THE MOVEMENT AND GROWTH PATTERNS OF YOUNG-OF-THE-YEAR BLACK ROCKFISH (*SEBASTES MELANOPS*) INHABITING TWO ROCKY INTERTIDAL AREAS OFF NORTHERN CALIFORNIA

by

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ABSTRACT

The Movement and Growth Patterns of Young-of-the-Year Black Rockfish, (*Sebastes melanops*) Inhabiting Two Rocky Intertidal Areas off Northern California

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Black rockfish (*Sebastes melanops*) recruit to shallow coastal habitats at four to six months of age. Habitats utilized include kelp and eelgrass beds, estuaries, and tidepools. Black rockfish are unique among *Sebastes* spp. in that they are found in tidepools as juveniles. The objective of this study was to determine if young-of-the-year black rockfish exhibit site fidelity and homing behavior while inhabiting rocky intertidal areas. In addition, growth rates, recruitment, and use of rocky intertidal areas as nursery grounds were examined. This research was conducted off northern California at two rocky intertidal sites within Redwood National and State Parks during 2007 and 2008. To test for site fidelity and homing behavior, fish were marked subcutaneously with unique color coded tags and displaced at distances ranging from 0 to 258 m from their original pool of capture. Site fidelity was observed in 38 percent of all fish tagged. Homing behavior was noted in 61 percent of the fish recaptured. Homing behavior was observed at all displacement distances used. Fish displaced 258 m, however, displayed the weakest homing behavior. Mean growth in length ranged from 0.204 to 0.343 mm d^{-1} between years. Throughout the residence period, growth rates increased. Recruitment varied highly among sites and between years. In 2008, a 34-fold increase in recruitment strength was noted compared to 2007. Within each year the relative abundance of black rockfish was highest during the months of June and July, with peak abundance occurring between mid-June and early-July. Maximum residence time observed for a recaptured fish was 67 d. Length of residency was similar among sites and between years. Results indicate that young-of-the-year black rockfish display site fidelity and homing behavior while inhabiting rocky intertidal areas. Furthermore, these findings strongly indicate that they use rocky intertidal areas as nursery grounds. This research provides important information for the management of rockfish and for future deliberations concerning marine protected areas off northern California.

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INTRODUCTION

As some resident intertidal fish species grow and mature they develop strong site fidelity and homing behaviors. Studies off Vancouver Island, Canada, have shown that tidepool sculpin (*Oligocottus maculosus*) display strong site fidelity and are capable of finding their way back to their home tidepool when displaced distances exceeding 100 m (Green 1971, Khoo 1974). Similar behavior has been observed in fluffy sculpin (*O. snyderi*) off Oregon (Yoshiyama et al. 1992). Here, marked fish showed site fidelity and homing behavior from distances as far as 85 m. Weaker homing behavior was reported for wooly sculpin (*O. globiceps*) (Yoshiyama et al. 1992). Utilizing displacement distances from 30 to 56 m, maximum homing behavior was 44 m for this species. While these studies have shown site fidelity and homing behavior in resident intertidal fishes, little is known about the movement patterns of pelagic transient fish species inhabiting the rocky intertidal.

Black rockfish (*Sebastes melanops,* Girard 1856) occur from western Alaska to southern California (Miller and Lea 1972). However, they are most common between southeast Alaska and northern California (Stewart and Love 2002). Over much of this range they support important commercial and recreational fisheries. Off northern California, black rockfish make up > 52 percent, by weight, of all commercial rockfish landings, representing an estimated annual value of $242,864 (CDFG 2007). From northern California to Washington, they comprise > 61 percent of all nearshore commercial rockfish landings (PacFIN 2008). Over this same area, they make up > 47 percent of the total recreational catch of rockfish (RecFIN 2008). Stock assessments off northern California and Oregon indicate that black rockfish populations are healthy (Sampson 2008, Wallace et al. 2008, PFMC 2008). However, their populations are still below historic levels. Consequently, studies of their early life history, especially in nearshore habitats, are critical to management concerns and the establishment of marine protected areas.

Black rockfish are a schooling pelagic species that tend to be found around kelp beds and rocky terrain habitats feeding opportunistically on fish, zooplankton, and microinvertebrates (Stewart and Love 2002, Studebaker and Mulligan 2008). Although observed from the surface to 366 m (Hart 1973), they prefer depths shallower than 54 m (Niska 1976). Black rockfish move progressively to deeper habitats with age. Parturition off Oregon reportedly occurs mid-January through mid-March (Bobko and Berkeley 2004). Off central and northern California, parturition occurs January through May (Stein and Hassler 1989). Spawning areas are unknown. Pelagic juveniles, four to six months of age, recruit to coastal waters shallower than 20 m in kelp and eelgrass beds (Byerly 1999), estuaries (Bayer 1981, Miller and Shanks 2004a), and tidepools (Laroche and Richardson 1980, Yoklavich and Boehlert 1987). Off northern California, recruitment may occur as early as May (Moring 1986, Cox 2007, Studebaker and Mulligan 2008).

Off northern California, young-of-the-year copper (*S. carnatus*), widow (*S. entomelas*), black, blue (*S. mystinus*), bocaccio (*S. paucispinis*), canary (*S. pinniger*), and grass rockfish (*S. rastrelliger*) have been observed in rocky intertidal areas (Moring 1972, 1976, 1986, Chadwick 1976, Cox 2007, Studebaker and Mulligan 2008). Of these species, black rockfish is the most common, typically occurring from May through August (Moring 1986, Cox 2007, Studebaker and Mulligan 2008). In spite of the obvious importance of this habitat, little is known about their movement and growth patterns while utilizing this area. In contrast, several studies have examined black rockfish movements (Mathews and Barker 1983, Culver 1987, Parker et al. 2007) and growth patterns (Ralston and Dick 2003, Worton and Rosenkranz 2003, Gallagher 2007,) in deeper, subtidal, habitats.

Previous studies have shown that black rockfish display limited movement patterns in subtidal habitats. Miller and Shanks (2004b) examined the otolith composition of larval and juvenile black rockfish off Oregon and Washington and showed that fish collected 120 to 460 km apart exhibited distinct geochemical signatures, indicating limited movement. Juvenile black rockfish inhabiting kelp and eelgrass bed habitats near Sitka Sound, Alaska (Byerly 1999), and an artificial reef in Humboldt Bay, California (Dewees and Gotshall 1974), showed no significant movement away from the study site for as long as 4 and 13 months, respectively. In 42 acoustically tagged adult black rockfish off Oregon, Parker et al. (2007) noted that 35 (83 percent) of the fish tagged displayed limited movement for as long as 340 d. Mean home range size observed in this study was 55±9 hectares. Although less conclusive, restrictive movement patterns have also been documented in adult black rockfish by Mathews and Barker (1983), and Culver (1987). Off Washington, five of eight fish recaptured by Matthews and Barker showed little or no movement away from their original capture site, while three individuals moved > 360 km away. Culver noted similar movement patterns off northern Oregon and

Washington. Here, 321 (69 percent) of the fish recovered displayed no appreciable movement away from their release site, whereas 143 (31 percent) moved considerable distances (16 to 555 km). Most black rockfish recovered away from their capture site in these studies moved toward the Columbia River, presumably in response to food availability. The maximum distance that a tagged adult black rockfish has been recorded to move is 619 km, Depoe Bay, Oregon to Puget Sound, Washington (Coombs 1979). While considerable movement was observed by Coombs, 75 percent of the fish recaptured exhibited site fidelity. Although these studies demonstrated that some black rockfish, especially adults, may move considerable distances, most research shows that the vast majority of black rockfish display little or no movement away from their capture site, indicating small home ranges and strong site fidelity (Dewees and Gotshall 1974, Coombs 1979, Mathews and Barker 1983, Culver 1987, Byerly 1999, Lea et al. 1999, Parker et al. 2007).

In addition to site fidelity, variable degrees of homing behavior have been observed in several rockfish species. Adult black-and-yellow rockfish (*S. chrysomelas*) returned to their capture site from displacements as far as 50 m (Hallacher 1984). However, fish displaced 1.5 km showed no homing behavior. In adult brown rockfish (*S. auriculatus*) displaced between 0.05 and 8.0 km, homing behavior was noted only as much as 1.6 km (Matthews 1990). In contrast, adult mebaru (*S. inermis*) off Japan have been shown to display homing behaviors from displacements as far as 4.5 km (Mitamura et al. 2002), adult copper and quillback rockfish (*S. maliger*) off Washington 8 km (Matthews 1990), and adult yellowtail rockfish off Oregon (Pearcy 1992) and Alaska

(Carlson and Haight 1972), 3.7 and 22.5 km, respectively. Although these results suggest that homing behavior is widespread within the genus *Sebastes*, no studies have specifically addressed homing behavior in juvenile or adult black rockfish. However, some data indicate that adult black rockfish may have the ability to home over short distances. Parker et al. (2007) noted that several acoustically tagged black rockfish off Oregon displayed repeated movements between two specific sites located approximately 1 km apart.

Temperature has been shown to be the primary factor affecting the growth of rockfish (Boehlert 1981, Boehlert and Yoklavich 1983). However, photoperiod, size (Boehlert 1981), food (Boehlert and Yoklavich 1983), oxygen, and hormones (Love et al. 2002) are also contributing factors. Research has also demonstrated that growth of rockfish can differ between species (Love et al. 1991), geographical location (Love et al. 2002), and habitat (Miller and Geibel 1973, Haldorson and Richards 1987, Love et al. 2007). Several studies have examined the growth rates of young-of-the-year black rockfish. These growth rates range from 0.03 to 0.51 mm d^{-1} (Boehlert and Yoklavich 1983, Gallagher 2007), although most black rockfish exhibited rates between 0.20 and 0.31 mm d^{-1} (Laroche and Richardson 1980, Bayer 1981, Boehlert and Yoklavich 1983). Black rockfish exhibit growth rates similar to juvenile splitnose (*S. diploproa*) (Boehlert 1981), widow, yellowtail (Woodson and Ralston 1991), blue (Love et al. 2007), cowcod (*S. levis*), and stripetail rockfish (*S. saxicola*) (Johnson et al. 2001). Although studies have documented black rockfish in tidepools as juveniles (Moring 1972, 1976, 1986, Cox 2007, Studebaker and Mulligan 2008), little is known about their growth patterns. What is known comes from studies collecting mean monthly averages and/or size ranges (Moring 1972, Studebaker and Mulligan 2008). While these data are useful for examining general growth patterns, without a technique to determine fish age, or data on sequential capture of individual fish, this information cannot be used to calculate growth rates.

The objective of this study was to determine if young-of-the-year black rockfish show site fidelity and homing behavior while inhabiting two rocky intertidal areas off northern California. In addition, growth rates, recruitment, and use of rocky intertidal areas as nursery grounds were examined.

METHODS AND MATERIALS

Two rocky intertidal sites were studied (Figure 1). Palmer's Point (N 41^{o}07'87", W 124^{o}09'84") is located approximately 9 km north of Trinidad Bay, Humboldt County, California and is within Patrick's Point State Park. Here, large boulders create isolated and discontinuous tidepools during tidal heights approximately < 0.3 m (Figure 2). Tidepool substrates primarily consist of cobble and gravel sediments. Common algae within tidepooools at this site include surfgrass (*Phylospadix scouleri*), coralline red algae and brown algae (*Egregia menziesii, Laminaria greonlandica, L. setchellii, Iridea cordata,* and *Hedophyllum sessile*). False Klamath Cove (N 41^{o}35'69", W 124^{o}06'31") is located approximately 18 km north of the Klamath River mouth, Del Norte County, California and is within Redwood National and State Parks. This site is similar to Palmer's Point in that large boulders form tidepools (Figure 3). Here, most tidepools are isolated at tidal heights approximately < 0.6 m. Sandy sediment largely dominates the substrate of tidepools at this site. Common algae within tidepoools at this site include surfgrass, green algae (*Ulva* spp.), red algae (*Porphyra* spp.), and brown algae (*Fucus gardneri*, *Odonthalia floccose*, *Pelvetiopsis limitata*, and *H. sessile*). Lacking any physical protection, both sites are openly exposed to hydrodynamic stresses imposed by wind and wave action (Figures 4 and 5).

I sampled black rockfish in tidepools at Palmer's Point and False Klamath Cove. Six tidepools were sampled from May through August 2007 at Palmer's Point (Figure 6). At False Klamath Cove, seven tidepools were sampled from May through August 2007.

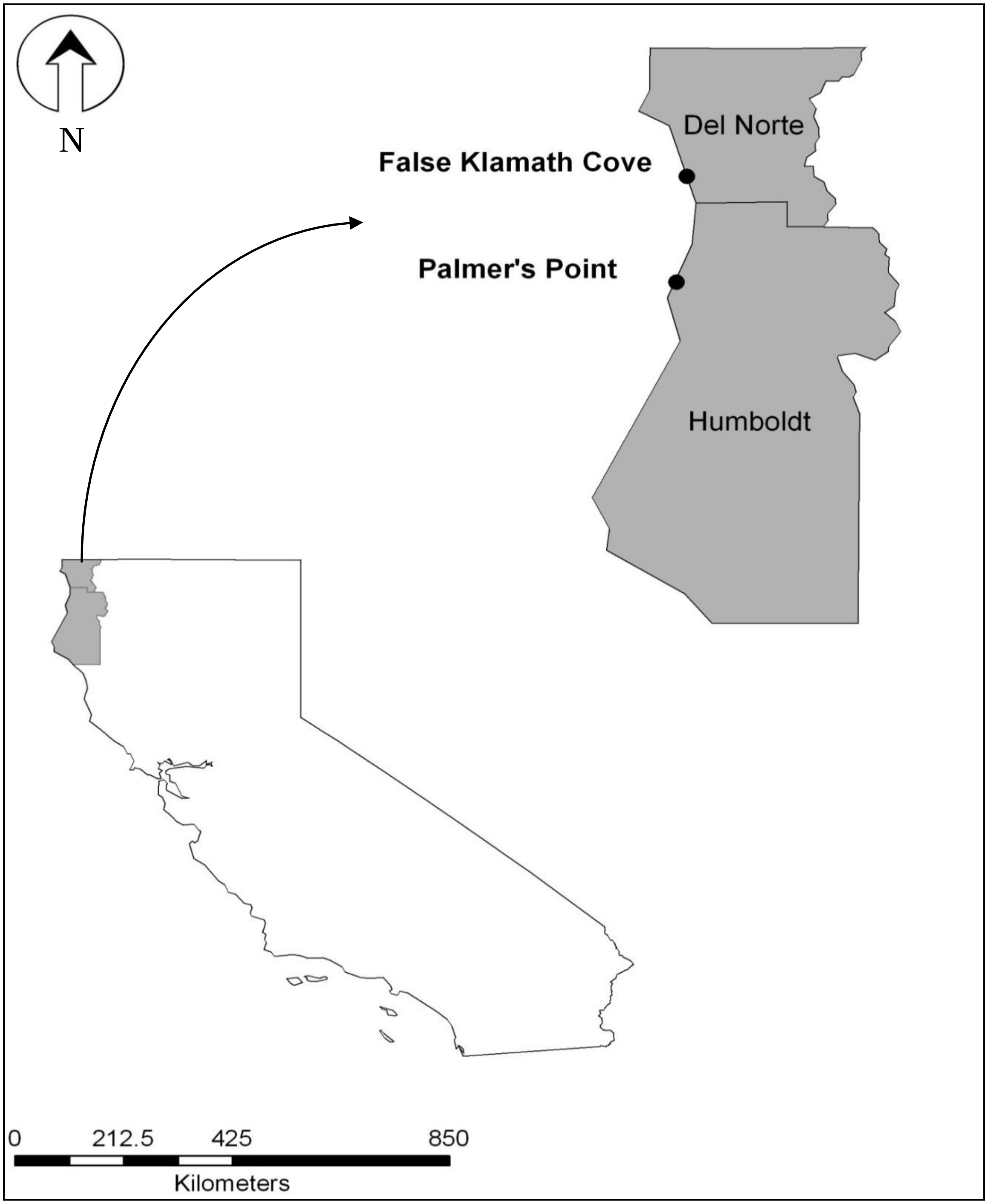

Figure 1. Palmer’s Point (N 41°07’87”, W 124°09’84”) and False Klamath Cove (N 41°35’69”, W 124°06’31”), Humboldt and Del Norte Counties, California.

