Abstract. – Movements of 25 yellowtail rockfish *Sebastes flavidus* on Heceta Bank, off Oregon, were studied by acoustical tagging and tracking during the summers of 1988–90. Some fish were tracked discontinuously up to 1 month after transmitters were inserted into their stomachs. In each year, some fish remained at the capture site after release or returned after displacement to a different release site. In 1990, the year of most intensive tagging, 11 of 12 fish were detected near the capture location 13 days after release in August 1990, including 3 of 4 fish displaced 0.5 nmi (0.9 km), all 4 fish displaced 2.0 nmi (3.7 km), and all 4 of the fish released at the capture site. One fish homed overnight from the release site 0.5 nmi away. In September 1990, 1 month after release, eight of these fish had dispersed up to 0.1–0.7 nmi (0.2–1.3 km) to the south of their capture location, suggesting a change in site fidelity. Pressure-sensitive transmitters showed that tagged yellowtail rockfish usually remained at midwater depths of 25–35 m, well above the sea floor depth of ~75 m. Rapid descents to nearbottom depths were common, but no obvious diel vertical or horizontal migrations were detected.

Manuscript accepted 13 July 1992.
Fishery Bulletin, U.S. 90:726–735 (1992).

Movements of acoustically-tagged yellowtail rockfish *Sebastes flavidus* on Heceta Bank, Oregon

William G. Pearcy
College of Oceanography, Oregon State University, Corvallis, Oregon 97331-5503

The yellowtail rockfish *Sebastes flavidus* is a common rockfish along the west coast of North America. It is caught by both commercial and recreational fishermen and was one of the most abundant rockfish species in commercial groundfish landings from the U.S. west coast from 1982 to 1990 (Pacific Fisheries Management Council 1991).

Schools of yellowtail rockfish may persist at the same location for many years. Carlson (1986) reported that a school of adult yellowtail rockfish in southeastern Alaska consisted of individuals from one or two year-classes and had negligible recruitment over an 11-year period. Because their aggregrations may be site-specific with limited interchange of adults, and because rockfish are long-lived, late-maturing, and of low fecundity (Gunderson et al 1980, Love et al. 1990, Eldridge et al. 1991), overfishing or disturbances, such as habitat modifications from offshore mining or petroleum development, may have long-lasting effects in a local area. On the other hand, a rockfish species whose individuals move freely from reef to reef may be less vulnerable to localized disturbances (Love 1979). The stability and areal range of rockfish aggregations have important implications for assessment, availability, and management of rockfish species.

The yellowtail rockfish is the most abundant, large-sized schooling fish seen from submersibles over the shallow, rocky areas on the top of Heceta Bank, a deep reef located ~55 km off the central Oregon coast (Pearcy et al. 1989; Figs. 1 and 2). Large pelagic schools, sometimes of a thousand or more individuals, were observed over shallow portions of the bank (<150 m) during the summer. Based on both observations from submersible dives and the occurrence of large echo-groups recorded by the ships' echosounders, these schools were often associated with pinnacles or high-relief topography (Pearcy et al. 1989).

During one dive, a school of yellowtail rockfish followed the submersible along the bottom for over an hour before abruptly turning and swimming back toward the location where the school was initially encountered (Pearcy et al. 1989). This observation and those of Carlson and Haight (1972), who found that individual rockfish returned to a home site in southeast Alaska after being displaced as far as 22.5 km, suggest that schools of yellowtail rockfish may have home ranges centered around a specific site on the bank.

Pelagic rockfishes, such as the yellowtail rockfish, may range over wider areas than benthic rockfishes. However, little is known about the vertical distribution or diel vertical migrations of yellowtail rockfish, or the relationships between vertical and horizontal movements.

This study used acoustical tracking to determine the horizontal and vertical movements and site-specificity of yellowtail rockfish on Heceta Bank. In this paper, I define site-specificity as the tendency of fish to inhabit a specific localized area as opposed to free-ranging or vagrant

