# Sex, Age, and Growth of Black Rockfish *Sebastes melanops* from a newly exploited population in the Gulf of Alaska, 1993–1999

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# Sex, Age, and Growth of Black Rockfish *Sebastes melanops* from a newly exploited population in the Gulf of Alaska, 1993–1999

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ABSTRACT: A newly exploited population of black rockfish *Sebastes melanops* were sampled from commercial landings in the Gulf of Alaska from 1993–1999 to identify issues in future management of this resource. Fish were measured, sexed, and sagittal otoliths were removed and aged. Males dominated the catches, comprising 71% of the samples. The majority of the catch was between 38 and 53 cm fork length, with a distinct mode at 39 cm fork length in 1997 in both the Kodiak and Alaska Peninsula Areas. Length-at-age for each year revealed differences in growth between sexes, with females larger than males. Growth differences between areas were observed but were significant for only males. The oldest fish aged was 48 years old, with the majority of the catch between 8 and 20 years old. Variations in year class strength were large and apparent in all areas. Strong recruitment events in 1979 and 1990 were tracked throughout the entire range of collection years and throughout the Gulf of Alaska. Research priorities for black rockfish in the Gulf of Alaska should focus on determining the relationship between sex-specific depth distributions, changes in sex compositions with respect to reproductive timing, age of maturity, and the affects of local and large scale environmental conditions on recruitment. Maintenance of a time series of biological data such as age and growth and monitoring specific fishing practices may offer indicators of long-term fishing effects on successful recruitment.

## INTRODUCTION

Black rockfish *Sebastes melanops* range from Alaska to California (Hart 1973) and are one of 30 rockfish (genus *Sebastes*) species that are commercially and recreationally harvested in the Gulf of Alaska (GOA). Commercial fishing for black rockfish in the GOA and the Aleutian Islands began in the early 1990s and is managed by the Alaska Department of Fish and Game (ADF&G) in both state and federal waters.

Black rockfish are harvested in the GOA (Figure 1) in directed jig fisheries and as incidental catch in jig, trawl, and longline fisheries for other groundfish species. The guideline harvest levels (GHLs) are based on a proportion of the allowable biological catch of black rockfish for the central GOA (260 mt) established by the North Pacific Fishery Management Council for nearshore fisheries with no valid biomass estimate and little stock assessment information (Claussen and Heifetz 1997). A total of 173 mt is divided among management areas and sections and was set low enough to accommodate potential black rockfish bycatch in other fisheries, distribute fishing effort, and attempt to avoid localized depletion (Jackson and Ruccio 1998). Directed fishing for black rockfish opens January 1 and closes when GHLs are met for each section or area.

Black rockfish landings averaged 184.6 mt (407,000 lbs) per year during 1990–1999 (Jackson and Ruccio 1998). Estimated annual exvessel value grew from $6,400 to over $240,000 from 1994 to 1999 (Alaska Department of Fish and Game, Kodiak, unpublished data), suggesting increased effort and growing economic importance of the fishery.

Black rockfish are slow growing and long-lived, have low natural mortality rates, and a high age at maturity (Leaman 1991; Wallace and Tagart 1994). Rockfish population dynamics are characterized by high variability in year-class strength; large year classes, which occasionally arise, are believed to be important to long-term maintenance of populations (Leaman and Beamish 1984). Past studies suggest that major oceanographic changes, such as El Niño, may influence

**Authors**: CARRIE L. WORTON works for the Alaska Department of Fish and Game, Division of Commercial Fisheries, 211 Mission Road, Kodiak, Alaska 99615. E-mail: carrie_worton@fishgame.state.ak.us. GREGG E. ROSENKRANZ works for the Alaska Department of Fish and Game, Division of Commercial Fisheries, 211 Mission Road, Kodiak, Alaska 99615.
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rockfish recruitment over broad geographic areas (Ralston and Howard 1995; Lenarz et al. 1995). The maximum recorded age for black rockfish is 50 years old (Meyer 2000) and the maximum recorded total length is 69 cm (J. Blackburn, Alaska Department of Fish and Game, Kodiak, personal communication). Age at 50% maturity for California black rockfish is approximately 6–8 years, with corresponding total lengths of 38–42 cm (Wyllie Echeverria 1987). Black rockfish begin recruiting into nearshore fisheries at approximately 4 years old (Wallace and Tagart 1994). In many rockfish species, females attain a larger size than males (Six and Horton 1977; Wyllie Echeverria 1987). Fertilization is internal, the eggs develop and hatch inside the ovary, and pelagic larvae may be released anytime from January to June (Kendall and Lenarz 1987; Wyllie Echeverria 1987). Although black rockfish are typically associated with nearshore rocky reef areas, tagging studies off Washington have shown that both minor and extensive migrations occur (Matthews and Barker 1983; Culver 1987; Ayres 1988). These life history characteristics, combined with a paucity of biological information on the species, make stocks difficult to manage and vulnerable to localized depletion.

Black rockfish life history research has occurred primarily in areas with well-established commercial fisheries. Fishery-independent stock assessments for nearshore rockfishes are difficult to implement due to a poor understanding of size- and sex-specific spatial distributions and problems related to gear selectivity (Parker et al. 2000). To date, ADF&G has not implemented a stock assessment program for black rockfish in the GOA. Other populations of black rockfish along the west coast have been harvested since the 1880s, so the GOA fishery provides an opportunity to study a relatively unexploited population of black rockfish at the northwestern limit of its range (Love et al. 2002).

The purpose of this study was to gather baseline biological information from a newly exploited population of black rockfish in the GOA to better develop an