Figure 2. Palmer's Point (N 41^{o}07'87", W 124^{o}09'84") at low tidal phase, Humboldt County, California.

Figure 3. False Klamath Cove (N 41°35’69”, W 124°06’31”) at low tidal phase, Del Norte County, California.

Figure 4. Aerial photograph of Palmer’s Point (N 41°07’87”, W 124°09’84”), Humboldt County, California. Tidepools were sampled from May through August 2007. The red dot depicts the study site. Image was obtained via Google Earth.

Figure 5. Aerial photograph of False Klamath Cove (N 41°35'69", W 124°06'31"), Del Norte County, California. Tidepools were sampled from May through August 2007 and June through August 2008. The red dot depicts the study site. Image was obtained via Google Earth.

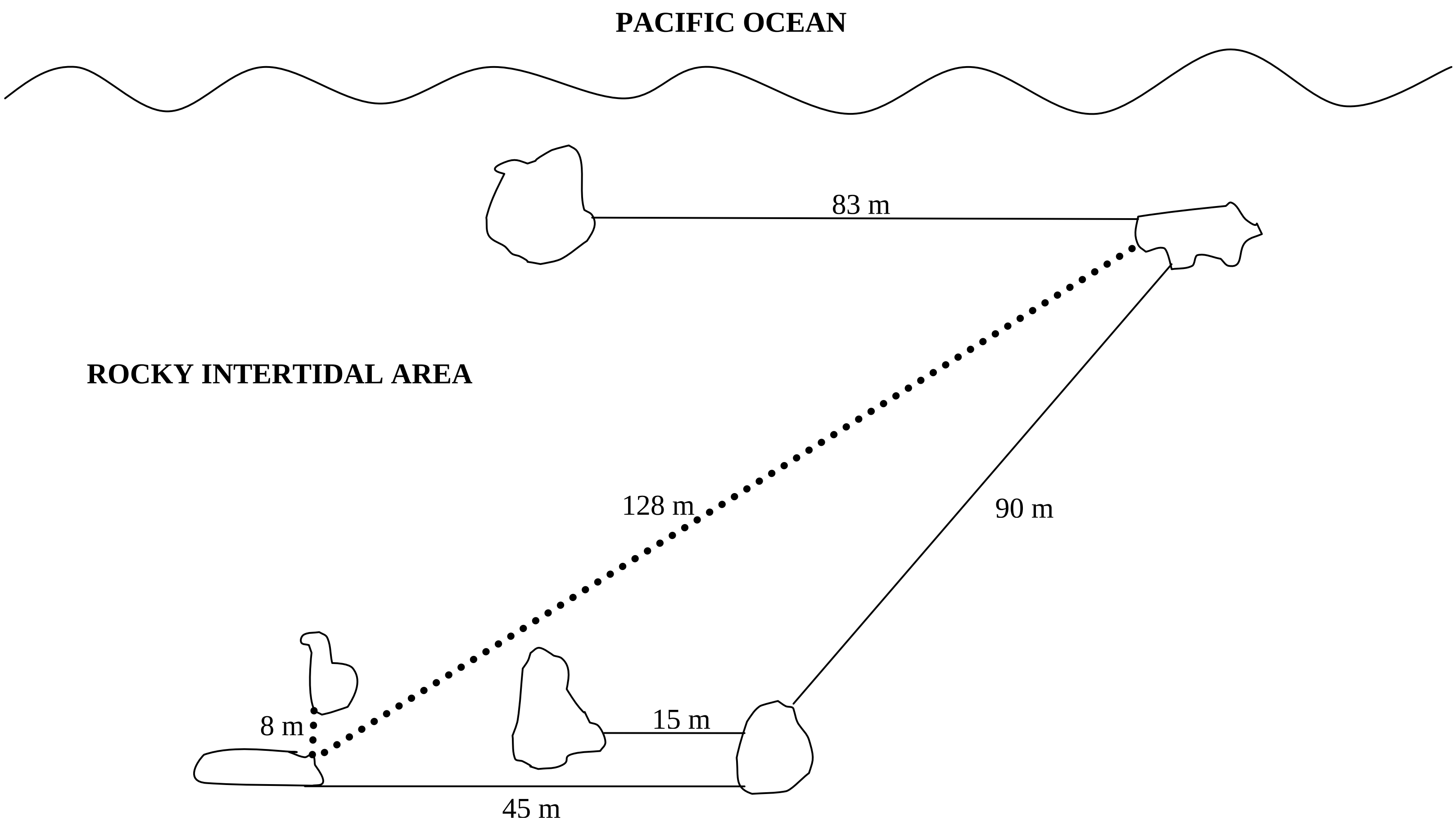

Figure 6. Diagram of tidepools sampled at Palmer’s Point, Humboldt County, California, from May through August 2007. Solid lines denote displacement distances. Dashed lines denote minimum and maximum distances between the tidepools sampled. Diagram not to scale.

In 2008, eight tidepools were sampled from June through August at False Klamath Cove (Figure 7). Palmer's Point was not sampled in 2008. Tidepools were selected based on the presence of black rockfish (Figure 8) and accessibility. Monitoring tidepools for black rockfish began in April in both years. At Palmer's Point, the maximum distance separating the tidepools sampled was 128 m, while the minimum was 8 m (Figure 6). The maximum tidepool depths ranged from 0.40 to 0.85 m. Maximum tidepool lengths ranged from 5.0 to 26.2 m, while the maximum widths ranged from 4.0 to 11.3 m. At False Klamath Cove, the maximum distance separating the tidepools sampled was 258 m, while the minimum was 7 m (Figure 7). The maximum tidepool depths ranged from 0.25 to 0.70 m. Maximum tidepool lengths ranged from 3.3 to 13.2 m, while the maximum widths ranged from 2.0 to 11.5 m.

Fish were collected during low tidal phases using handheld dip nets. Total length was measured to the nearest millimeter. All fish were marked subcutaneously with unique color coded fluorescent visible implant elastomer tags (Northwest Marine Technology, Washington, USA). Visible implant elastomer colors green, orange, pink, red, and yellow were used (Figure 9). Marks were applied using a 0.3 cubic centimeter syringe with a 29-gauge needle. The pelvic girdle, caudal peduncle, and the base of pectoral, anal, and dorsal fins were used as tagging locations. Fish were tagged from May through July in 2007 and June through July in 2008. Concurrent with fish sampling, water quality parameters (temperature, salinity, dissolved oxygen, and pH) were measured in each tidepool using a Yellow Springs Instrument model 600XL sonde.

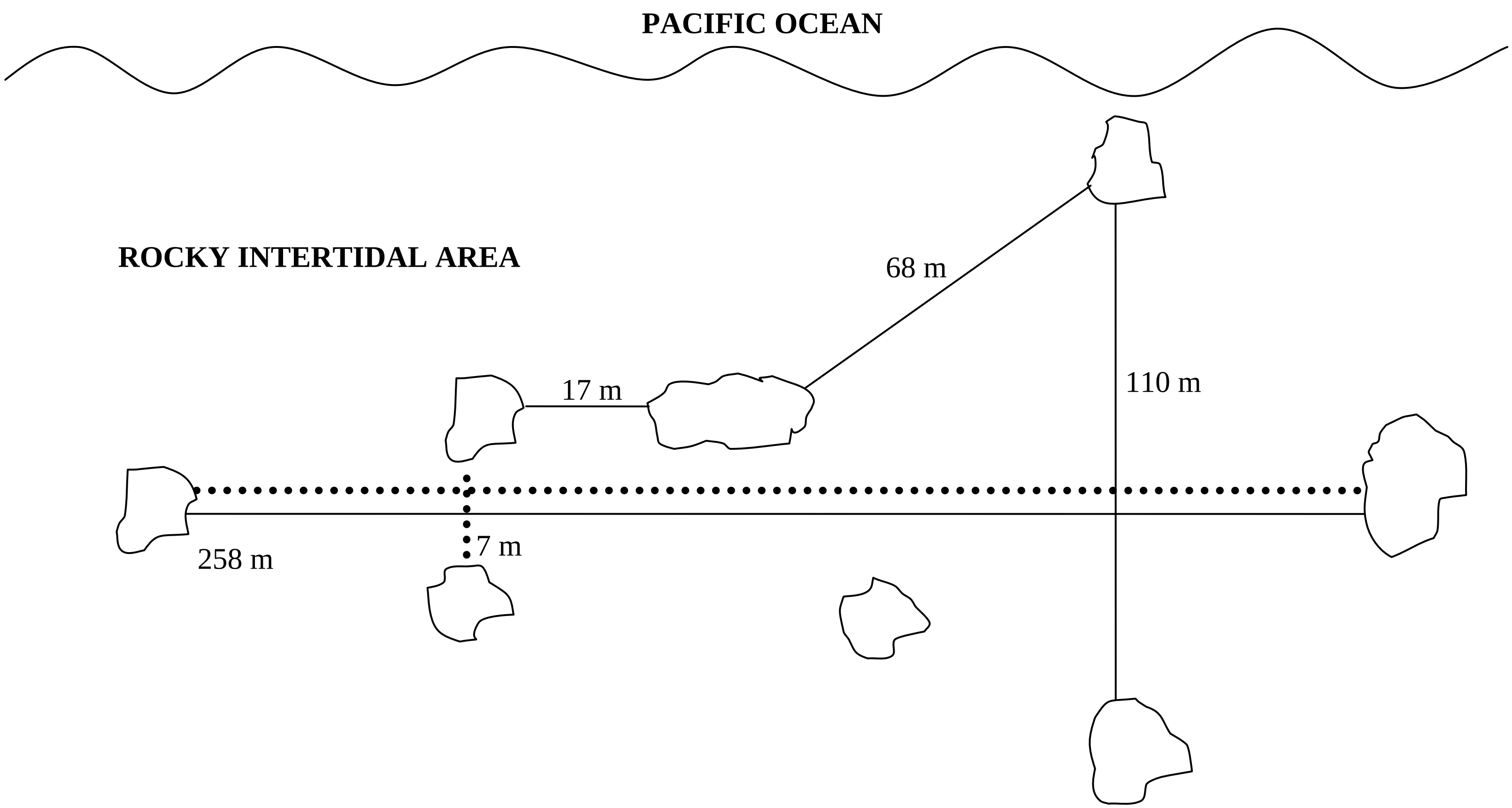

Figure 7. Diagram of tidepools sampled at False Klamath Cove, Del Norte County, California, from May through August 2007 and June through August 2008. Solid lines denote displacement distances. Dashed lines denote minimum and maximum distances between the tidepools sampled. The 258 m displacement distance was not implemented during 2007. Diagram not to scale.

Figure 8. Two newly settled young-of-the-year black rockfish (*S. melanops*).

Figure 9. Young-of-the-year black rockfish (*S. melanops*) displaying two orange visible implant elastomer tags positioned at the base of the anal, and second dorsal fins.

Site fidelity is described as the reoccurrence of a fish in the same general area as its release (Lea et al. 1999, Parker et al. 2007). Homing behavior is described as the reoccurrence of an individual fish within the same tidepool at two different low tides (Williams 1957). The assumption is that the fish does not remain in the tidepool during high tide. Rather it leaves, and then returns at low tide, displaying homing behavior. In my study, a fish tagged and released back into its tidepool of original capture and subsequently recaptured in the same tidepool at a different low tide would be categorized as displaying homing behavior, with the assumption that the fish left its tidepool during high tide and then returned prior to low tide. A “home pool” is defined, following Green (1971), as the tidepool that the fish was originally captured in. A “transplant pool” is referred to as the tidepool that the fish was displaced into, whereas a “nearby pool” refers to all other tidepools sampled excluding that of the home pool and transplant pool. In this study “site fidelity” is defined as the recapture of a marked fish within a home, nearby, and/or transplant pool, while “homing behavior” is defined as the recapture of a marked fish within its home pool, regardless of displacement distance. “Recruitment” is referred to as the transition from the pelagic juvenile stage to the benthic juvenile stage. “Initial recruitment” is referred to as the time when fish first appear in the rocky intertidal area.

The following assumptions for tagged fish were made in this study: 100 percent tag retention and survivorship was attained and fish behavior and growth patterns do not differ from that of non-tagged fish. In a laboratory study examining visible implant elastomer tag retention, survivorship, and growth rates between tagged and non-tagged young-of-the-year black rockfish, Lomeli (2004) noted 100 percent tag retention, and found that survivorship and mean growth rates of tagged fish did not differ significantly ($P > 0.05$) from those of non-tagged fish.

Testing Site Fidelity and Homing Behavior

To determine if black rockfish exhibit site fidelity and homing behavior, displacement experiments of both newly marked and recaptured fish were performed. Depending on which tidepool the fish was tagged or recaptured within, fish were either displaced into a transplant pool or released back into the tidepool from which they were captured. Additional displacements, using recaptured fish, were performed and included in the data set. Therefore, the number of displacements and recaptures is greater than the total number of fish tagged. Of the fish displaced outside their tidepool of capture, all were translocated into tidepools that were regularly sampled. While surrounding tidepools were examined for recaptures, they were not routinely sampled. At Palmer's Point, fish were displaced into tidepools 0, 15, 45, 83, and 90 m from their original pool of capture (Figure 6). At False Klamath Cove, fish were displaced into tidepools 0, 17, 68, 110, and 258 m from their original pool of capture (Figure 7). Only during 2008 were fish displaced 258 m away. For consistency and comparison within each site, displacement distances remained the same throughout a sampling season. Displacement distances used in previous homing studies of rocky intertidal fishes and the physical features of the sites influenced the displacement distances used in this study. Because black rockfish are pelagic and a transient species of the rocky intertidal area, most displacement distances used in this study exceed those of previous homing studies involving resident demersal rocky intertidal fishes (Stephens et al. 1970, Green 1971, 1973, Khoo 1974, Craik 1981, Yoshiyama et al. 1992).

Analysis of Results

Fish that were tagged and then recaptured in intervals of ≥ 7 d apart were used to calculate growth and percent growth in length (mm d^{-1}). For example, a fish tagged on day 1 and recaptured on day 6, a 5 d period, would not be used for calculating growth and percent growth in length as its recapture intervals were not ≥ 7 d apart, whereas a fish tagged on day 1 and recaptured on day 8, a 7 d period, would be used. Because some fish were recaptured more than once, more than one growth measurement may have been obtained from an individual fish. For example, a fish tagged on day 1 and recaptured on day 9 and day 21 would generate two growth measurements: day 1 to day 9, and day 9 to day 21. Growth and percent growth in length were calculated using the following formulas:

$$\text{growth in length} = \frac{(\Delta l)}{(\Delta t)} = \frac{(l_{t2} - l_{t1})}{(t_2 - t_1)}$$

$$\text{percent growth in length} = \frac{\left(\frac{\Delta l}{\Delta t}\right)}{\left(\frac{\Sigma l}{2}\right)} = \frac{\left(\frac{l_{t2} - l_{t1}}{t_2 - t_1}\right)}{\left(\frac{l_{t1} + l_{t2}}{2}\right)}$$

where t_2 is the time of final capture and t_1 the time of initial capture, and where l_2 and l_1 represent length at those respective times.