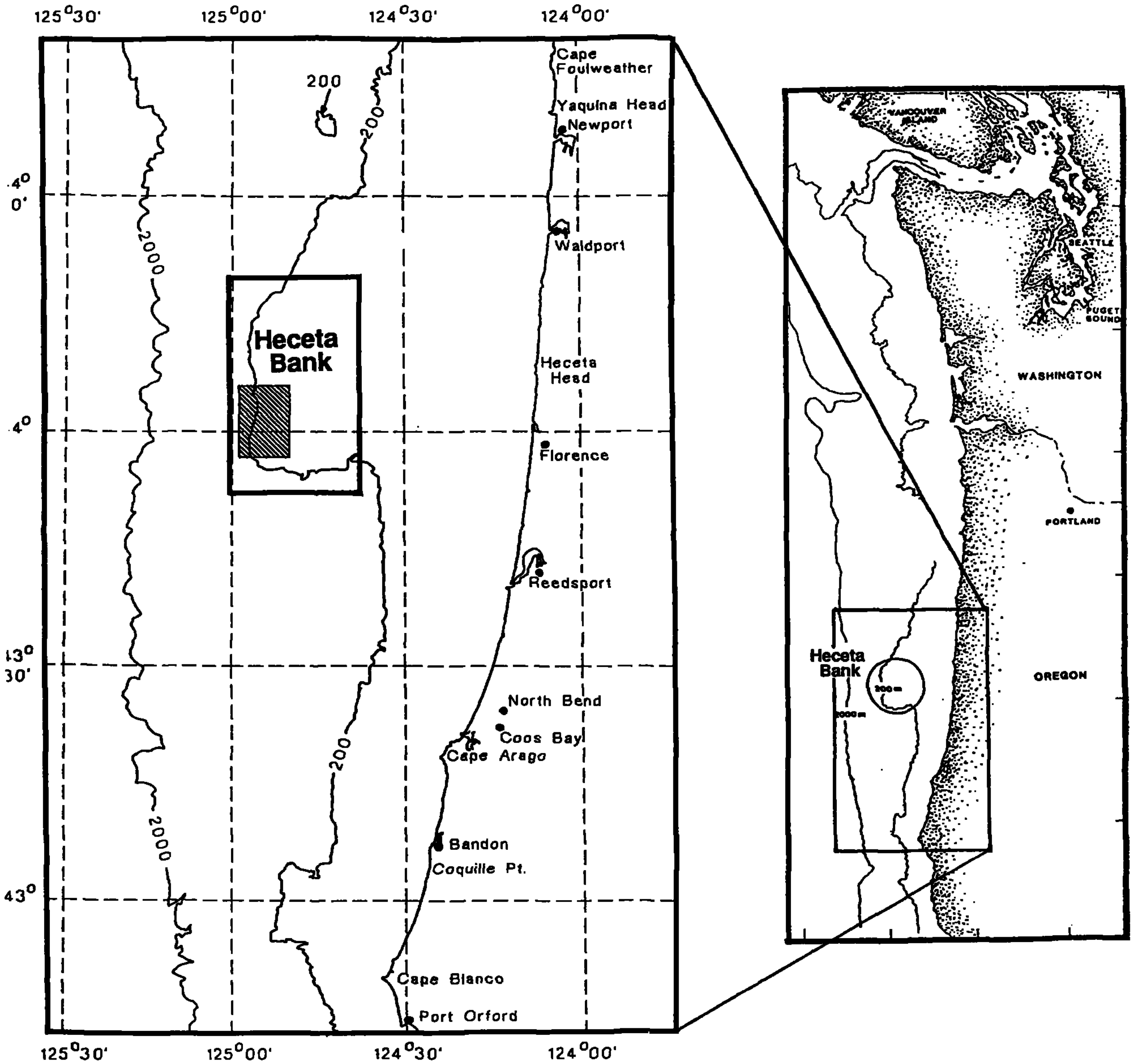

Figure 1
Location of Heceta Bank off Oregon. Hatched area of the bank encompasses the area of this study as shown in Figure 2 (depth contours in meters).

behavior. Homing is defined as returning to a site formerly occupied instead of to equally probable locations. Homing does not imply a direct, straight-line course back to the home site.

Yellowtail rockfish are ideal for acoustical tracking because they are common, large in size, and do not suffer from the lethal embolisms of other rockfishes when brought to the surface, but instead expel swimbladder gases during decompression*.

* Bubbles of gas were observed emanating from the region of the opercle as yellowtail rockfish were reeled from about 2–3 m depth to the surface. By immersing fish in tanks aboard ship, these bubbles were seen forming and being expelled from under the thin skin between the last gill and the cleithrum anterior to the base of the pectoral fin. Samples of the gas were collected in syringes and analyzed with a microgasometer using the methods of Scholander et al. (1955). The gas was comprised of about 75% oxygen, indicating that gases from the swimbladder were released without causing lethal embolisms when yellowtail rockfish were rapidly decompressed.

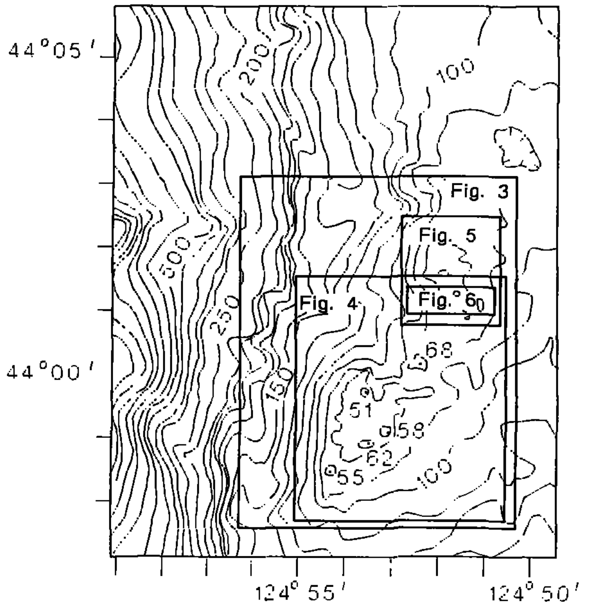

Figure 2
Topography of the southern portion of Heceta Bank and the areas encompassed in Figures 3–6. Depths are in meters.

Table 1
Information on tag retention in 5 yellowtail *Sebastes flavidus*, and 5 black *S. melanops*, rockfishes aboard ship (S) and in the laboratory ashore (L). ARM = tags with hooks (anti-regurgitation mechanisms).

Date	S/L	Tag	Days to regurgitate (or die)
S. flavidus			
Sep 1988	S	External	(3)
	S	Stomach	1,2,(6)
Aug 1990	L	Stomach–ARM	11
S. melanops			
Apr 1990	L	Stomach	1
	L	Stomach–ARM	9
Jul 1990	L	Stomach	0.5
	L	Stomach–ARM	2,89

Methods

Yellowtail rockfish were captured with hook-and-line during the daytime and placed in deck tanks with circulating seawater. Acoustical transmitters were inserted into the stomachs of large (42–54 cm fork length), active, uninjured, unanesthetized fish with a 1 cm diameter rod. Most fish were males. Fish were released within 15 min at the capture site or within 30 min at displaced locations. Displaced fish were released over bottom topography and depths known to be inhabited by yellowtail rockfish (except in 1988), and within 2 nmi of the capture location to facilitate survey of several release sites during a cruise. They were tracked using a directional hydrophone and acoustical receiver. Four fish tracked during 1989 were also tagged with external Floy tags.

Preliminary tagging

Before this study began, a few tests were conducted in circulating seawater tanks aboard ship or in the laboratory to evaluate methods of tagging pelagic rockfishes on five yellowtail and five black rockfishes (Table 1). Dummy tags of the same dimensions and weight as those used in the study were inserted into the stomach or attached externally to the side of fish under the dorsal fin. The external tag attachment, similar to the one used by Matthews et al. (1990) for benthic rockfish, caused one fish to list to one side and interfered with its swimming. It died after 3 days in the ship's tank. Three fish with tags inserted in their stomachs had normal orientation in deck tanks and were more active. One of these fish died after 6 days.

