over a substantial time frame.

The overall goal of this study was to determine whether rockfishes and lingcod from offshore oil platforms in the Santa Barbara Channel would home back to their platforms of capture if translocated to a natural reef at Anacapa Island. We acoustically tagged 79 rockfishes and lingcod from three oil platforms in the Santa Barbara Channel and translocated them inside historically rich rockfish habitat of comparable depth inside the Anacapa Island State Marine Reserve. Automated acoustic receivers were deployed at both Anacapa Island and each of the three oil platforms to monitor the movements of fishes at Anacapa Island and around the oil platforms. Receivers were downloaded and maintained every two months for a 2-yr period Using presence-absence data, we quantified the proportion of fishes that homed, degree of site fidelity to the translocated area, their movements at Anacapa Island and around the platforms.

Significant Results:

Twenty-five percent of fishes translocated to Anacapa Island homed back to the platforms from which they were originally caught. Ten individuals of vermilion rockfish (*S. miniatus*), one brown rockfish (*S. auriculatus*) and 9 lingcod all homed back to the platforms. The minimum straight-line distances traveled were 11 km (lingcod to Gail), 17 km (brown rockfish to Gilda) and 18 km (vermilion rockfish to Grace). The residence time of fishes at Anacapa Island before leaving the island to return to the platforms ranged from 1 to 47 d (mean, 14.7 d). The mean transit, or travel time from Anacapa Island back to the platforms was 1.4 d (lingcod), 11.1 d (vermilion rockfish), and 17.1 d (brown rockfish).

A larger proportion (75%) of tagged fishes did not home and were detected either within the Anacapa Island acoustic receiver array, or moved out of the range of detection. One bocaccio (*S. paucispinis*) and 1 widow rockfish (*S. entomelas*) were detected for a short period of time at Platform Gail, but returned to Anacapa Island. These individuals may have tried to home, but were unsuccessful. Three individuals (blue, *S. mystinus*, flag, *S. rubrivinctus*, vermilion rockfishes) were detected for a short time at Santa Cruz Island on acoustic receivers deployed by the Pfleger Institute of Environmental Research (PIER). Those individuals may also have tried to home, or expanded their home range.

The probability of movement was calculated for fishes based on their presence or absence between two different monitored sites. Vermilion rockfish showed a higher probability of remaining at Platform Grace after they homed (65%) compared to Anacapa Island (26%).

Lingcod were most likely to move back to Platform Gail and remain there (77%). The high probabilities of movement back to Platforms Gail and Grace indicate that the platforms may be a preferred habitat type for individuals of these species.

In the reciprocal experiment whereby fishes were translocated from a natural reef to either Platform Grace or Gilda, 2 bocaccio, a copper, and a flag rockfish (21% of the total) homed back to the natural reef up to 6 km away. However, a larger proportion (79%) did not home and remained at their platforms of release, suggesting that the platforms provided suitable habitat for the translocated fishes.

Results of this study demonstrate that although 25% of tagged fishes successfully homed back to the platforms, 75% remained at Anacapa Island or moved to an unmonitored area of the Channel. Therefore, translocation is a possible mitigating option, but the costs of a large-scale project may exceed the benefits of doing so.

This study, coupled with the previous site fidelity study (Lowe et al. 2009) bolsters the significance of OCS oil platforms as important habitat for many species of groundfishes in the East Santa Barbara Channel. Movements of individuals between platforms and natural reef habitat suggest that these fishes are capable of navigating a large area of the Channel that includes Anacapa Island, patch reefs, and possibly Santa Cruz Island as well.

STUDY PRODUCTS

MASTERS THESIS

2009 Anthony, K.M. Translocation, homing behavior and habitat utilization of groundfishes around offshore oil platforms in the East Santa Barbara Channel. Master's Thesis, Department of Biological Sciences, California State University Long Beach. pp. 69.

PAPERS

2009 Anthony, K.M., C.G. Lowe, and M.S. Love. Translocation, homing behavior, and habitat utilization of groundfishes around offshore oil platforms in the East Santa Barbara Channel. Marine and Coastal Fisheries. Manuscript in prep.

PAPERS PRESENTED

Anthony, K.M. May 2009. Translocation, homing, and habitat use of oil platform-associated groundfishes in the Santa Barbara Channel. Southern California Academy of Sciences. Palos Verdes, CA. **(*Best student paper in Fisheries – American Institute of Research Fisheries Biologists*)**

Anthony, K.M., C.G. Lowe, and M.S. Love. November 2007. Translocation and homing of oil platform associated fishes from offshore oil platforms in the Santa Barbara Channel. Annual Meeting of the Western Society of Naturalists. Ventura, CA. ***(Honorable mention - Best student paper award in Ecology)***

Lowe. C.G., T. Mason, L. Bellquist, D. Topping, B. Hight, and J. Caselle. November 2007. What do we know about movement patterns and habitat use of rocky reef associated gamefishes and why is it essential for MPA design? Annual Meeting of the Western Society of Naturalists, Ventura, CA.

Anthony, K.M. May 2007. Movements and survivorship of rockfishes associated with offshore oil platforms in the Santa Barbara Channel. Santa Monica Bay Aquarium.

TRANSLOCATION, HOMING BEHAVIOR AND HABITAT UTILIZATION OF GROUNDFISHES AROUND OFFSHORE OIL PLATFORMS IN THE EAST SANTA BARBARA CHANNEL

EXECUTIVE SUMMARY

Information Needed

Populations of some deepwater species of rockfishes, particularly bocaccio and cowcod, have been severely depleted on natural reefs due to overfishing. But in the last 13 years, submersible surveys conducted by Love et al. (2003) have shown higher densities of larger adults of some of these overexploited species residing around Pacific Outer Continental Shelf (OCS) platforms compared to nearby natural reefs of comparable depths. The platforms provide complex structure to which fishes associate, but they are also difficult to fish around as their support stanchions and crossmembers tends to snag fishing gear. In some cases, the depth of the structures exceeds legal fishing limits. As such, it has been argued that offshore oil platforms function like *de facto* marine reserves (Love et al. 2003).

Furthermore, because oil platforms span the depth of the water column, they may also function like pinnacles, providing recruitment habitat for larvae and young-of-the-year (YOY) and the resources required for growth. Typically, reef-associated fishes move to deeper habitat as they mature (Lowe and Bray 2006). At offshore oil platforms, there is evidence that recruits or young-of-the-year (YOY) fishes may move deeper along the structure as they mature, where they inhabit the base and associated shell mound as adults (Love et al. 2003). However, the extent to which fishes remained site attached (site fidelity) to the platforms as adults was unclear, until Lowe et al. (2009) quantified the movements of some representative species of rockfishes (*Sebastes* spp.) and lingcod (*Ophiodon elongatus*) around three oil platforms in the Santa Barbara Channel.

Using acoustic telemetry technology, Lowe et al. (2009) tagged 100 platform-associated groundfishes and monitored their movements around the oil platforms over a period of two years. They found varying degrees of site fidelity among species and between individuals, with some individuals showing detections at their platforms of capture through the end of the study period. While some moved out of the range of detection after varying periods of time, some individuals of vermilion rockfish (*Sebastes miniatus*) were documented to have moved from a shallow to deeper platform. Recent studies have demonstrated that offshore oil platforms not only harbor, but may also contribute to the stock replenishment of economically important groundfish species in the Santa Barbara Channel (Love et al. 2003, Lowe et al, 2009).

Despite the apparent importance of offshore oil platforms to fishes associated with them, California's platform decommissioning policy requires total removal of the structure. Full decommissioning often requires the use of explosives to dislodge the support structure from the seafloor. As a result, these severing explosions can kill fish found within a vicinity (< 1 km) of the platform (Bull and Kendall 1994). This will undoubtedly have adverse impacts on the local populations of some overexploited groundfish species.

Unlike the Gulf of Mexico, where states have adopted a Rigs-to-Reef program, partial removal or reefing of the platform structure is not permitted offshore of California. Therefore, mitigating the effects of decommissioning before platform removal by translocating fishes from a platform to a natural reef of comparable depth may be a viable option to salvage a portion of these populations. The movements of rockfishes and lingcod around oil platforms in the Santa Barbara Channel have been assessed (Lowe et al. 2009), but it is unknown whether translocated fishes from oil platforms would remain at their sites of release on a natural reef, or home back to the platforms. Using acoustic telemetry to monitor the movements of tagged rockfishes and lingcod around nearby natural reefs and offshore oil platforms will determine the viability of a translocation mitigation option, and reveal new information about the movement patterns of displaced fishes and how they assess their habitat.

Traditionally, tag and recapture techniques have been used to determine movements and site fidelity; however, because these methods are dependent on fishing effort, the resulting data have low spatial and temporal resolution. Acoustic telemetry allows for continuous, long-term monitoring with high spatial and temporal resolution. Lowe et al. (2009) acoustically tagged 100 rockfishes and lingcod at three offshore oil platforms in the East Santa Barbara Channel. Data showed that tagged individuals were detected on both sides of the platforms, indicating movement around the structure over time. Furthermore, some individuals were detected moving between different platforms over 5 km. Therefore, a second study to examine movement between natural reef and platform habitat after displacement would help determine whether translocation is a viable mitigating alternative, and provide new knowledge about the movements and habitat utilization of rockfishes and lingcod around offshore oil platforms and nearby natural reefs.

The goal of this study was to determine whether rockfishes and lingcod translocated from three oil platforms in the East Santa Barbara Channel would home back to their sites of capture if released on a natural reef of comparable depth. 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 and on natural reef inside the Anacapa Island State Marine Reserve, 3) retrieved, downloaded, and maintained automated acoustic receivers every 2 months, and 4) quantified the residence time, transit time, proportion of fish that did and did not home, and the probability of movement.

Research Summary

We acoustically tagged 79 fishes (representing 12 species of rockfishes, *Sebastes* spp., and lingcod, *Ophiodon elongatus*) from three OCS oil platforms in the East Santa Barbara Channel (Platforms Gail, Gilda, and Grace) and translocated them to a natural reef inside the Anacapa Island State Marine Reserve to test whether they would home back to their platforms of capture. In a reciprocal experiment, we also tagged 18 rockfishes and one lingcod from a natural reef near Platform Grace and translocated those individuals to either Platform Grace or Gilda. All fishes were caught using hook and line at or near the seafloor. Fishes were kept in chilled seawater on the boat before, during, and after being surgically fitted with individually coded acoustic transmitters. At each platform, two automated acoustic receivers were deployed on the north and south vessel mooring cables, except for Platform Grace, which only had a north mooring. The second receiver was deployed inside the southeast quadrant of the jacket beneath the platform.

Twenty-five percent of fishes translocated to Anacapa Island homed back to the platforms from which they were originally caught. Ten individuals of vermilion rockfish (*S. miniatus*), one brown rockfish (*S. auriculatus*) and 9 lingcod homed back to the platforms. The minimum straight-line distances traveled were 11 km (lingcod to Gail), 17 km (brown rockfish to Gilda) and 18 km (vermilion rockfish to Grace). The residence time of fishes at Anacapa Island before leaving the island to return to the platforms ranged from 1 to 47 d (mean, 14.7 d). The mean transit, or travel time from Anacapa Island back to the platforms was 1.4 d (lingcod), 11.1 d (vermilion rockfish), and 17.1 d (brown rockfish).

After their return to the platforms, several individuals were detected on both receivers stationed on either side of the platforms, indicating movement around the structure. Based on the pattern of detections over time, some also exhibited diel movement, spending more time on one side of the platform during the day. In addition, a vermilion rockfish and 2 lingcod moved between two different platforms after returning from Anacapa Island. One lingcod in particular traveled at least 44 km between platforms and even back to Anacapa Island during the course of the study period.

A larger proportion (75%) of tagged fishes did not home and were detected either within the Anacapa Island acoustic receiver array, or moved out of the range of detection. One bocaccio (*S. paucispinis*) and 1 widow rockfish (*S. entomelas*) were detected for a short period of time at Platform Gail, but returned to Anacapa Island. These individuals may have attempted to home, but were unsuccessful. Three individuals (blue, *S. mystinus*, flag, *S. rubrivinctus*, vermilion rockfishes) were detected for a short time at Santa Cruz Island on acoustic receivers deployed by the Pfleger Institute of Environmental Research (PIER). Those individuals may also have tried to home, or may have just shifted their home range.

The probability of movement was calculated for fishes based on their presence or absence between two different monitored sites. Vermilion rockfish were most likely to remain at Platform Grace after they homed (65%), compared to those that remained at Anacapa Island (26%). Lingcod were most likely to move back to Platform Gail and remain there (77%). The high probabilities of movement back to Platforms Gail and Grace indicate that the platforms may be a preferred habitat type for individuals of these species.

In the reciprocal experiment whereby fishes were translocated from a natural reef to either Platform Grace or Gilda, 2 bocaccio, a copper, and a flag rockfish (21% of the total) homed back to the natural reef up to 6 km away. However, a larger proportion (79%) did not home and remained at their platforms of release, suggesting that the platforms provided suitable habitat for the translocated fishes.

Results of this study demonstrate that, although 25% of tagged fishes successfully homed back to the platforms, 75% remained at Anacapa Island or moved to an unmonitored area of the Channel. Therefore, translocation is a feasible mitigating option, but the costs of a large-scale project may exceed the benefits of doing so.

This study, coupled with the previous site fidelity study (Lowe et al. 2009) bolsters the significance of OCS oil platforms as important habitat for many species of groundfishes in the East Santa Barbara Channel. Movements of individuals between platforms and natural reef habitat suggest that these fishes are capable of navigating a large area of the Channel that includes Anacapa Island, patch reefs, and possibly Santa Cruz Island as well.

Translocation, homing behavior and habitat utilization of groundfishes around offshore oil platforms in the East Santa Barbara Channel

Kim M. Anthony, Christopher G. Lowe, and Milton S. Love

Abstract

Several offshore oil platforms in the Santa Barbara Channel harbor large numbers of adult rockfishes, of which some species have been depleted on nearby natural reefs as a result of overfishing. In the near future, some of California's offshore platforms will be considered for decommissioning; however, the State's policy for removal would have deleterious consequences on these populations. To test an option that may mitigate the effects of platform removal, we acoustically tagged 79 platform-associated rockfishes and lingcod from three offshore oil platforms in the east Santa Barbara Channel and translocated them to a natural reef inside the Anacapa Island State Marine Reserve to determine whether fish would home back to their platforms of capture, or take residency at their new location. In a reciprocal experiment, we translocated 19 fishes from a natural reef and released them at two oil platforms to assess habitat preference. Twenty-five percent of all tagged fishes translocated to Anacapa Island returned to their home platforms, traveling distances ≥18 km. Those that did not home either took residency at Anacapa Island, moved to Santa Cruz Island, or swam out of the range of detection. Although a small proportion of fish (21%) homed back to a natural reef, a higher proportion (79%) remained at their platforms of release. Homing to platforms in relatively short times indicates that translocating fishes may be an effective mitigating tool for only some species. Results from these experimental manipulations provided insight into habitat evaluation and utilization of some platform-associated fishes.

Introduction

Twenty-six oil and gas platforms are currently situated along the southern California coastline from Point Arguello to Huntington Beach, ranging from 2-16 km offshore and in 11-363 m of water (Love et al., 2003). Many of the platforms were installed as early as the mid-1960s (Love et al., 2003), but were intended only as temporary structures. In the near future, many platforms are expected to be decommissioned due to reduced production as the oil resource is depleted. Worldwide, a variety of offshore oil and natural gas platform decommissioning options have been developed in conjunction with regulatory agencies including: (1) leaving the structure in place, (2) partially removing it to a depth of 15-55 m and leaving the remaining underwater structure standing, (3) toppling it such that the support jacket lays on the ocean floor, and (4) total removal to 4.5 m below the mud line. In the Gulf of Mexico, widespread support of coastal states for artificial reef development led to a Rigs-to-Reef program under the National

Fishing Enhancement Act of 1984 (Dauterive, 2000). Proponents, such as sport diving organizations and fishermen, view platform reefing as ecologically beneficial to supporting their industries. However, in California, platform reefing has been a controversial issue, in part due to some public perception and disapproval of allowing oil companies to break their contracts, which require complete removal and restoration of the marine habitat.

This decommissioning debate has brought forth important concerns regarding the ecological importance of offshore oil platforms. It has been argued that because of their offshore location, depth and difficulty in fishing near them, oil platforms have become *de facto* marine protected areas (Love et al., 2003), and, because the platform support structure (jacket) spans the depth of the water column, they also act like structurally complex pinnacles. Long-term research by Love et al. (2003) demonstrated that higher abundances of adult rockfishes (*Sebastes* spp.), including some overfished species (e.g., cowcod, *S. levis*, and bocaccio, *S. paucispinis*), occur around the bases of platform structures in the Santa Barbara Channel compared to many neighboring natural reefs. Based on these results, Helvey (2002) suggested that platforms may be Essential Fish Habitat for many species listed on the Pacific Groundfish Fishery Management Plan.