The statistical software package NCSS (2007 edition, Jerry Hintze, Kaysville, Utah, USA) was used for analyzing data. Logistic regression analysis was used to test if displacement distance, total length, and/or water quality parameters had a significant effect ($P < 0.05$) on site fidelity and homing behavior. Site fidelity and homing behavior were used as discrete dependent variables, categorized as either a "Yes" or "No" depending on whether a fish displayed the behavior, while displacement distance, total length, and water quality parameters were used as numeric independent variables. One-way analysis of variance (ANOVA) was used to determine if mean growth rates of black rockfish differed significantly among sites and between years. Growth and percent growth in length were used as response variables, while site and year were used as factor variables. One-way ANOVA was also used to test if monthly mean sea surface temperature differed significantly between years during the recruitment and residence period of the black rockfish studied. Sea surface temperature data were obtained through the National Oceanic and Atmospheric Administration's National Data Buoy Center, buoy station 46027 (N 41°51'10", W 124°22'52") located 15 km west northwest of Crescent City, Del Norte County, California. In this analysis, the mean daily sea surface temperature of the selected month was used as the response variable, while year was used as the factor variable. A p-value of ≤ 0.05 was considered significant in this study.

This study was conducted under the Institutional Animal Care and Use Committee protocol number 0607.F.194.A.

RESULTS

Site Fidelity and Homing Behavior

Combined, a total of 3,560 displacement experiments were conducted using 2,031 marked black rockfish from May through August 2007 and June through August 2008 (Table 1). Of the displaced fish, 1,528 recaptures were made, representing 766 individuals. Site fidelity was observed in 37.7 percent of the 2,031 fish tagged, while homing behavior was noted in 60.5 percent of the fish recaptured. Home pools accounted for 60.5 percent of all recoveries, nearby pools 27.8 percent, and transplant pools 11.6 percent. Of the fish recaptured, 385 (19.0 percent) were recaptured two or more times, of which 178 (8.8 percent) were recaptured exclusively within their home pool.

The total number of fish displaced, tagged, and recaptured varied among sites and between years. At Palmer's Point, 723 displacement experiments were conducted using 406 marked black rockfish in 2007. At False Klamath Cove, 521 displacement experiments were conducted in 2007, using 196 marked fish. In 2008, an additional 2,316 displacement experiments were conducted at False Klamath Cove using 1,429 marked fish (Table 1). Overall, 317 recaptures were made at Palmer's Point representing 189 individual fish. Of the 317 fish recaptured, from the 723 displaced, 220 (30.4 percent) were caught within their home pool, 47 (6.5 percent) within a nearby pool, and 50 (6.9 percent) within a transplant pool (Table 2). At False Klamath Cove, 325 recaptures were made in 2007, representing 112 individual fish. Of the 325 fish recaptured, from the 521

Table 1. Total number and percent of young-of-the-year black rockfish (*S. melanops*) tagged, displaced, and recaptured at Palmer's Point and False Klamath Cove, Humboldt and Del Norte Counties, California, from May through August 2007 and June through August 2008. Number caught values represent the number of fish, marked and unmarked, that were caught throughout the sampling period. Number displaced values represent the total number of displacement experiments conducted using both newly marked and recaptured fish. Individuals recaptured values represent the number of individual fish caught one or more times. Overall recaptured values represent the sum of all recapture events. Percent of fish tagged values represent the percent of fish that were caught and tagged and was calculated using the following formula: No. tagged / (No. caught – Overall recaptured + Individual recaptures). Overall recaptured values in parentheses represent the percent of fish recaptured from the number of fish displaced. Individuals recaptured values in parentheses represent the percent of fish recaptured from the number of fish tagged.

Site and year	No. caught	No. tagged	No. displaced	Individuals recaptured	Overall recaptured	% of fish tagged
Palmer's Point – 2007	736	406	723	189 (46.6)	317 (43.8)	66.8
False Klamath Cove – 2007	530	196	521	112 (57.1)	325 (62.3)	61.8
False Klamath Cove – 2008	17,910	1,429	2,316	465 (32.5)	886 (38.3)	8.2
Total	19,176	2,031	3,560	766 (37.7)	1,528 (42.9)	11.0

Table 2. Total number and percent of young-of-the-year black rockfish (*S. melanops*) recaptured, by displacement distance, at Palmer's Point, Humboldt County, California, from May through August 2007. Values in parentheses represent percents.

				Total number and overall percent recaptured in		
Displacement distance (m)	No. displaced	No. recaptured	% Recaptured	Home pool	Nearby pool	Transplant pool
0	286	137	47.9	116 (40.6)	15 (5.2)	6 (2.1)
15	74	32	43.2	27 (36.5)	1 (1.4)	4 (5.4)
45	68	32	47.1	17 (25.0)	6 (8.8)	9 (13.2)
83	221	83	37.6	44 (19.9)	13 (5.9)	26 (11.8)
90	74	33	44.6	16 (21.6)	12 (16.2)	5 (6.8)
Total	723	317	43.8	220 (30.4)	47 (6.5)	50 (6.9)

displaced, 218 (41.8 percent) were caught within their home pool, 79 (15.2 percent) within a nearby pool, and 28 (5.4 percent) within a transplant pool (Table 3). In 2008, at False Klamath Cove, 886 recaptures were made representing 465 individual fish. Of the 886 fish recaptured, from the 1,429 displaced, 487 (20.9 percent) were caught within their home pool, 283 (12.2 percent) within a nearby pool, and 116 (5.0 percent) within a transplant pool (Table 3).

Site fidelity was observed in 43.8 percent of the fish tagged at Palmer's Point, whereas at False Klamath Cove, site fidelity was noted in 62.3 percent of tagged fish in 2007 (Tables 1, 2 and 3). In 2008, at False Klamath Cove, site fidelity was observed in 38.3 percent the fish tagged (Tables 1 and 3). Over the displacement distances of 0 to 90 m at Palmer's Point, in 2007, the percent of fish displaying site fidelity ranged from a high of 47.9 percent at 0 m to a low of 37.6 percent at 83 m (Table 2). At False Klamath Cove, site fidelity ranged from a high of 76.5 percent at 17 m to a low of 48.7 percent at 68 m in 2007 (Table 3). In 2008, site fidelity ranged from a high of 47.5 percent at 0 m to a low of 9.4 percent at 258 m. A total of 49 fish (25.9 percent) were caught twice, while 28 (14.8 percent) were caught > 2 times at Palmer's Point (Table 4). Mean number of times that a fish was recaptured was 1.7. The maximum number of times that a fish was recaptured was six. Of the fish tagged at False Klamath Cove in 2007, a total of 22 (11.2 percent) were caught twice, while 55 (49.1 percent) were caught > 2 times (Table 5). In 2008, 121 (8.4 percent) fish were recovered twice, whereas 110 (8.8 percent) were caught > 2 times. Mean number of times that a fish was recaptured was three in 2007 and two in 2008. The maximum number of times that a fish was recaptured was nine in 2007 and

Table 3. Total number and percent of young-of-the-year black rockfish (*S. melanops*) recaptured, by displacement distance, at False Klamath Cove, Del Norte County, California, from May through August 2007 and June through August 2008. Values in parentheses represent percents.

					Total number and overall percent recaptured in		
Year	Displacement distance (m)	No. displaced	No. recaptured	% Recaptured	Home pool	Nearby pool	Transplant pool
2007	0	355	232	65.4	156 (43.9)	61 (17.2)	15 (4.2)
	17	34	26	76.5	17 (50.0)	4 (11.8)	5 (14.7)
	68	78	38	48.7	24 (30.8)	12 (15.4)	2 (2.6)
	110	54	29	53.7	21 (38.9)	2 (3.7)	6 (11.1)
	Total	521	325	62.3	218 (41.8)	79 (15.2)	28 (5.4)
2008	0	983	467	47.5	264 (27.0)	173 (17.4)	30 (3.0)
	17	354	149	42.1	69 (19.5)	29 (8.2)	51 (14.4)
	68	353	119	33.7	75 (21.2)	39 (11.0)	5 (1.4)
	110	361	126	34.9	78 (21.6)	39 (10.8)	9 (2.5)
	258	265	25	9.4	1 (0.03)	3 (1.1)	21 (7.9)
	Total	2,316	886	38.3	487 (21.0)	283 (12.2)	116 (5.0)

Table 4. Total number of times that individual young-of-the-year black rockfish (*S. melanops*) were recaptured at Palmer's Point, Humboldt County, California, from May through August 2007.

	Number of times recaptured					
	1	2	3	4	5	6
No. recaptured	112	49	13	8	6	1
% of tagged fish	27.6	12.1	3.2	2.0	1.5	0.2
% of recaptures	59.3	25.9	6.9	4.2	3.2	0.5

Table 5. Total number of times that individual young-of-the-year black rockfish (*S. melanops*) were recaptured at False Klamath Cove, Del Norte County, California, from May through August 2007 and June through August 2008.

		Number of times recaptured								
Year		1	2	3	4	5	6	7	8	9
2007	No. recaptured	35	22	18	16	8	6	6	0	1
	% of tagged fish	17.9	11.2	9.2	8.2	4.1	3.1	3.1	0	0.05
	% of recaptures	31.3	19.6	16.1	14.3	7.1	5.4	5.4	0	0.08
2008	No. recaptured	234	121	58	34	12	4	0	2	0
	% of tagged fish	16.4	8.4	4.1	2.4	0.9	0.3	0	0.1	0
	% of recaptures	50.3	25.8	12.7	7.5	2.8	0.9	0	0.4	0

eight in 2008. Days at liberty ranged from 1 to 44 d at Palmer's Point. At False Klamath Cove, days at liberty ranged from 1 to 67 d in 2007 and 1 to 55 d in 2008. Mean days at liberty was 7 d at Palmer's Point and 5 d at False Klamath Cove in both 2007 and 2008.

Homing behavior was observed in 30.4 percent of the fish displaced and 69.4 percent of the fish recaptured at Palmer's Point (Table 2). Over the displacement distances of 0 to 90 m, the percent of fish displaying homing behavior ranged from a high of 40.6 percent at 0 m to a low of 19.9 percent at 83 m (Table 2, Figure 10). A significant difference ($P < 0.05$), though subtle, in homing behavior was noted between fish displaced ≤ 15 m and fish displaced ≥ 45 m. Recovery rates were highest in fish displaced 0 and 15 m (Table 2, Figure 10). In general, homing success decreased with increased displacement distance. At False Klamath Cove, 41.8 percent of the fish displaced exhibited homing behavior in 2007 and 20.9 percent in 2008 (Table 3). Over the displacement distances of 0 to 110 m in 2007, the percent of fish that displayed homing behavior ranged from a high of 50.0 percent at 17 m to a low of 30.8 percent at 68m (Table 3, Figure 11). Over the displacement distances of 0 to 258 m in 2008, the percent of fish that displayed homing behavior ranged from a high of 27.0 percent at 0 m to a low of 0.03 percent at 258 m (Table 3, Figure 12). In both years homing success was greatest in fish displaced 0 and 17 m. Although recovery rates were highest in fish displaced at these distances, no significant difference ($P > 0.05$) was found between homing success and displacement distance in 2007. However in 2008, a significant difference was noted. During this year a significant difference ($P < 0.01$) was observed between fish displaced ≤ 110 m and fish displaced 258 m. Of the 265 fish displaced

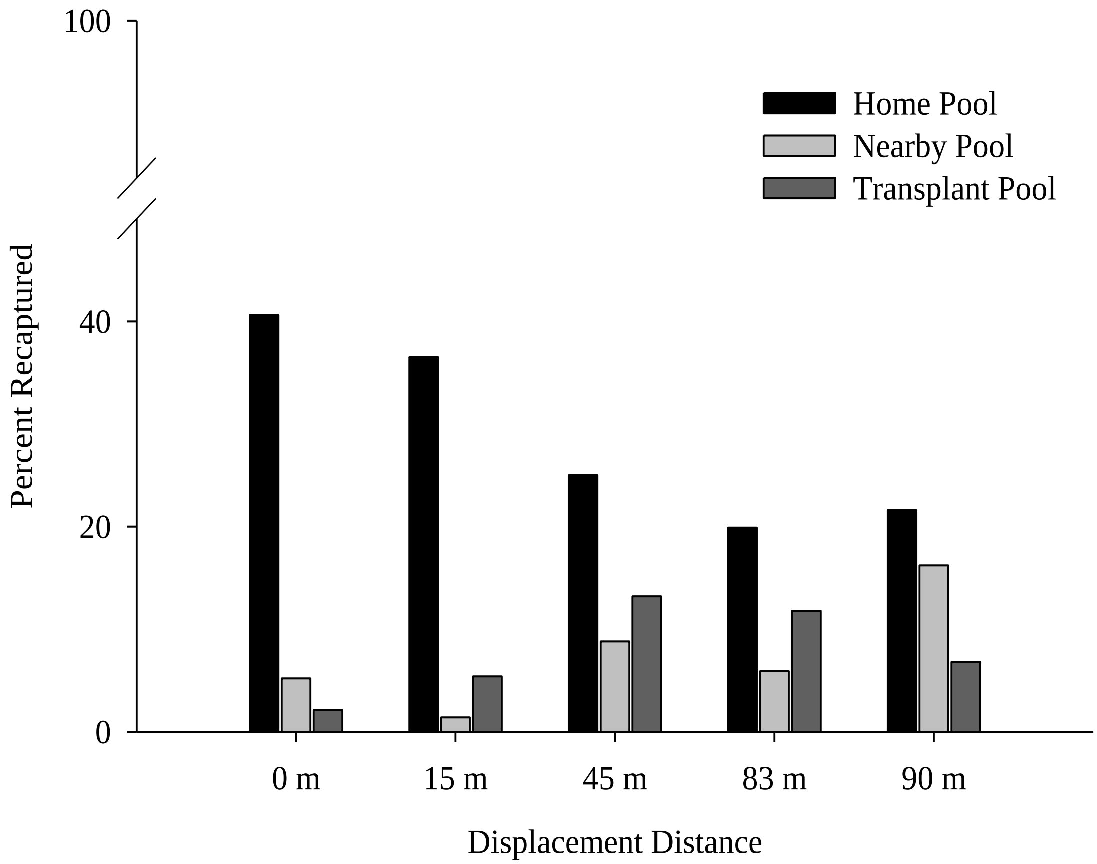

Figure 10. Percent of young-of-the-year black rockfish (*S. melanops*) recaptured, by displacement distance, at Palmer's Point, Humboldt County, California, from May through August 2007.