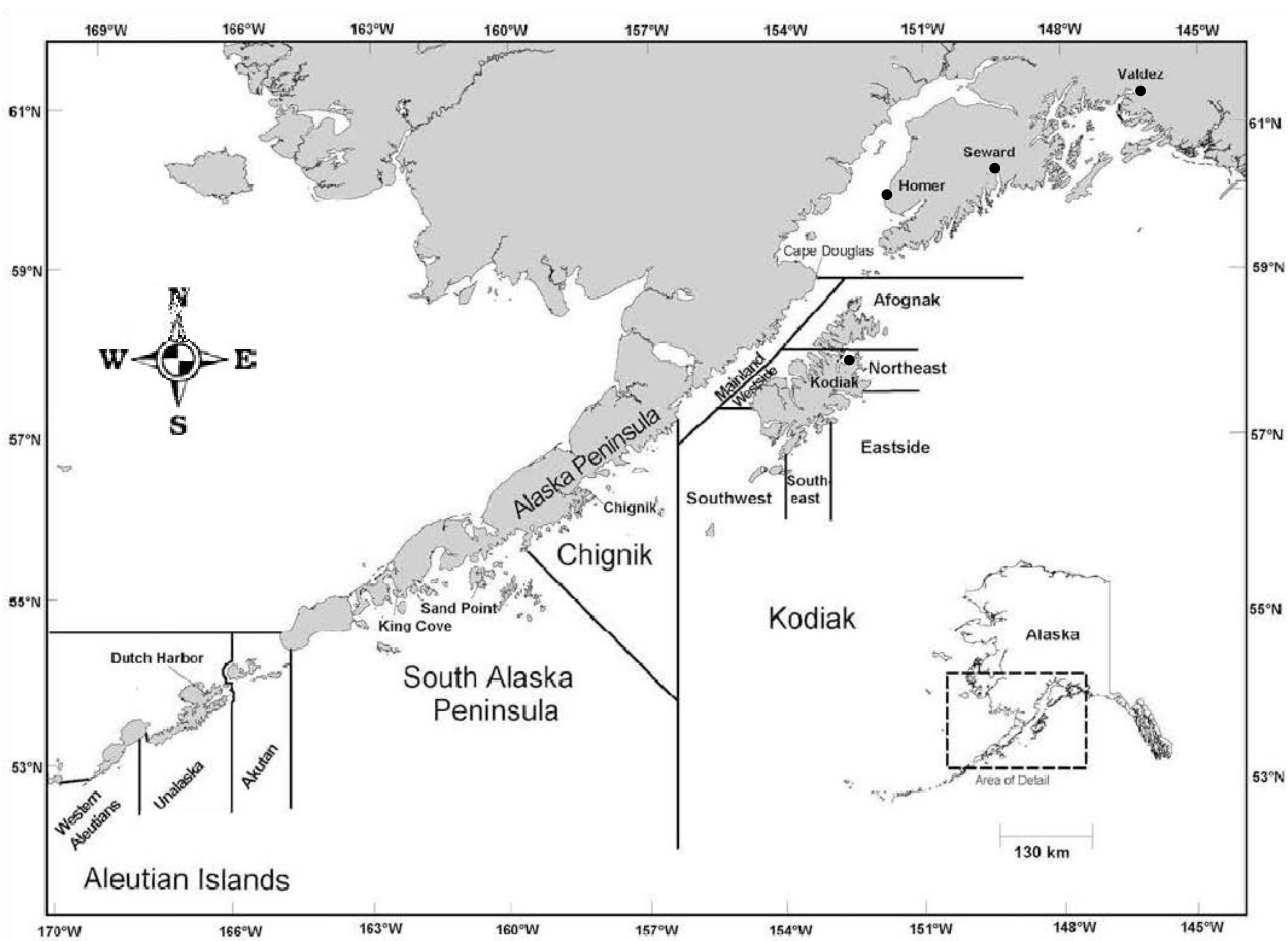


Figure 1. Map showing areas and sections used by the Alaska Department of Fish and Game in management of the commercial black rockfish fishery in the Gulf of Alaska.

understanding of potential management issues. Our paper summarizes size, sex, growth, and age data collected during 1993–1999 from GOA black rockfish harvests and makes recommendations for future research.

# METHODS

## Study Area

The study area spans the GOA from Cape Douglas to Unalaska Island, a distance of over 1,100 km, and offshore to 371 km (Figure 1), the 200 nautical mile Exclusive Economic Zone boundary. This area is divided into the Kodiak, Chignik, South Alaska Peninsula, and Aleutian Islands Management Areas. Beginning in 1997, the Kodiak Area was further subdivided into 7 Kodiak Sections, and the Aleutian Islands Area into 3 Aleutian Islands Sections.

## Sampling

Beginning in 1993, black rockfish were sampled at shoreside processing facilities from individual vessel deliveries in the ports of Kodiak, Chignik, King Cove, Sand Point, and Dutch Harbor (Figure 1). Samples from the Chignik and the South Peninsula Areas were collected from 1996 to 1999, and samples from the Aleutian Islands Areas were collected only in 1999. Effort was made to sample 100% of the shoreside landings, but due to the sporadic nature of the fishery this was not always feasible, so deliveries were sampled opportunistically. A random sample of 100 fish was selected for biological sampling from each vessel delivery, and a minimum of 30 fish were randomly subsampled for sex and age determination. When possible, fish were weighed from each sampled delivery and an average weight calculated to the nearest 0.1 kg. Harvesters were interviewed at the time of delivery to determine fishing effort, gear type, fishing location, depth, and composition of bycatch species. Black rockfish were identified using criteria established by Kramer and O'Connell (1988) or Hart (1973).

## Sex, Age, and Length Measurement

Sex, fork length (FL), and gonad condition were recorded, and otoliths were collected for aging. Sex and gonad condition were confirmed using macroscopic examination and criteria established by Westrheim (1975). The black rockfish were typically processed in-the-round, so evisceration was seldom possible, therefore sex was usually determined by external examination of the urogenital papillae (Moser 1967). To minimize sex identification error, fish were recorded as unknown when the examination was inconclusive.

Two sagittal otoliths were removed from each fish, were cleaned, and stored dry. Age was estimated using the break and burn method described by Chilton and Beamish (1982) and MacLellan (1997). Accuracy of this aging method has been validated by Wallace and Tagart (1994), therefore determining accuracy was not specifically addressed in this study.

Two readers successively aged all samples collected from 1993 to 1999. Precision was used to test the reproducibility of the age estimates between or within readers on 20% of the samples collected from 1994 to 1998. Specifically, otoliths were reread by the same reader or by a second reader and any discrepancies in aging were resolved using another otolith from the same specimen and taking a third reading. The assigned age was the age with the highest frequency of occurrence. Average percent error (Beamish and Fournier 1981) was used to measure precision of age estimates between or within readers.

## Data Analyses

Length-age data were separated by area, however data from the Chignik and the South Alaska Peninsula Areas were combined, hereafter referred to as the Alaska Peninsula Area, to increase sample sizes for the purpose of this report. Samples from the Aleutian Islands Area (Table 1) were not sexed and initial examination determined sample sizes were too small for meaningful analysis. Fork length and age frequency distributions from the Kodiak and the Alaska Peninsula Areas were compared graphically for each year. Age data from the Kodiak Area were examined by section to detect differences in age composition.