Because toppling or complete removal of oil platforms often requires the use of explosives to dislodge the support structure from the seafloor, these decommissioning options will invariably result in deleterious effects on all marine life associated with (e.g., invertebrates, fishes) and passing by (e.g., marine mammals, turtles) the platforms. In the Gulf of Mexico, the use of explosives on 2 oil platforms (32 m depth) resulted in the fatal concussion of most fishes with swim bladders within 1 km of the platform (Bull and Kendall, 1994). On the west coast of the United States, commercial and recreational fishing pressures have had a significant negative impact on groundfishes, particularly rockfishes (Lenarz, 1987; Love et al., 2002). The additional loss of adult rockfishes associated with decommissioned oil platform could potentially reduce the overall population reproductive output. Additionally, the absence of structure spanning all depths of the water column greatly reduces the chances of recruitment and settlement. These factors combined imply that important rockfish and other groundfish stocks could be adversely affected by decommissioning processes.

Historically, the rockfish fishery has generated revenue of one billion dollars per year (Lenarz, 1987), but has suffered from decreasing landings since the mid 1980s as a result of overfishing (Love et al., 1998). In 2001, the California Department of Fish and Game implemented protections for some species of the genus *Sebastes* in southern California, but overall numbers and the sizes of rockfishes on natural reefs continue to fall (Love et al., 1998).

Despite the declines, large numbers of adult rockfishes (some classified as overexploited) have long been known to inhabit the bases of platforms (Love et al., 2003), but their movements around them were not known until Lowe et al. (2009) quantified the site fidelity, or site attachment, of 100 individuals of *Sebastes* spp. and lingcod (*Ophiodon elongatus*) associated with oil platforms. Results showed that fishes moved around the platform structure, but exhibited variability in site fidelity among species and between conspecifics. Some individuals showed high site fidelity to the platforms (e.g., up to 760 d), while others left their platforms of capture shortly after release. Patterns of movement showed that many individuals held home ranges (area an animal uses on a daily basis), at least temporarily, around the oil platforms for extended periods of time.

Animals with home ranges may stray (e.g., brief migrations for spawning, feeding or predator avoidance), but they must be able to return to that same area, rather than to a different or comparable site, a behavior called homing (Gerking, 1959), which has important fitness implications for a species. An established home range provides resources necessary for the survival and reproduction of an individual, but individuals may leave for any number of reasons including spawning, changes in habitat, or competition. There are, however, risks associated with leaving a home range, especially for fishes that are closely associated with structure. For example, transiting over areas of discontinuous topography or through expanses of open water can be hazardous. Previous studies have documented homing in several species of rockfishes (e.g., Carlson and Haight, 1972; Markevich, 1988; Matthews, 1990ab; Pearcy, 1992; Lea et al., 1999) with the intention of determining whether a homing ability exists or testing for habitat preference. It is unclear how fish assess habitat quality, but moving in and out of areas with an ability to home suggests that they are able to do so.

There is an increasing amount of evidence supporting the notion that oil platforms provide ecologically important habitat for rockfishes (Love et al., 2003) and may even offer higher quality habitat than nearby natural reefs (Lowe et al., 2009). Therefore, finding viable mitigation alternatives to reduce the mortality of fishes during the decommissioning process is needed. One mitigation option may be to translocate individuals from oil platforms to natural reefs prior to decommissioning. Theoretical benefits include salvaging a proportion of the rockfish population and directly restoring nearby overfished natural reefs. In order to assess the practicality of this option it is essential to know whether fish translocated from an oil platform to a natural reef will home back to the platform from which they are taken from. If they home, how quickly will they return to the platform, and are there species specific differences in homing behavior? In addition to translocating fish from an oil platform to a natural reef, translocating fish from a natural reef to an oil platform may offer insight into how fish assess habitat quality. Previous translocation experiments released tagged fish over contiguous habitat, in relatively shallow depths, and primarily along a coastline, all of which offer navigational aids to return. None have challenged homing ability by releasing fish in high-relief rockfish habitat and across distances and depths that exceed their known limits. If rockfishes home back to oil platforms, or conversely, if they home back to a natural reef after translocation to an oil platform, then these results may have important implications to the decommissioning process of offshore platforms to protect rockfish stocks.

The goal of this study was to translocate groundfishes associated with 3 oil platforms of varying depths in the Santa Barbara Channel. Unlike previous displacement experiments, fishes in this study were released across substantial distances over discontinuous habitat and deep water to a natural reef inside the Anacapa Island State Marine Reserve. Their movements were monitored at Anacapa Island, homing events were recorded and patterns of movement around the oil platforms were parsed. Finally, habitat quality of oil platforms was tested by translocating fishes from a nearby natural reef to 2 platforms of comparable depth.

Materials and Methods

Study Site

The Santa Barbara Channel is bound on the south by the Northern Channel Islands (Anacapa, Santa Cruz, Santa Rosa, and San Miguel) and is approximately 100 km long, 50 km wide, with depths exceeding 230 m mid channel (Figure 1). This area is an oceanographic transition region between the colder waters north of Point Conception and warmer water of the Southern California Bight. The Channel is characterized by a seafloor topography that features soft sediment with patches of hard bottom. Most of the seafloor comprises sand, but offshore oil platforms throughout the Channel may constitute some significant hard substrate fish habitat in the middle of the channel on the edge of the Ventura Shelf.

In the eastern Channel north of Anacapa Island, oil platforms Gail (225 m depth), Gilda (61 m), and Grace (91 m) are situated approximately 11 km, 17 km, and 18 km away from northeast Anacapa Island, respectively. The closest platforms are approximately 5 km apart from each other, while Platforms Gail and Grace are separated by 8 km (Figure 1).

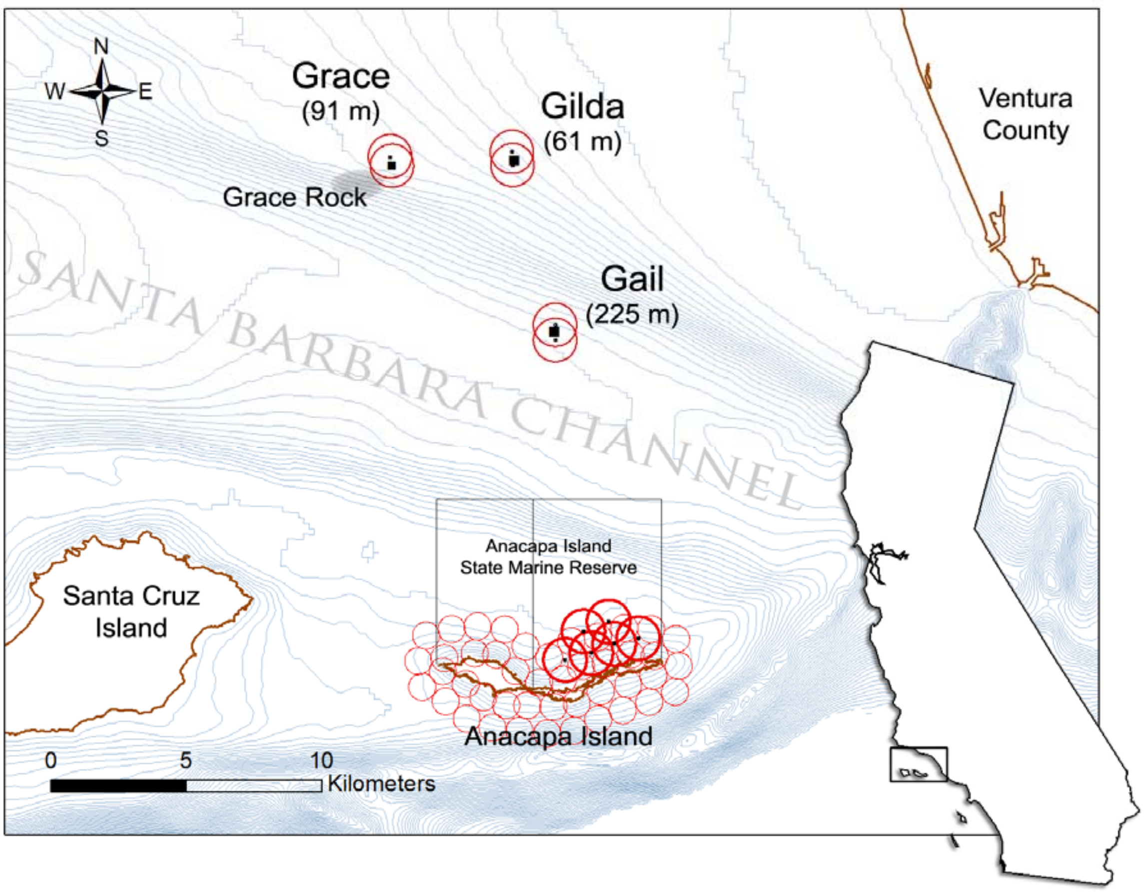

Figure 1. Map of study site off the coast of Ventura County in the east Santa Barbara Channel. Inset of California shows the geographic location of the Santa Barbara Channel, bound by a box. Depth contours are 10 m. Each of the 3 oil platforms and their respective depths are labeled with a solid black square, with black dots on either side of Platforms Gail and Gilda representing vessel mooring buoys where VR2 monitors were stationed. Platform Grace has only one north

buoy. A natural low-relief rock reef, Grace Rock, is represented by a gray shaded area southwest of Platform Grace. Circles surrounding the dots at each oil platform and at Anacapa Island characterize 800 m detection zones around each VR2 monitor. Smaller, lighter circles in a 2-tiered array around Anacapa Island indicate 500 m detection zones around VR2 monitors deployed by the Pfleger Institute for Environmental Research (PIER) through October 2006.

Tagging

All fishing was conducted from an 8 m vessel, which allowed for close access to the platform structure. While fishing on and near the bottom in depths ranging from 61 to 225 m, fishes were caught on conventional hook and line using baited circle hooks. Once landed, fishes were held on the vessel's live well in chilled ($10^{o} \pm 2^{o}$ C) seawater. The condition of all fishes was assessed upon landing. Most suffered from some form of barotrauma, or combination of signs, for example, bloated abdomen, distended eyes, air bubbles under skin, or stomach protruded through mouth. Fishes judged to be in good condition and with milder symptoms were held for tagging. Moribund fishes were euthanized and kept for other research purposes (Rogers et al., 2008), and live untagged fishes too small for tagging were released to a depth of 38 m in an upside-down, weighted milk crate (Jarvis and Lowe, 2008) at the site of capture.

One hundred groundfishes were surgically fitted with V13 acoustic transmitters (Vemco, Inc. model V13-R04K, 13 mm diameter x 36 mm length), which were coated in a blend of paraffin and beeswax (2.3:1) to reduce immuno-rejection. Transmitters were programmed to emit a 69 kHz pulse train pseudo-randomly between 150 and 300 s. The pulse train contained information unique to the identification number for each transmitter. The nominal battery life for these transmitters was estimated at 4 yr.

All fishes were anaesthetized in a cooler containing cold seawater with 20 ppm clove oil. In the early stages of tagging, fish with overinflated swim bladders were vented with an 18-gauge hypodermic needle. However, to minimize handling time and risk of puncturing their vital organs, venting was discontinued. A 1.5 cm incision was made approximately 1 cm from the ventral midline of the fish, between the pelvic fins and the anal vent through the peritoneum. A V13 transmitter was carefully inserted into the abdominal cavity and the incision was closed with 1 or 2 interrupted dissolvable sutures (Ethicon Chromic Gut, Johnson & Johnson). An external identification tag was inserted into the dorsal musculature of each fish. Fishes were subsequently held on the vessel's insulated, chilled seawater live well for transport.

Acoustic Receiver Deployment

Passive acoustic tracking was utilized to monitor the movements and homing events of tagged and translocated fishes. Contrary to traditional tag and recapture methods, acoustic telemetry provides finer scale data on both spatial and temporal movements. Moreover, data collection is not dependent upon fishing effort (Lowe and Bray 2006).

The northeast side of Anacapa Island was chosen as a natural reef site to translocate fishes because of its accessibility and proximity to the platforms, its historically rich rockfish habitat, and because the entire north side is a state marine reserve, which offered additional protection from fishing pressure. Automated omni-directional acoustic receivers (VR2, Vemco Ltd.) were deployed at depths from 55 m to 80 m, comparable to 2 of the 3 oil platforms of study (Figure 1). Depths of receivers deployed at Anacapa Island exceeded traditional scuba diving limits, so VR2 receivers were retrieved from depth using acoustic releases (Sub Sea Sonics, San Diego). Acoustic releases were attached between an anchor (pair of 11 kg biodegradable sand bags) and the VR2 receiver with a float (Figure 2). Upon retrieval, the acoustic release transducer was deployed over the side of vessel at each location and a 35.7 kHz signal was sent to the acoustic release to initiate a rapid electrolytic dissolution of the link wire connecting the receiver-acoustic release unit to the sand bags. Once released from the sand bag anchor the receiver-acoustic release unit floated to the surface for recovery.

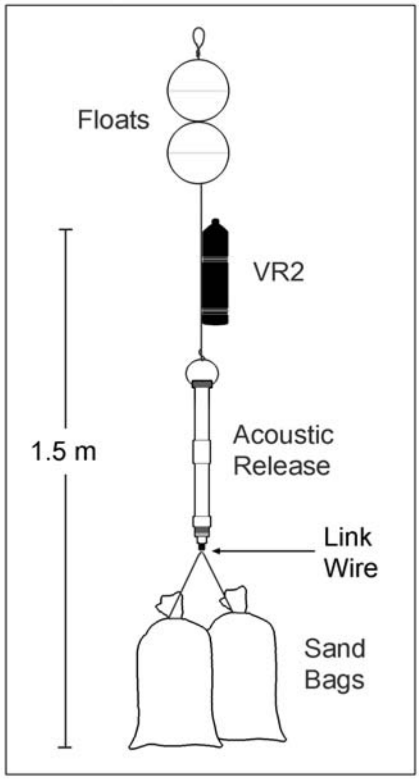

Figure 2. Monitor deployment setup used at Anacapa Island. Two sand bags functioned as an anchor to which the acoustic release was attached at the link wire. The VR2 monitor was secured to the acoustic release with 3/8-inch mooring line with cable ties. Two floats kept the setup upright in the water column. The VR2 was set at approximately 1.5 m above the ocean floor.

VR2 receivers were also deployed on each of the 3 oil platforms' north and south mooring buoys, situated approximately 250 m from either side of the platform, except for Platform Grace, which only had one mooring on its north side. A second receiver at Platform Grace was deployed inside the southeast quadrant of the platform jacket, at a depth of 12 m. Due to security restrictions, VR2 receiver deployment was not possible at Platform Gilda until 20 October 2006, over 2 mos after the initial deployment of all VR2s. Two VR2 receivers deployed on the north and south sides of each platform provided a detection coverage area around the jacket out to approximately 1 km (Lowe et al., 2009). Scuba divers attached the receivers to the support vessel mooring cables at a depth of 18 m. VR2 receivers were estimated to have a detection range of approximately 800 m, based on range tests performed before any fish was tagged and released. VR2 receivers recorded and stored the date and time of detection and the unique identification code of the transmitter in each tagged fish inside the detection range.

VR2 receivers were retrieved and downloaded every 2 mos as weather permitted and rebatteried every 6 mos over the 620 d study period. Several VR2s were either lost or could not be deployed due to either mechanical error or strong swell events, therefore gaps in data are indicated where these events occurred.

Translocation From Platforms to Anacapa Island

The travel from each of the oil platforms to the site of release at Anacapa was approximately 11 km, 17 km, and 18 km from Gail, Gilda, and Grace, respectively, taking from 15 to 45 min depending on sea conditions. Initially at the release site, tagged fish were lowered in a 1 m^3 vinyl-coated mesh cage to the bottom at 58 m and held there over night to ensure survival. The next morning, the cage was pulled to 18 m and met by a team of divers who assessed the fishes' health; divers released healthy-looking, actively swimming fish. Forty-four individuals were caged and released by this method and immediately swam to the bottom on their own. It was observed, however, that fishes were subject to currents or swell and had no shelter inside the cage. As a result, they were often forced up against the vinyl mesh or into each other, causing abrasions on their skin and eyes. Because caging fishes ensured that they were surviving after the tagging and translocation, after 23 September 2006, all tagged individuals were released at Anacapa Island without being held in a cage to reduce the stress of caging and hand-release. Fishes were thereafter assisted to the bottom from the surface in an upside-down weighted milk crate lowered to 38 m and held in place, allowing them to swim away on their own.

Translocation From a Natural Reef to Platforms

To test whether fishes would home back to natural reef habitat after translocation to an oil platform, 19 individuals were translocated from a natural reef to 2 platforms. Using the same fishing and tagging procedures as at platforms, fishes were caught from a large low-relief rock reef west and south of Platform Grace (called "Grace Rock") and transported and released at either Platform Grace (1 km away) or Gilda (6 km) (Figure 1).

Acoustic Monitoring

In addition to the stationary VR2 receivers, mobile acoustic surveys were conducted around each platform and Anacapa and Santa Cruz Islands in an attempt to relocate tagged fish that had moved outside the range of VR2 receivers. A portable, vessel-borne receiver (Vemco, Inc. model VR100) connected to a directional hydrophone suspended off the starboard gunwale was used while slowly motoring around the platforms and islands. By using the directional hydrophone and vessel-borne receiver it was possible to obtain specific locations of tagged fishes. The VR100 receiver automatically recorded GPS location, signal strength, and fish transmitter ID after each detection. Because stationary VR2 receivers were not deployed on the natural reef Grace Rock, mobile acoustic surveys utilizing the VR100 onboard receiver determined whether any fishes homed back to the natural reef. This was only done on an intermittent basis. After downloading, data from the VR2 and VR100 receivers were processed and stored in an Access and Excel database, respectively, until further analysis.