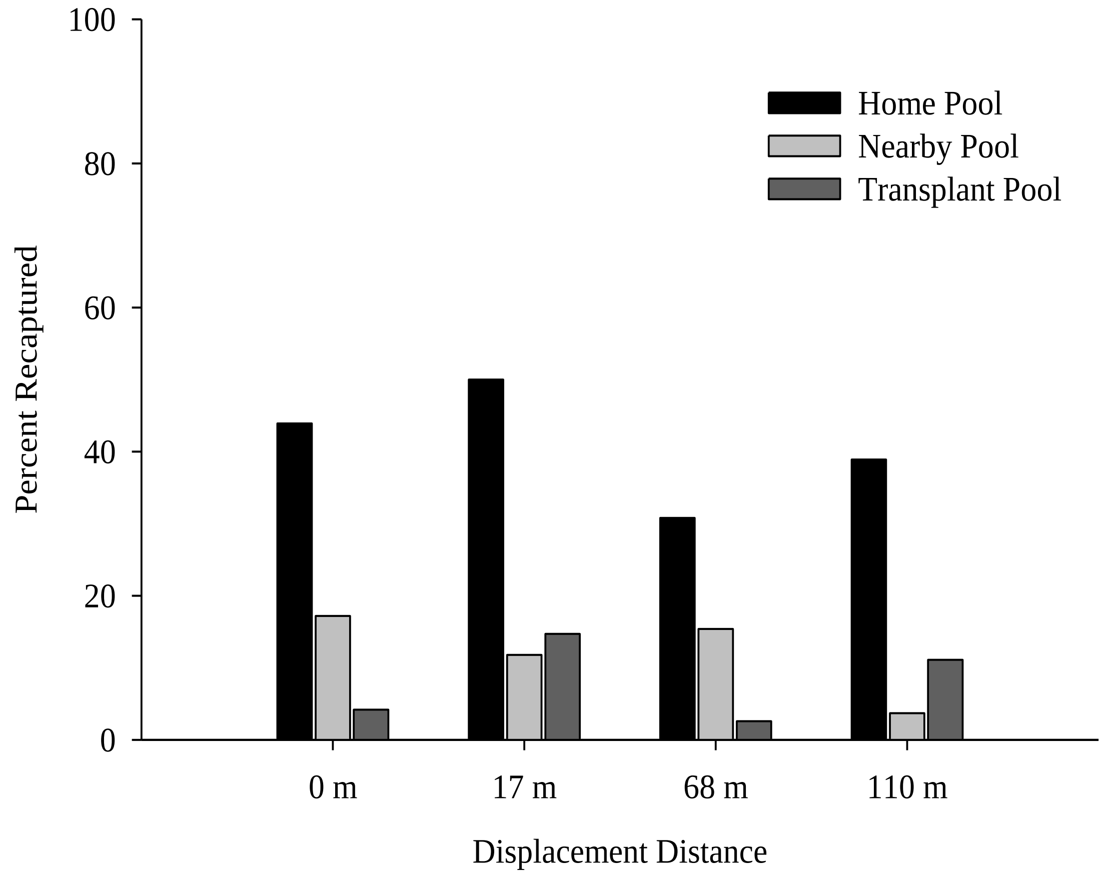

Figure 11. Percent of young-of-the-year black rockfish (*S. melanops*) recaptured, by displacement distance, at False Klamath Cove, Del Norte County, California, from May through August 2007.

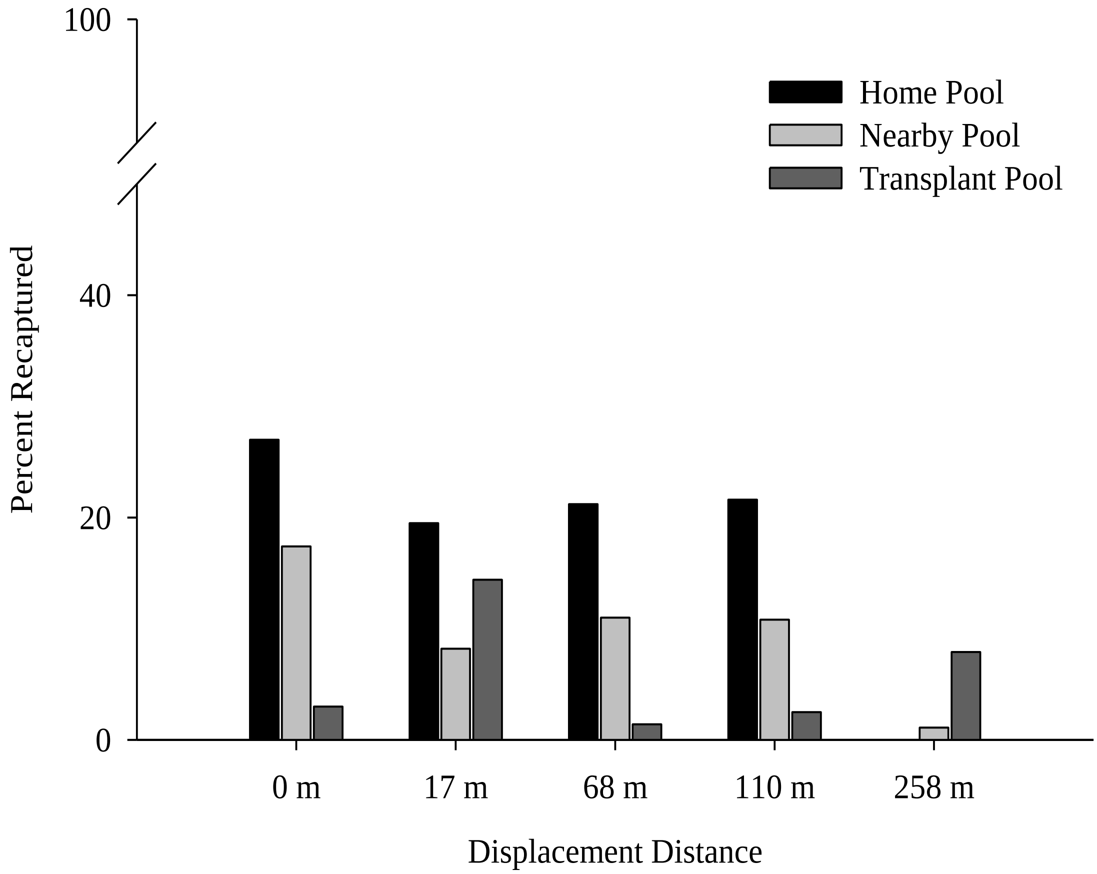

Figure 12. Percent of young-of-the-year black rockfish (*S. melanops*) recaptured, by displacement distance, at False Klamath Cove, Del Norte County, California, from June through August 2008.

258 m, only one of the 25 fish recaptured (0.03 percent) was observed to home successfully (Table 3, Figure 12). For the 24 fish that did not exhibit homing behavior, 21 were recaptured within their transplant pool, while the remaining three were caught within a nearby pool. Minimum and maximum distances that these three fish were observed away from their home pool were 68 and 79 m. The maximum number of times that a fish was recaptured from being displaced 258 m was once. For fish displaced ≤ 110 m, no significant difference ($P > 0.05$) was noted between homing success and displacement distance. Percent returns of fish displaced ≤ 110 m ranged from 19.5 percent at 17 m to 27.0 percent at 0 m (Table 3, Figure 12). Total length and water quality parameters had no significant effect ($P > 0.05$) on these fishes site fidelity or homing behavior.

Of the 189 individual fish recaptured at Palmer's Point, 44 (23.3 percent) were caught two or more times exclusively within their home pool. The maximum number of times that a fish was recaptured within its home pool was five. This was observed in four individuals. In addition to being recaptured within its home pool once, from a 0 m displacement, one fish successfully homed back from a distance of 45 m three times, while another homed back from a distance of 83 m four times (Table 6). The maximum number of times that an individual returned from a given displacement distance was four. This occurred in fish displaced at the 0 and 83 m displacement distances (Table 6). At False Klamath cove, 67 (59.8 percent) of the 112 individual fish recaptured in 2007 were recaptured exclusively within their home pool at least once, while 39 (34.8 percent) were caught two or more times. In 2008, 214 (46.0 percent) of the 465 individual fish were

Table 6. Total number of times that individual young-of-the-year black rockfish (*S. melanops*) exhibited homing behavior, by displacement distance, at Palmer's Point, Humboldt County, California, from May through August 2007. Total values represent the summation of individual fish that homed successfully multiplied by the number of times that they homed successfully.

	Number of times that fish homed successfully				
Displacement distance (m)	1	2	3	4	Total
0	66	17	4	1	116
15	15	6	0	0	27
45	8	3	1	0	17
83	28	6	0	1	44
90	7	0	3	0	16
Total	124	64	24	8	220

recovered exclusively within their home pool at least once, whereas 95 (20.4 percent) were recaptured two or more times. The maximum number of times that a fish was recaptured, solely within its home pool, was nine in 2007 and eight in 2008. This pattern was observed in one fish in 2007 and two fish in 2008. For the 2007 fish that was recaptured nine times, all returns were from a 0 m displacement. For the two fish recaptured in 2008, combined returns were from a 0 m displacement eight times, a 68 m displacement once, and a 110 m displacement seven times. The maximum number of times that an individual returned to its home pool from a given displacement distance was nine in 2007 and seven in 2008 (Tables 7 and 8). This occurred in fish displaced at the 0 and 110 m displacement distances, respectively.

Of the 218 fish to display homing behavior at False Klamath Cove in 2007, 162 homed successfully on two or more occasions (Table 7). Of the 487 fish to show homing behavior in 2008, 318 successfully homed on two or more occasions (Table 8). The mean number of times that a fish exhibited homing behavior was two in both 2007 and 2008. The maximum number of times that a fish exhibited homing behavior was nine in 2007 and eight in 2008.

Nearby and transplant pools accounted for 30.6 percent of the fish recaptured at Palmer's Point. Minimum and maximum distances that a fish was observed away from its home pool were 15 and 128 m. Mean distance that a fish was observed away from its home pool was 60 m. The maximum number of times that a fish was recaptured, outside its home pool, was six. This behavior was observed in one fish displaced 45 m and subsequently recaptured five times within its transplant pool and once within a nearby

Table 7. Total number of times that individual young-of-the-year black rockfish (*S. melanops*) exhibited homing behavior, by displacement distance, at False Klamath Cove, Del Norte County, California, from May through August 2007. Total values represent the summation of individual fish that homed successfully multiplied by the number of times that they homed successfully.

	Number of times that fish homed successfully									
Displacement distance (m)	1	2	3	4	5	6	7	8	9	Total
0	30	17	11	4	2	4	0	0	1	156
17	10	2	1	0	0	0	0	0	0	17
68	10	4	2	0	0	0	0	0	0	24
110	6	0	5	0	0	0	0	0	0	21
Total	56	46	57	16	10	24	0	0	9	218

Table 8. Total number of times that individual young-of-the-year black rockfish (*S. melanops*) exhibited homing behavior, by displacement distance, at False Klamath Cove, Del Norte County, California, from June through August 2008. Total values represent the summation of individual fish that homed successfully multiplied by the number of times that they homed successfully.

	Number of times that fish homed successfully							
Displacement distance (m)	1	2	3	4	5	6	7	Total
0	68	39	18	7	6	1	0	264
17	41	5	3	1	1	0	0	69
68	40	9	3	2	0	0	0	75
110	19	13	6	2	0	0	1	78
258	1	0	0	0	0	0	0	1
Total	169	132	90	48	35	6	7	487

pool 55 m away. Overall, the number of fish recaptured within nearby and transplant pools were similar. At False Klamath Cove, nearby and transplant pools accounted for 32.9 percent of the fish recaptured in 2007 and 45.4 percent in 2008. Minimum and maximum distances that a fish was observed away from its home pool in 2007 were 7 and 110 m. In 2008, the minimum and maximum distances that a fish was observed away from its home pool were 4 and 258 m. The mean distance that a fish was observed away from its home pool was 27 m in 2007 and 51 m in 2008. The increase observed in the mean distance away from a home pool in 2008 was most likely due to the addition of the 258 m displacement distance. Excluding this displacement distance, the mean distance that a fish was observed away from its home pool is 36 m. Overall, most recaptures, outside the home pool, occurred within nearby pools (Table 3, Figure 12).

Recruitment, Residence, and Growth

At time of recruitment to the rocky intertidal in 2007, mean total length was approximately 48 mm at both sample locations (Table 9). In 2008, mean total length of recruits to settle during the first week of June, at False Klamath Cove, was approximately 51 mm. By early-to-mid-August, mean total length had increased 26 mm to 74 mm at Palmer’s Point. At False Klamath Cove, mean total length had increased 22 mm to 70 mm in 2007 and 17 mm to 68 mm in 2008.

Black rockfish were observed inhabiting the rocky intertidal area at Palmer’s Point for 77 d (Table 10). At False Klamath Cove, they were noted inhabiting the rocky intertidal area for 73 d in 2007 and 77 d in 2008. The relative abundance of black

Table 9. Overall abundances and lengths of young-of-the-year black rockfish (*S. melanops*) collected, by month, at Palmer's Point and False Klamath Cove, Humboldt and Del Norte Counties, California, from May through August 2007 and June through August 2008.

	Palmer's Point 2007			False Klamath Cove 2007			False Klamath Cove 2008		
Month	No.	Mean size	Range	No.	Mean size	Range	No.	Mean size	Range
May	13	48.7	46 – 50	9	47.8	45 – 51	0	n/a	n/a
June	413	52.8	42 – 62	362	52.1	42 – 62	2,203	57.1	46 – 68
July	296	57.6	47 – 77	158	59.0	47 – 85	14,369	60.5	48 – 76
August	14	74.4	64 – 83	1	70.0	-	1,338	68.5	54 – 93
Total	736			530			17,910		

Table 10. Duration that young-of-the-year black rockfish (*S. melanops*) were observed at Palmer’s Point and False Klamath Cove, Humboldt and Del Norte Counties, California, from May through August 2007 and June through August 2008.

Site	Initial observation date	Final observation date	Duration (d)
Palmer’s Point	31 May 2007	15 August 2007	77
False Klamath Cove	21 May 2007	02 August 2007	73
False Klamath Cove	02 June 2008	18 August 2008	77

rockfish was highly variable among sites and between years (Tables 1 and 9, Figure 13). Among sites, in 2007, 736 black rockfish were observed at Palmer's Point, whereas at False Klamath Cove, 530 were noted. Between years, at False Klamath Cove, a 34-fold increase in the relative abundance of black rockfish was observed, 530 in 2007 vs. 17,910 in 2008. The relative abundance of black rockfish was greatest during the months of June and July (Table 9, Figure 13), with peak abundance occurring between mid-June to early-July in 2007 and in early-July in 2008.

Although black rockfish were observed inhabiting the rocky intertidal area for over 72 d (Table 10), most fish recaptured exhibited a residence time of < 3 weeks (Figure 14). Mean length of residency of recaptured fish noted at Palmer's Point was 12 d. At False Klamath Cove, the mean length of residency of recaptured fish was 16 d in 2007 and 9 d in 2008. Maximum length of residency observed at Palmer's Point for a recaptured fish was 55 d (Figure 14). At False Klamath Cove, the maximum length of residency observed was 67 d in 2007 and 61 d in 2008. While the length of residency of recaptured black rockfish varied among sites and between years, recaptured fish were noted upon every sampling trip throughout the entire period that black rockfish were observed inhabiting the rocky intertidal area.