Stomach insertion of tags was used in this study. This method is quick and minimizes handling and trauma to the fish (Stasko and Pinock 1977). The major disadvantage was possible regurgitation of tags (Table 1 and Results), although Stasko and Pincock (1977) reported that transmitters inserted into the stomachs of many other species of fishes were not disgorged. During the last year, to increase the retention of tags in the stomachs, one or two small (no. 18 steel dry fly) hooks were attached to the ends of tags with epoxy as anti-regurgitation mechanisms (ARM's). Hooks protruded 2 mm from the tag. In experiments in large aquaria or tanks in the laboratory, tags with ARM's stayed inside either black rockfish *S. melanops* or yellowtail rockfish a total of 2, 9, 11, and 89 days compared with 0.5, 1, 1, and 2 days (and one that died after 6 days) for controls without ARM's (Table 1).

Equipment

Acoustical tracking equipment (VEMCO Ltd.) was used in this study, including a VR-60 receiver with preset channel frequencies, a telemetry decoder and display unit, directional hydrophone, and transmitters or tags with five different crystal-controlled frequencies. Transmitters were 16 mm in diameter, 48–65 mm in length, with batteries of 4.5, 9, 21, and 60 days rated life-span. In 1990, transmitters with the same frequencies had different pulse widths and pulse periods which were decoded and displayed by the receiver. The transmitters had a rated range of 500–1500 m.

Pressure-telemetering transmitters with battery durations of 4.5 days were used in 1989 and 1990. The pulse rates of these transmitters were linearly proportional to pressure, and individual calibrations were incorporated into the receiver program. The manufacturer claimed accuracy was 5% of the full range, or 5 psi (~3 m depth), similar to my test of two tags lowered vertically on a metered line at sea. Data on depths of fish and time of day from these transmitters were printed at regular intervals aboard ship and stored in the receiver. During 1989, depths and times were recorded manually every 5 min or less. During 1990, data on time and depth were stored automatically by the receiver every 0.5 sec. Median depths were calculated for every 25-sec period and plotted by computer.

Field procedures

Research was conducted using either the RV *William A. McGaw*, a 32 m ship used to support submersible research, or the FV *Corsair*, an 18 m trawler. Echosounders were used to scout concentrations of fish over the shallow (60–90 m) portions of Heceta Bank. When dense midwater schools of fish were detected, weighted fishing lines with jigs were lowered to catch fish. Only yellowtail rockfish were caught from these midwater schools, which were usually at depths of 20–40 m. Often the schools were so compact that our fishing weights bounced off fish at these depths. If yellowtail rockfish were readily caught, our position was recorded and an anchored surface float was released from the *Corsair* to provide a fixed reference to prevent drifting off-station and assist tracking of fish.

Transmitter signals were detected with a directional hydrophone attached to the end of a 4 m rotatable pole mounted to the side of the vessels. The hydrophone pole was rotated through 360° until the signal strength of a transmitter was maximal. Then the vessel headed directly toward the transmitter. Signal strength increased as the range closed. When signal strength was equally high in all directions or when the direction of the signal decreased rapidly, we assumed that the fish was in the vessel's immediate vicinity and our location was then determined by LORAN C. Repeated positions for stationary transmitters on the bottom were within 0.1 nmi (~180 m) from one another. Repeatable accuracy of Loran C for one vessel is about 100 m (Dugan and Panshin 1979).

Results

Horizontal movements

1988 (Fig. 3) Four yellowtail rockfish were caught near the bottom, tagged, and released during September 1988. Three fish were released where they were caught, and the fourth was displaced about 1 nmi seaward of its catch location. Fish 1 was caught and released over a shallow (71 m), high-relief rocky area of Heceta Bank on 15 September (Fig. 3). Three locations were determined immediately after release, three after 12 h, and two after ~24 h. All locations were within 0.5 nmi of one another, and the last was 0.1 nmi from the capture site. Fish 2 and 3 were caught, released, and detected once over the southernmost shallow portion of Heceta Bank at a depth of 80 m on 13 September. One of these fish was located ~0.75 nmi (1400 m) east of its capture location after 7 h. The other fish was found within 200 m of the release site 17 h after release.

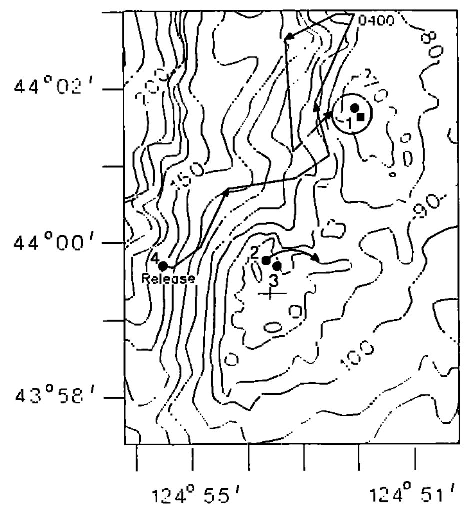

Figure 3
Locations and tracks of yellowtail rockfish *Sebastes flavidus* tagged and released in 1988. Fish 1, released 15 September at 1919 h (●), was located 24 h later (■), and was found within the open circle (O) during seven intervening fixes. Fishes 2, 3, and 4 were released 13 September (●) and followed indicated paths. Fish 3 moved less than 200 m.

To determine if a stationary transmitter location was the result of a regurgitated tag, the submersible *Delta*, with a separate hydrophone and receiver, dove on Fish 3, which remained close to the release site. The ship maintained position over this transmitter as the submersible was launched. Although a strong signal was recorded from the transmitter, its bearing changed frequently, indicating that the tag was moving and had not been regurgitated. This was confirmed when the bearing of the transmitter changed 180° as a school of several hundred fish swam under the submersible. The fish transmitting the signal had two external Floy tags but was not seen.

The fourth fish was captured at the southern high spot of Heceta Bank (80 m depth, same date and capture site as Fishes 2 and 3) and released 27 min after capture 1.3 nmi offshore in a habitat where yellowtail rockfish were rarely seen—where the bottom was 150 m, flat, and comprised of fine sediments. Between 1727 h on 7 September and 0730 h the next day, this fish was tracked continuously (Fig. 3). It moved to the northeast until 0400 h, turned south, but then resumed its northeasterly course, ending up near the 75 m depth contour just west of a shallow region of the bank, about 2 nmi from its capture location.