Length-age relationships were modeled using the von Bertalanffy growth equation for initial graphical comparison by sex and area, and secondarily using Cerrato's (1990) parameterization of the von Bertalanffy growth equation:

$$L(t) = l_1 + (l_2 - l_1)\frac{1-\rho^{t-\tau_1}}{1-\rho^{\tau_2-\tau_1}} ,$$

where $L(t)$ represents FL at age $t$ (years), and $\tau_1$=8 years to correspond with the approximate age at the onset of maturity, and $\tau_2$=20 years to correspond with the age when growth slows substantially. Parameters we estimated were mean fork length at ages 8 and 20 years (subsequently referred to as $l_8$ and $l_{20}$) and the

Table 1. Black rockfish sample sizes by management area, Gulf of Alaska, 1993–1999.

| | Kodiak | | Chignik | | S. Alaska Peninsula | | Aleutian Islands | | Totals | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | Fork Lengths | Otoliths | Fork Lengths | Otoliths | Fork Lengths | Otoliths | Fork Lengths | Otoliths | Fork Lengths | Otoliths |
| 1993 | 4,263 | 287 | 0 | 0 | 0 | 0 | 0 | 0 | 4,263 | 287 |
| 1994 | 781 | 186 | 0 | 0 | 0 | 0 | 0 | 0 | 781 | 186 |
| 1995 | 1,077 | 326 | 0 | 0 | 0 | 0 | 0 | 0 | 1,077 | 326 |
| 1996 | 402 | 152 | 159 | 112 | 0 | 0 | 0 | 0 | 561 | 264 |
| 1997 | 3,098 | 1,022 | 480 | 31 | 257 | 10 | 8 | 8 | 3,843 | 1,071 |
| 1998 | 2,580 | 966 | 185 | 13 | 40 | 9 | 0 | 0 | 2,805 | 988 |
| 1999 | 1,768 | 882 | 215 | 101 | 162 | 49 | 94 | 92 | 2,239 | 1,124 |
| Total | 13,969 | 3,821 | 1,039 | 257 | 459 | 68 | 102 | 100 | 15,569 | 4,246 |

Ford growth parameter $r$ (Ricker 1975; Quinn and Deriso 1999). We used nonlinear regression assuming additive error structure for all model fitting.

We calculated bootstrap confidence regions for the parameter estimates to compare size-at-age and growth between sexes within the same area and between each sex from different areas. Specifically, we created 2,000 replicate data sets by sampling with replacement from the data used in each model fitting. A parameter vector was estimated for each replicate, then Hotelling's $T^2$ statistic (Johnson and Wichern 1992) was calculated and used as a multivariate metric to retain 95% of the replicates closest to the mean parameter vector. Pairwise scatterplots of these parameter estimates were constructed, allowing graphical comparison of $r$, $l_8$, and $l_{20}$ for different segments of the black rockfish population.

# RESULTS

## Fishery and Sampling

Black rockfish were commercially harvested primarily from nearshore areas in the GOA by mechanical and hand jigs. Harvests occurred in all management areas and were sampled at the ports of Kodiak, Chignik, and Sand Point, and Dutch Harbor (Table 1). Fishing depths ranged from 10 to100 m, but 40 m was the most frequently fished depth. The average individual weight of black rockfish harvested from all areas in all years was 1.96 kg.

A total of 15,569 fish were sampled from 1993 to 1999 during the months of February through September, with 77% of the samples taken between April and June. Ninety percent of the fish sampled were caught

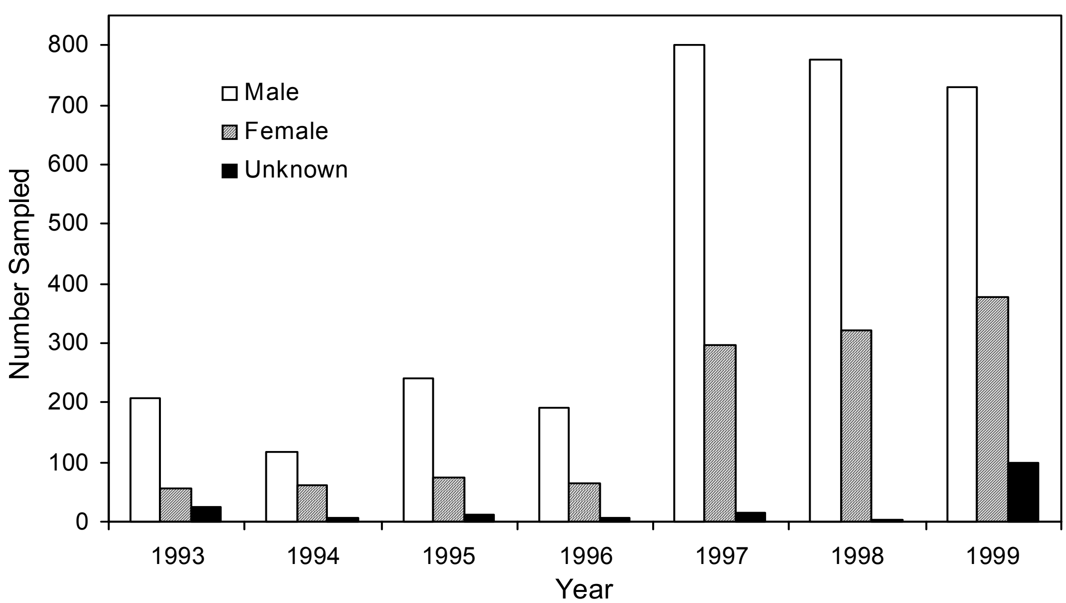


Figure 2. Black rockfish sample sizes by sex in the Gulf of Alaska, 1993–1999.

in the Kodiak Area ($n$ = 13,969). Of all black rockfish sexed, 3,065 were males, 1,251 were females, and only 165 were identified as unknown. Males dominated the catch (Figure 2), accounting for 71% of the fish for which sex was determined. The number of females in the harvest has steadily increased since 1993. Of the 397 that were sexed by internal examination, 70% were males indicating that no bias was introduced when sexing by external examination. None of the females were found in gravid condition.

## Length, Age, and Sex Distributions

Lengths for the majority of the black rockfish harvest in the Kodiak and Alaska Peninsula Areas ranged from 38 to 52 cm FL (Figures 3 and 4). In 1997, a distinct