Growth in length of individual recaptured black rockfish at Palmer's Point ranged from 0 to 0.750 mm d^{-1} (0 to 0.010 percent growth in length) in 2007 (Table 11, Figures 15, 16, 17 and 18). At False Klamath Cove, growth in length ranged from 0.008 to 0.737 mm d^{-1} (0.002 to 0.011 percent growth in length) in 2007 and 0 to 0.714 mm d^{-1}

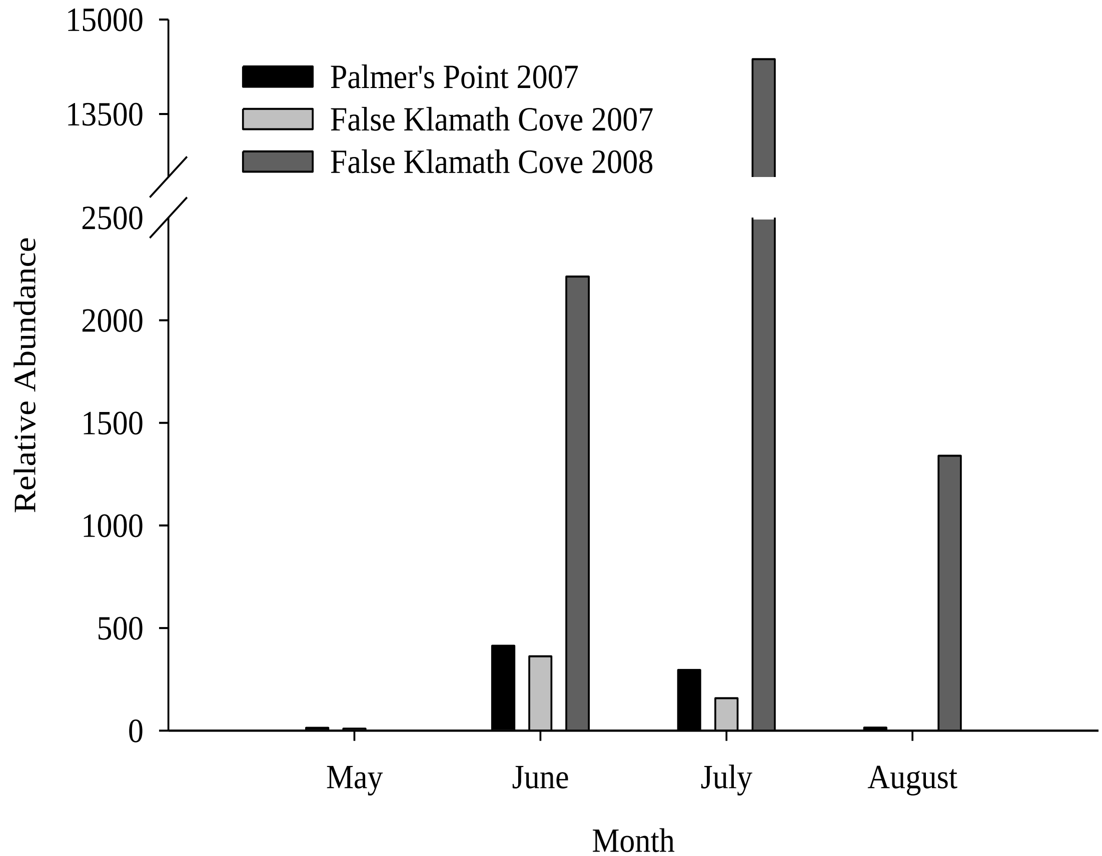

Figure 13. Relative abundance of young-of-the-year black rockfish (*S. melanops*) at Palmer’s Point and False Klamath Cove, Humboldt and Del Norte Counties, California, from May through August 2007 and June through August 2008.

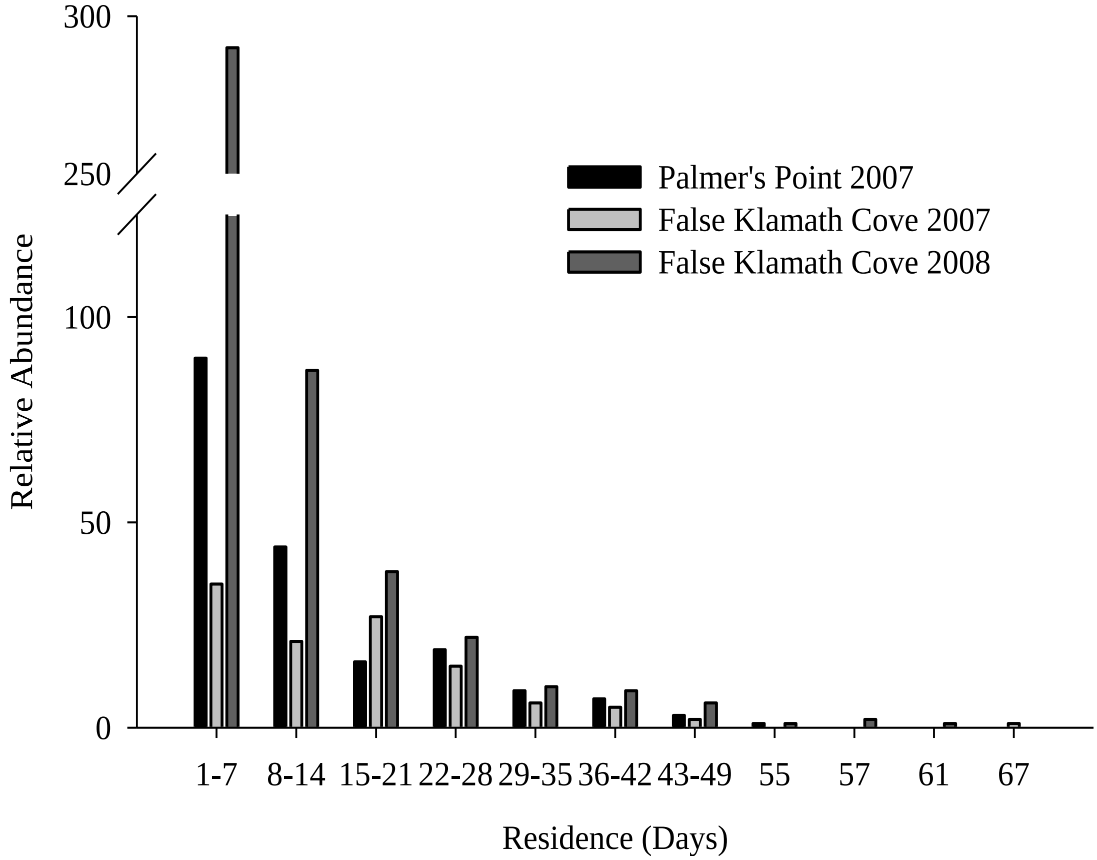

Figure 14. Residence time, in days, of young-of-the-year black rockfish (*S. melanops*) recaptured at Palmer's Point and False Klamath Cove, Humboldt and Del Norte Counties, California, from May through August 2007 and June through August 2008.

Table 11. Growth and percent growth in length (mm d^{-1}) of young-of-the-year black rockfish (*S. melanops*) recaptured at Palmer's Point and False Klamath Cove, Humboldt and Del Norte Counties, California, from May through August 2007 and June through August 2008. Values in parentheses represent two standard error.

			Growth in length (mm d^{-1})		Percent growth in length (mm d^{-1})	
Site	Year	No.	mean	range	mean	range
Palmer's Point	2007	115	0.327 (±0.024)	0.000 – 0.750	0.0056 (±0.0004)	0.000 – 0.010
False Klamath Cove	2007	109	0.343 (±0.026)	0.008 – 0.737	0.0061 (±0.0004)	0.002 – 0.011
False Klamath Cove	2008	210	0.204 (±0.016)	0.000 – 0.714	0.0034 (±0.0002)	0.000 – 0.009

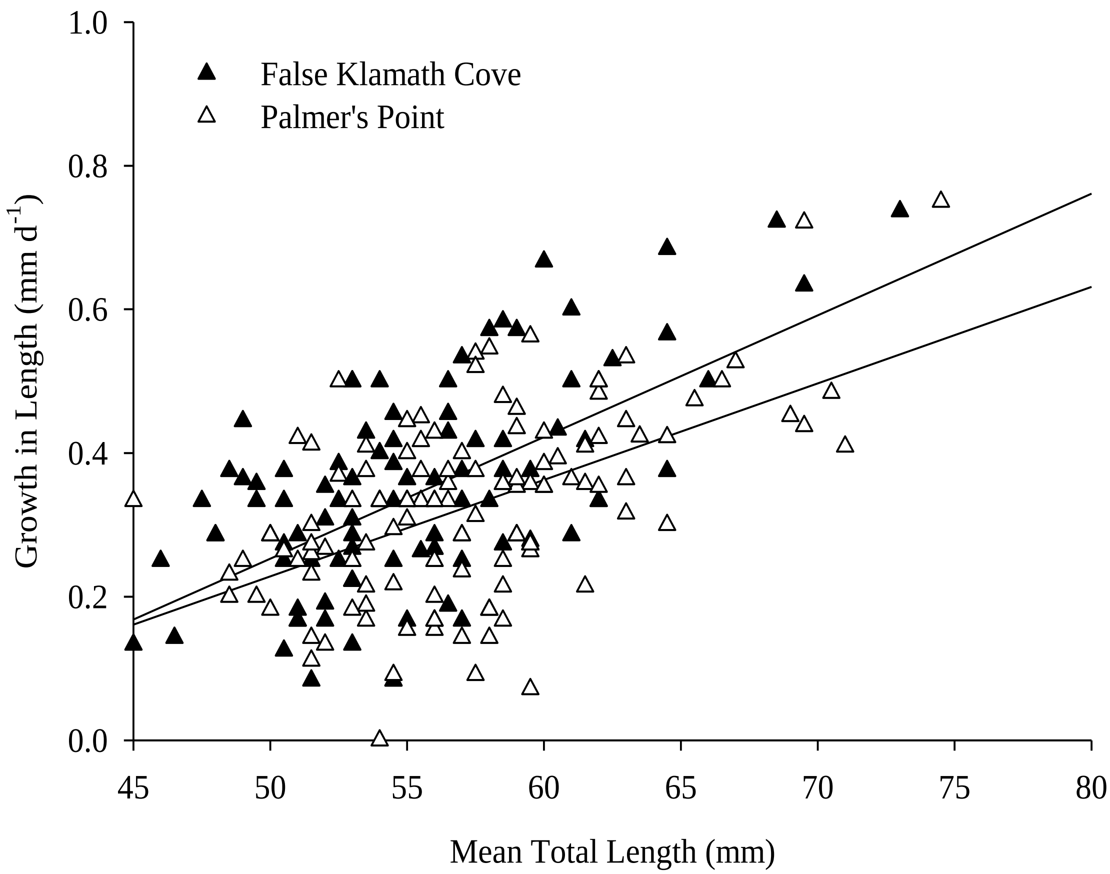

Figure 15. Growth in length (mm d^{-1}) of young-of-the-year black rockfish (*S. melanops*) recaptured at Palmer's Point and False Klamath Cove, Humboldt and Del Norte Counties, California, from May through August 2007. Lines represent linear trendlines for the selected data.

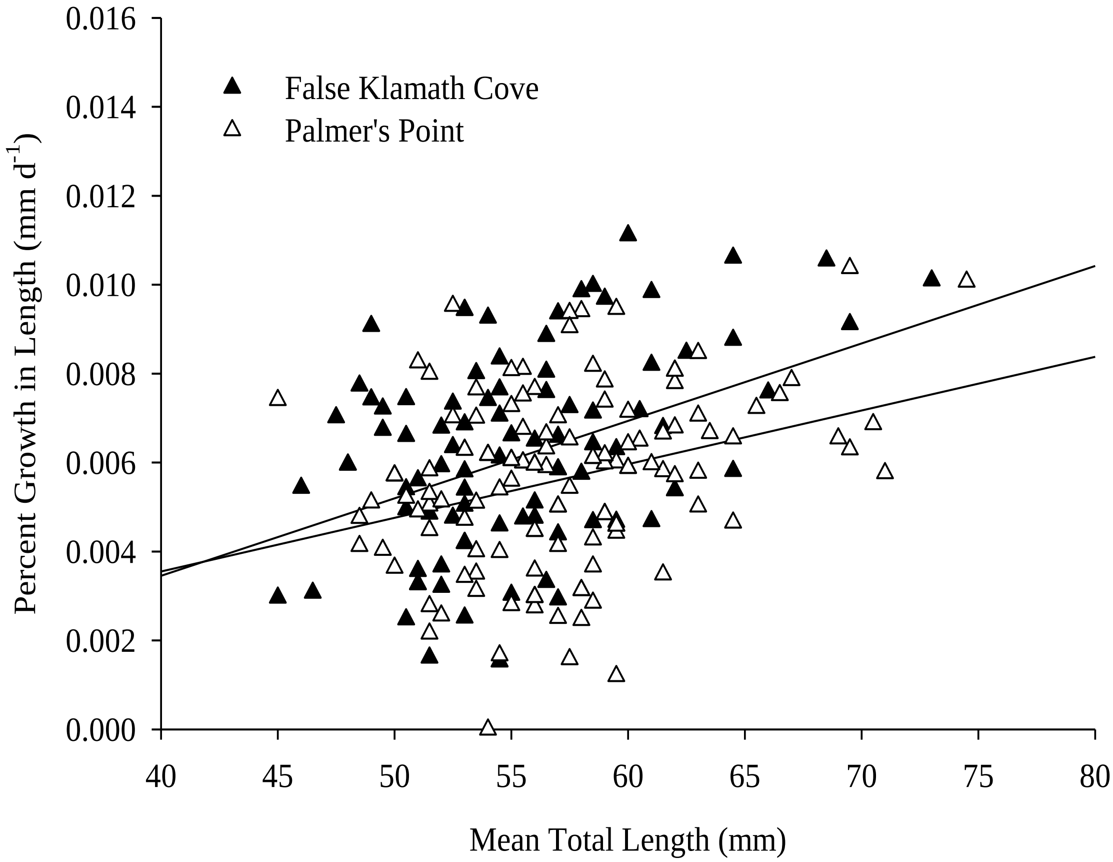

Figure 16. Percent growth in length (mm d^{-1}) of young-of-the-year black rockfish (*S. melanops*) recaptured at Palmer’s Point and False Klamath Cove, Humboldt and Del Norte Counties, California, from May through August 2007. Lines represent linear trendlines for the selected data.