Data Analysis

Because transmitter deployment (i.e. fish release) spanned 2 consecutive summers, data were analyzed from the day each fish was released, defined as "days since released." Analyses were performed for the translocation of fishes from a platform to Anacapa Island. A fish was considered present at any given location if it was detected on a receiver at least 3 times in 1 d. Based on that criterion, telemetry data were used to determine patterns in detection, which were used as an indicator of movement. If a fish was detected on 2 or more VR2 receivers, patterns of movement were more clearly defined. The database was queried to verify how many fishes homed, how many did not, and to determine transit and residence times. Transit times were log transformed to normalize the data before performing a two-sample *t*-test.

Daily detection plots confirmed the length of detection time and the locations of individuals, and date-time scatter plots revealed patterns in movement. Chi-squared analysis was used to determine whether homing was a random behavior or species specific. A Mann-Whitney test was used to determine if there was a difference in residence times of fish at Anacapa Island. Two-sample *t*-tests were used to (1) determine whether there was a difference in the size of fish that homed compared to those that did not home and (2) discern differences in transit time from Anacapa Island to platforms.

Due to sample size and the absence of VR2 receiver coverage on the natural reef, Grace Rock, data for fishes that were translocated from a natural reef to 1 of 2 oil platforms were analyzed differently. The goal of mobile acoustic surveys on the natural reef was to determine whether fishes homed back from the oil platforms at which they were released at. Surveys were not performed regularly; therefore, a fish was defined as present if it was detected by the VR100 receiver at least twice within an hour. Fish were considered to have homed if they were located with the VR100 and directional hydrophone (pointing away from the platform) outside the 800 m detection zone of the VR2 receiver stationed on the southeast quadrant of Platform Grace (see Figure 13). Additionally, those individuals would not have been detected by either of the platform VR2 receivers at the same time as the VR100.

Finally, a transition matrix was developed to determine the probability of where a fish would move after it homed back to the platforms (Gotelli, 2001). By determining the presence of a species on a day-to-day basis, a probability of detection was calculated for each combination of locations (e.g. Anacapa to Gail, Gail to Grace, Grace to Anacapa, etc.). Assuming the ability of a fish to be detected at any location was equal, the probability of detection was used as an estimation of movement probability. Calculations derived from the transition matrix resulted in a prediction of the movement of rockfishes and lingcod between different monitored locations. Based on site fidelity data from Lowe et al. (2009), who determined the maximum time for a rockfish to move away from a platform was 175 d, a conservative estimate was made that rockfishes tagged from the same platforms in this study would move within 200 d of their release, if they would move at all, over the 620 d monitoring period. Thus, the transition matrices were calculated out to 200 d for vermilion rockfish and lingcod.

Results

One-hundred fishes representing 12 species were caught and fitted with acoustic transmitters. Of these, 2 transmitters with ID codes 3793 and 3710 were removed from the database because one rockfish was known to have died and its transmitter was lost at Anacapa Island; the other transmitter prematurely failed, yielding no data. Therefore, acoustic data were analyzed for 79 fish translocated from Platforms Gail, Gilda, and Grace to Anacapa Island (Table

1), and 19 fish that were translocated from a Grace Rock to either Platform Grace or Gilda (Table 2).

Some catch and release related mortality was expected, from the time of release up to approximately 10 d (Lowe et al., 2009), indicated by an initial sharp decline in the number of fish detected at Anacapa Island; however, some of this decline was coupled with a concomitant increase in the number of fishes detected at the platforms (Figure 3). Three VR2 receivers were lost at Anacapa Island between 22 Sep 06 and 20 Dec 06, but immediately after VR2 receivers were replaced (20 Dec 06, near day 145), the number of fishes detected increased for a short time before gently tapering off over time. Declines in detections at Anacapa Island were considered as movements to areas outside of VR2 detection range. Fish detected at the platforms were those that homed, but they too, slowly moved out of the range of detection throughout the course of the study.

Table 1. Tagging summary of all fishes translocated from platforms Gail, Gilda, or Grace to a natural reef inside Anacapa Island State Marine Reserve. Total lengths (TL) in cm.

Common Name	Species	Species Code	Size Range (TL in cm)	Platform (# of fish)		
				Gail	Gilda	Grace
Lingcod	*Ophiodon elongatus*	OELO	66.0-94.0	10	-	-
Mexican rockfish	*Sebastes macdonaldi*	SMAC	51.0	1	-	-
Greenblotched rockfish	*Sebastes rosenblatii*	SGBL	35.0	1	-	-
Brown rockfish	*Sebastes auriculatus*	SAUR	30.0, 37.0	-	2	-
Vermilion rockfish	*Sebastes miniatus*	SMIN	24.0-35.5	-	7	30
Copper rockfish	*Sebastes caurinus*	SCAU	25.5, 44.0	-	2	4
Widow rockfish	*Sebastes entomelas*	SENT	27.0-31.0	-	-	4
Squarespot rockfish	*Sebastes hopkinsi*	SHOP	28.2, 28.7	-	-	2
Blue rockfish	*Sebastes mystinus*	SMYS	27.0-34.0	-	-	5
Bocaccio	*Sebastes paucispinis*	SPAU	28.5-32.0	-	-	5
Flag rockfish	*Sebastes rubrivinctus*	SRUB	23.6-28.2	-	-	5
Starry rockfish	*Sebastes constellatus*	SCON	27.0	-	-	1

Table 2. Tagging summary of all fishes translocated from a natural reef, Grace Rock, to either Platforms Grace or Gilda. Total lengths (TL) in cm.

Common Name	Species	Species Code	Size Range (TL in cm)	Release Platform (# of fish)	
				Grace	Gilda
Lingcod	*Ophiodon elongatus*	OELO	34.0	1	-
Copper rockfish	*Sebastes caurinus*	SCAU	40.3, 40.6	2	-
Vermilion rockfish	*Sebastes miniatus*	SMIN	32.0 - 32.9	1	2
Greenspotted rockfish	*Sebastes chlorostictus*	SCHL	24.5 - 35.0	7	-
Bocaccio	*Sebastes paucispinis*	SPAU	31.0 - 46.0	3	2
Flag rockfish	*Sebastes rubrivinctus*	SRUB	23.0	-	1

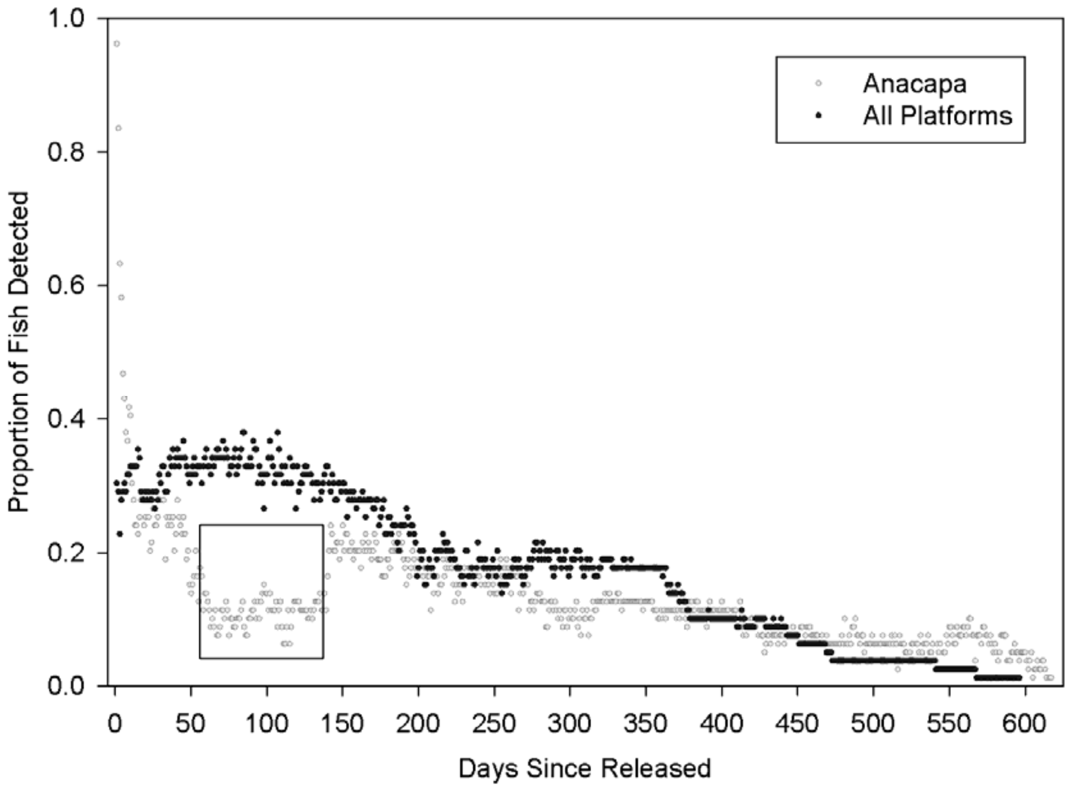

Figure 3. Proportion of tagged rockfishes and lingcod detected inside the VR2 acoustic array at Anacapa Island (gray dots) and at all 3 oil platforms (black dots) each day since fish were released. The black box surrounds detections spanning 88 d where 3 VR2 receivers were lost at Anacapa Island.

Although decreases in the number of fishes detected over time were evident, a high rate of survival was expected based on aforementioned cage trials. For example, a tagged vermilion rockfish was recaptured at Platform Gilda with a healed incision and healthy external ID tag insertion point (Figure 4) after approximately 3 mos at liberty. A date-time scatter plot of detections provided evidence of its recovery and movement around Anacapa Island before returning to the platform.

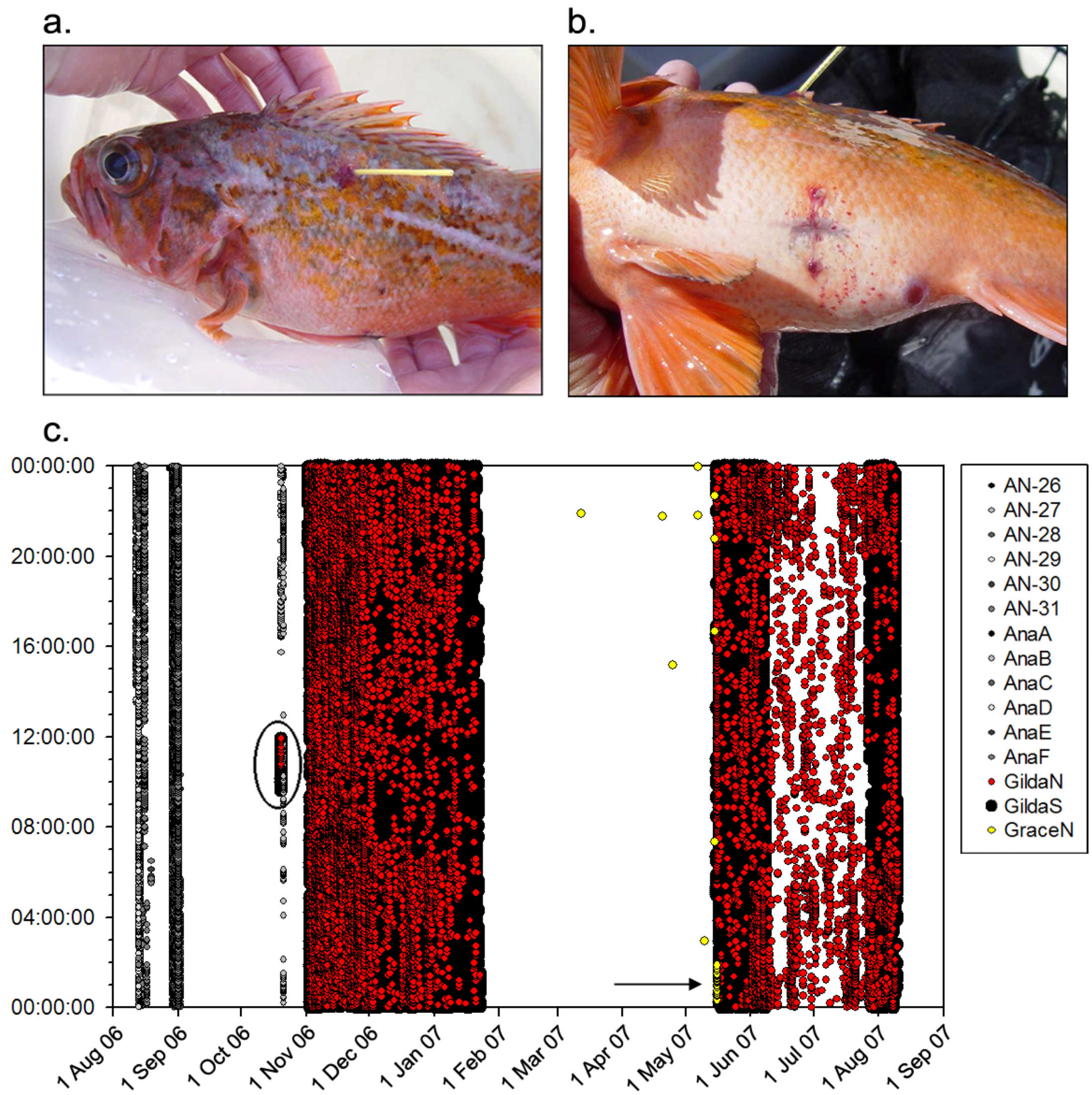

Figure 4. Recaptured tagged vermilion rockfish showing (a) a healthy insertion around its external ID tag and (b) ventral view of a healed incision where a transmitter was surgically fitted into its abdominal cavity. Panel (c) shows the date-time scatter plot of this fish, SMIN 3784, detected at several stations at Anacapa Island, subsequently at Platform Grace (circled), where it was recaptured and translocated to Anacapa again. The horizontal arrow points toward detections at Platform Grace.

Tagged fishes were consistently detected in mobile acoustic surveys at both Anacapa Island and the platforms throughout the course of the study; sometimes individuals were located inside the 800 m detection zones that were not detected by the stationary VR2 receivers.

Of 79 fishes tagged and translocated to Anacapa Island, 25.3% of individuals (11 rockfishes, 9 lingcod) homed back to the oil platforms. All but one of these fishes returned to their platforms of capture. One vermilion rockfish (SMIN 3784) was recaptured at Platform Gilda, but the time of arrival at the platform could not be determined due to the lack of VR2 receiver coverage there until the day it was recaptured on 20 Oct 2006 (Figure 4). This fish showed minor signs of barotrauma (slightly distended eyes and bloated abdomen), but was otherwise in good condition and swimming freely in the live well. It was taken back to Anacapa Island for a second time. Twelve days later on 2 Nov 2006, SMIN 3784 arrived at Platform Gilda again. After a long period of absence, this fish was detected periodically at Platform Grace until 15 and 16 May 2007 (arrow in Figure 4 points to those detections). It was last detected at Platform Grace on 16 May 2007 at 01:52 h and moved back to Platform Gilda at 05:00 h the same day. This individual was also one of the smaller vermilion rockfish to home (29.0 cm TL, range 27.5-35.3 cm TL).

Straight lines drawn from the site of release at Anacapa Island to each of the 3 platforms were assumed minimum distance homing routes (Figure 5). Lingcod traveled a minimum distance of 11 km back to Platform Gail, vermilion rockfish, 18 km to Grace, and brown rockfish, 17 km to Gilda. One vermilion rockfish (SMIN 3795) was detected at Gail before returning to Grace, increasing its travel distance by 1 km (19 km total).

Table 3. Summary of all fishes that homed after translocation from platforms Gail, Gilda, or Grace to Anacapa Island. Each species is represented by a shorthand code and unique ID number. Total lengths (TL) in cm.

Common name (Genus species)	Platform	Code	TL (cm)
Lingcod (*Ophiodon elongatus*) *N* = 9 out of 10	Gail	OELO 3704	84.0
		OELO 3719	82.0
		OELO 3733	78.0
		OELO 3736	94.0
		OELO 3742	65.0
		OELO 3767	90.0
		OELO 3777	89.0
		OELO 3781	89.5
		OELO 3787	74.0
Brown rockfish (*Sebastes auriculatus*) *N* = 1 out of 2	Gilda	SAUR 3783	37.0
Vermilion rockfish (*Sebastes miniatus*) *N* = 10 out of 37	Grace	SMIN 3743	33.0
		SMIN 3752	35.3
		SMIN 3758	35.3
		SMIN 3768	34.0
		SMIN 3771	27.5
		SMIN 3784	29.0
		SMIN 3785	30.2
		SMIN 3790	32.0
		SMIN 3795	32.0
		SMIN 3797	33.8

The proportion of fishes that homed back to the oil platforms was not equal, with 3 species, lingcod, brown and vermilion rockfishes, having a higher probability to home than other species ($\chi^2 = 16.43$, $df = 1$, $p < 0.0001$).

All fishes that homed did so in a mean (± SD) of 14.7 ± 30.6 d after their release. This lag time was referred to as residence time at Anacapa Island (range <1-47 d). Lingcod stayed at Anacapa Island for only 0.96 ± 1.22 d before homing, vermilion, 23.7 ± 39.7 d, and the brown rockfish homed after 47.4 d (Figure 6). Lingcod spent significantly less time at Anacapa Island before homing than did vermilion rockfish ($W = 55.0$, $p = 0.005$, $df = 17$).