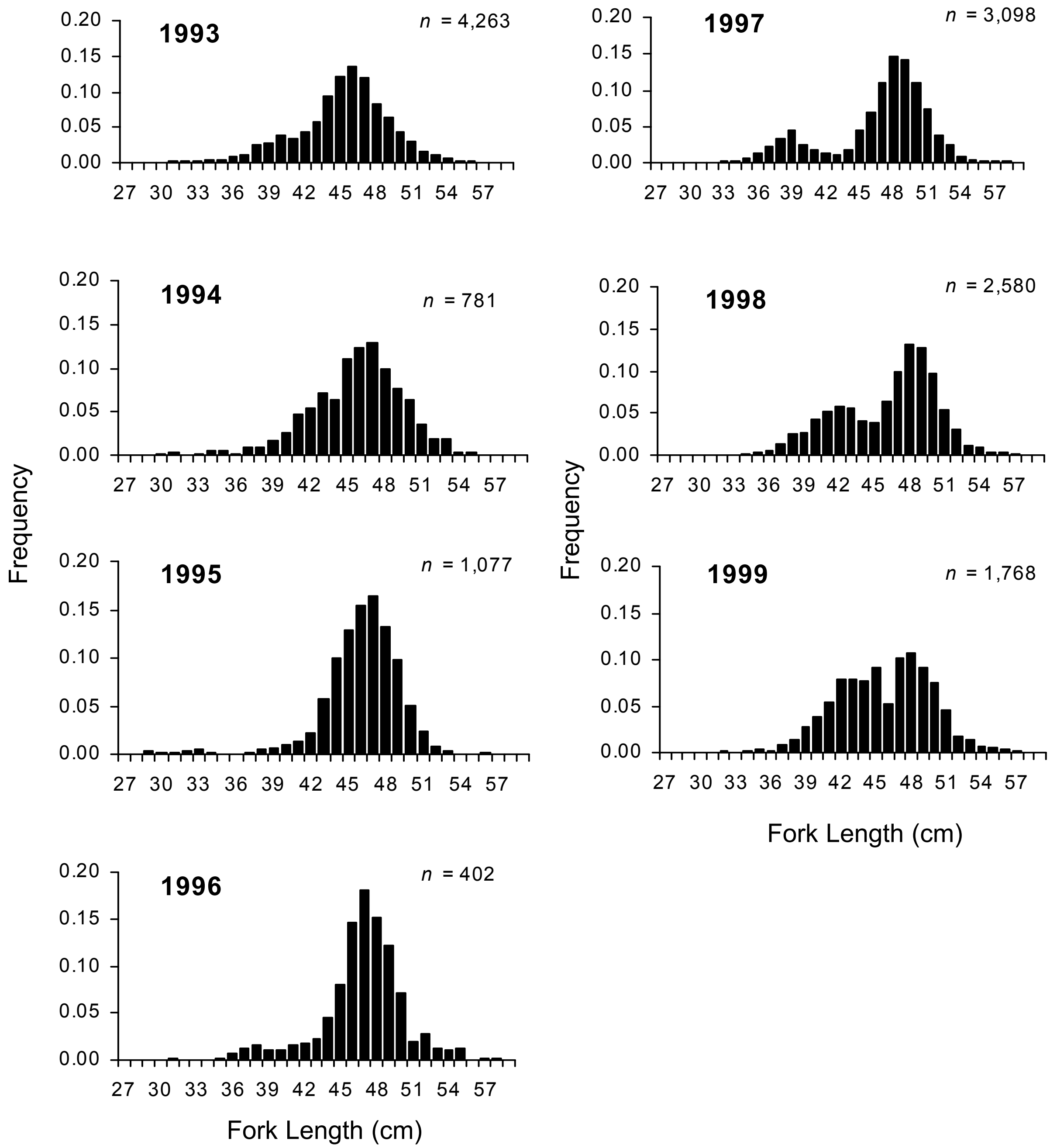


Figure 3. Fork length distributions of black rockfish sampled from the Kodiak Area commercial harvest, 1993–1999.

mode of 39 cm FL fish was present in the Kodiak Area and moved through the harvest in successive years, while the Alaska Peninsula Area showed a similar mode of 37 cm FL fish in 1998. Black rockfish populations in both areas appear to have experienced recruitment in recent years (Figure 3 and 4).

There was good agreement in otolith age estimates between readers. Average percent error of otolith ages for samples from 1994 to 1998 was 1%, well below 3%, which is a typical standard used in black rockfish aging studies (K. Munk, Alaska Department of Fish and Game, Juneau, personal communication).

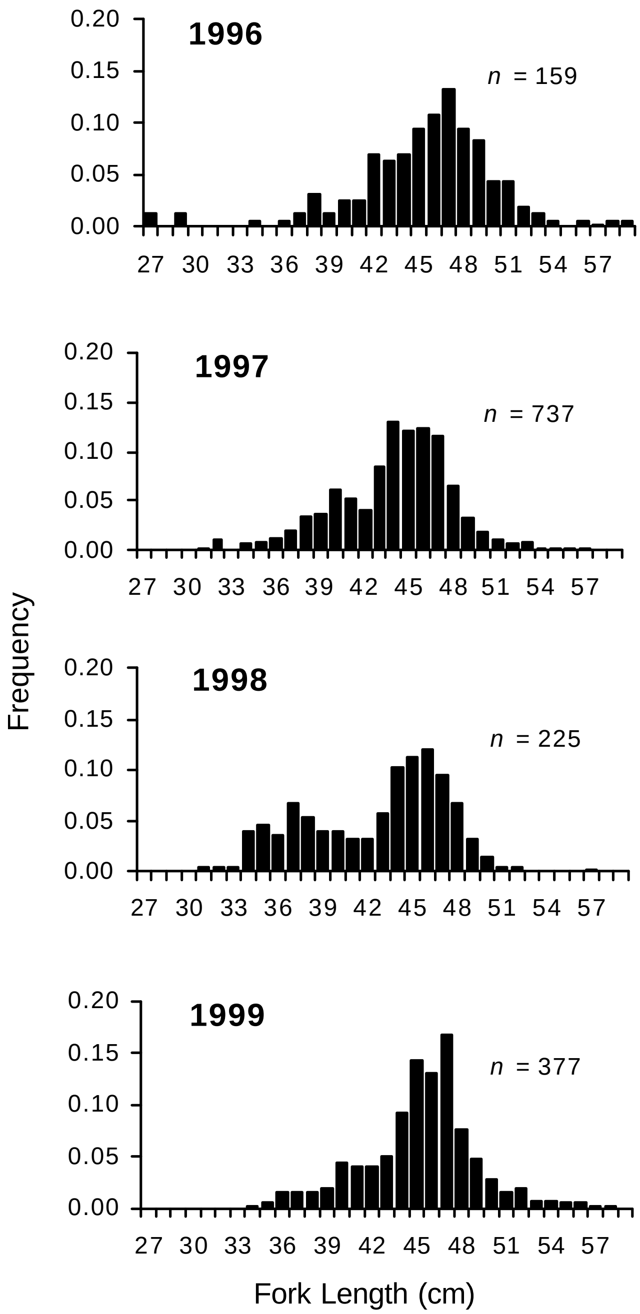


Figure 4. Fork length distributions of black rockfish sampled from the Alaska Peninsula Area commercial harvest, 1996–1999.