1989 (Fig. 4) Two experiments were conducted in 1989 to further investigate horizontal movements: one involved three fish caught and released with pressure-telemetering transmitters at a station on 21 August (1 fish) and 24 August 24 (2 fish). The other experiment included six fish, three of which were released at the capture site and three displaced 1.1 miles away, on 25 August. All fish were caught in midwater at ~79 m.

Fish 2 in the first experiment was released at site A and was tracked continuously for 11 h after release. During this time it stayed within ~0.2 nmi of the release site, which was marked by a surface buoy. We returned to this location 36 h later and found this fish 0.5 nmi to the east. After 1.5 h it returned to the release site and was located several times in this vicinity during the next 56 h (Fig. 4).

Two other fish were caught, tagged, and released 3 days later, at site B, and tracked for about 24 h. Acoustical signals of these two fish stayed within 0.2 nmi of the release location during this period.

In the second experiment, six fish were caught at site B on 25 August. Three fish (10, 11, 12) were released at the capture location and three (7, 8, 9) were displaced 1.1 nmi to the northeast of site C and released in 77 m of water. When we returned to these locations 9 days later, two (7 and 9) of the three tags from fish displaced to site C were detected and remained there over the next 36 h. Distinctive double pings from these two tags were heard on the receiver, indicating that the tags had been regurgitated and were on the bottom.

Fish 10 and 11, which were released at capture site B, were detected ~0.1 nmi south of site B 9 days after capture. Signals from the third fish (12) were not detected. The transmitter from displaced Fish 8 was detected ~0.4 nmi to the east of the capture site. Within the next 36 h, this fish moved to within 0.2 nmi of the capture location, and its last position was 0.3 nmi from the capture site.

The submersible *Delta* was used to dive on one of the tags that was stationary at the displacment location (site C). This transmitter was found lying on top of a large rock.

1990 (Figs. 5 and 6) During 1990, transmitters with ARM's were inserted into 12 yellowtail rockfish. All fish were caught during early evening (1900 h) on 15 August in mid-

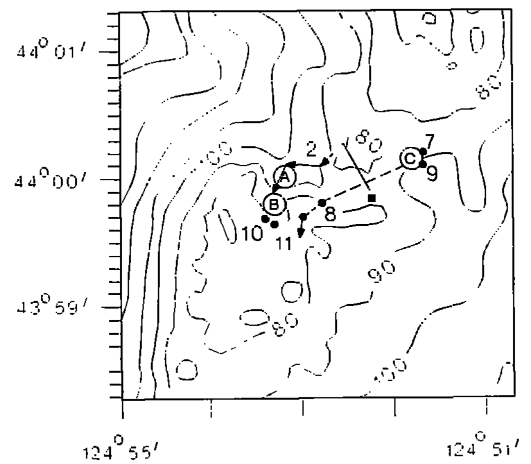

Figure 4
Locations and tracks of yellowtail rockfish *Sebastes flavidus* released in 1989. See text for details. Dashed line is the assumed path of Fish 8.

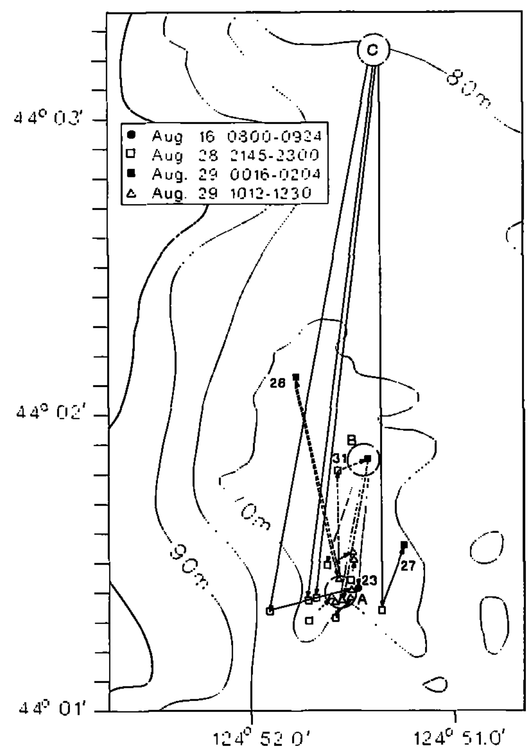

Figure 5
Tracks of 11 yellowtail rockfish *Sebastes flavidus* captured at site A and released at sites A (dashed lines), B (dotted lines), and C (solid lines) on 15 August 1990. Symbols designate dates and times that positions were obtained (see legend).

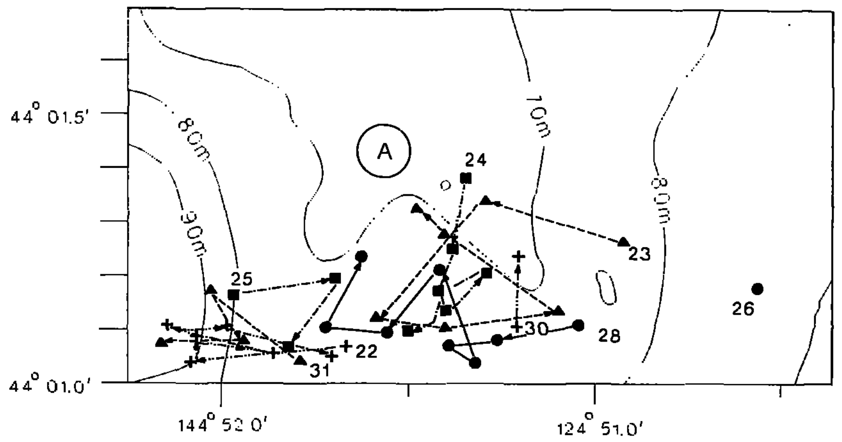

Figure 6
Tracks of eight of the yellowtail rockfish *Sebastes flavidus* released on 15 August, one month later during the period 16–18 September 1990. Symbols designate positions of each fish.

water above a 68 m rocky bottom. Four of these fish were released at capture site A, four at 0.5 nmi to the north (site B, bottom depth 70 m), and four at 2.0 nmi to the north (site C, bottom depth 87 m) (Fig. 5). The two release sites to the north of the capture site had high-relief bottom topography, similar to the capture site. In addition, schools of rockfish, similar in appearance acoustically to those comprised of yellowtail rockfish, were observed in the vicinity of the two displacement sites. Since yellowtail rockfish are numerous over shallow (<100 m) rocky ridge, boulder, and cobble habitats of Heceta Bank, and schools of yellowtail rockfish were seen from submersibles near release sites B and C (Pearcy et al. 1989, Hixon et al. 1991), I assumed that the transplant release sites were habitable by yellowtail rockfish.