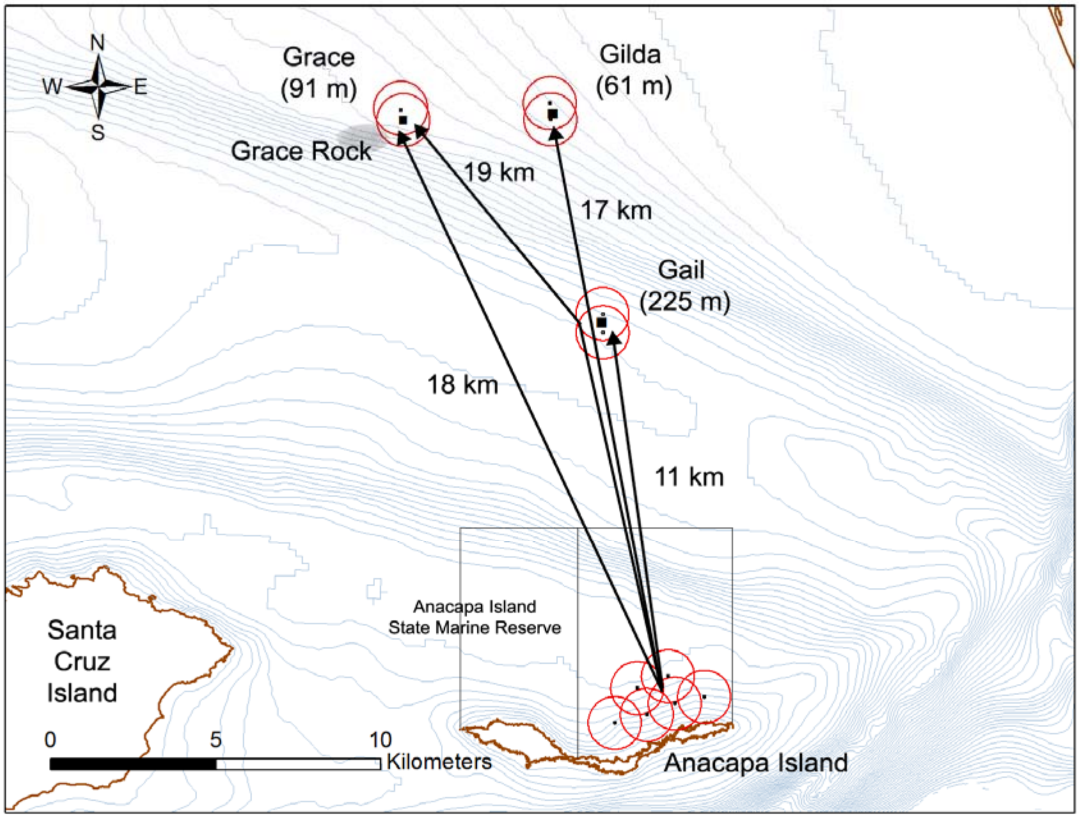

Figure 5. Map showing minimum distance travel routes (in km) for individuals that homed after translocation to Anacapa Island State Marine Reserve (boundary shown) from each of 3 oil platforms (black squares) in the Santa Barbara Channel, Gail, Gilda, and Grace. Depths of each platform are indicated in parentheses. Depth contours are in 10 m increments. Circles indicate 800 m detection zones around each of 12 stationary VR2 receivers (black dot).

The length of time between the last detection at Anacapa Island and the first detection at a platform for all fish that homed was fewer than 3 wks. This time span was considered transit time, assuming the last detection at Anacapa Island was the time an individual left the island and the first detection at a platform was the arrival time. Lingcod had the shortest mean transit time (1.4 ± 1.22 d) with the fastest individual homing 11 km in 10.5 h. Lingcod had the shortest mean transit time (1.4 ± 1.22 d) with the fastest individual homing 11 km in 10.5 h. Vermilion

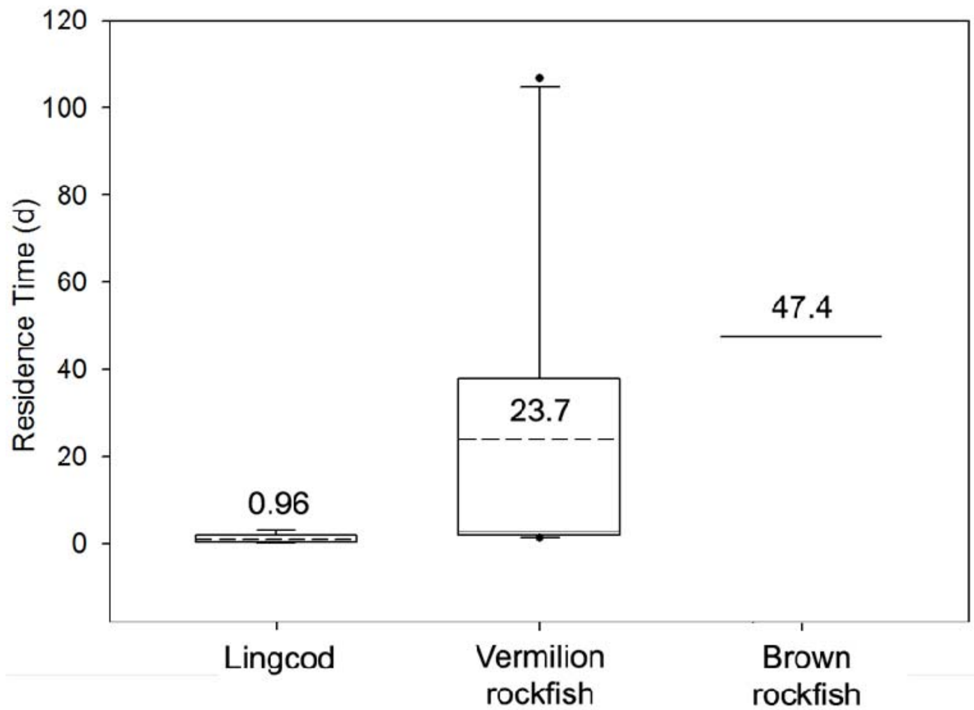

Figure 6. Box plots of residence times expressed in days that lingcod, vermilion rockfish, and one brown rockfish spent at the translocation site, Anacapa Island, before leaving and homing back to their oil platforms of capture. Values shown are means, which are also indicated by the dotted line, except for the brown rockfish, for which only one individual homed. Upper and lower hinges represent 75th and 25th percentiles, respectively, while the median is shown as a solid line inside the box (visible only for vermilion rockfish). Vertical bars show the minimum and maximum values with outliers indicated by black dots.

rockfish mean transit time was 11.1 ± 19.0 d (fastest individual took 2 d), and the brown rockfish took 17.1 d for transit (Figure 7). There was a highly significant difference in log transit time between lingcod and vermilion rockfish ($p = 0.001$, $df = 16$, $t = -4.21$).

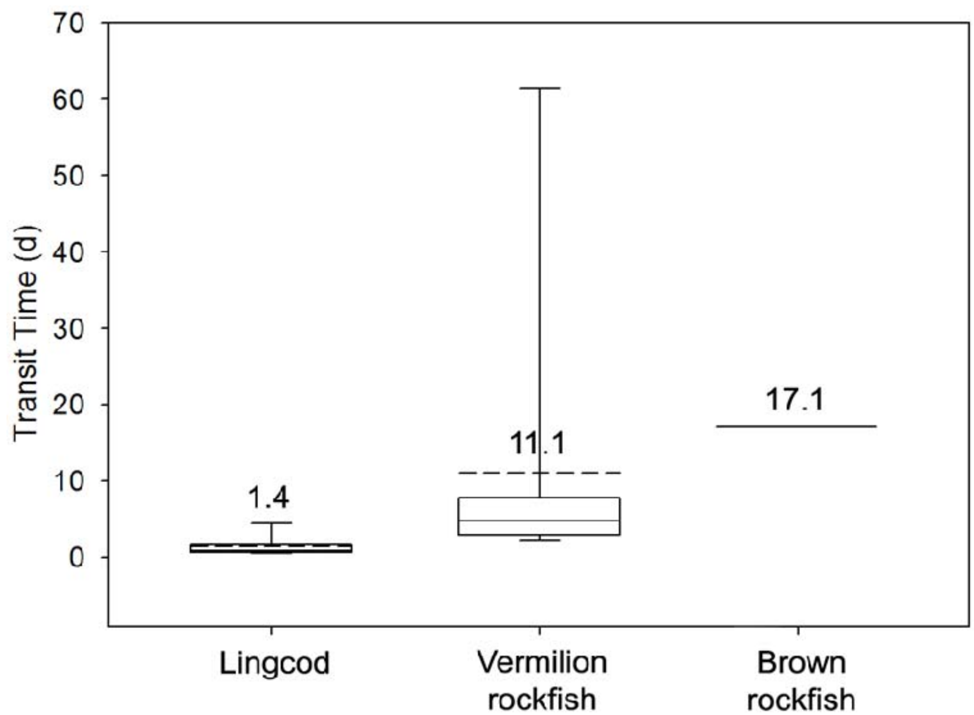

Figure 7. Box plots of transit times expressed in days from Anacapa Island to platforms from which individuals of lingcod, vermilion rockfish, and one brown rockfish were caught. Values represent the mean number of days between the last detection at Anacapa Island and the first detection at the oil platforms; dotted lines also indicate means. Upper and lower hinges represent 75th and 25th percentiles, respectively, while the median is shown as a solid line inside the box (visible only for vermilion rockfish). Vertical bars show the minimum and maximum values with outliers indicated by black dots.

Lingcod that homed left the VR2 receiver array at Anacapa Island after 10:00 h, but most (n = 6 out of 9) left Anacapa Island at night between 20:00 h and 22:00 h. Vermilion rockfish, however, did not show a trend and left the array at all hours of the day.

Excluding lingcod, all vermilion and brown rockfishes that homed were significantly larger (32.6 ± 2.88 cm TL (± SD)) compared to those that did not (30.2 ± 4.32 cm TL) ($p < 0.04$, $df = 67$, $t = 1.8$). Vermilion rockfish that homed were statistically larger (32.2 ± 2.63 cm TL) than those that did not (29.9 ± 2.71 cm TL ($p = 0.01$, $df = 35$, $t = 2.3$).

Some fish exhibited diel patterns in their movement while at either their Anacapa Island or at their home platform (Figure 8). Vermilion rockfish SMIN 3771 (Figure 8a) was detected at Anacapa Island for several days before leaving to return to Platform Grace. Once there, this fish was detected on both north and south stationed VR2 receivers, showing more detections between

06:00 h and 19:00 h on the south side of Platform Grace. Lingcod OELO 3736 had many fewer detections around Platform Gail, but was clearly present through the end of the study.

Several individuals exhibited movement between platforms and back to Anacapa Island without being transported (Figure 9). Two vermilion rockfish (SMINs 3795 and 3790) were detected at Platform Gail before homing back to Platform Grace, traveling at least 19 km. SMIN 3784 (see Figure 4) homed to Platform Gilda from Anacapa Island twice, moved to Platform Grace then back to Platform Gilda, traveling a total distance of 27 km. Lingcods OELO 3787 and OELO 3777 homed from Anacapa Island back to Platform Gail, moved to Platform Grace and then returned to Platform Gail, each moving a minimum of 27 km. OELO 3767 traveled 35 km, having homed to Platform Gail, moved to Platform Grace and returned to Platform Gail, but moved to Platform Grace for 2 wk before going undetected. OELO 3704, after homing back to Platform Gail, moved back to Anacapa Island for nearly 4 mo before homing to Platform Gail again for just 3 wk, only to return to Anacapa Island. Total distance traveled was at least 44 km. From early March 2008 through the remainder of the study, this lingcod was detected at Anacapa Island.

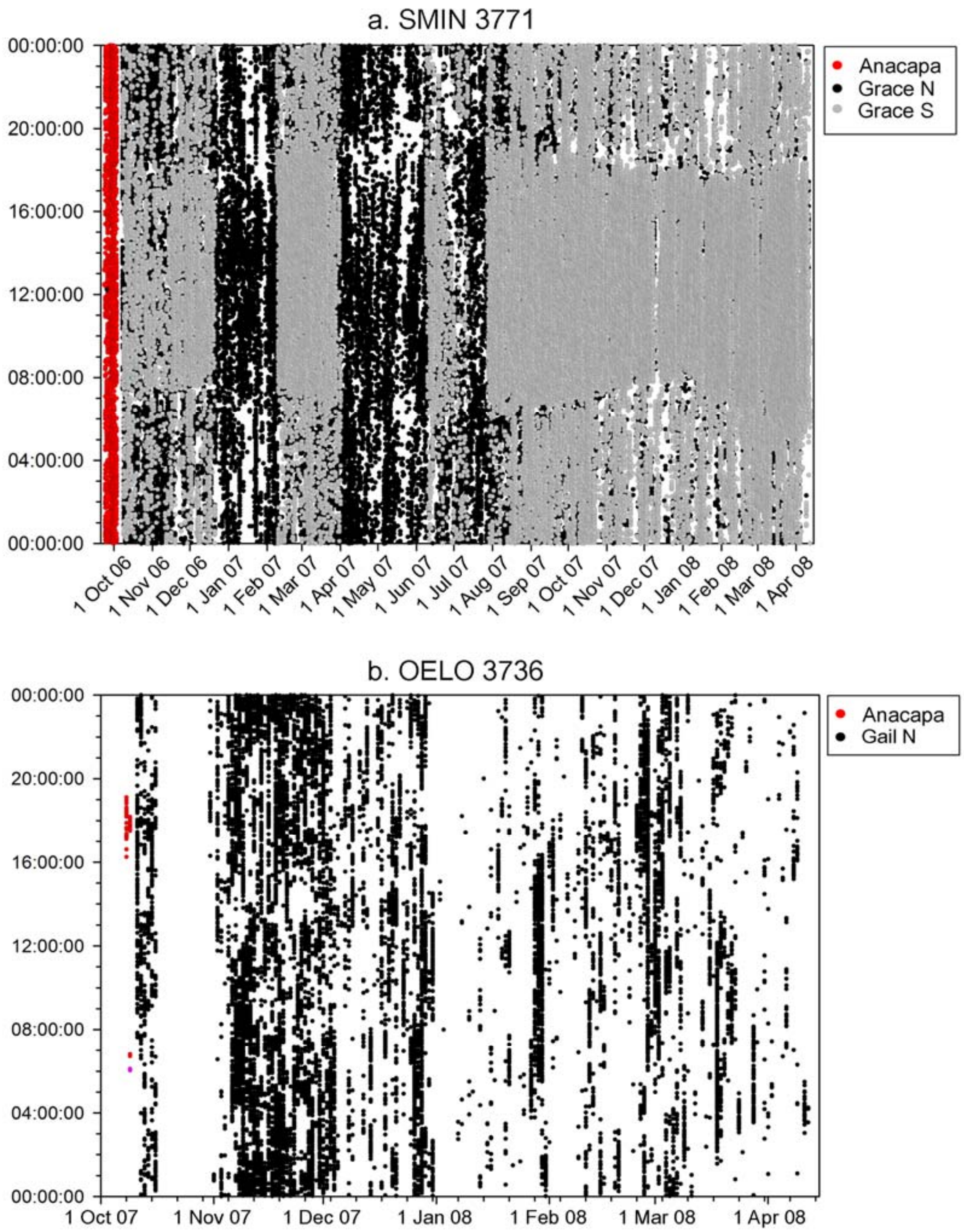

Figure 8. Date-time scatter plots of (a) vermilion rockfish SMIN 3771 showing movement from Anacapa Island to Platform Grace with subsequent movement around the north (black dots) and south (gray dots) sides of the platform. SMIN 3771 also showed a diel pattern in movement, indicated by a thick band of gray dots between 06:00 h and 19:00 h. (b) Movements of lingcod OELO 3736 revealed homing from Anacapa Island back to Platform Gail, with infrequent detections on the north stationed VR2.

Five vermilion rockfish (SMINs 3743, 3752, 3785, 3795, and 3797) that homed to Platform Grace moved out of the range of detection (Figure 9). All 5 individuals detected at Platform Grace left between 25 Oct and 16 Nov in 2006 and 2007. One lingcod (OELO 3767) left Platform Gail and was subsequently detected at Platform Grace, after which it left on 6 Feb 2007. None of these individuals were detected for the remainder of the study, nor were they located during mobile acoustic surveys.