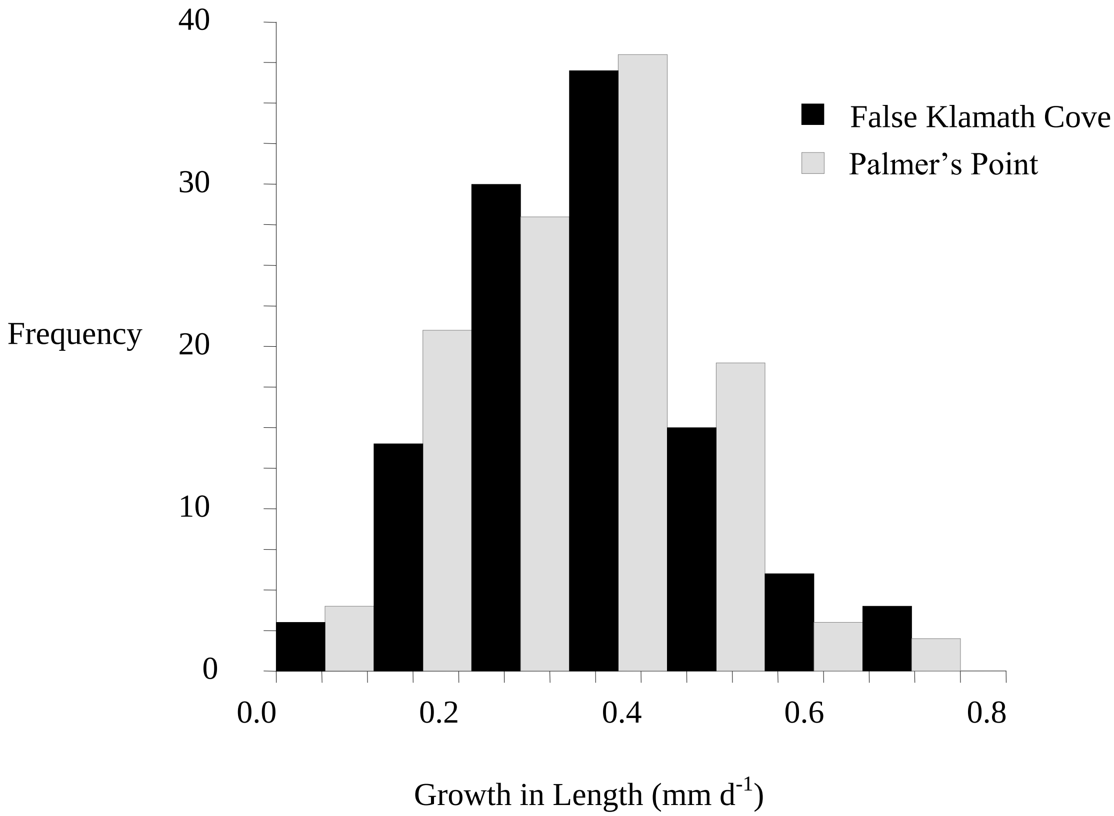

Figure 17. Growth in length (mm d^{-1}) of young-of-the-year black rockfish (*S. melanops*) recaptured at Palmer's Point and False Klamath Cove, Humboldt and Del Norte Counties, California, from May through August 2007.

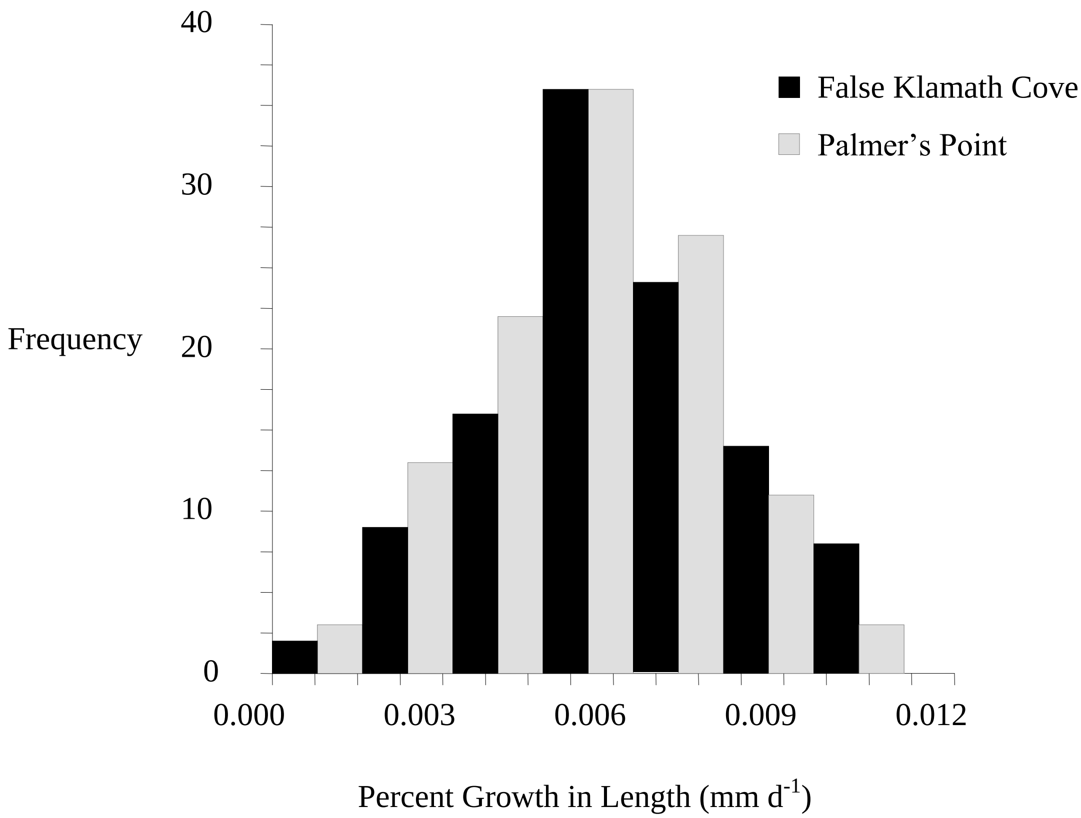

Figure 18. Percent growth in length (mm d^{-1}) of young-of-the-year black rockfish (*S. melanops*) recaptured at Palmer’s Point and False Klamath Cove, Humboldt and Del Norte Counties, California, from May through August 2007.

(0 to 0.009 percent growth in length) in 2008. Mean growth in length noted at Palmer's Point was 0.327 mm d^{-1} (0.0056 percent growth in length) (Table 11). At False Klamath Cove, mean growth in length observed was 0.343 mm d^{-1} (0.0061 percent growth in length) in 2007 and 0.204 mm d^{-1} (0.0034 percent growth in length) in 2008. Among sites, in 2007, mean growth and percent growth in length of black rockfish did not differ significantly ($P > 0.05$). A significant difference ($P < 0.01$) in both mean growth and percent growth in length, however, was observed between years, with higher mean growth rates occurring in 2007 (Table 11, Figures 19, 20, 21, 22, 23 and 24). In both years, mean growth rates of black rockfish increased throughout the sample period (Table 12). Among sites and between years, the highest mean growth rates occurred in July and August and were noted to coincide with the highest monthly mean sea surface temperatures (Table 12).

Water Quality

A significant difference ($P < 0.01$) in the monthly mean sea surface temperature was noted between years off northern California during the recruitment and residence period of the black rockfish studied, with warmer sea surface temperatures occurring in 2007 (Table 13, Figure 25).

Among the tidepools sampled, temperature, dissolved oxygen, and percent saturation values were highly variable, while salinity and pH were relatively stable (Table 14). For all water quality measurements, minimum values were recorded during early-

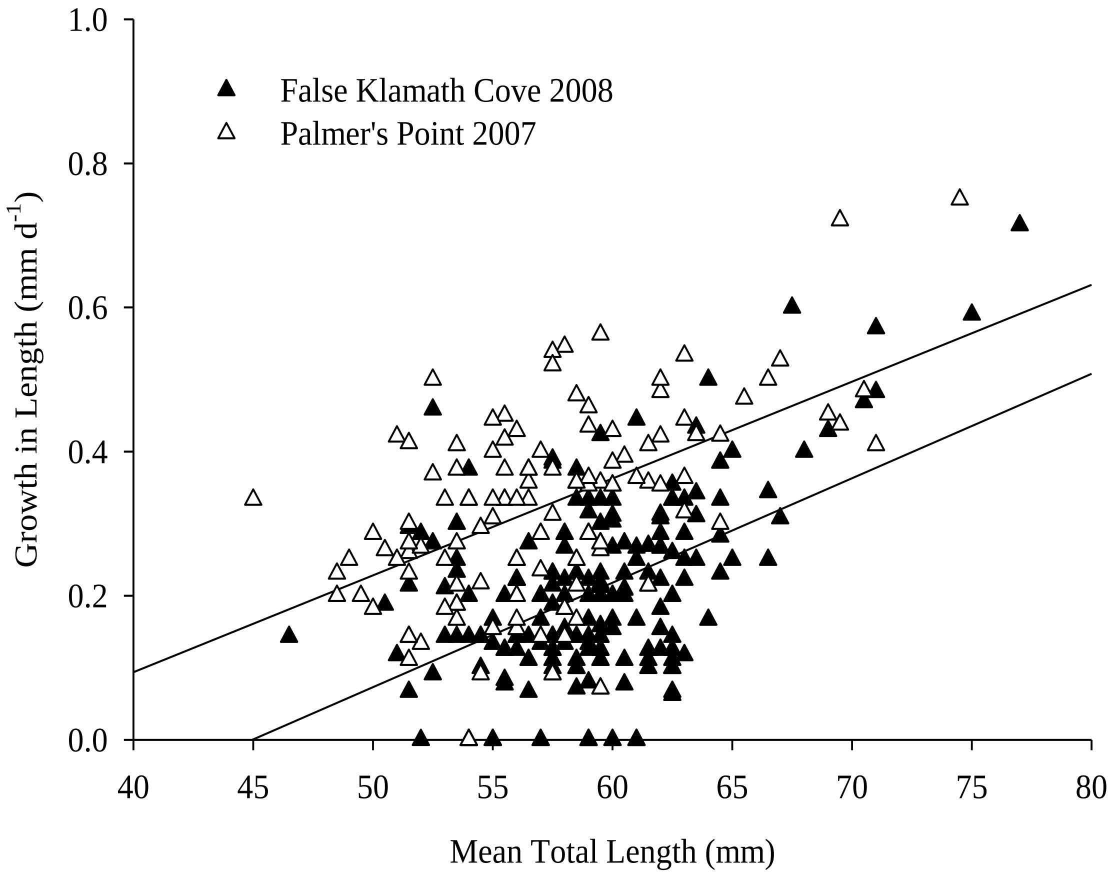

Figure 19. Growth in length (mm d^{-1}) of young-of-the-year black rockfish (*S. melanops*) recaptured at Palmer's Point from May through August 2007 and False Klamath Cove from June through August 2008, Humboldt and Del Norte Counties, California. Lines represent linear trendlines for the selected data.

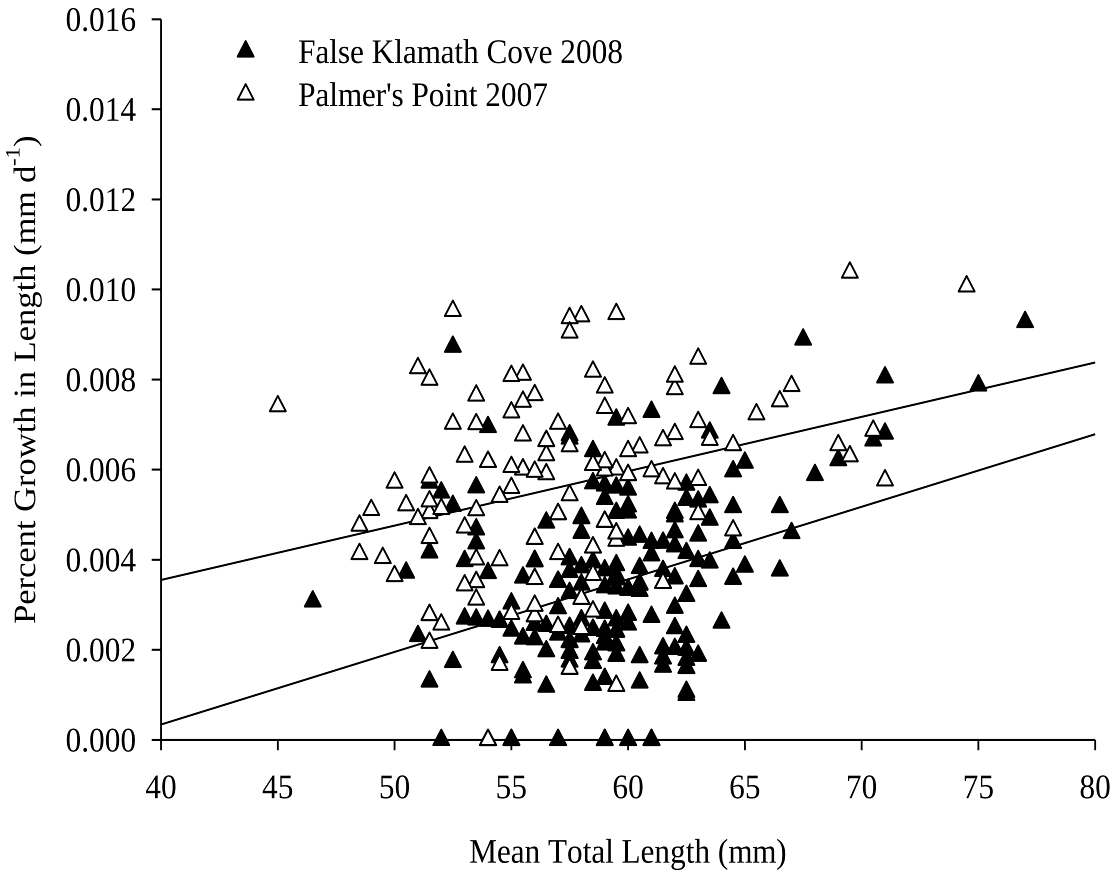

Figure 20. Percent growth in length (mm d^{-1}) of young-of-the-year black rockfish (*S. melanops*) recaptured at Palmer’s Point from May through June 2007 and False Klamath Cove from June through August 2008, Humboldt and Del Norte Counties, California. Lines represent linear trendlines for the selected data.

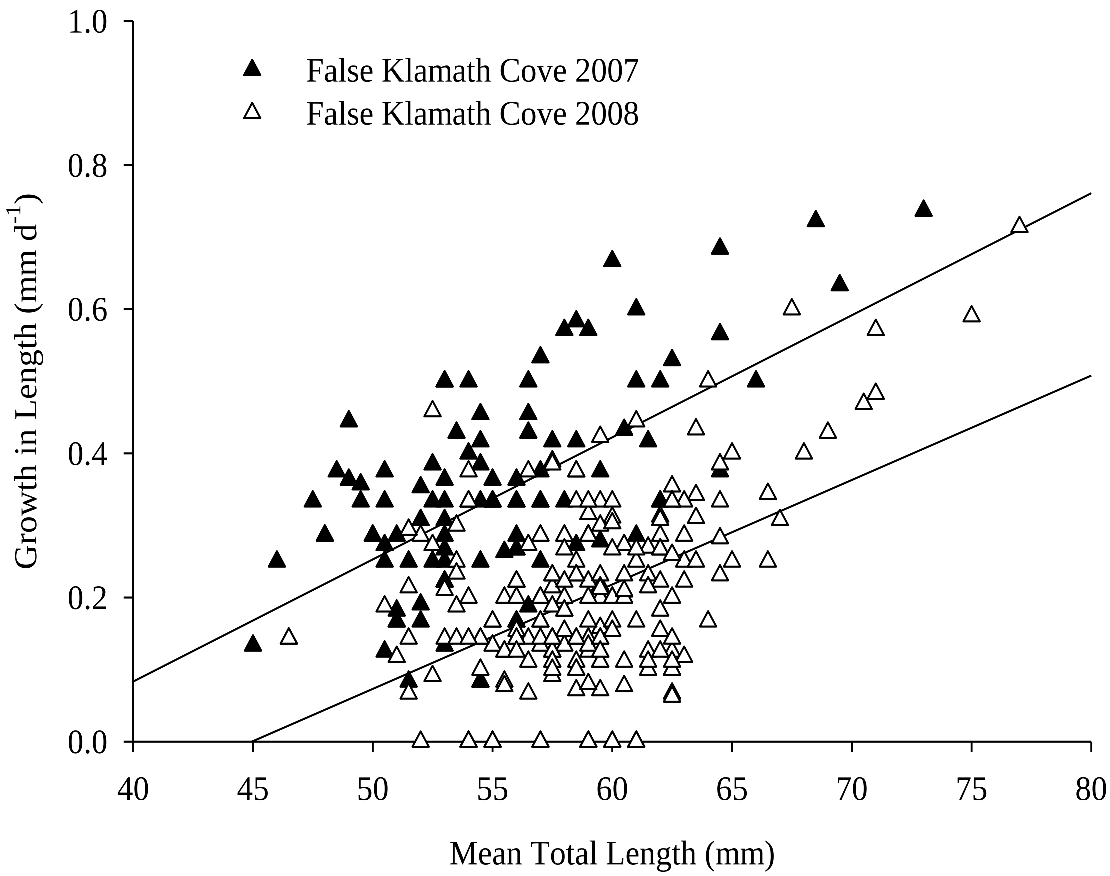

Figure 21. Growth in length (mm d^{-1}) of young-of-the-year black rockfish (*S. melanops*) recaptured at False Klamath Cove, Del Norte County, California, from May through August 2007 and June through August 2008. Lines represent linear trendlines for the selected data.