The morning after the releases, all four of the transmitters in fish released at capture site A were detected within 0.1 nmi of site A. One of the fish (23) released 0.5 nmi to the north returned to the capture site overnight, after 17 h. No transmitters were detected at the other two release sites on the following day when the ship passed over these locations and departed the bank.

Eleven of the twelve fish were located 13 days after release when we returned to Heceta Bank, including all four released at site C (2.0 nmi to the north) (Fig. 5). The missing transmitter was from site B. All 11 fish were found at least once within 0.15 nmi of the capture site (Fig. 5). These results are evidence for a strong homing tendency.

Two fish that were caught and released at the original capture location (site A) showed the most extensive short-term movements (Fig. 5). Fish 26 was located 0.8 nmi and Fish 31 was found 0.5 nmi north of site A during the night and early morning of 28–29 August, 14 days after release. Both returned to site A about 11 h later. Fish 27, displaced to site C, was found 0.15 nmi east of capture site A and then moved 0.24 nmi to the north during a 2-hour period on the evening of 29 August.

One month after releases, we returned to the capture location to study longer-term movements. No transmitters were detected in the immediate vicinity of the original capture location. Using an expanding rectangular search pattern, 8 of the 12 transmitters were discovered, all south and a distance of ~0.1–0.7 nmi from the capture location. Locations of these fish were determined over the next 2.5 days during three periods between submersible operations. The fish were scattered along a 1.1 nmi east-west axis (Fig. 6). Most fish demonstrated short-term movements of over 0.1 nmi (our nominal error of navigation) during these 2.5 days. Two fish (23 and 28) moved ~0.5 nmi. Only one fish (22) ended up near the location where it was initially found on this cruise. None of these eight fish was found closer than 0.1 nmi to the original capture site, and most were 0.4 nmi away. There was no evidence that these fish stayed in a common school or within a small home range, as found earlier in the summer.

Vertical movements

Pressure-telemetering (depth sensor) transmitters were used during 1989 and 1990, but due to problems with the receiver, limited data were obtained. Figure 7 shows the maximum and minimum depths for 10-min intervals for three fish monitored almost continuously during 21–22 and 24–25 August 1989. Fish were usually in midwater, inhabiting depths of 25–50 m where the bottom was ~75 m. Short-duration vertical movements were seen for all fish, usually rapid descent/ascent ("bounce") dives to or close to the bottom, followed by rapid vertical ascents back to depths of 25–35 m. Fish 2 made nine of these "bounce dives" to the bottom during the early morning of 24 August over about a 4 h period. Other than this series of dives, there was little evidence for any diel patterns in the frequency of vertical migrations of fish that were tagged. Fish 3 either regurgitated its transmitter or rested on the bottom after 0700 h on 25 August (Fig. 7).

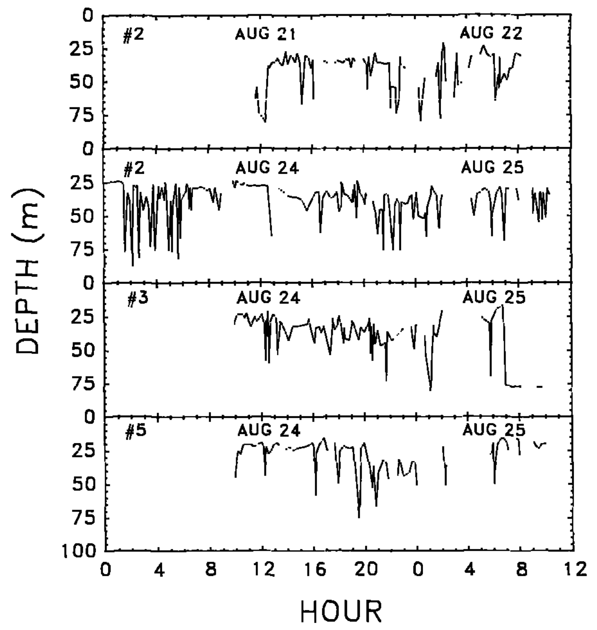

Figure 7
Depths of yellowtail rockfish *Sebastes flavidus* nos. 2, 3, and 5 measured with pressure-telemetering transmitters during 21–25 August 1989. Bottom depths 75–99 m during this period.

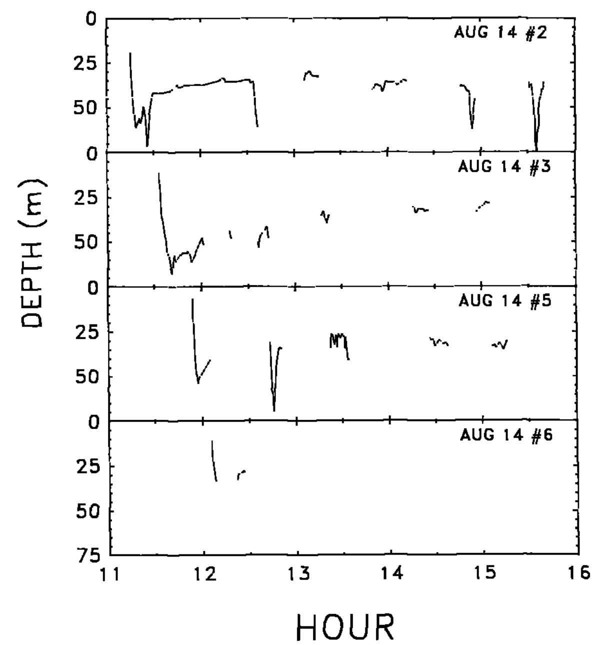

Figure 8
Depths of yellowtail rockfish *Sebastes flavidus* nos. 2, 3, 5, and 6 measured with pressure-telemetering transmitters during 14 August 1990. Bottom depths 75–80 m.