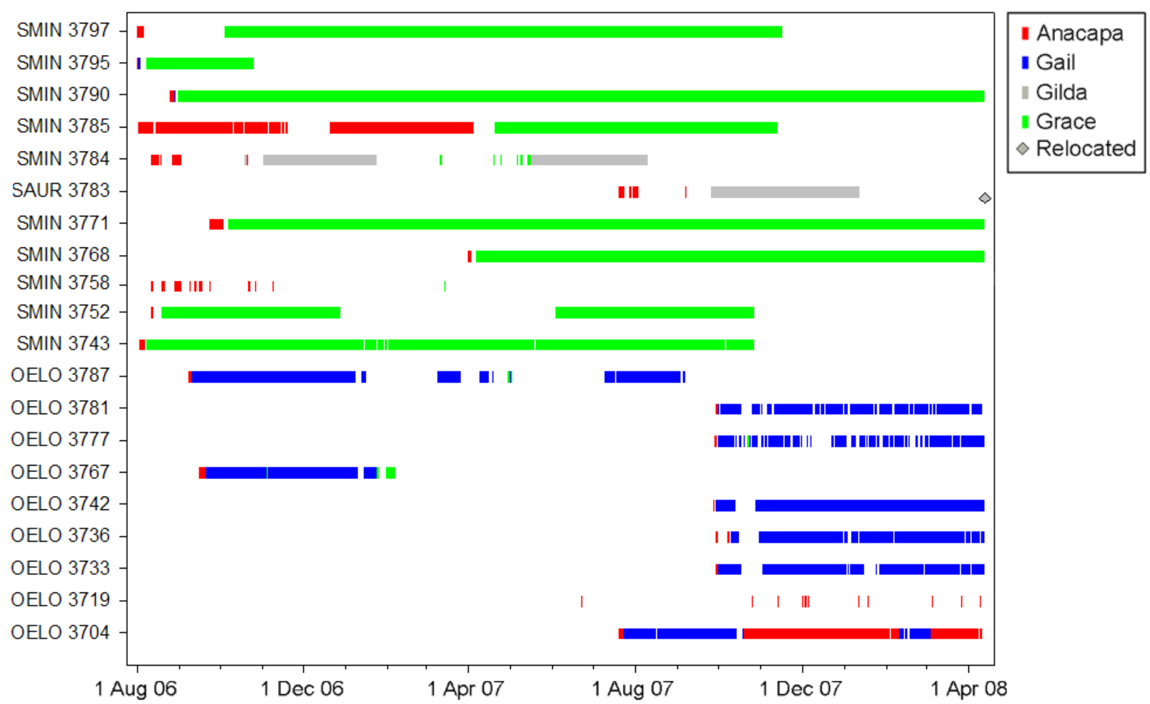

Figure 9. Daily detection plot of all fish that homed: vermilion rockfish (SMIN), brown rockfish (SAUR), and lingcod (OELO). For each individual along the y-axis, a colored mark exists for each date (x-axis) it was detected at Anacapa, Platforms Gail, Gilda, or Grace. The gray diamond on the last day of SAUR 3783 indicates that the fish was relocated during mobile acoustic surveys with the VR100, after months of remaining undetected by the stationary VR2 receivers. Vermilion SMIN 3784 homed to Platform Gilda and was subsequently recaptured in Oct. 2006. It was taken to Anacapa Island for a second time and homed again, back to Platform Gilda.

After release at Anacapa Island 2 individuals (bocaccio, SPAU 3772 and widow rockfish, SENT 3753) were detected at Platform Gail for a short period of time before being detected again at Anacapa Island (Figure 10). These fish were not considered as having homed, as they did not return to Platform Grace, their original platform of capture. However, movement to Platform Gail and back to Anacapa Island was noteworthy.

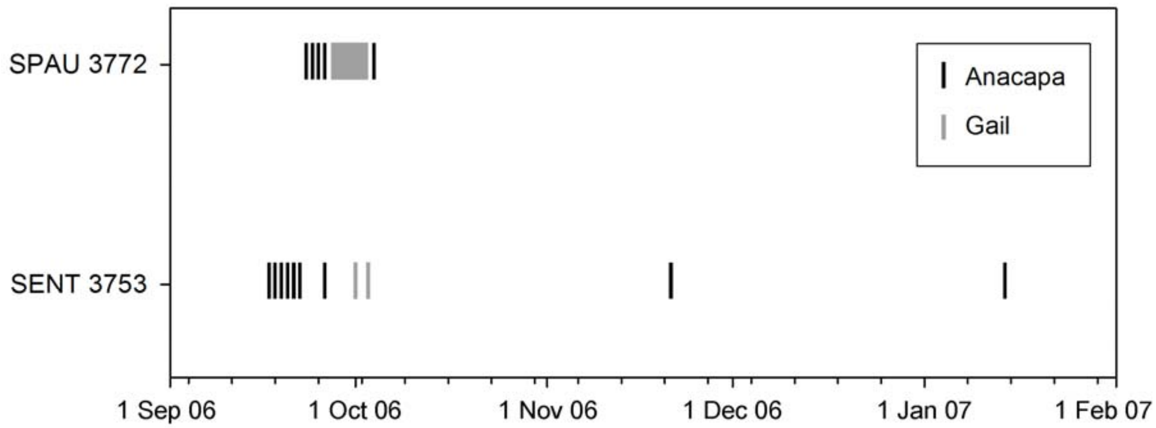

Figure 10. Daily detection plot of a bocaccio (SPAU 3772) and a widow rockfish (SENT 3753) that were translocated from Platform Grace to Anacapa Island. Neither fish homed back to Platform Grace, but moved from Anacapa Island (black marks) to Platform Gail (gray marks), then back to Anacapa Island before moving out of the range of detection for the remainder of the study period. Each mark represents at least 3 detections in a single day.

Fifty-nine fish did not home and were either detected within the Anacapa Island array or moved out of the range of detection for some portion or during most of the 620 d monitoring period (Figure 11). Individuals and species that did not home included one lingcod, bocaccio (*S. paucispinis*), Mexican rockfish (*S. macdonaldi*), greenblotched (*S. rosenblatti*), starry (*S. constellatus*), copper (*S. caurinus*), brown (*S. auriculatus*), squarespot (*S. hopkinsi*), widow (*S. entomelas*), blue (*S. mystinus*), flag (*S. rubrivinctus*), and vermilion rockfishes. While many individuals went undetected after varying amounts of time (days to months) after release, 12 individuals continued to be detected very close to, or up through the end of the study period, indicative of residency. It cannot be discerned whether fishes that disappeared moved to an unmonitored area or died, but post-release mortality was most likely to occur within 10 d of initial release (Lowe et al., 2009).

Residence time of fish at Anacapa Island can be further illustrated with date-time scatter plots, which provide additional evidence of the survival and movement of fish between VR2 receivers. A date-time scatter plot of a fish that died after release would show a graph of solid marks, as its carcass and/or tag would sit on the bottom, transmitting continuously without movement (see Lowe et al., 2009). Two examples of fishes that appeared to take up residency at Anacapa were a flag rockfish (SRUB 3734) and a bocaccio (SPAU 3760), whose date-time scatter plots showed clear movements in their detections. Flag rockfish SRUB 3734 (Figure 12a) showed considerable movement between several VR2 receivers in the array and those of the Pfleger Institute of Environmental Research (PIER). After going undetected for nearly a month, it returned to the area around VR2 receiver AnaF for the remainder of the study period. Similarly, bocaccio SPAU 3760 (Figure 12b) moved between PIER VR2s before it maintained residency around VR2 receiver AnaF. SPAU 3760 also showed a diel pattern in movement, as it was detected heavily between 06:00 h and 19:00 h, moving farther away from the station at night.

Figure 11. Daily detection plot of all fishes that did not home after translocation from oil platforms to Anacapa Island. Individuals are listed along the y-axis with their shorthand code and ID number: vermilion (SMIN), flag (SRUB), copper (SCAU), brown (SAUR), blue (SMYS), widow (SENT), bocaccio (SPAU), squarespot (SHOP), starry (SCON), greenblotched (SGBL), Mexican (SMAC), and lingcod (OELO). Presence of an individual is marked for each date (x-axis) during the course of the study. The gray diamond associated with SMIN 3794 indicates that the individual was located with the VR100 receiver. The gap in detections between 23 Nov 2006 and 20 Dec 2006 (shaded bar) represents a time when 3 of six VR2 receivers at Anacapa Island were lost.


OELO 3717
SMAC 3770
SGBL 3745
SCON 3778
SAUR 3782
SHOP 3789
SHOP 3779
SENT 3788
SENT 3774
SPAU 3766
SPAU 3765
SPAU 3760
SPAU 3703
SMYS 3757
SMYS 3755
SMYS 3748
SMYS 3738
SMYS 3732
SCAU 3786
SCAU 3763
SCAU 3759
SCAU 3740
SCAU 3737
SCAU 3726
SRUB 3792
SRUB 3791
SRUB 3746
SRUB 3744
SRUB 3734
SMIN 3799
SMIN 3798
SMIN 3796
SMIN 3794
SMIN 3764
SMIN 3762
SMIN 3761
SMIN 3754
SMIN 3751
SMIN 3749
SMIN 3747
SMIN 3741
SMIN 3739
SMIN 3731
SMIN 3730
SMIN 3728
SMIN 3723
SMIN 3718
SMIN 3716
SMIN 3713
SMIN 3712
SMIN 3711
SMIN 3707
SMIN 3702
SMIN 3701
SMIN 3700
1 Aug 06
1 Sep 06
1 Oct 06
1 Nov 06
1 Dec 06
1 Jan 07
1 Feb 07
1 Mar 07
1 Apr 07
1 May 07
1 Jun 07
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1 Aug 07
1 Sep 07
1 Oct 07
1 Nov 07
1 Dec 07
1 Jan 08
1 Feb 08
1 Mar 08
1 Apr 08

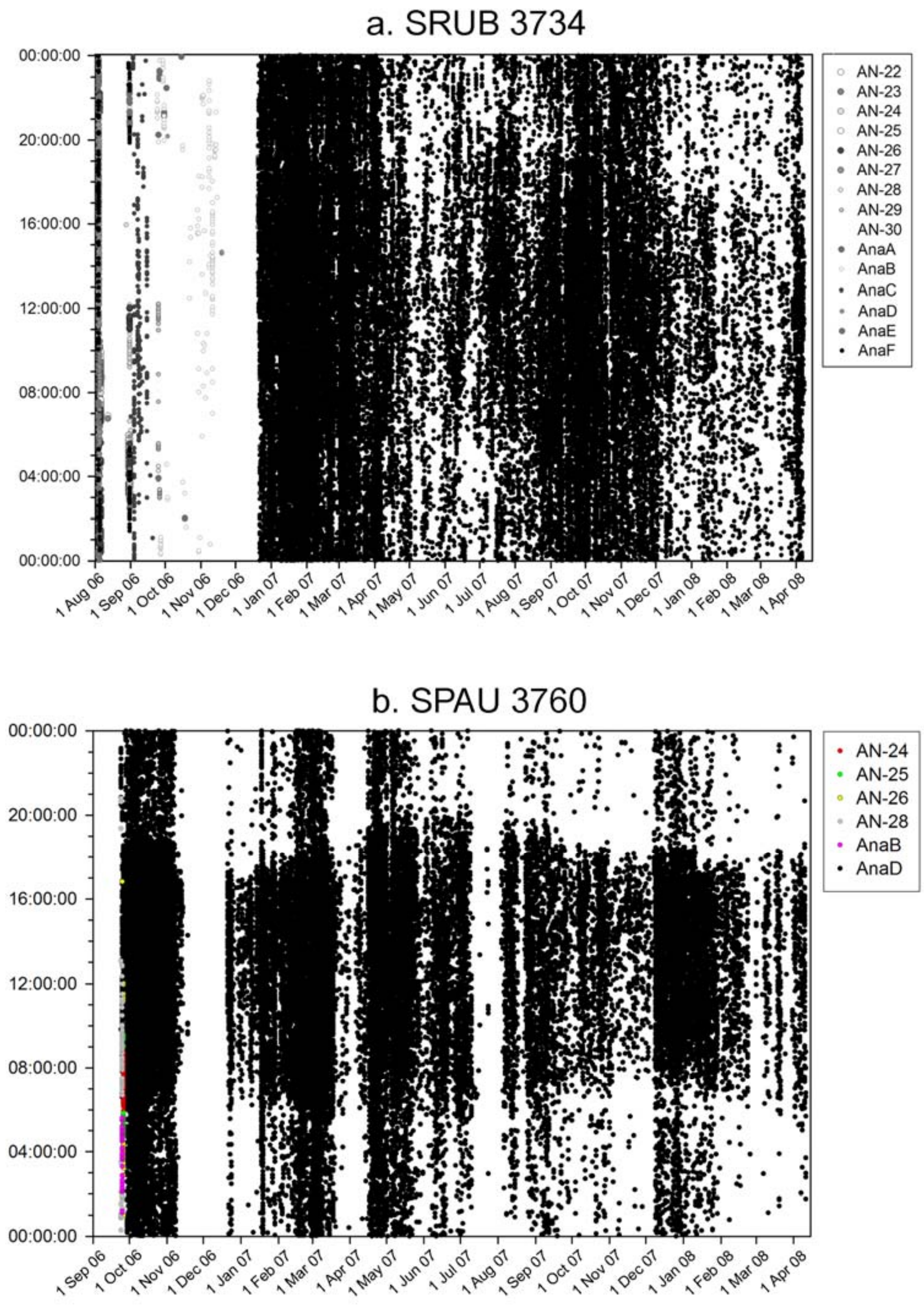


Figure 12. Date-time scatter plots of individuals that did not home back to the oil platforms, but appeared to take up residency within the VR2 acoustic array at Anacapa Island, indicated by patterns of detection at different receivers. Each dot represents the time of day (y-axis) and the date (x-axis) on which the individual was detected at different VR2 receivers. VR2s labeled AN-# were owned and maintained by the Pfleger Institute of Environmental Research (PIER) through 6 Oct 2006.

Shortly after their release at Anacapa Island, a flag (SRUB 3746, 25.0 cm TL), blue (SMYS 3748, 32.7 cm), and a vermilion (SMIN 3751, 29.5 cm) rockfish moved to Santa Cruz Island, where they were detected by VR2 receivers maintained by PIER. All fish remained at Anacapa Island from 2-7 d before they moved out of the range of detection and were subsequently detected at PIER receivers SC-01 and SC-04 inside the Scorpion State Marine Reserve (Figure 13). Although 4 additional VR2 receivers were deployed around the east end of Santa Cruz Island, no fishes were detected at those locations. VR2 receivers were removed by PIER in October 2006, therefore it was not possible to know if any other fishes after that date also moved to Santa Cruz Island.

Eighteen rockfishes and one juvenile lingcod were translocated from a natural reef (called Grace Rock) west and south of Platform Grace (Figure 1) to either Platform Grace (up to 1 km away) or Platform Gilda (6 km away) (Table 2). Grace Rock has not been mapped with side scan sonar, but is known to be a very large, low-relief rock reef habitat that harbors several species of rockfishes. Because there were no VR2 receivers stationed at Grace Rock, it cannot be determined when fish arrived there, but mobile acoustic surveys verified that 4 of 19 (21.1%) fish translocated homed back to Grace Rock from either Platforms Grace or Gilda (Table 4). A flag rockfish (SRUB 3708) and a copper rockfish (SCAU 3714) left Platform Gilda for Platform Grace before homing back to Grace Rock (Figure 14), traveling a minimum distance of 6 km. The flag rockfish was not detected at Platform Grace after 4 Sep 2007, but was detected on 3 separate occasions at Grace Rock to the end of the study period (11 Apr 2008). After being detected at Grace Rock, the copper rockfish moved into the detection range of Platform Grace, where it remained until 30 Dec 2007, after which it was not detected again during the study. Two bocaccio (SPAUs 3721 and 3750) also moved to Platform Grace before returning to Grace Rock from Platform Grace, 1 km away (Figure 15). Each of the bocaccio showed movement back and forth between Platform Grace and Grace Rock; SPAU 3721 was last detected at Grace Rock to the end of the study, and SPAU 3750 was last detected at Platform Grace on 29 Mar 2008.

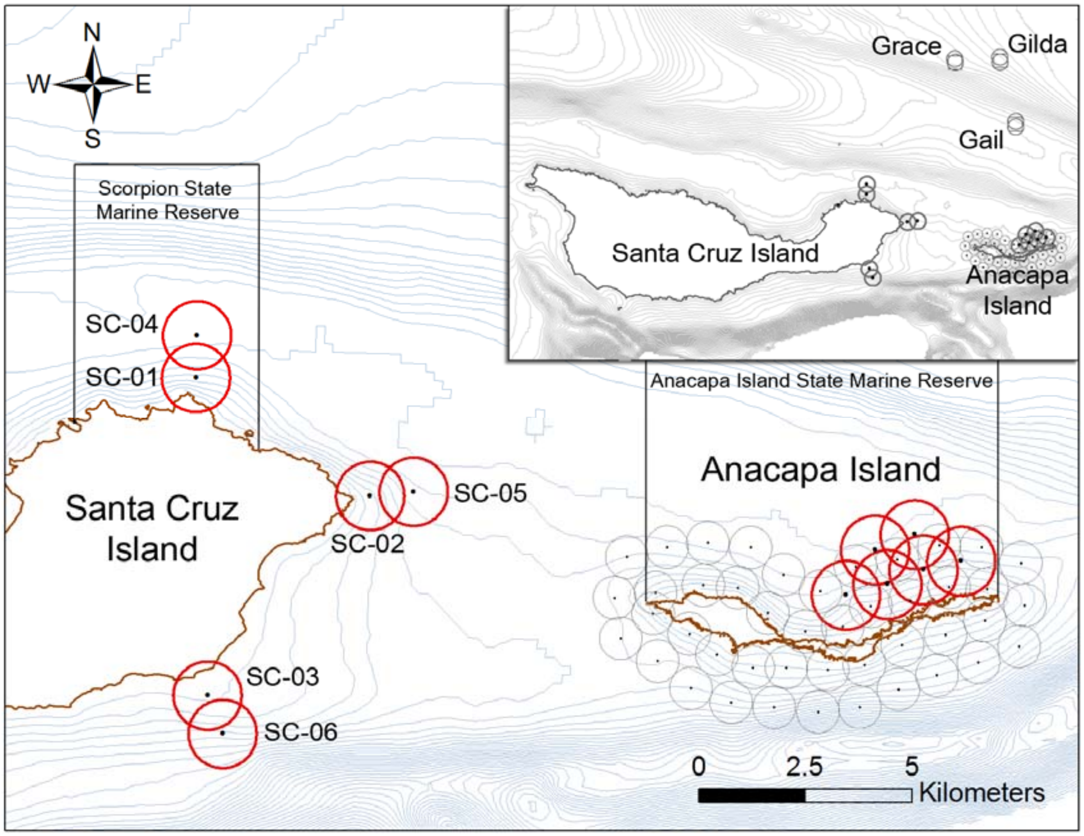


Figure 13. VR2 receivers at Santa Cruz Island maintained by the Pfleger Institute of Environmental Research (PIER) up to October 2006. Inset shows the location of Santa Cruz and Anacapa Islands relative to Platforms Gail, Gilda, and Grace. Three rockfish (flag SRUB 3746, blue SMYS 3748, and vermilion SMIN 3751) moved from Anacapa Island to receivers SC-01 and SC-04 at Santa Cruz Island. Red circles represent 800 m detection zones around VR2 receivers. Small gray circles represent 500 m detection zones around PIER VR2 receivers at Anacapa Island. Black lines bound the Scorpion and Anacapa Island State Marine Reserves. Depth contours are in 10 m increments.