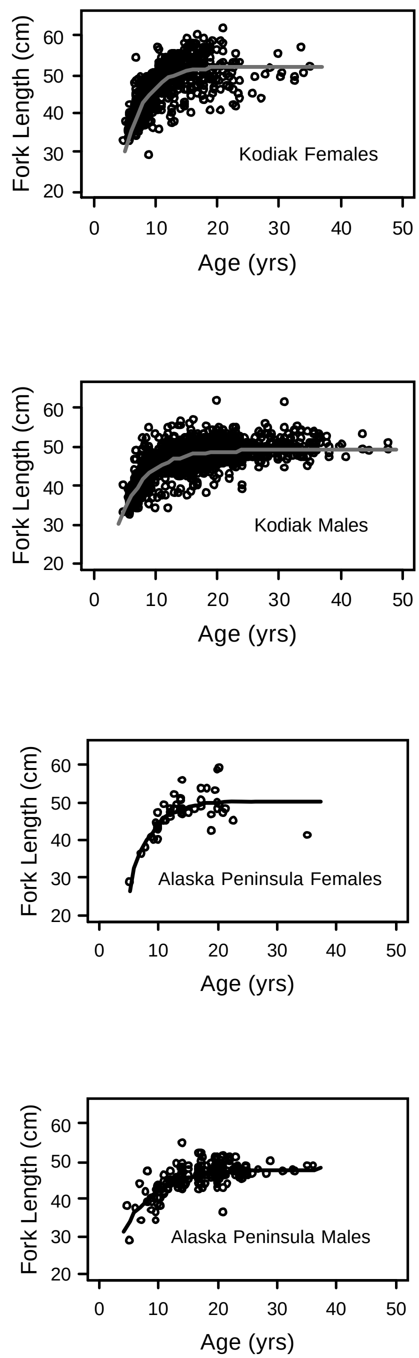


Figure 5. Black rockfish length-age data and von Bertalanffy model fits for Kodiak and Alaska Peninsula Area samples, 1993–1999. Length data are measured as fork length. Data were jittered along the x-axis for plotting.

Plots of observed and von Bertalanffy-predicted length-at-age (Figure 5) as well as analysis of residuals (Quinn and Deriso 1999) indicated adequate model fits to the data. Male-female differences in growth and length-at-age are apparent, with greater numbers of females at sizes larger than 52 cm and less than 45 cm. Parameter estimates indicate that mean fork length is greater for females than for males at ages 8 and 20 years, and the growth parameter ($r$) is smaller for females than males (steeper slope of fitted curves in Figure 5; Table 2). Variability in fork length was also greater for females than for males at older ages in both the Kodiak and Alaska Peninsula Areas. Pairwise scatterplots of 95% confidence regions for the parameter estimates (Figures 6, 7, and 8) provide a means of comparing growth and length-at-age for male and female black rockfish and demonstrate the effect of sample size on hypothesis tests. Large sample sizes for the Kodiak Area produced tight confidence regions for both males and females that are disjointed in three-dimensional parametric space (Figure 6), indicating statistically significant multivariate differences. Fork length at ages 8 and 20 (parameters $l_8$ and $l_{20}$) were statistically different between males and females, but the growth parameter ($r$) was not (note overlap along $x$-axis in Figure 6, top 2 plots). For the Alaska Peninsula Area, low female sample size ($n = 50$) produced broad 95% confidence regions that were not distinct from the confidence regions for males (Figure 7). The nature of the plots, however, indicates that a modest increase in female sample size would produce statistically significant differences in the parameters. Comparisons between males from the Kodiak and Alaska Peninsula Areas (Figure 8) reveal the need for larger sample sizes. Broad overlapping confidence regions of Alaska Peninsula Area males along the x-axis produce no significant differences from the Kodiak Area. From a multivariate perspective, the parameters are significantly different, but taken individually, only $l_{20}$ for males was significantly different between the Kodiak and Alaska Peninsula Areas.

Table 2. Cerrato's parameterization estimates of the von Bertalanffy model for black rockfish growth, Gulf of Alaska, 1993–1999.

| | Kodiak Area | | Alaska Peninsula Area | |
|---|---|---|---|---|
| Parameter[a] | Males | Females | Males | Females |
| $\rho$ | 0.793 | 0.755 | 0.837 | 0.763 |
| $l_8$ | 41.7 | 42.7 | 39.7 | 39.8 |
| $l_{20}$ | 48.7 | 51.8 | 47.0 | 50.0 |

[a] $\rho$ is the Ford growth parameter; $l_8$ = length at age 8; $l_{20}$= length at age 20.

Large variations in year-class strength were evident in plots of Kodiak Area age distributions (Figure 9). The strong 1979 year class (age 14 in 1993) dominated the sampled catch from 1993 to 1997, and a year class spawned in 1985 (age 8 in 1993) was a large component of the catch from 1994 to 1998. Fish spawned in 1990 have been a large component of the

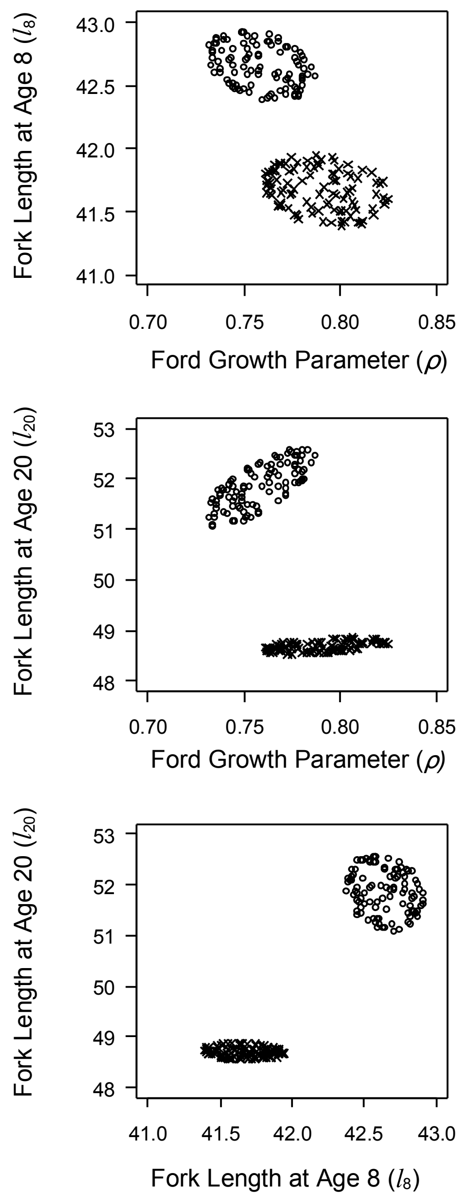


Figure 6. Scatterplots of bootstrapped 95% confidence regions for von Bertalanffy parameter estimates, Kodiak Area female (**o**, $n$ = 1,134) and male (×, $n$ = 2,665) black rockfish. Plots are parameter values for the 100 replicates most distant from the bootstrap mean.

harvest since 1997. Ages ranged from 4–48 years old, the majority of the catch was between 8 and 20 years old, and only 5% exceeded 25 years of age. From 1993 to 1999, black rockfish began recruiting to the fishery between 4 and 6 years of age.