Vertical excursions of fish during late morning and afternoon of August 1990 showed a similar pattern, with fish occupying midwater depths and occasionally diving to deep water (Fig. 8). The records for Fishes 2 and 3 show that these fish descended toward the bottom immediately after release and then rose to progressively shallower depths during the next several hours. Synchronous vertical movements of several fish were not common (Figs. 7, 8) but some did occur among the three fish tracked during 25 August 1990 (Fig. 8). Sometimes fish dove as the vessel approached, perhaps a response to ship noise (Ona and Godoe 1990), but at other times fish descended when the vessel was not underway.

Maximum rates of descent for fish shown in Figure 8 were 0.16–0.40 m/sec; maximum ascents were 0.15–0.31 m/sec. Figure 9 shows the dive of Fish 5 after release, with the most rapid descent during the first minute, and slower rates in the next 3 minutes. Rapid vertical movements were also observed during 1989, with maximum rates of descent of 0.15–0.45 m/sec, and rates of ascent of 0.15 m/sec.

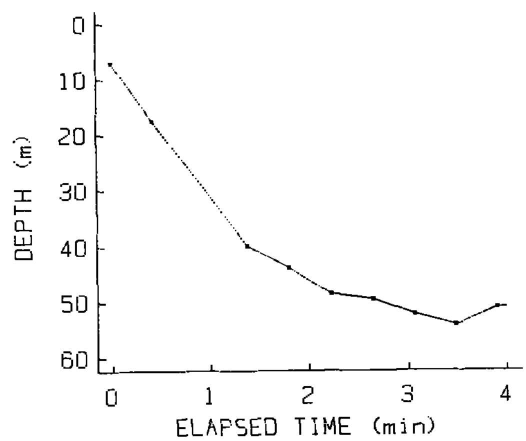

Figure 9
Initial descent of yellowtail rockfish *Sebastes flavidus* no. 5, starting at 1154 h, 14 August 1990, after release at the surface (see Fig. 8).

Discussion

Homing and horizontal movements

During all three years of the study, yellowtail rockfish on Heceta Bank demonstrated site fidelity and homing. Displaced fish returned from as far as 2 nmi from their capture site, and those released over rocky habitat and at similar depths returned to the location of capture in 1990. Eleven of twelve fish tagged in 1990 returned to or remained close to the original capture site 13 days after release. One fish that was displaced 0.5 nm returned overnight to the location where it was captured.

Carlson and Haight (1972) also found that adult yellowtail rockfish returned to their home site, some from as far as 22.5 km, some after displacement to other yellowtail schools, and some after 3 months in captivity. In both studies, yellowtail rockfish homed even if released at sites where the habitat was similar to that at the capture site and near other schools of yellowtail rockfish. This demonstrates fidelity to a home site.

Not all yellowtail rockfish demonstrate site fidelity, however. Eight of ten recoveries of 153 yellowtail rockfish tagged in Puget Sound were from the open Washington coast, 58–2214 days after release, indicating an offshore migration probably related to the onset of maturation of these fish (Mathews and Barker 1983). In another study, Stanley (1988) tagged 4622 yellowtail rockfish in Queen Charlotte Sound, British Columbia during 1980 and 1981. As of 1987, the five that were recovered moved from <10 km to >300 km. Of 9417 yellowtail rockfish tagged southwest of Vancouver Island, 24 were recovered. Twelve moved <10 km while others were recovered 23 to >500 km from the tagging location (Stanley 1988).

The degree of site fidelity and movement of yellowtail rockfish may be related to the bottom topography of the tagging location. This appears to be the case for black rockfish, another offshore pelagic species. Culver (1987; B.N. Culver, Wash. Dep. Fish., Montesano, pers. commun.) found that black rockfish tagged over a 5-year period from rocky habitats of northern Washington exhibited "no significant movement," whereas fish tagged in areas that had sandy sediments or small pinnacles off the central Washington and northern Oregon coast displayed appreciable movements. Perhaps yellowtail rockfish on Heceta Bank, and other rocky banks, are less mobile than those inhabiting areas with level seafloors.

Carlson and Haight (1972) found that fish displaced to sites across open water with depths >100 m returned to the site of capture with much less frequency than did fish released along the adjacent coast in shallower depths. One fish in my study, released in relatively deep water off Heceta Bank and tracked continuously for 14 hours (Fish 4, Fig. 3), was not oriented toward its home site. These observations suggest that homing is most effective over relatively shallow water (<100 m), even though yellowtail rockfish are basically midwater fish. Homing may also be influenced by topography. Matthews et al. (1987) reported that displaced copper and quillback rockfishes *S. caurinus* and *S. maliger* returned to high-relief, but not to low-relief, reefs.

The sensory mechanisms and environmental cues used for homing and home-site recognition by yellowtail rockfish are not known. Possibly the fish on Heceta Bank recognized familiar topography and prominent "landmarks." Movements of up to 0.75 nmi by yellowtail rockfish (Figs. 5 and 6) indicate that they do not always have as small a home range and may range over a large portion of the bank. Perhaps they learn visual "landmarks" over much of the bank in this way.

One fish returned to its home site from 925 m after only 11 hours, mainly during the night when recognition of visual landmarks would have been more difficult. This fish returned home more rapidly than substrate-associated copper and quillback rockfishes that took 8–25 days to return home after displacement of only 500 m (see Matthews 1990 for this and summary of homing by other rockfishes). This suggests oriented or directed movement.