Table 4. Summary of rockfishes that homed from platforms Grace or Gilda after translocation from a natural reef, Grace Rock.

Common Name	Species	Code	TL (cm)	Release Platform
Bocaccio	*Sebastes paucispinis*	SPAU 3721	31	Grace
Bocaccio	*Sebastes paucispinis*	SPAU 3750	31	Grace
Copper rockfish	*Sebastes caurinus*	SCAU 3714	46	Gilda
Flag rockfish	*Sebastes rubrivinctus*	SRUB 3708	23	Gilda

Residence times of the 2 boccacio (SPAUs 3721 and 3750) at Platform Grace before homing to Grace Rock could not be determined, due to the intermittent pattern of detections of each fish (Figure 14). It cannot be discerned whether fishes were leaving the platform for short periods of time, or moving inside the platform structure in areas where detections were occluded. However, the distinction in detections between their 2 sites of detection was clear for the copper (SCAU 3714) and flag (SRUB 3708) rockfishes that homed from Platform Gilda just 15.1 h and 17.7 h, respectively, after release.

A larger proportion of fishes did not home back to Grace Rock (*n* = 15/19, 78.9%) and stayed within the 800 m detection zones of the VR2 receivers stationed at each of the Platforms Gilda and Grace (Table 5). Four examples of non-homing fishes are illustrated in Figure 15. The juvenile lingcod (OELO 3709, 34.0 cm TL), a greenspotted (SCHL 3775), and a copper rockfish (SCAU 3706) did not home from Platform Grace, despite its close distance to Grace Rock. All 3 of these individuals were detected at Platform Grace by either the VR2 or the VR100 receivers up to the last day of the study. A bocaccio (SPAU 3720) did not home back to Grace Rock from Platform Gilda and was detected there until the end of the study. Three vermilion rockfish, SMINs 3705 (32.9 cm TL), 3724 (34.0 cm) and 3725 (32.0 cm), were detected for only a short period of time after 2 were translocated to Platform Gilda (22.6 and 71.1 h), and one to Platform Grace (63.2 d). None were detected with the VR100 receiver after their release. Due to the close proximity of location and times of detections, it was indeterminable whether a greenspotted (SCHL 3715) and a copper (SCAU 3706) rockfish (comprising 10.5% of the total) homed back to Grace Rock.

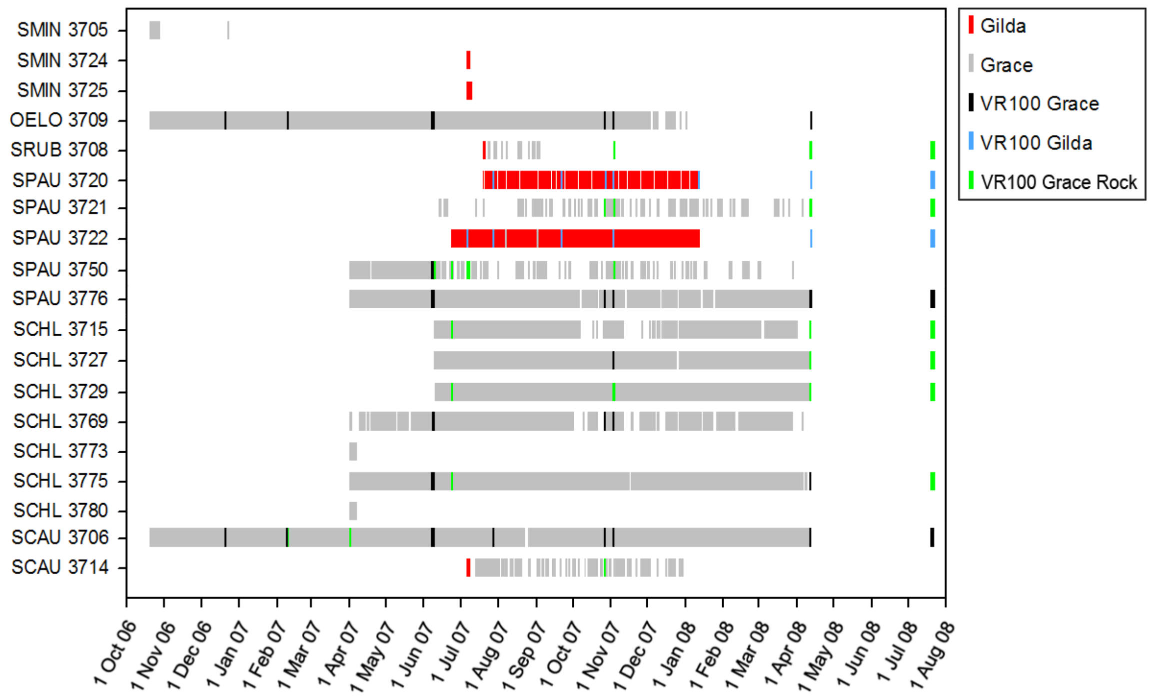


Figure 14. Daily detection plot of fish that were translocated from a natural reef, Grace Rock, to Platform Gilda or Grace. The mobile acoustic surveys were conducted with a VR100 receiver at different sites, indicated by the black, blue, and green marks. All VR2 receivers were retrieved in April, but one last mobile acoustic survey was conducted in July 2008.

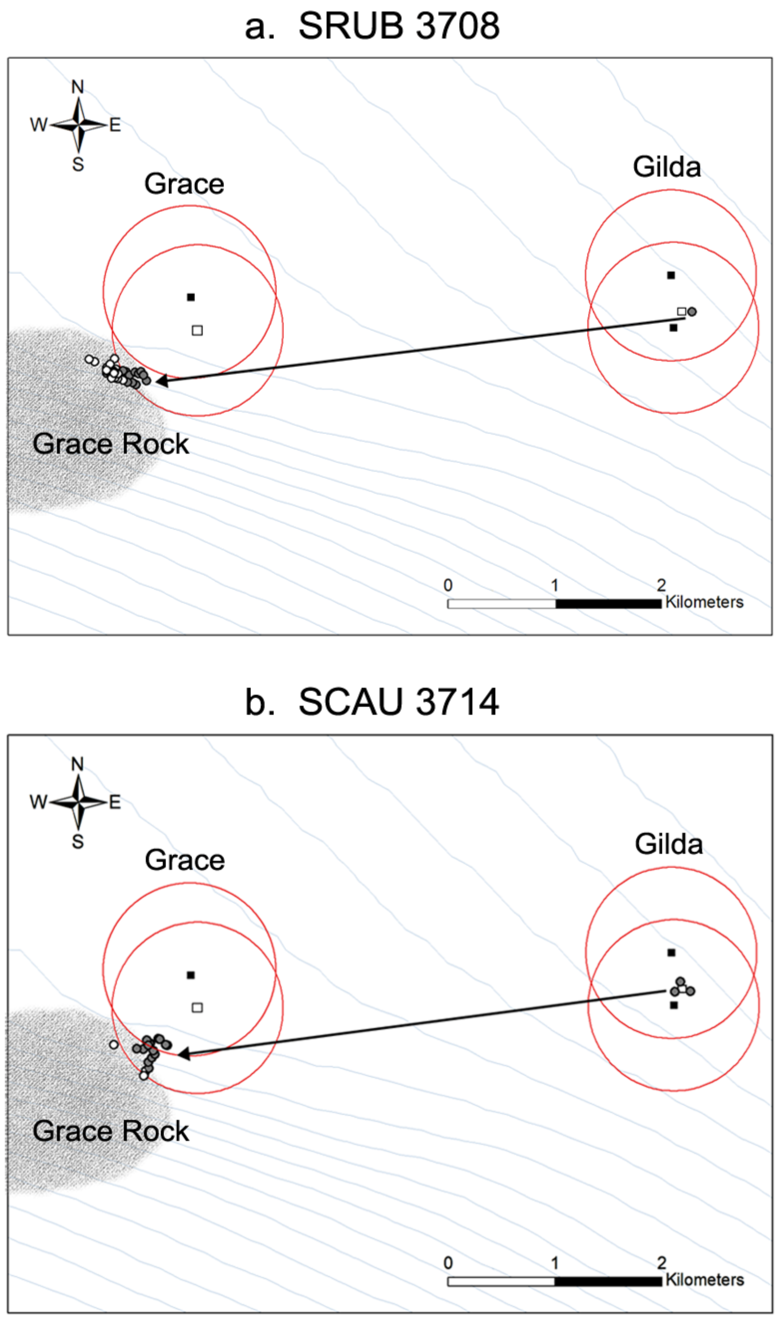
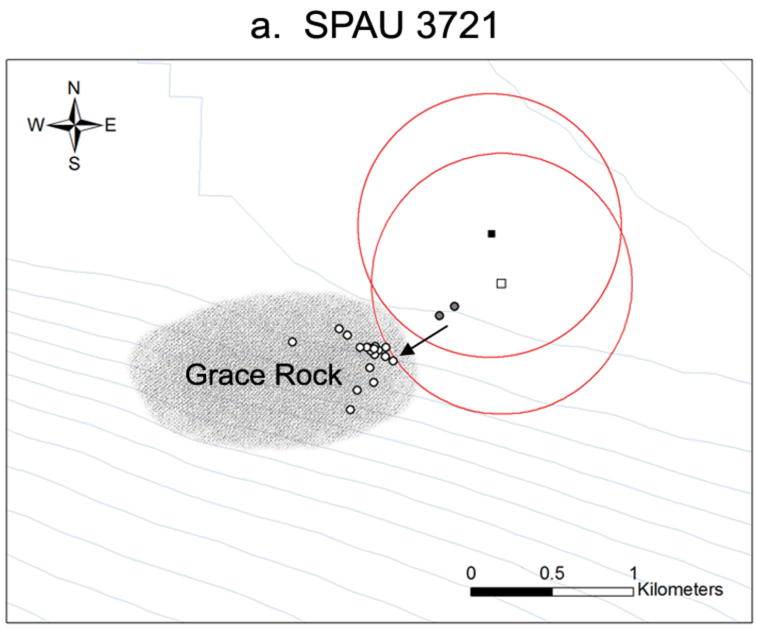


Figure 15. Detections of translocated (a) flag rockfish (SRUB 3708) and (b) a copper rockfish (SCAU 3714) that homed from Platform Gilda (62 m depth) to a natural reef, Grace Rock (106-122 m depth), from where they were originally captured. The straight-line minimum distance of travel was 6 km. Arrows indicate the direction of travel for each fish. Shaded dots represent GPS locations of detections received by the stationary VR2 receivers, while open dots represent detections by the directional hydrophone of the VR100 receiver. Black squares show the locations of stationary VR2s; open squares represent an approximate area that each oil platform occupies at the seafloor.



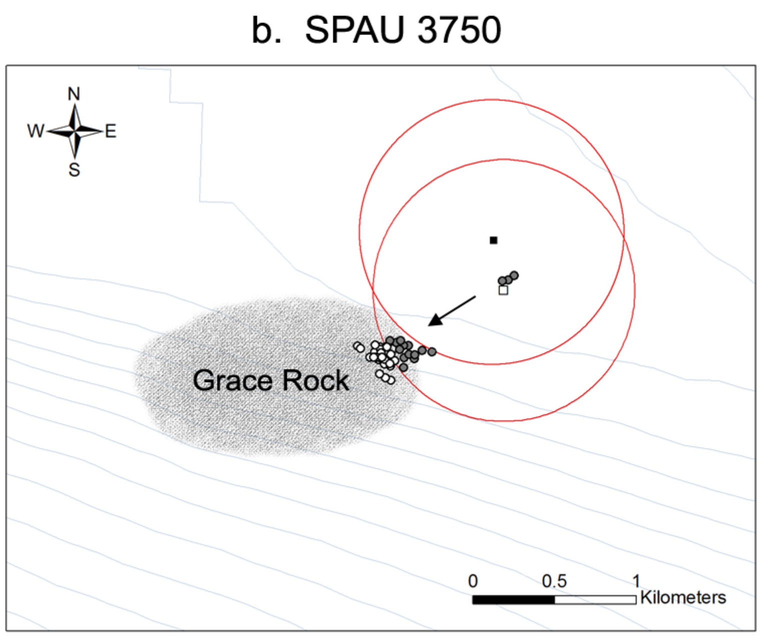


Figure 16. Detections of 2 translocated bocaccio (a) SPAU 3721 and (b) SPAU 3750 that homed from Platform Grace (91 m depth) to a natural reef, Grace Rock (106-122 m), from which they were originally captured. The minimum distance of travel was 1 km. Arrows indicate the direction of travel for each fish. Small circles represent locations of detections received by the directional hydrophone of the VR100 receiver (open) and by the stationary VR2 receivers (shaded).

Table 5. Summary of lingcod and rockfishes that did not home to the natural reef, Grace Rock, after reverse translocation to platforms Gilda or Grace. Individuals are identified by their species and transmitter ID codes. Total lengths (TL) in cm.

Common Name	Species	Code	Size Range TL (cm)	Release Platform
Lingcod	*Ophiodon elongatus*	OELO	34.0	Grace
Greenspotted rockfish	*Sebastes chlorostictus*	SCHL	24.0 - 32.5	Grace
Bocaccio	*Sebastes paucispinis*	SPAU	32.5, 46.0	Grace, Gilda
Vermilion rockfish	*Sebastes miniatus*	SMIN	32.0 - 34.0	Grace, Gilda
Copper rockfish	*Sebastes caurinus*	SCAU	40.3	Grace

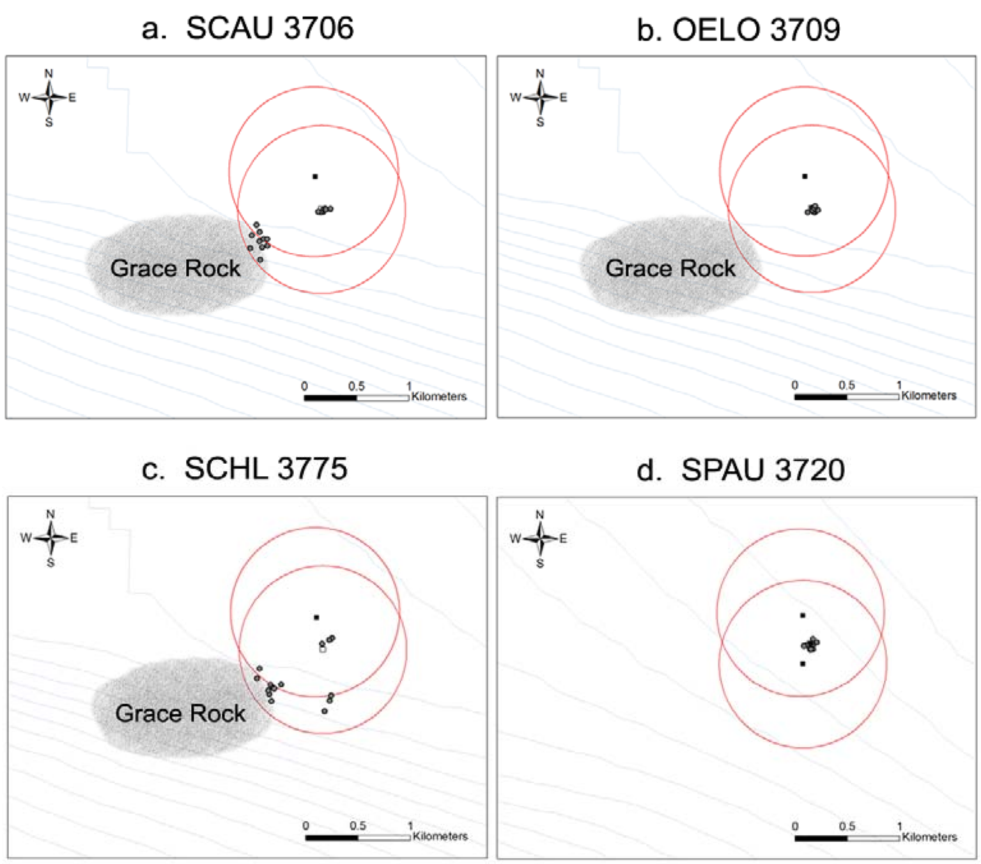


Figure 17. Examples of fishes that were translocated to Platforms Grace (a) greenspotted rockfish (SCHL 3775), (b) lingcod (OELO 3709), (c) copper rockfish (SCAU 3706) and Gilda (d) bocaccio (SPAU 3720) from a natural reef, Grace Rock, but did not home and remained inside the 800 m detection zones of the stationary VR2s.