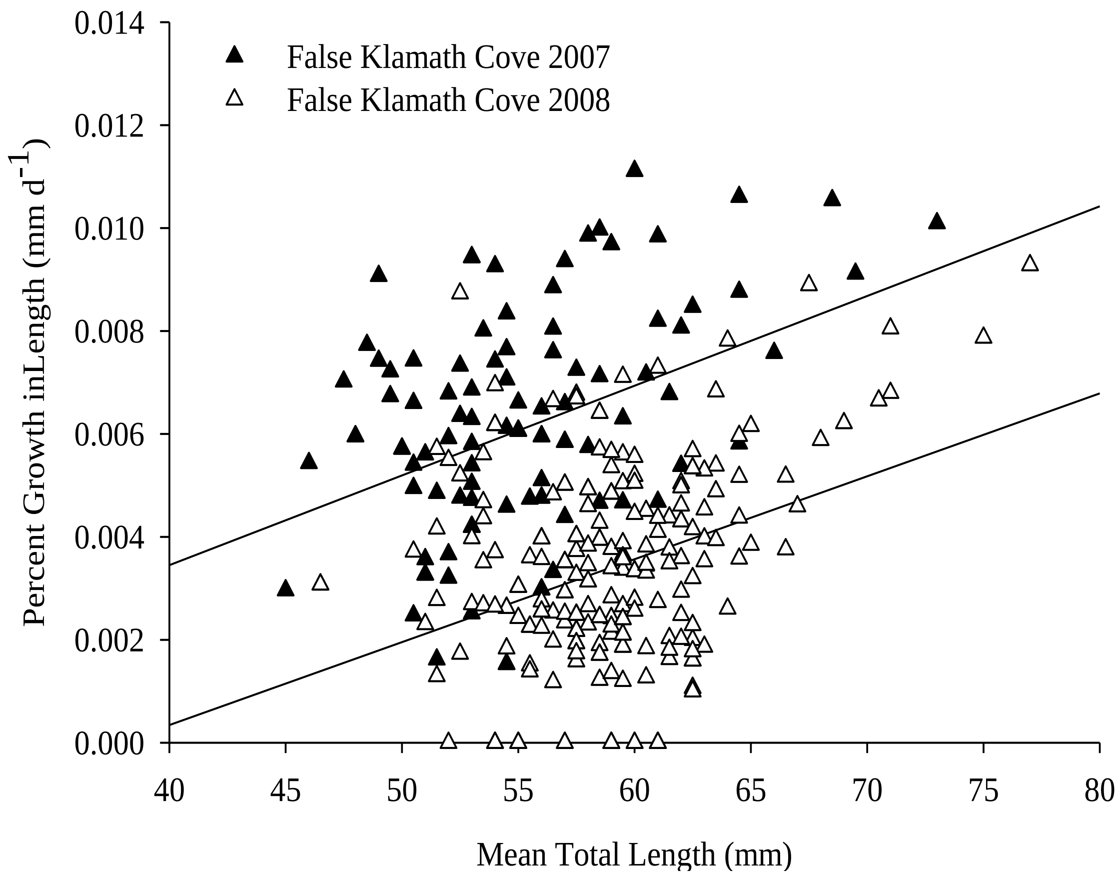

Figure 22. Percent growth in length (mm d^{-1}) of young-of-the-year black rockfish (*S. melanops*) recaptured at False Klamath Cove, Del Norte County, California, from May through August 2007 and June through August 2008. Lines represent linear trendlines for the selected data.

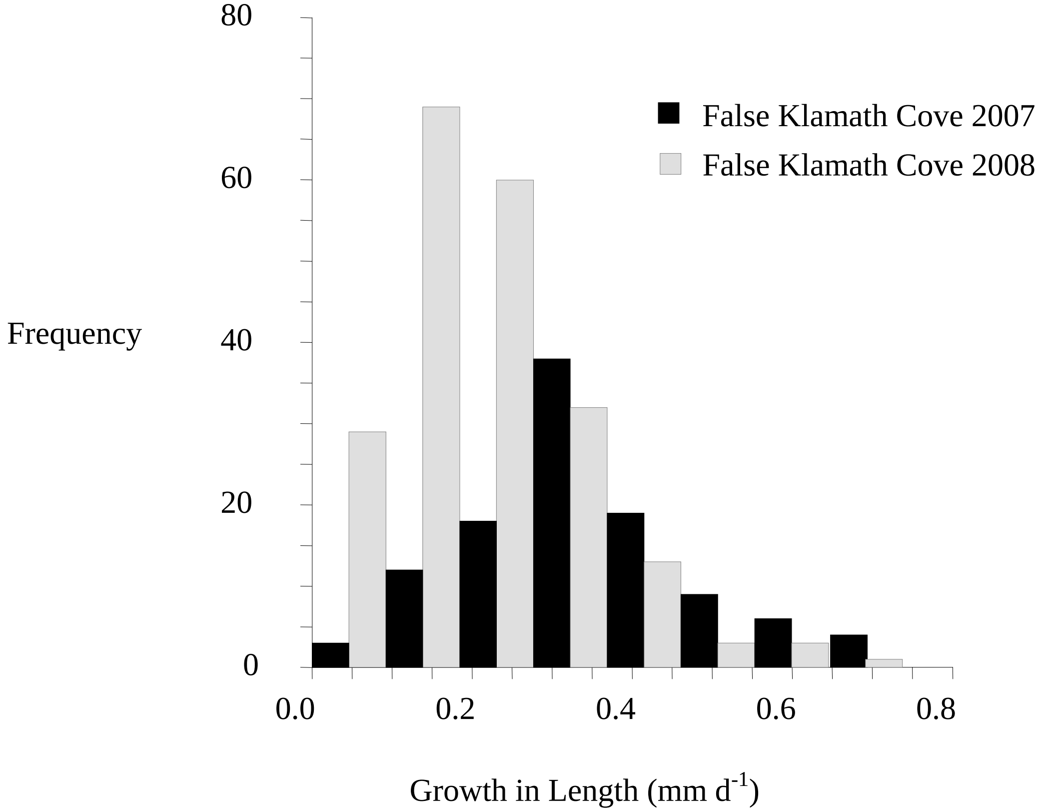

Figure 23. Growth in length (mm d^{-1}) of young-of-the-year black rockfish (*S. melanops*) recaptured at False Klamath Cove, Del Norte County, California, from May through August 2007 and June through August 2008.

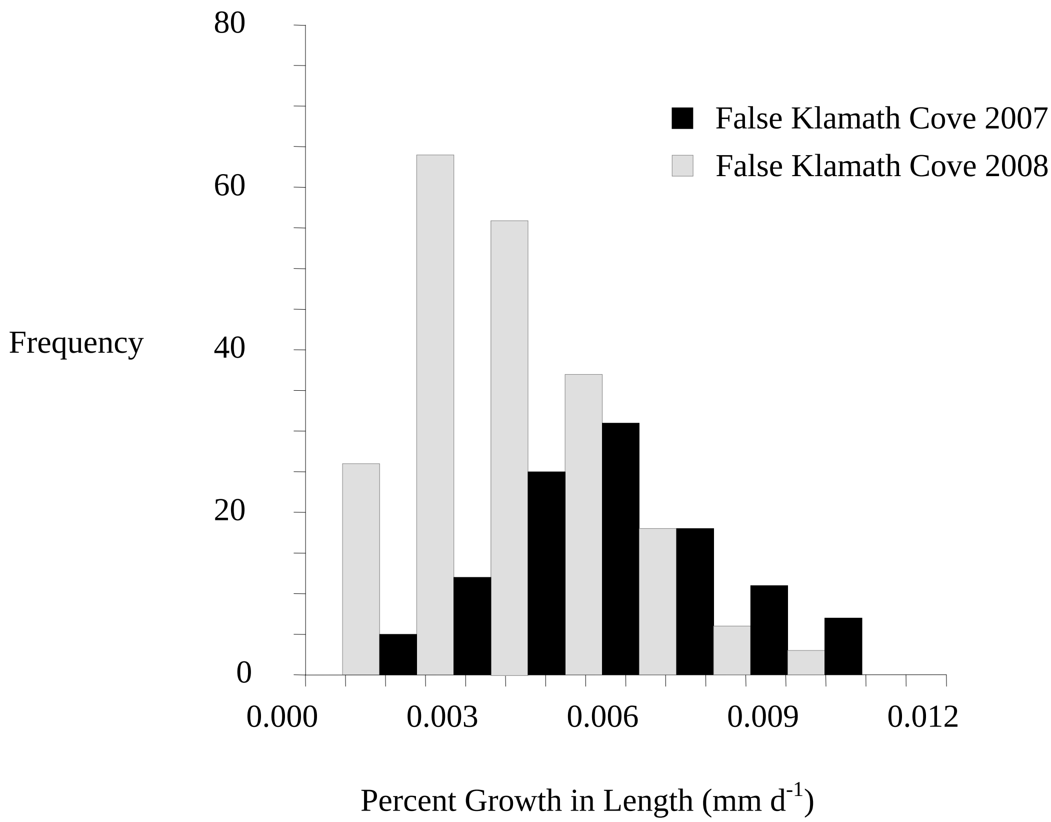

Figure 24. Percent growth in length (mm d^{-1}) of young-of-the-year black rockfish (*S. melanops*) recaptured at False Klamath Cove, Del Norte County, California, from May through August 2007 and June through August 2008.

Table 12. Monthly mean growth in length (mm d^{-1}) of recaptured young-of-the-year black rockfish (*S. melanops*) and corresponding mean sea surface temperatures collected at Palmer’s Point and False Klamath Cove, Humboldt and Del Norte Counties, California from June through August 2007 and 2008. Sea surface temperature was obtained from the National Oceanic and Atmospheric Administration’s National Data Buoy Center, buoy station 46027 (N 41°51’10”, W 124°22’52”) located 15 km west northwest of Crescent City, Del Norte County, California. SST = sea surface temperature in degree Celsius.

	Palmer’s Point 2007				False Klamath Cove 2007				False Klamath Cove 2008			
Month	No.	Mean size	Range	Mean SST	No.	Mean size	Range	Mean SST	No.	Mean size	Range	Mean SST
June	24	0.301 (±0.038)	0.111 - 0.444	9.95	55	0.286 (±0.028)	0.083 – 0.500	9.95	50	0.154 (±0.028)	0 – 0.375	8.91
July	27	0.342 (±0.042)	0.091 – 0.533	12.65	30	0.453 (±0.050)	0.286 – 0.737	12.65	33	0.248 (±0.042)	0.063 – 0.600	10.47
August	1	0.750	n/a	12.53	0	n/a	n/a	12.53	3	0.571 (±0.166)	0.429 – 0.714	11.63

Table 13. Significance in differences of mean monthly sea surface temperature collected from June through August 2007 and 2008. Sea surface temperature was obtained through the National Oceanic and Atmospheric Administration's National Data Buoy Center, buoy station 46027 (N 41°51'10", W 124°22'52") located 15 km west northwest of Crescent City, Del Norte County, California. ^{o}C = degrees Celsius.

	Year and mean sea surface temperature (^{o}C)		
Month	2007	2008	P-value
June	9.95	8.91	< 0.01
July	12.65	10.47	< 0.01
August	12.53	11.63	< 0.01

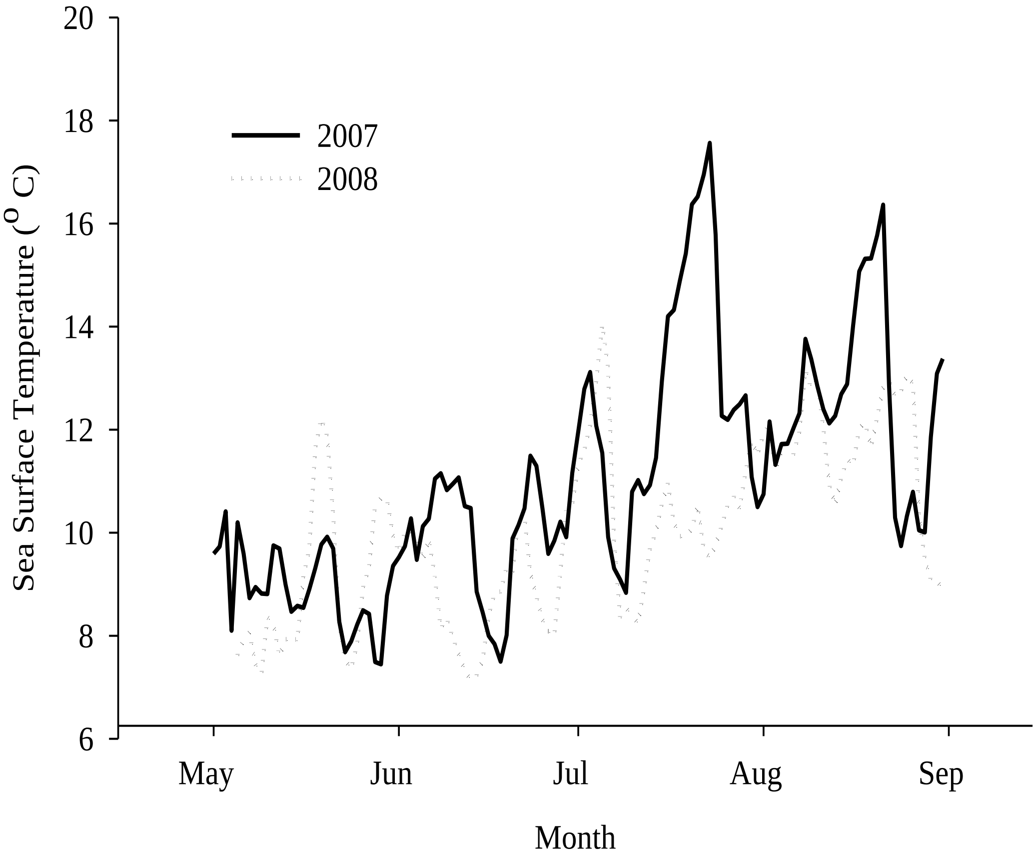

Figure 25. Mean daily sea surface temperature collected from May through August 2007 and 2008. Sea surface temperature was obtained through the National Oceanic and Atmospheric Administration's National Data Buoy Center, buoy station 46027 (N 41°51'10", W 124°22'52") located 15 km west northwest of Crescent City, Del Norte County, California. ^{o}C = degrees Celsius.