Eight of the twelve fish tagged in August 1990 were relocated 1 month after release but were all south of the capture location and scattered in an east-west direction. None was found within 0.1 nmi of the capture site. This dispersal from the capture site suggests reduced site fidelity and perhaps seasonal dissociation of individuals from the large schools observed earlier during the summer. This dispersal may be associated with seasonal changes, perhaps related to mating behavior and the fact that most of the fish tagged were large males. Carlson and Barr (1977) reported that the spatial distribution and activity of yellowtail and dusky (*S. ciliatus*) rockfishes differed markedly between May–October, when they were seen in the water column and apparently actively feeding, and November–April, when they withdrew into crevices between boulders. Although no distinct seasonal changes are known in the bathymetric distribution of yellowtail rockfish (J. Tagart, Wash. Dep. Fish., Olympia, pers. commun., Aug. 1991), the spatial distributions of other species of rockfishes are known to change seasonally (Miller and Geibel 1973, Patten 1973, Matthews et al. 1987). Several species of juvenile rockfishes are known to move to deeper reefs with the onset of fall and winter storms (Love et al. 1991). It would be interesting to learn if the yellowtail rockfish of Heceta Bank disperse and become more benthic during the late fall and winter, and then if they eventually regroup at the original capture location next spring after spawning, or instead acquire new home sites on the bank. Studies are obviously needed on seasonal and long-term movements of yellowtail rockfish.

Diel vertical movements

Most yellowtail rockfish were seen swimming above the bottom during submersible dives on Heceta Bank. However, a few were observed resting on the sea floor. More fish were observed inactive on the bottom during night than day dives. The tagged yellowtail rockfish of Heceta Bank were pelagic, swimming far above the bottom most of the time. Data from pressure-telemetering tags show that fish dove toward the bottom but remained there only briefly. Only one fish with a pressure transmitter either rested on the bottom for an extended period or disgorged its transmitter (Fig. 7).

Little is known about the diel vertical distribution of rockfishes. Schools of *S. entomelas* and *S. proriger* are known to rise off the bottom during the night and become more diffuse than dense schools on the bottom during the day (Leaman et al. 1990). Rockfish may intercept vertically-migrating pelagic organisms that constitute their primary prey, feeding closer to the surface at night or during crepuscular periods and descending with their prey during the day. Sometimes vertically migrating prey, such as euphausiids, are advected onto banks and seamounts and trapped near the bottom during the day where they are devoured by rockfishes (Isaacs and Schwartzlose 1965, Chess et al. 1988, Genin et al. 1988, Hobson 1989). Euphausiids are often the primary prey of adult yellowtail rockfish (Lorz et al. 1983). About 50% of the diet by weight of yellowtail rockfish from Heceta Bank was comprised of euphausiids (Brodeur and Pearcy 1984). However, vertically-migrating mesopelagic fishes and shrimp were the primary food items of yellowtail rockfish collected in deeper water (137 m bottom depth) along the southern edge of Astoria Canyon (Pereyra et al. 1969).

Yellowtail rockfish from Heceta Bank did not demonstrate obvious diel changes in their behavior by either rising closer to the surface at night or swimming over deeper water to intercept more oceanic organisms. Such behavior has been observed for other species of rockfishes (Chess et al. 1988, Leaman et al. 1990), and predatory shore fishes are known to migrate offshore at night to feed in midwater (Hobson 1968). One yellowtail rockfish on Heceta Bank with a pressure-telemetering transmitter made more dives to the bottom during night than day.

The reasons for dives to the bottom are unclear. One possible explanation is that these dives assist the fish in localizing their position on the bank and preventing drift of the school away from their home station. Surface currents often set the ship away from tagged fish that appeared to be geostationary. Yellowtail rockfish must be able to orient to a specific site and swim against prevailing currents to maintain their position.

Tagging-tracking techniques

Sonic tags inserted into the stomachs of yellowtail rockfish without retention hooks were useful for tracking fish for several days. Most fish showed detectable movements up to 2 days after release. Horizontal movements greater than the accuracy of fixes were found in one fish 10 days later, but this was an exception. Depth sensor tags provided reliable information on the retention of tags since fish were almost always in midwater. Fish with depth transmitters remained in midwater up to 5 days, the rated duration of the batteries. One pressure-sensitive tag (Fish 3, Fig. 7) was apparently regurgitated after 22 h and fell to the bottom. If ARM's were employed on tags, fish movements were measurable for 1 month after release. One ARM tag dropped to the bottom immediately after the fish was released, demonstrating that restraining hooks are not a guarantee that tags will stay in the stomach. Eight of the twelve fish with non-pressure telemetering ARM tags that were relocated moved significant distances 30 days after the release of fish, indicating long-term retention of transmitters.

Effects of the transmitter on behavior of the fish are not known. However, one fish apparently schooled soon after release. Although fish dove toward the bottom immediately after release, they rose to typical midwater depths after less than an hour. These observations suggest that the trauma of being caught, tagged, and released, and the added weight of the transmitter, did not have prolonged effects and tagged fish behaved normally.

Acknowledgments

This research was supported by the Department of Interior's U.S. Minerals Management Service (Cooperative Agreement 14-12-0001-30445). NOAA's National Undersea Research Program provided supplemental shiptime and submersible support. I thank J.P. Fisher, B.N. Tissot, R. Albright, and the Captain of the FV *Corsair*, W. Dixon, and his crew for conducting this research at sea, J.P. Fisher for his help with analyses of the data, and J.P. Fisher, A. Schoener, M.A. Hixon, and two anonymous reviewers for helpful comments on the manuscript. A. Ebeling and M.A. Hixon provided the microgasometer and advice to determine the composition of gas escaping from decompressed yellowtail rockfish.

Citations

Brodeur, R.D., and W.G. Pearcy
1984 Food habits and dietary overlap of some shelf rockfishes (genus *Sebastes*) from the northeastern Pacific Ocean. Fish. Bull., U.S. 82:269–293.

Carlson, H.R.
1986 Restricted year-class structure and recruitment lag within a discrete school of yellowtail rockfish. Trans. Am. Fish. Soc. 115:490–492.

Carlson, H.R., and L. Barr
1977 Seasonal changes in spatial distribution and activity of two species of Pacific rockfishes, *Sebastes flavidus* and *S. ciliatus*, in Lynn Canal, southeastern Alaska. Mar. Fish. Rev. 39(3):23–24.

Carlson, H.R., and R.E. Haight
1972 Evidence for a home site and homing of adult yellowtail rockfish, *Sebastes flavidus*. J. Fish. Res. Board Can. 29: 1011–1014.