Eight of 17 (47%) fish (eliminating 2 fish whose locations were indeterminable) were detected at Platform Grace and Grace Rock within a short time period (Figure 14). A greenspotted rockfish (SCHL 3729) was detected several times after its release at both Platform Grace and Grace Rock. Two detections were recorded on 3 Nov 2007—one at 14:02 h inside the detection range of Platform Grace, and the next detection occurred at 14:08 h at Grace Rock with the VR100 mobile receiver and directional hydrophone. The next detection was recorded at Platform Grace just 12 min later at 14:20 h. This is just one example of an individual that was detected at both locations within a small temporal scale.

Matrix loops were constructed for all vermilion rockfish and all lingcod that homed to make predictions about where that species was most likely to be detected based on where it had previously been detected and how long it stayed there before moving. Assuming the ability to detect a fish at each site was equal for all fish, the probabilities calculated can be used as a measure of the probability of movement between those sites (Anacapa Island, Platforms Gail, Gilda, or Grace).

Vermilion rockfish exhibited the most diverse movement patterns, exhibiting 7 combinations of movement: Anacapa Island to Platforms Gail, Gilda, and Grace, Platform Grace to Anacapa Island, and remaining at Anacapa Island, or at Platforms Gilda or Grace (Figure 18). Once at Platform Grace, vermilion rockfish caught and taken from there were most likely to stay there if they returned (64.5% probability of being detected). Alternatively, fish that were translocated to Anacapa Island had a 26.3% probability of staying inside the acoustic receiver array. The third site most frequently visited by vermilion rockfish was Platform Gilda, where the probability of fish remaining there was 12.0%. Movement probabilities between other platforms and Anacapa Island were low—2 out of the 7 times fish moved after they homed they were predicted to move to Anacapa Island from either Platform Gilda and Grace. However, the overall likelihood of those movements was less than 1% (0.15 and 0.23%, respectively). Ten of 37 (27%) vermilion rockfish successfully homed, of which 40% (n = 4/10) visited Platforms Gail, Gilda, Grace, or Anacapa Island before returning to Platform Grace.

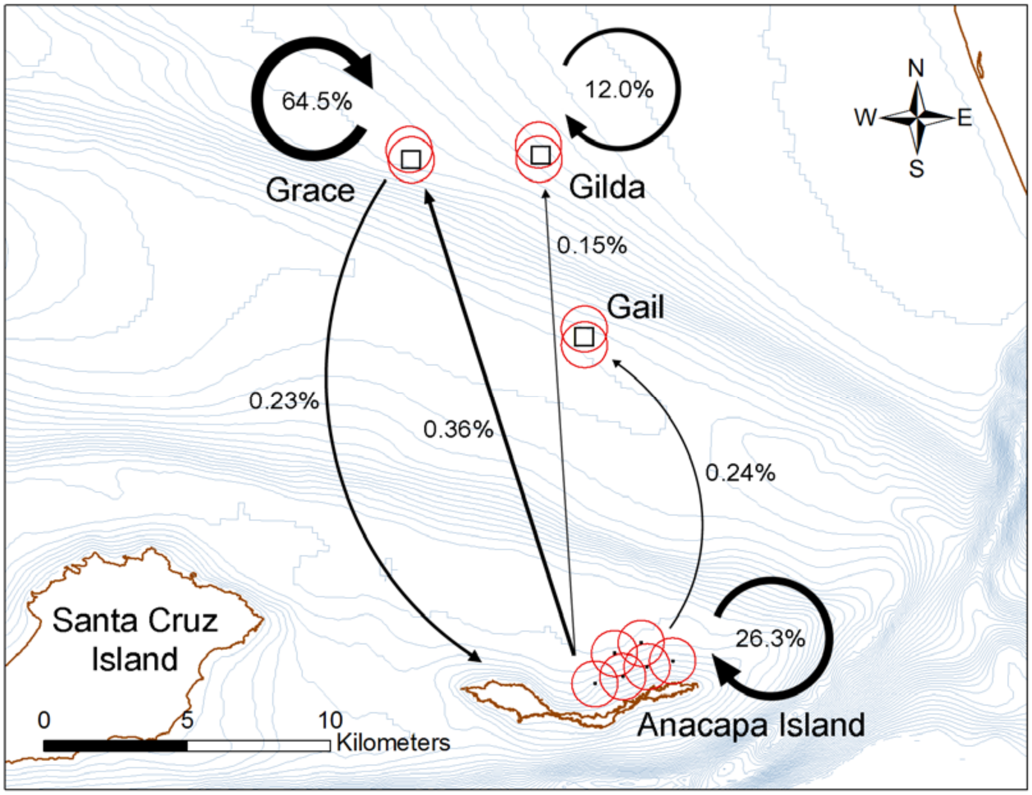


Figure 18. Matrix loop for the probabilities of vermilion rockfish movement overlayed on a GIS map for each site monitored during the study period. Probability of movement was calculated over a 200 d period. Thicker lines emphasize the increased probability of movement in the direction of the arrow.

Lingcod showed movement to either Anacapa Island or Platform Gail (Figure 19), regardless of where they were detected previously. Lingcod had the highest probability of being detected at Platform Gail (77.3%), or Anacapa Island (22.3%). To a much lesser extent, fish moved to Anacapa Island or Platform Gail from all other locations (1.18% or less).

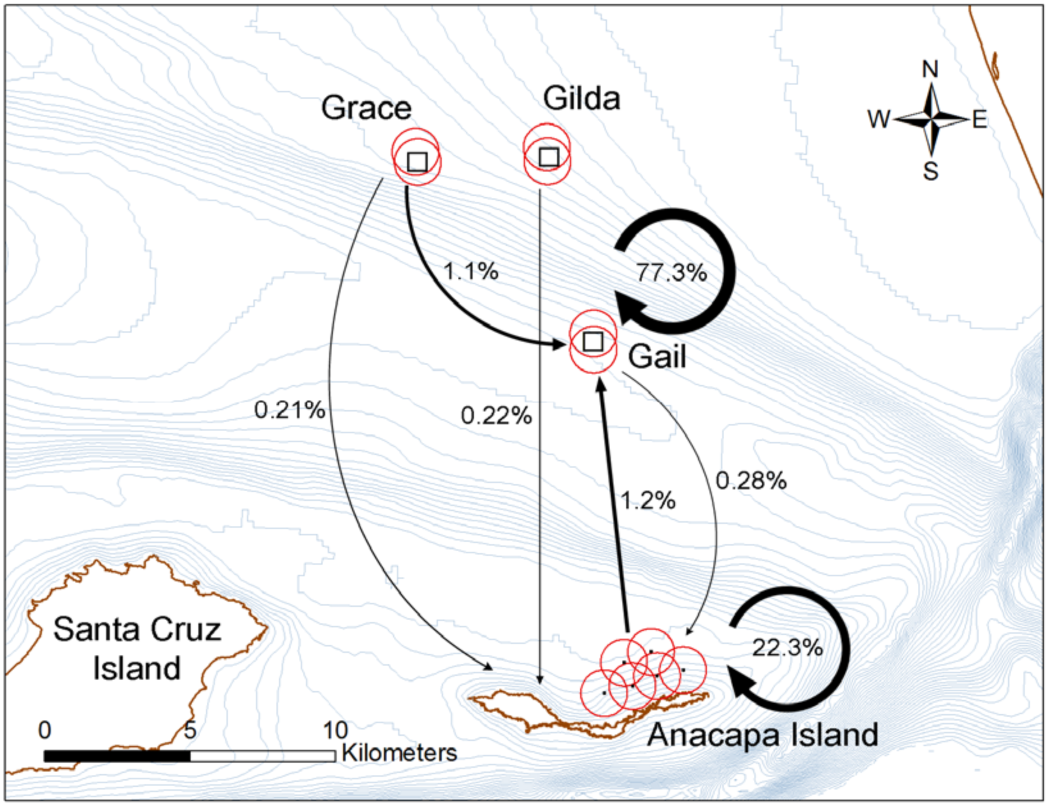


Figure 19. Matrix loop for the probabilities of lingcod movement overlayed on a GIS map for each site monitored during the study period. Probability of movement was calculated over a 200 d period. Thicker lines emphasize the increased probability of movement in the direction of the arrow.

Discussion

<u>Acoustic Tagging and Rockfish Survival</u>

Tag and recapture has been a standard method used to assess movements and population structure of large numbers of fishes, but because it is dependent on fishing effort, it can be exceedingly time consuming and the data collected is typically low in resolution. While these methods are still used, acoustically tagging fishes generates much finer scale temporal and spatial data and has been used to fill in gaps from previous tag and recapture studies. Acoustic telemetry has grown increasingly popular in the last 20 years, but there are limitations that must be considered during data analysis. Any tagging procedure places a fish under stress and risks its post-release survival, but an acoustic tag can be more invasive, as it is often surgically implanted. Moreover, acoustic telemetry studies on high relief reefs or offshore oil platforms present additional difficulties because fishes that associate with structure can situate themselves in such a way that transmitter emission can be interrupted and/or go undetected. Despite these challenges, acoustic telemetry was the best option for this study and we were confident that the techniques used in handling fish greatly increased their chances for survival.

Because of the depths of the offshore oil platforms in this study, any fish with a swim bladder was subject to some degree of decompression stress. Most fishes brought to the surface were afflicted with a visible sign of barotrauma, e.g. the most common was exophthalmia and/or "crystallized" eyes (effect of microbubbles localized in eye tissue), bloated abdomen, inverted stomach protruding through mouth, and air bubbles under skin. Despite pressure-related injuries, Jarvis and Lowe (2008) observed post-release survival after a 2 d recompression in cages at 68% for 168 individuals comprising 19 species; the degree of barotrauma, however, was independent of survival. Holding time of the fish in a live well at surface water temperature was largely influential on mortality, likely due to the abrupt change in temperature from bottom to surface waters. In the current study, rockfishes were immediately placed in a chilled seawater live well (~10^{o}C), which dramatically reduced the sea surface to seafloor temperature differential and prolonged the survival of the fish during transport. Furthermore, venting swim bladders with hypodermic needles to alleviate pressure was eliminated early in the tagging portion of the study in order to decrease handling time and the risk of inflicting further injury. Surgical implantation of the transmitter almost always released air from the body cavity enough to allow the tagged fish to gain ample neutral buoyancy and move freely in the live well. Additional evidence of translocation survival was supported by how well most fish looked after holding them in cages at depth and the rigor at which they swam towards the sea floor after release, and also by (1) detecting individuals that homed, (2) recapturing a tagged vermilion rockfish at Platform Gilda, and (3) the ability to detect their movement between VR2 receivers at Anacapa Island and the platforms through the end of the study.

Rockfishes are frequently associated with structure, be it boulders, rock piles, outcrops, or constructed artificial habitat (Yoklavich et al., 2000; Caselle et al., 2002; Love and York, 2005, 2006; Love et al., 2006; Lowe and Bray 2006). Much like a high relief natural reef, signal transmission can be greatly reduced or occluded altogether if a tagged fish situates itself under an outcrop or between rocks. However, based on a previous tagging study monitoring the site fidelity of rockfishes and lingcod to oil platforms (Lowe et al., 2009), tagged individuals were detected on the platforms for over a 2 yr period. Moreover, the use of a mobile VR100 receiver with a directional hydrophone allowed for the location of fish that may have gone undetected by either of the 2 deployed VR2 receivers at each platform or at Anacapa Island. Therefore, if present, tagged fishes were highly likely to be detected by the VR2 receivers.

Emigration From Anacapa Island

Since their release at Anacapa Island, the proportion of tagged fishes detected quickly declined in the first 10 d, reflecting a departure from the receiver array. Because detections at all 3 oil platforms subsequently increased, some of the immediate decline in detections of tagged fish at Anacapa Island during the first 50 d represents individuals that homed back to the platforms. The additional decrease in the proportion of fishes detected was compounded by the loss of 3 VR2 receivers at Anacapa Island; however, that decrease in detections was not attributed solely to mortality or movement outside the array. The increase in detections just before 150 d since fishes were released illustrates the deployment of replacement receivers. Although there was a steady decline in the number of fishes throughout the study period, the proportion detected at both Anacapa Island and the platforms fluctuated daily, indicative of individuals moving in and out of the receiver array, or around habitat that would occlude signal transmission. Lowe et al. (2009) observed a similar pattern of emigration after releasing tagged rockfishes and lingcod directly at their platforms of capture. Ten days after their release, there was a rapid decrease in the number of fishes detected, followed by a slower, steady decline through the duration of the study. The slow decline was attributed to emigration, as fishes were reported to have moved from one platform to another, or away from areas of detection for long periods of time.

It was assumed that moribund and deceased fishes would likely have been carried away by currents and removed from detection range within several days of release. It is also possible that predators (e.g., sharks and sea lions) may have eaten weakened individuals and those tags could be detected while in the predator; however, tags should pass through a predator's digestive system in 2-14 d (Papastamatiou and Lowe, 2004). By the end of the 620-day monitoring period, only a few individuals were still being detected at either Anacapa Island or the platforms. From 2004 to 2006, Lowe et al. (2009) monitored the site fidelity of groundfishes from the same oil platforms, and reported a similar pattern in detection after release, with a sharp decrease during the first 6 d (attributed to post-release mortality and emigration) and a gradual decline over the course of the study. Over time, rockfishes likely emigrated away from platforms to other unmonitored locations, which may also explain the behavior of individuals in the current study. This emigration theory was supported by detections of tagged fishes moving from shallower to deeper platforms over time.

Homing Behavior

The ability to return to a home range after displacement, or homing, is a well documented phenomenon in fish behavior (Carlson and Haight, 1972; Hallacher, 1984; Markevich, 1988; Matthews, 1990a, 1990b; Pearcy, 1992; Hartney, 1996; Lea et al., 1999; Marnane, 2000; Starr et al., 2004). One of the earliest reports of homing in rockfishes was presented by Carlson and Haight (1972) after displacing yellowtail rockfish (*Sebastes flavidus*) off southeast Alaska from their site of capture. Many tagged fish homed back, including one individual that traveled as far as 22.5 km. With the exception of Carlson and Haight (1972), previous displacement studies have tested homing ability within continuous habitat or along a depth contour, providing a habitat boundary to follow. Fishes in the current study were translocated from their sites of capture offshore, across the channel basin (>200 m depth) and discontinuous habitat. Despite these physical barriers, lingcod, vermilion and brown rockfishes successfully homed back to their platforms of capture, supporting the hypothesis that rockfishes and lingcod removed from their resident oil platforms can home if translocated to Anacapa Island.

The seafloor topography between Anacapa Island and Platforms Gail, Gilda, and Grace is largely a stretch of soft sediment with depths reaching > 230 m, presenting a large expanse of open water over discontinuous habitat. Vermilion and brown rockfishes were able to navigate back, even through depths exceeding their known limits, 200 m and 55 m, respectively (Miller and Lea, 1972). Notably, the homing distances observed in this study are the farthest reported for lingcod, vermilion and brown rockfishes. It is not known whether these fishes were swimming along the seafloor while homing or whether they were in midwater or near the surface. Nevertheless, traversing these distances poses a greater challenge and risk, especially for relatively small fish, when crossing deep, open water, than when following habitat along the coastline.

The total lengths of vermilion and brown rockfishes that homed were significantly larger than those that did not home, and, with the exception of one individual, all were probably adults (range 27.5-35.3 cm TL). Vermilion rockfish mature as early as 31 cm, or 4 yr, while 50% of brown rockfish are mature between 24 and 31 cm, or 4-5 yr (Love et al., 2002). Smaller, younger fish tend to occupy larger areas than adults that have established home ranges or territories (Larson 1980a; Lowe and Bray, 2006) and are therefore expected to move more. In addition, they typically make ontogenetic shifts to deeper water as they mature (Love et al., 1991), but not necessarily across stretches of open water. Smaller fish that were translocated in this study did not home, and instead took up residency at Anacapa Island, or were not detected. Results indicate that among adults, individuals have variable propensities to home, while subadults showed a much lower probability of homing. Younger individuals may not develop an ability to home until they grow larger (Mathews and Barker, 1983), at which time they require additional resources that would compel them to expand or shift their home ranges (Lowe and Bray, 2006). For example, leaving a home range or territory to increase social interactions, e.g. spawning (Topping et al., 2006; Mason, 2008), and being able to return is important for the success of populations.

All fish that homed did so relatively quickly, leaving Anacapa Island after an average of 14.7 d following their release and taking from less than 24 h to travel back to the platforms (e.g. the fastest lingcod homed 11 km in 10.5 h) up to 17 d (brown rockfish, 17.5 km). Compared to previous experiments displacing rockfishes, results from the current study reveal how quickly lingcod and rockfish can not only recover from catch, release, and tagging stress, but also quickly orient themselves in a new environment and navigate home. Matthews (1990a) actively tracked copper and quillback (*S. maliger*) rockfish after displacing them 500 m from their home site and found that these species also homed quickly after release—after just 1-5 d. After translocation, short residence times at the site of release may be explained by a strong proclivity to home, or competition with resident fishes. Because of its protection inside a marine reserve, rockfish at the site of translocation at Anacapa Island were not subject to fishing mortality, which might otherwise make space available for new residents. This area of reef may have had well-established residents with territories, which could influence establishment of new colonizers (Larson, 1980b).