Age data from all areas combined, and plotted by year spawned, revealed both spatial synchronicity and variability in year class strength across the GOA (Figure 10). The strong 1979 year class, and weak year classes from 1977–1978, 1980, 1983, and 1987–1989

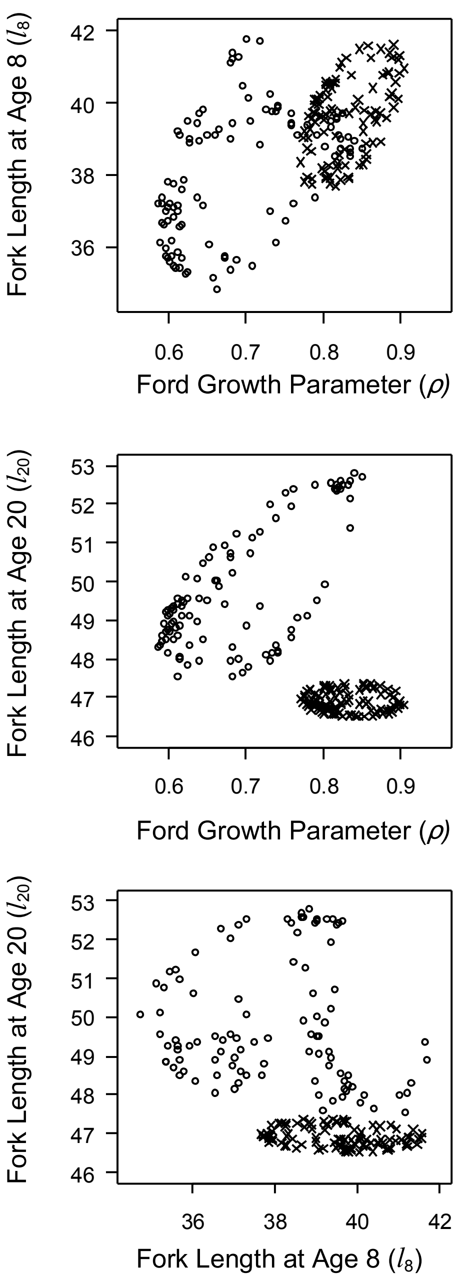


Figure 7. Scatterplots of bootstrapped 95% confidence regions for von Bertalanffy parameter estimates, Alaska Peninsula Area female (**o**, $n$ = 50) and male (×, $n$ = 218) black rockfish. Plots are parameter values for the 100 replicates most distant from the bootstrap mean.

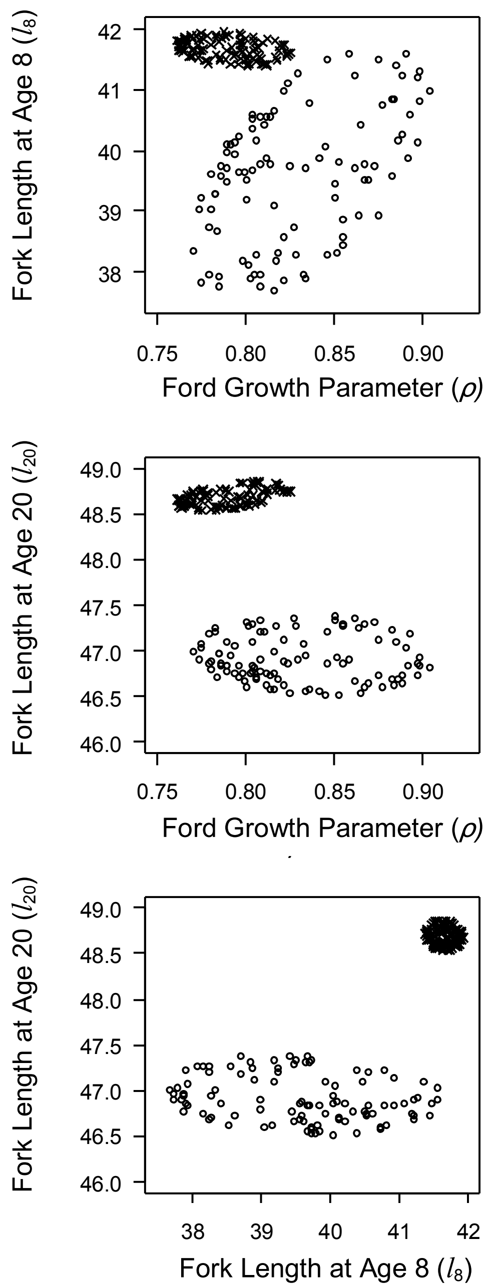


Figure 8. Scatterplot comparisons of bootstrapped 95% confidence regions for von Bertalanffy parameter estimates, Kodiak (×, $n$ = 2,665) and Alaska Peninsula (**o**, $n$ = 218) Area male black rockfish.

are generally evident in all sections. The 1990 year class appears to have produced good recruitment to all management sections except in the Southwest Section of the Kodiak Area, where sample size was low ($n = 98$), and in the Alaska Peninsula Area. Similarly, the 1991 year class is a large component of the catch in the Southeast, Southwest, Westside, and Mainland Sections of the Kodiak Area, but much weaker in the Afognak and Northeast Sections of the Kodiak Area and the Alaska Peninsula Area.