Chess, J.R. , S.E. Smith, and P.C. Fischer
1988 Trophic relationships of the shortbelly rockfish, *Sebastes jordani*, off central California. Calif. Coop. Oceanic Fish. Invest. Rep. 29:129–136.

Culver, B.N.
1987 Results from tagging black rockfish (*Sebastes melanops*) off the Washington and northern Oregon coast. *In* Proc., Int. rockfish symp., p. 231–239. Univ. Alaska Sea Grant Rep. 87-2, Fairbanks.

Dugan, R.F., and D.A. Dashin
1979 How to get the most out of LORAN-C. Oregon State Univ. Ext. Mar. Advis. Prog. SG-54, Corvallis, 12 p.

Eldridge, M.B., J.A. Whipple, M.J. Bowers, B.M. Jarvis and J. Gold
1991 Reproductive performance of yellowtail rockfish, *Sebastes flavidus*. Environ. Biol. Fish. 30:91–102.

Genin, A., L. Haury, and P. Greenblatt
1988 Interactions of migrating zooplankton with shallow topography: Predation by rockfishes and intensification of patchiness. Deep-Sea Res. 35:151–175.

Gunderson, D.R., P. Callahan, and B. Goiney
1980 Maturation and fecundity of four species of *Sebastes*. Mar. Fish. Rev. 42(3):74–79.

Hixon, M.A., B.N. Tissot, and W.G. Pearcy
1991 Fish assemblages of rocky banks of the Pacific Northwest. Final Rep. to U.S. Dep. Int., Minerals Manage. Serv., MMS 91-0052, Oregon State Univ., Corvallis, 409 p.

Hobson, E.S.
1968 Predatory behavior of some shore fishes in the Gulf of California. U.S. Fish. Wildl. Serv. Res. Rep. 73, 92 p.
1989 Predation on ocean krill. Science (Wash. DC) 243:237.

Isaacs, J.D., and R.A. Schwartzlose
1965 Migrant sound scatterers: Interaction with sea floor. Science (Wash. DC) 150:1810–1813.

Leaman, B.M., R. Kieser, P. Withler and R.D. Stanley
1990 *W.E. Ricker* hydroacoustic cruise to study rockfish behavior off northern Vancouver Island, March 14–23, 1990. Can. Manuscr. Rep. Fish. Aquat. Sci. 2091, 63 p.

Lorz, H.V., W.G. Pearcy, and M. Fraidenburg
1983 Notes on the feeding habits of the yellowtail rockfish, *Sebastes flavidus*, off Washington and in Queen Charlotte Sound. Calif. Fish Game 69:33–38.

Love, M.S.
1979 Isolation of olive rockfish, *Sebastes serranoides*, populations off southern California. Fish. Bull., U.S. 77:975–983.

Love, M.S., P. Morris, M. McCrae, and R. Collins
1990 Life history aspects of 19 rockfish species (Scorpaenidae: *Sebastes*) from the southern California Bight. NOAA Tech. Rep. NMFS 87, 38 p.

Love, S.M., M.H. Carr, and L.J. Haldorson
1991 The ecology of substrate-associated juveniles of the genus *Sebastes*. Environ. Biol. Fish. 30:225–243.

Mathews, S.B., and M.W. Barker
1983 Movements of rockfish (*Sebastes*) tagged in northern Puget Sound, Washington. Fish. Bull., U.S. 82:916–922.

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

Matthews, K.R., B.S. Miller, and T.P. Quinn
1986 Movement studies of nearshore demersal rockfishes in Puget Sound, Washington. *In* Proc., Int. rockfish symp., p. 63–72. Univ. Alaska Sea Grant Rep. 87-2, Fairbanks.

Matthews, K.R., T.P. Quinn, and B.S. Miller
1990 Use of ultrasonic transmitters to track demersal rockfish movements on shallow rocky reefs in Puget Sound, Washington. *In* Parker, N., et al. (eds.), Fish marking techniques, p. 375–379. Am. Fish Soc. Symp. 7, Bethesda.

Miller, D.J., and J.J. Geibel
1973 Summary of blue rockfish and lingcod life histories; a reef ecology study; and giant kelp, *Macrocystis pyrifera*, experiments in Monterey Bay, California. Calif. Fish Game Fish Bull. 158, 137 p.

Ona, E., and O.R. Godoe
1990 Fish reaction to trawling noise: The significance to trawl sampling. *In* Karp, W.A. (ed.) Developments in fisheries acoustics: A symposium held in Seattle, 22–26 June 1987. Rapp. P.-V. Reun. Cons Int. Explor. Mer 189:159–166.

Pacific Fisheries Management Council
1991 Status of the Pacific coast groundfish fishery through 1991 and recommended acceptable biological catches for 1992. Pac. Fish. Manage. Counc., Portland, 69 p.

Patten, B.G.
1973 Biological information on copper rockfish in Puget Sound, Washington. Trans. Am. Fish. Soc. 102:412–416.

Pearcy, W.G., D.L. Stein, M.A. Hixon, E.K. Pikitch, W.H. Barss, and R.M. Starr
1989 Submersible observations of deep-reef fishes of Heceta Bank, Oregon. Fish. Bull., U.S. 87:955–965.

Pereyra, W.T. , W.G. Pearcy, and F.E. Carvey
1969 *Sebastes flavidus*, a shelf rockfish reeding on mesopelagic fauna, with consideration of ecological implications. J. Fish. Res. Board Can. 26:2211–2215.

Scholander, P.F., L. Van Dam, C.L. Claff, and J.K. Kanwisher
1955 Micro gasometric determination of dissolved oxygen and nitrogen. Biol. Bull. (Woods Hole) 109:328–334.

Stanley, R.D.
1988 Shelf rockfish (silvergray, yellowtail, and canary rockfish. *In* Fargo, J., et al. (eds.), Groundfish stock assessments for the west coat of Canada in 1987 and recommended yield options for 1988, p. 227–272. Can. Tech. Rep Fish. Aquat. Sci. 1617.

Stasko, A.B., and D.G. Pincock
1977 Review of underwater biotelemetry, with emphasis on ultrasonic techniques. J. Fish. Res. Board Can. 34:1261–1285.