Assuming the last detection at the Anacapa Island array was representative of when the fish attempted to home, no discernable seasonal or daily pattern in departure time was apparent. Demersal rockfishes from Gail (225 m) occupy an environment where little or no light penetrates to the seafloor. Therefore, movements were likely independent of a circadian rhythm. Similarly, a greenspotted rockfish (*S. chlorostictus*) tagged and monitored at Platform Gail by Lowe et al. (2009) showed no periodicity in its fine-scale movement behavior around the platform; conversely, clear diel patterns in movements were observed for other species on shallower Platforms Gilda and Grace, where light is able to penetrate to the seafloor. However, 6 of 9 lingcod left the array at Anacapa Island between 20:00 h and 22:00 h. Lingcod were previously reported to have made movements at night (Matthews, 1992; Yamanaka and Richards, 1993). These combined results infer that adult lingcod exhibit nocturnal behavior when in shallower areas, but may not necessarily exhibit nocturnal behavior when in deeper water. While the time of day and season during which homing occurred did not vary significantly, the departure time from the platforms after fish homed may have coincided with reproductive cycles. Five vermilion rockfish (all adults) left Platform Grace between 25 October and 16 November, and one lingcod left Platform Gail on 6 February. Although it was not known where these fish may have moved, all departed during a time that correlates with spawning season for these species (Love et al., 2002). Lowe et al. (2009) recorded an adult lingcod departing from Platform Gail and arriving in shallow water (~ 20 m) at Santa Cruz Island (9 km away) in mid January. The same individual was detected again at Platform Gail only 2 d later. It was hypothesized that this was a female moving into a shallow reef to spawn, as this is a characteristic behavior for females of this species (Love, 1996). Typically adults that leave for spawning return to their home ranges. If their departure from the platforms was for spawning, then the 5 vermilion rockfish and one lingcod in this study should have been detected again by March or April. Because they were not detected again at the platforms that may indicate that they left for purposes other than spawning, or moved to different locations after spawning.

Non-Homing Fish

Two rockfishes (bocaccio, SPAU 3772 and widow rockfish, SENT 3753) that left Anacapa Island were detected for short periods of time at Platform Gail before apparently traversing back to Anacapa Island and subsequently falling out of detection altogether. This behavior may be representative of fish that left Anacapa Island to home, but were either unsuccessful at it, or moved to other unmonitored areas. Despite an apparent failure to home, this bocaccio and widow rockfish were able to navigate between natural and platform habitat, a distance covering at least 22 km over open water. Homing has not previously been reported for bocaccio or widow rockfishes, but Hartmann (1987) has reported long-distance movements of juvenile bocaccio (recaptured up to 148 km away) tagged from an oil platform in the north Santa Barbara Channel. Based on these data, bocaccio, while capable of long-distance movements, may not have a strong homing ability. In his study, Hartman (1987) tagged widow rockfish, but none were recaptured away from their tagging sites, which would imply that this species exhibits strong site fidelity. Lowe et al. (2009) also found that widow rockfish show high site fidelity to offshore platforms.

Fish that did not home took up residence at Anacapa Island inside the acoustic array, evidenced by patterns of movement between VR2 receivers. For example, a bocaccio (SPAU 3760) showed a diel pattern in its movement, also indicative of recovery and normal behavior at their site of release. Because the area where fish were released is a historically rich rockfish fishing ground, it is unlikely that it provided unsuitable habitat for translocated fish. However, this may not have been the case for other fish that moved outside the array. It is also possible that fish not detected at the platforms after departing Anacapa Island may have tried to home and failed (e.g., were lost, or consumed by a predator along the way); however, it is also possible that they moved to an unmonitored area.

Some fish showed movement within the array and to other parts of the island. For example, shortly after its release, a vermilion rockfish (SMIN 3747) from Platform Grace was detected on several VR2 receivers maintained by the Pfleger Institute of Environmental Research (PIER) on the north side of Anacapa Island (see Figure 13), covering an approximate distance of 4 km. It is possible that this individual was assessing its new surroundings before it moved out of the detection area. A flag, blue, and vermilion rockfish (all adults) left Anacapa Island between 2-7 d after release in July and August, but all were detected on the northeast side of Santa Cruz Island inside the Scorpion State Marine Reserve 1-8 d later. The time of their departure coincides with larval release for all 3 species (Love et al., 2002); however, upon implantation of the transmitters, none of the fish were observed to be gravid. Their relatively fast transit times suggest that fish may have been familiar with the area between Anacapa and Santa Cruz Islands, or alternatively, they were able to navigate along depth contours between the islands. Furthermore, no fish were detected on the east or the southeast VR2 receiver, which suggests that the transit route may have been along a deeper contour to get to the northeast receiver location. The short residence times (< 1 h to 5 d) may be an indicator that the monitored area of Santa Cruz Island was unsuitable habitat, or the fish were simply passing through the area.

Variation in movement away from Anacapa Island might be explained by age, as smaller younger fish did not home, or individual differences in behavior. Furthermore, species specific differences in movement may exist. Hyde et al. (2008), through genetic analysis, recently described a cryptic species of vermilion rockfish. Although virtually identical in appearance, they are segregated by depth. Vermilion rockfish, *Sebastes miniatus*, is the shallower species, inhabiting depths to 100 m, while the sunset rockfish, *Sebastes crocotulus*, is found in depths greater than 100 m. All "vermilion rockfish" in the current study were identified as *Sebastes miniatus*. We were, however, able to collect fin clips from 5 individuals for genetic identification from Platforms Gilda (61 m) and Grace (91 m) post hoc; John Hyde (pers. comm. 2009) confirmed that both *S. miniatus* and *S. crocotulus* were present at Platforms Gilda and Grace, likely because young fish of both species occupy similar depths. As adults, sunset rockfish emigrate to deeper water than vermilion rockfish. While it is possible that we misidentified the cryptic species, which may explain some of the variation in the movements of vermilion rockfish, it is equally possible that any subadults of sunset rockfish we may have caught were too small to tag and therefore, released.

Movements Between Platforms and Anacapa Island

Home ranges are defined areas that are used by individuals on a routine basis (Mace et al., 1983). Home ranges have not been previously estimated for lingcod, but for fish OELO 3704, its home range may include Platform Gail and area around Anacapa Island based on its movements between Anacapa and Platforms Gail and Grace. It is not clear why lingcod and vermilion rockfish should make such large migrations between platforms and natural habitat. Fishes may be forced to leave their home ranges for periods of time due to changes in water conditions, food resources, spawning, competition, or habitat quality, among other factors (Lowe and Bray, 2006).

In the current study, some individuals made notable movements (or no movements at all) between platforms and Anacapa Island. Larson (1980a, 1980b) described three behavioral patterns of space use for black and yellow (*S. chrysomelas*) and gopher rockfishes (*S. carnatus*): territorial, non-territorial, and commuters, whose home ranges included discontinuous habitat. The spatial scale at which Larson made his observations was significantly smaller, but the movement patterns of several fish in the present study might best be categorized as site-specific (exhibiting little or no movement or repeatedly returning to the same site), transient (passing through monitored areas for short periods of time before going undetected for the duration of the study), or "long-distance" commuters. The differences in movement patterns observed for fish in the current study could be attributed to this same phenomenon, where some individuals are more likely to remain resident, while others are more likely to move based on changes in environmental conditions, conspecific density, or food availability.

Site-specific movement patterns were exhibited by all non-homing fish and a vermilion rockfish (SMIN 3784) that homed to Gilda. This individual was recaptured by our field crew, translocated to Anacapa Island for a second time, and quickly returned to Platform Gilda just 12 d later. This same individual moved to Platform Grace, but returned to Platform Gilda for a third time and for the duration of the study period. Transient patterns of movement were observed in a flag (SRUB 3746), blue (SMYS 3748), and vermilion (SMIN 3751) rockfish, all individuals that moved from Anacapa to Santa Cruz for a short period of time. Four lingcod (OELOs 3704, 3767, 3777, 3787) may be described as long-distance commuters that homed back to Platform Gail and also made additional migrations between platforms and even back to Anacapa for extended periods of time.

Translocation from Grace Rock to Platforms Gilda and Grace

The purpose of the translocation from natural habitat to oil platforms was to gain insight to whether fish were able to assess the quality of their new environment and make a decision to stay or leave. In fewer than 24 h after their release, a flag and a copper rockfish left Platform Gilda and returned to the natural reef, Grace Rock. A quick response to leave was also observed for fish translocated to Anacapa Island, which might simply be explained by an innate behavior to home immediately after displacement. However, the larger proportion of non-homing individuals for both this experiment and the fish translocated to Anacapa Island suggests that this was likely not the case. Fish may be able to quickly orient themselves and navigate within their home ranges much quicker than when in unfamiliar territory; translocating individuals inside their established home ranges might explain the short residence times at sites of release before homing. Residence times of 2 bocaccio on Platform Grace were indeterminable, but both moved back to Grace Rock. However, because of the close proximity of Grace Rock to Platform Grace, it is possible that those individuals were translocated within their established home ranges.

Fifteen of 19 (78.9%) fish translocated from Grace Rock to platforms did not home and either remained associated with platform structure, or moved out of the range of detection. Three vermilion rockfish remained at either Platforms Grace or Gilda for 16-63 d before departure, and were not detected thereafter for the remainder of the study. One individual (SMIN 3705) released at Platform Grace disappeared on 28 October 2006 for nearly 1 mo, after which it was detected on the platform on 23 December for 8 min before going undetected for the duration of the study. While it is possible that this adult vermilion rockfish (32.9 cm TL) left the platform to spawn (spawning season is from November through March), it does not explain the departure of the other 2 adults (34.0 and 32.0 cm TL) from Platform Gilda in July. One juvenile lingcod (OELO 3709, 34.0 cm TL) translocated from Grace Rock to Platform Grace remained closely associated with the platform structure. This behavior was consistent for similarly sized lingcod that were displaced by Yamanaka and Richards (1993), who reported that juvenile lingcod did not tend to move and remained in the area of their release during the study period.

In some cases, individuals may have home ranges that include both the platform and natural reef habitat, or, alternatively, they may have expanded their home ranges after being translocation to include areas associated with the platform. The flag (SRUB 3708) and copper rockfishes (SCAU 3714) that were translocated to Platform Gilda were detected at Platform

Grace or Grace Rock and on several different days. Because of its proximity to the platform, some individuals may be regularly moving between Grace Rock and the platform. Matthews and Reavis (1990) observed the same copper and quillback rockfishes on an artificial and natural reef located 400 m apart. Although actual home range sizes were not quantified, it is likely that those individuals were utilizing both habitats. Larger home ranges or the expansion of a home range after displacement may explain the extensive movements of vermilion rockfish and lingcod between platforms and Anacapa Island.

<u>Probability of Movement Between Platforms and Natural Habitat</u>

For the first 200 d after release, vermilion rockfish had the highest probability of remaining at Platform Grace after homing (64.5%), in part because most fish were originally taken from there and fish in all but one case homed back to their original platforms. The exception was a vermilion rockfish (SMIN 3784) that was recaptured at Platform Gilda, which was originally from Platform Grace, but appeared to take up a new residency at the former. As such, its movement and retention at Platform Gilda contributed to the 12.0% probability that vermilion rockfish would remain there. They were also 22.3% more likely to be detected at Anacapa Island in the first 200 d, which can be attributed to non-homing fish that remained at Anacapa Island or at least one fish that stayed inside the array for a longer period of time before homing.

Lingcod traveled between Platform Grace and Anacapa Island, both located in shallower depths than their home Platform Gail. It has been established that lingcod are migratory, exhibiting sexual segregation, with females tending to inhabit greater depths offshore, but will move inshore to spawn where shallower-living males guard nests (Miller and Geibel, 1973; Smith et al., 1990; Matthews, 1992; Love, 1996; Jagielo, 1990; Jagielo, 1999). It is unlikely that Platform Grace would be used as a spawning and nesting site because of its depth (91 m), but it is possible that lingcod are going to Platform Grace for food (e.g., high abundance of smaller rockfishes). Acoustically tagged lingcod have been reported to leave areas of detection frequently, but returned to the same sites (Starr et al., 2004; Yamanaka and Richards, 1993). Similarly, both vermilion rockfish and lingcod in this study were frequently absent for varying periods of time, but movement away from home platforms with subsequent returns indicates that platforms are important components of their home ranges.

Mechanisms of Homing and Navigation

It is generally accepted that the mechanism for long-distance navigation and homing in animals is based on a magnetic sense (e.g. birds, Mora et al., 2004; turtles, lobsters, and mollusks, Cain et al., 2005; fish, Walker, 1998; and recently in bats, Holland et al., 2008), although some may utilize a combination of electroreception and magnetic fields, as in elasmobranchs (Kalmijn, 1982). In addition to achieving directionality with a magnetic compass (e.g. Kirschvink, 1997; Mora et al., 2004; Wiltschko et al., 2007), birds rely heavily on their sharp visual sense and are known to use landmarks to aid their navigation. Conversely, in the aquatic environment, especially in deep water, visibility can be poor and landmarks are often absent, therefore, marine animals likely employ auxiliary modes of navigation. Walker et al. (2002) proposed a physiological mechanism for magnetic reception based on a chain of magnetically sensitive particles found in the nose of the rainbow trout (*Oncorhynchus mykiss*). It is not unlikely that the physiological process is conserved in many vertebrate taxa, although this theory remains controversial (Holland et al., 2008). Previous experiments with reef fish suggest that a combination of sensory modalities, including chemical, olfaction, auditory and visual cues are utilized for navigation depending on environmental conditions and distance from targets (e.g., Walker et al., 1997; Tolimieri et al., 2004; Mitamura, 2005; Døving et al., 2006; Mann et al., 2007).

While it is not always clear what compels fish to move when they do, a behavioral response such as homing must confer a fitness advantage for a species. The movement of fish between platforms, and between natural habitat and platforms suggests that the risks associated with leaving protective habitat (e.g. predation, disorientation, loss of habitat) and traversing great distances outweigh the costs of staying. Alternatively, the frequency of homing events might also indicate that the risks of leaving are low. Variation in temporal and spatial patterns of homing, movements, and area use among species and between individuals in this study illustrates behavioral plasticity present in adult rockfish and lingcod populations around offshore oil platforms; this, among other factors, may reduce competition and contribute to population stabilization.

Management

Results of this study have revealed significant and previously unknown movement behaviors and space use patterns for platform-associated groundfishes, which may have important implications not only for the management of these species, but to the platform decommissioning process as well. One of the goals of this project was to determine whether removing fish from oil platforms and ensuring their survival was a logistically feasible mitigation option to platform decommissioning. From a management perspective, the question should be broken down into two parts—one of survivability and the other of mitigation. Based on the longer-term patterns in detection after release, rockfishes and lingcod could indeed, be successfully translocated. Nonetheless, because a proportion of fishes (25% overall) homed back to platforms and did so relatively quickly after release (23 d), translocation for individuals with inclinations to home would probably not be a practical method for mitigation. Conversely, a larger proportion of fish did not home and appeared to have taken residency at Anacapa Island. Because fish that homed were larger, translocation for smaller individuals may be a more reasonable option. While it may work better for some species (e.g. widow, squarespot, blue rockfish) than others (lingcod, vermilion, and brown rockfish) the success of a large-scale translocation would depend on a multitude of biological and logistical factors, size of individuals, condition and care in handling of the fish, timing of platform removal, and the effort and financial costs.

Conclusion

Oil platforms are analogous to high-relief reefs that break the surface or offshore pinnacles in that they span the entire depth of the water column. As such, they may serve an important function for juvenile rockfishes that recruit to the upper limits of the structure and make ontogenetic movements toward the base of the jacket as they mature (Love et al. 1991; Love 1996; Lea et al. 1999). Adults at the bases of platforms may experience changes in their resource requirements, which could drive some individuals away from the platforms, but their return home indicates that they provide resources perhaps not available on nearby natural reefs.

The variation in movement observed in this study demonstrates a behavioral plasticity in rockfish and lingcod that may be important in reducing competition and density-dependent mortality on oil platforms and reefs with high abundances of fish. The oil platforms in this study may function not only as *de facto* marine reserves, but producers and exporters of adult stocks as well.

Because of their relative isolation from natural habitat, it was originally hypothesized by Lowe et al. (2009) that offshore oil platforms would retain fish for longer periods of time than natural habitat, but movements between platforms suggested that there may be connectivity between Platforms Gail, Gilda, and Grace. In the current study, translocating individuals revealed a wider-spread area of use for some species between platforms, Anacapa Island (and possibly Santa Cruz Island), and Grace Rock. Platforms Gail, Gilda, and Grace and nearby islands are well within migratory ranges of several species associated with the platforms and some individuals may be utilizing areas larger than the habitat surrounding base of the platforms.

Moreover, translocated fishes have an inclination to home back to their platforms of capture and the probability of remaining closely associated with them is high for some species and some individuals. Although offered natural, high-relief rockfish habitat, homing over 18 km across open water and discontinuous habitat further supports the hypothesis that offshore oil platforms may provide higher quality habitat than natural reefs in the east Santa Barbara Channel.

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