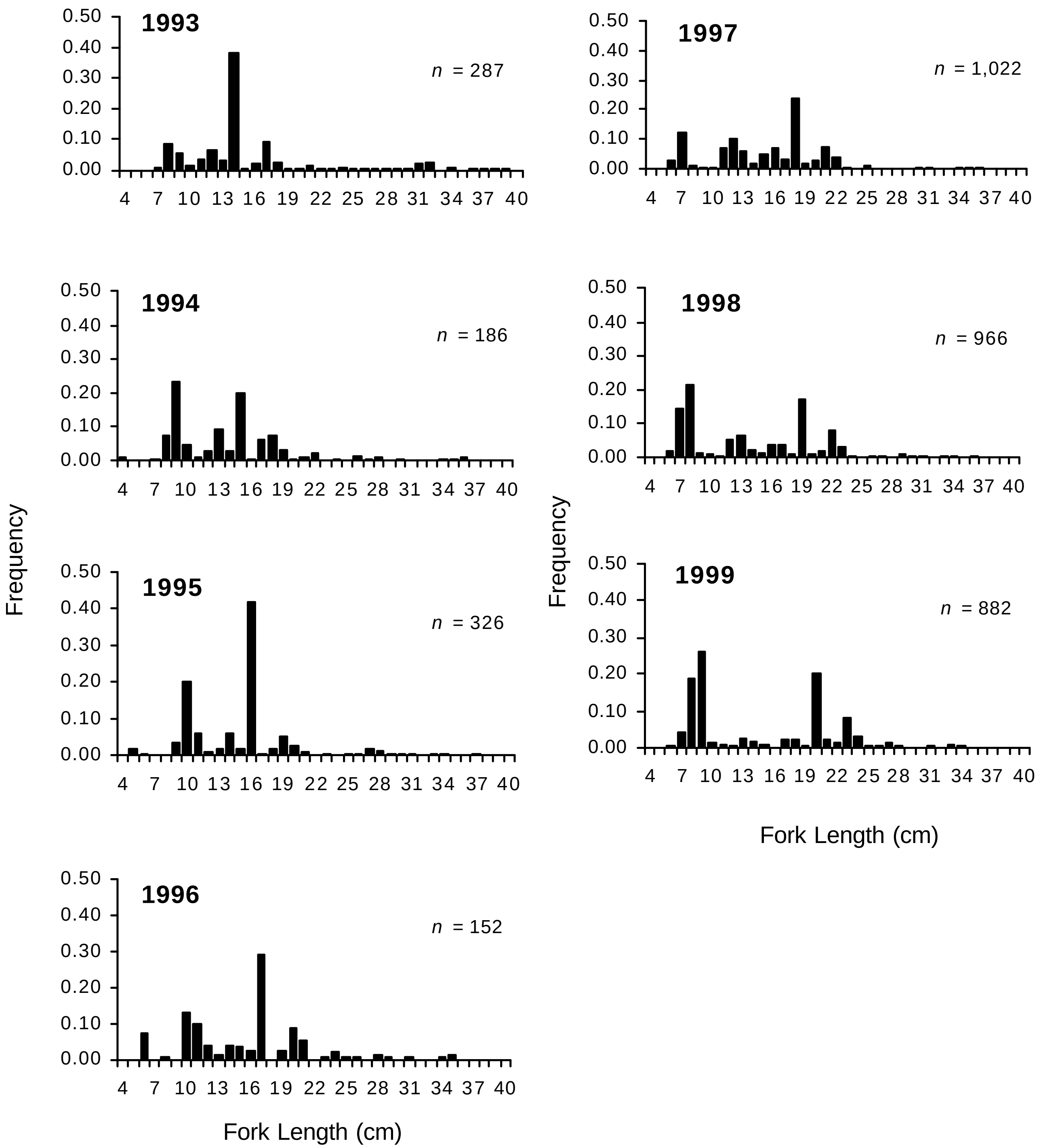


Figure 9. Age distributions of black rockfish sampled from the Kodiak Area commercial harvests, 1993–1999.

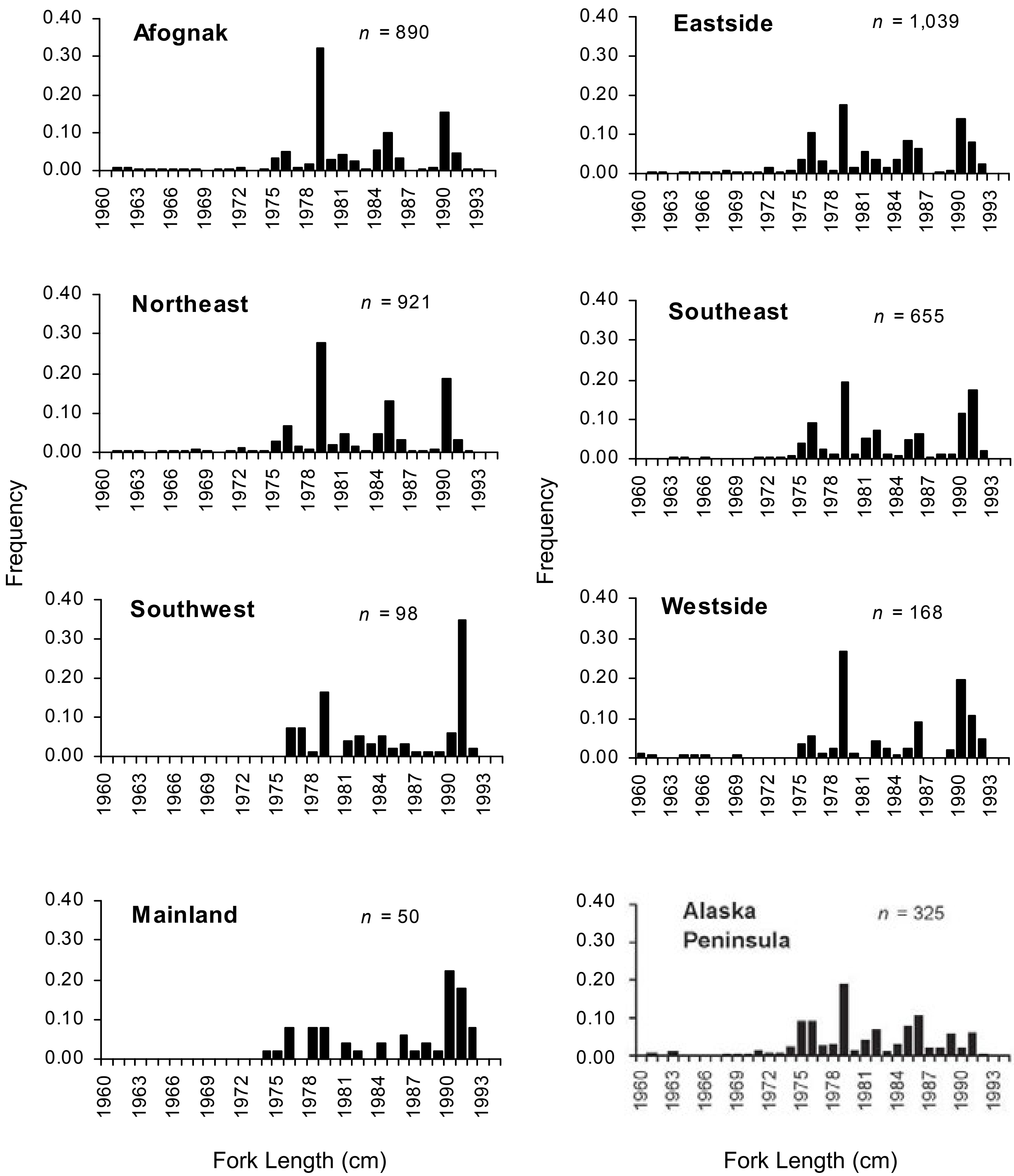


Figure 10. Black rockfish age distributions by year spawned for the Alaska Peninsula Area and management sections of the Kodiak Area in the Gulf of Alaska, 1993–1999.

## DISCUSSION

The large number of males found in the GOA commercial harvests we sampled is a common feature of black rockfish fisheries. Meyer (2000) found that the proportion of males was significantly higher in sport fishery harvests from the Kodiak and Homer Areas (central GOA) than from Seward and Valdez Areas, which border the central GOA to the northeast. Field (1984) found that males dominated the overall catch, but females were slightly more abundant in deeper waters (>75 m) off Southeast Alaska. By comparison, the male-female ratio in the Washington commercial catch changed from substantially more males to more females over an 11-year period (Wallace and Tagart 1994).