Table 14. Temperature, salinity, dissolved oxygen, percent saturation, and pH measured at Palmer's Point and False Klamath Cove, Humboldt and Del Norte Counties, California, from May through August 2007 and June through August 2008. ^{o}C = degrees Celsius, ppt = parts per thousand, mg/L = milligrams per liter, n/a = data not collected.

Site	Year	Month	Temperature (^{o}C)	Salinity (ppt)	Dissolved Oxygen (mg/L)	% saturation	pH
Palmer's Point	2007	May	10.26 - 10.75	32.39 - 33.69	3.87 - 6.59	41.6 - 71.3	6.99 - 7.42
		June	8.94 - 12.56	29.28 - 34.24	1.67 - 18.28	19.0 - 209.1	7.07 - 8.30
		July	11.58 - 16.17	32.02 - 34.01	2.32 - 15.68	26.6 - 185.3	6.67 - 8.02
		August	11.17 - 11.29	33.18 - 33.69	6.98 - 7.67	78.7 - 95.2	n/a
False Klamath Cove	2007	May	10.74 - 13.55	25.19 - 32.26	7.80 - 17.40	85.5 - 202.7	7.09 - 8.16
		June	10.62 - 19.08	29.19 - 34.18	2.82 - 18.77	32.7 - 221.4	7.19 - 8.67
		July	12.44 - 17.17	31.69 - 33.71	2.77 - 15.08	33.0 - 181.1	6.54 - 8.20
		August	14.39 - 15.18	30.82 - 31.36	4.19 - 8.04	50.1 - 96.7	n/a
False Klamath Cove	2008	June	8.02 - 15.89	22.37 - 33.85	2.53 - 15.84	26.6 - 179.7	6.38 - 8.11
		July	10.28 - 18.72	27.43 - 33.43	2.34 - 11.39	26.5 - 130.0	6.74 - 8.03
		August	10.80 - 14.17	30.26 - 33.20	2.79 - 11.14	32.8 - 127.9	6.92 - 7.64

morning sampling times, whereas maximum readings occurred in late-morning and early-afternoon. The minimum temperature noted was 8.94^{o}C, whereas the maximum was 19.08^{o}C. The minimum dissolved oxygen value observed was 1.67 mg/L, while the maximum was 18.77 mg/L. None of the water quality parameters measured appeared to be limiting to black rockfish observed in tidepools throughout this study.

DISCUSSION

Site Fidelity and Homing Behavior

Results from this study clearly indicate that young-of-the-year black rockfish show site fidelity to intertidal pools. These findings support other juvenile rockfish tagging studies conducted in subtidal habitats (Dewees and Gotshall 1974, Hartmann 1987, Hoelzer 1988, Byerly 1999, Johnson 2000). In Carmel Bay, California, 24 percent of tagged young-of-the-year gopher rockfish (*S. carnatus*) showed site attachment to specific kelp canopies for as long as 2 months (Hoelzer 1988). Further, 65 percent of the fish recaptured were recovered within 2 m of their original kelp canopy of capture. Similar behavior was noted in age-1 copper and quillback rockfish off Sitka Sound, Alaska. These marked fish showed site fidelity to eelgrass and kelp habitats from May through late-summer (Johnson 2000).

In addition to site fidelity, this research also shows that black rockfish exhibit homing behavior to specific tidepools. This behavior has also been documented in other intertidal fishes such as cottids (Green 1973, Khoo 1974, Richkus 1978, Yoshiyama et al. 1992), blennies (Stephens et al. 1970), and opaleye (*Girella nigricans*) (Williams 1957). Off Vancouver Island, Canada, tidepool sculpin have been shown to display homing behavior from displacements as far as 122 m (Khoo 1974), and off Oregon as far as 76 m (Yoshiyama et al. 1992). Smoothhead sculpin (*Artedius lateralis*), rosylip sculpin (*Ascelichthys rhodorus*), and rockpool blenny (*Hypsoblennius gilberti*) have shown returns from displacements as far as 40, 44, and 45 m, respectively (Stephens et al. 1970

Yoshiyama et al. 1992). Although the above studies have demonstrated site fidelity and homing behavior in resident benthic species, the present study is the first to document this behavior in juvenile rockfish inhabiting rocky intertidal areas.

The percent of black rockfish to exhibit site fidelity varied between years, with higher recovery rates occurring in 2007 (Tables 1, 2 and 3). Lower recruitment levels and a higher percent of fish tagged in 2007 are most likely the causes for the difference observed. In 2007, 67 and 62 percent of the fish captured were tagged at Palmer’s Point and False Klamath Cove, respectively, whereas in 2008, only 8 percent of the fish captured were tagged at False Klamath Cove (Table 1). The higher number of recruits, tagging times and tagging locations used limited the number of fish that could be marked in 2008. Had a greater proportion of fish been tagged, a higher percent of fish would likely have been recaptured. For example, numerous tidepools in 2008 held several hundred black rockfish at any one time. During these periods of high fish abundance, tidepools were fished in accordance with fish health, tidal height, and daily workload. Obviously, not all fish could be captured within these tidepools. On several occasions tagged fish were observed and not captured. These visual sightings were not included in the data. Although effort differed between years, the percent of fish recaptured in 2008 was relatively high compared to previous juvenile rockfish tagging studies done in other habitats, which range from 6 to 28 percent (Dewees and Gotshall 1972, Hartmann 1987, Hoelzer 1988, Byerly 1999, Johnson 2000).

At both sites, over both years, homing behavior was noted at all displacement distances used (Tables 2 and 3, Figures 10, 11 and 12). However, fish displaced 258 m at

False Klamath Cove in 2008 exhibited weak homing behavior, as only one fish (0.03 percent) was observed to home back to its tidepool of origin (Table 3, Figure 12). At displacement distances ≤ 110 m, the percent of fish to show homing behavior in 2007 was relatively high, ranging from 19.9 percent at 83 m to 40.6 percent at 0 m at Palmer's Point, and 30.8 percent at 68 m to 50.0 percent at 0 m at False Klamath Cove (Tables 2 and 3). In 2008, at False Klamath Cove, recovery rates ranged from 19.5 percent at 17 m to 27.0 percent at 0 m (Table 3). These results indicated that distance was a significant factor affecting the homing ability of black rockfish. What additional factors affect this behavior is uncertain though olfaction, vision, and water depth have been shown to influence homing ability in other rockfish. (Carlson and Haight 1972, Pearcy 1992, Love et al. 2002, Mitamura et al. 2002, 2005). In Maizura Bay, Japan, Mitamura et al. (2005) showed that vision-blocked mebaru exhibited similar homing behaviors to non-vision-blocked mebaru, but that mebaru with plugged olfaction pits displayed weak homing behaviors, indicating that they predominantly use olfaction cues, rather than vision, for homing. In yellowtail rockfish, vision does appear to be an important sense affecting their homing behavior. Off southeast Alaska, Carlson and Haight (1972) noted that recovery rates of yellowtail rockfish displaced to sites across stretches of deep water were less than those seen in fish displaced to sites along the mainland coast (10.5% vs. 49.5%, respectively), suggesting they use underwater landmarks for homing. In the present study, fish displaced 258 m displayed weak homing behavior as only one of the 265 fish displaced (0.03 percent) returned to its home pool. While fish displaced 258 m displayed weak homing behavior, the percent to show site fidelity was relatively high (9.4 percent).

This recovery rate is comparable to other rockfish tagging studies off central and southern California, which have noted site fidelity in 6, 7, and 8 percent of canary, copper, and black-and-yellow rockfish tagged, respectively (Lea et al. 1999), and 5.7, 10.6, and 12.5 percent of bocaccio, olive (*S. serranoides*), and starry rockfish (*S. constellatus*) tagged, respectively (Hartmann 1987).

Research has shown that the degree of homing behavior displayed by adult rockfish differs between species. In general, most studies have demonstrated that adults are capable of returning from displacement distances exceeding 2 km (Carlson and Haight 1972, Matthews 1990, Pearcy 1999, Mitamura et al. 2002). These studies support the homing behavior exhibited by black rockfish in this study. In adult and subadult intertidal fishes, research has shown that age has an effect on homing performance. Gibson (1967) showed that younger longspined bullhead (*Acanthocottus bubalis*) exhibited poorer homing ability compared to older conspecifics. This behavior has also been noted in tidepool sculpin (Craik 1981). Research suggests that homing behavior increases with age as the fish learn and remember landmarks in their surrounding environment. Whether homing behavior differs with age in rockfish is unknown.

The significant difference observed between homing success and displacement distance at Palmer's Point is somewhat misleading. While recovery rates were highest in fish displaced ≤ 15 m, the proportion of fish to exhibit homing behavior from displacements of ≥ 45 m was still relatively high, ranging from 19.9 percent at 83 m to 25.0 percent at 45 m. These data indicate that the displacement distances used may have been too conservative. Had displacement distances been extended to approximately 250 m, it is likely that the significant difference observed between fish displaced ≤ 15 m and fish displaced ≥ 45 would not have occurred. Comparing recovery rates from fish displaced 83 and 90 m at Palmer's Point to fish displaced 68 and 110 m at False Klamath Cove in 2008 yields similar results, indicating similar behavioral patterns.

Growth

Mean growth rates observed in the present study ranged from 0.204 to 0.343 mm d^{-1} (0.0034 to 0.0061 percent growth in length, respectively) between years (Table 11). These findings are comparable to other growth studies of juvenile rockfish species, including black rockfish (Boehlert 1981, Boehlert and Yoklavich 1983, Woodson and Ralston 1991, Johnson et al. 2001, Love et al. 2007). A review of 21 field growth studies on 17 juvenile rockfish species by Love et al. (1991) found that 65 percent of the fish examined exhibited mean growth rates between 0.20 to 0.30 mm d^{-1}. Some of the rockfish species examined in that study included pelagic species such as yellowtail, shortbelly (*S. jordani*), black, blue and olive rockfish, all of which occur off northern California (Love et al. 2002). Mean growth rates of black rockfish noted in the Love et al. (1991) review ranged from 0.20 to 0.30 mm d^{-1}. The overall mean growth rate of black rockfish was 0.257 mm d^{-1}.

A significant difference ($P < 0.01$) in the monthly mean sea surface temperature was observed between years off northern California during the recruitment and residence period of the black rockfish studied, with warmer sea surface temperatures occurring in 2007 (Table 13, Figure 25). Coinciding with these differences in sea surface temperature was a significant difference ($P < 0.01$) in both mean growth and percent growth in length, with higher growth rates occurring in 2007. Although growth differed significantly between years, growth within a particular year increased during the months of highest sea surface temperatures (Table 12). Similar growth patterns have been noted for pelagic juvenile shortbelly rockfish (Woodson and Ralston 1991). In Woodson and Ralston's six-year study investigating the interannual variation in growth rates of several juvenile rockfish species off central California, they found maximum mean growth of shortbelly rockfish to coincide with the warmest January sea surface temperatures, whereas the lowest growth coincided with the coldest January sea surface temperatures. This pattern, however, contrasts with that observed in greenstriped rockfish (*S. elongates*) cowcod, and stripetail rockfish, which show decreased growth during the months of highest sea surface temperatures (Johnson et al. 2001).

The relative abundance of black rockfish in 2008 was notably higher than that observed in 2007. Consequently, it is plausible that the differences noted in growth between years could have resulted from density-dependent growth and intraspecific competition. Evidence of reduced growth rates due to density-dependence has been observed in several fish species including English sole (*Parophrys vetulus*) (Peterman and Bradford 1987), striped surfperch (*Embiotoca lateralis*) (Holbrook and Schmidt 1992), Pacific herring (*Clupea pallasii*) (Tanasichuk 1997), mebaru (Plaza et al. 2002), and redfish (*S. mentella*) (Saborido-Rey et al. 2004).

The diets of black rockfish were not examined in this study. Consequently, it is uncertain what effect prey concentrations may have had upon the differences observed in growth. In a laboratory growth study of young-of-the-year black rockfish, Boehlert and Yoklavich (1983) found that growth was controlled by temperature, but limited by food. Maximum mean growth rates were observed at 12 and 18^{o}C under maximum daily feeding rations. Their maximum growth rates were comparable to the growth rates noted in the present study, 0.267 to 0.314 mm d^{-1} vs. 0.204 to 0.343 mm d^{-1}, respectively. Further, in the review of several field and laboratory growth studies of juvenile rockfish, Love et al. (1991) described that the maximum growth rates of laboratory reared rockfish, fed to satiation, were comparable to mean growth rates calculated from field studies. This review indicates that the growth of young-of-the-year rockfish in the field may not be food limited, suggesting that temperature may be the primary factor affecting growth in the wild.

Recruitment and Residence

Off northern California, young-of-the-year black rockfish are typically observed inhabiting rocky intertidal areas late-May through mid-August (Moring 1986, Cox 2007, Studebaker and Mulligan 2008), approximately an 85 d period. Length of residency observed in this study ranged from 73 to 77 d (Table 10). The mean length of residency was 76 d. This result is comparable to that noted by Studebaker and Mulligan (2008), which noted an average residence time of 67 d. In the present study tidepools were surveyed prior to any observed rockfish recruitment. However, initial recruitment could have occurred prior to that noted on days when tidal heights were too high to sample. If this was the case, the initial recruitment and residence times for black rockfish reported here may be slightly underestimated.

Although black rockfish were observed inhabiting the rocky intertidal area for over 72 d, most recaptured fish displayed a length of residency of < 3 weeks. Because recaptured fish were observed throughout the entire residence period, these data indicate that black rockfish enter and rotate throughout the rocky intertidal area in “pulses” over the course of their residence period. Length of residency and use of this habitat, however, appears to vary among individuals within these pulses.

Future Research

The rocky intertidal area is a complex and demanding habitat for marine life. Large fluctuations in temperature, salinity, oxygen, turbulence, and wave energy characterize this habitat. Black rockfish are unique among *Sebastes* spp. in that they are observed in rocky intertidal pools as juveniles. While food, structure, and protection from predators are obvious factors, it is not clear what influences black rockfish to recruit and use specific areas within this habitat. Only tidepools with black rockfish were sampled in this study. Although water quality parameters fluctuated temporally (Table 13), they did not appear to have an effect ($P > 0.05$) on site fidelity or homing behavior. Therefore, the tidepools sampled in this study are assumed to exhibit the chemical and/or physical parameters preferred by young-of-the-year black rockfish. What these parameters are and how they might influence habitat selection, however, was not examined in this study. Future research comparing the chemical and physical parameters of tidepools exhibiting black rockfish to those void of black rockfish could offer insight into what mechanisms influence habitat selection by black rockfish inhabiting rocky intertidal areas. These data could inform managers of areas most likely to be utilized by black rockfish and help in the design and implementation of marine protected areas off northern California.

In this study, black rockfish were observed in tidepools with temperatures exceeding 19^{o}C. While studies have noted that young-of-the-year black rockfish can withstand temperatures near or above 18^{o}C (Gonor and Thum 1970, Boehlert and Yoklavich 1983), it is unknown what their thermal optimum is. Boehlert and Yoklavich (1983) did not identify a thermal optimum in their study, which observed growth rates of black rockfish at 7, 12, and 18^{o}C, although the highest rate of growth was noted at 18^{o}C. Black rockfish were also observed in tidepools exhibiting dissolved oxygen levels ranging from 1.67 to 18.77 mg/L in this study. While tolerance to low dissolved oxygen levels has been documented in resident intertidal fishes, it has not been reported in a transient fish species such as black rockfish. Research identifying optimum water quality parameters would also be useful to managers estimating juvenile black rockfish growth, survival, and mortality rates and would further our understanding of juvenile black rockfish physiology.

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