Little is known of sex-specific black rockfish behavior to determine if the unequal sex compositions found in the harvests are a product of gear selectivity of males over females. Recent black rockfish surveys conducted in late summer (August) in the GOA have shown no significant differences in sex ratios, indicating that each sex responds similarly to jig gear (Dan Urban, Alaska Department of Fish and Game, Kodiak, personal communication). The unequal sex composition in the catch may be due to reproductive timing. Fishers in the GOA regularly target shallower nearshore areas, close to common ports, where black rockfish are more accessible and fishing is most economical. O'Connell (1987) suggested that female black rockfish migrate offshore during parturition making them unavailable to the nearshore fishery. Most black rockfish sampled in our study were taken between April and June, and none of the females we sampled were in gravid condition. Parturition in black rockfish is estimated to occur between January and May in northcentral California and is believed to occur later in northern latitudes (Wyllie Echeverria 1987). This characteristic could delay the capture of most adult females in Alaskan fisheries to mid summer and may explain why males dominate harvests from April through June in the central and western GOA fisheries. Black rockfish, including some in gravid condition, have been captured more than 445 km offshore, suggesting a reproduction-related migration off the continental shelf (Dunn and Hitz 1969). Pacific ocean perch *S. alutus* have been documented to move into deeper waters before fertilization and the release of larvae (Gunderson 1977; Leaman and Beamish 1984).

Changes in sex composition of fishery catches may also reflect changes in fishing effort patterns. Wallace and Tagart (1994) suggested that the change in sex ratios of black rockfish in Washington fishery harvests reflects declining numbers of inshore black rockfish, where males are more abundant, and a shift of fishing effort to offshore areas, where females are more abundant. Sadovy and Eklund's (1999) study on Nassau grouper *Epinephelus striatus* and jewfish *E. itajoara* found higher numbers of females than males at exploited spawning sites, suggesting that sex-selective fishing occurs on spawning aggregations. Differences in the sex composition of catches between the Kodiak Area and the North GOA Area may be due to a longer history of sport and commercial fishing in Seward (Meyer 2000). The slight increase in the female proportion of the harvests in the GOA in recent years may indicate changes in fishing pressure as well. The demand for black rockfish has increased in the last decade, increasing the range of marketable sizes of fish from >2.5 kg to all sizes. This increased retention of smaller fish, which are also comprised of more females, could also contribute to the increases of females seen in the harvests.

Growth differences between sexes apparent in the GOA, wherein females grow faster and larger than males, is a common feature of rockfish (Wilkins 1980). Studies in Washington and Oregon also found that black rockfish females grow faster and larger than males (Six and Horton 1977; Wallace and Tagart 1994). Differences in growth between the Kodiak and the Alaska Peninsula Areas may reflect differences in latitude. Black rockfish from the Alaska Peninsula Area (lat 56°20′N–54°30′N), grew slower and attained a smaller size than Kodiak Area black rockfish (lat 58°51′N–56°20′N). This trend is even more apparent when comparing Alaskan fish with those from Washington and Oregon (Wallace and Tagart 1994). Higher ocean temperatures at lower latitudes usually result in higher growth rates (Beverton and Holt 1959; Boehlert and Kappenman 1980). While growth differences of rockfish at different latitudes have been documented in many rockfish species (Beverton and Holt 1959; Boehlert and Kappenman 1980; Field 1984; Wilkins 1980), latitudinal variation in temperature may not be the only factor affecting differences in growth since this trend is not prevalent for all rockfish species (Boehlert and Kappenman 1980; Haldorson and Love 1991). Food availability and water temperature were the two major factors affecting variations in growth rates of juvenile *Sebastes* in the laboratory (Boehlert and Yoklavich 1983) and in field studies conducted over large geographic distances and on the same reefs (Love et al. 1991). Investigation into food habits of black rockfish and environmental differences between the Kodiak and the Alaska Peninsula Areas may offer explanations of these growth differences.

Age at 50% maturity has been estimated to be between 6 and 8 years old for California (Wyllie Echeverria 1987) and Washington black rockfish (Wallace and Tagart 1994), and there is evidence that black rockfish mature at larger sizes and older ages (10–11 years old) at higher latitudes (Field 1984). With black rockfish recruiting to the GOA jig fishery at 4–6 years old and growth declining by age 8 (indicating the onset of maturity), it is likely fish are being harvested prior to or during the onset of maturity. While this fishing practice can affect the sustainability of the resource (Mason 1998), it appears that from 1993 to 1999, strong recruitment events in the GOA have offset or masked these effects of fishing pressure on the population. Conversely, the longevity of the species and delayed recruitment to the fishery may mask changes in the population and take 5 to 10 years to detect (Leaman 1991).

Others (Leaman and Beamish 1984; Ralston and Howard 1995) have found variability in year-class strength. Strong 1979 year classes seen in the GOA commercial harvests were also apparent in the sport harvests from Kodiak and Homer (Meyer 2000). Occurrence of similar recruitment patterns in the Kodiak and Alaska Peninsula Areas, which are approximately 650 km apart, indicate broad regional conditions influenced this year class. Larger sample sizes would enhance the recruitment patterns revealed throughout the GOA and clarify the differences between areas.

Other species have shown similar recruitment patterns over large areas. Strong year classes of Pacific ocean perch coincide throughout the Oregon-British Columbia region (Gunderson 1977). Although regional factors help explain some recruitment events, local differences cannot be ignored. Weak recruitment of the 1990 year class to the Alaska Peninsula Area, which was a dominant year class in the Kodiak Area, suggests that local differences as well as regional differences may influence recruitment patterns. The strong presence of the 1990 and 1991 year classes in every sample year suggests the differences in year classes between Kodiak and the Alaska Peninsula Areas are not aging error.

Recruitment failures that were apparent in all GOA Areas coincided with El Niño events in 1976–1977, 1982–1983, and 1986–1987 (Bailey et al. 1995; Armaral 2002). In addition, above average ocean temperatures near Kodiak (Blau and Dooley 1995) and Seward (Royer 1985) during these years further suggest El Niño influences in the GOA. The effects of El Niño on recruitment was apparent with the poor blue rockfish *S. mystinus* and yellowtail rockfish *S. flavidus* year classes (Ralston and Howard 1995), and the reduction of first-year recruitment of most rockfish species in California (Lenarz et al. 1995). Successful recruitment depends on favorable environmental conditions for larval survival at a specific time during spawning (Ralston and Howard 1995; Berkeley and Markle 1999; Parker et al. 2000). Decreases in food resources for larval and juvenile rockfish are believed to adversely affect recruitment (McGowan 1984; Lenarz et al. 1995; Roemmich and McGowan 1995).

El Niño effects may explain some of the variability in black rockfish year-class strength in the GOA, but caution must be used when making assumptions in the absence of concurrent studies on local environmental conditions. MacFarlane and Norton's (1999) study of embryonic development in *Sebastes* spp. suggests that the nutritional condition of larvae at birth, as well as environmental factors, influence survival and year-class strength. Regardless of how complex the process of recruitment may be, rockfish life history traits such as long life, late maturity, and many reproductive years successfully buffer against years of recruitment failure (Leaman and Beamish 1984).

Future research on black rockfish in the GOA should focus on the relationship between sex-specific depth distributions and reproductive timing, sex composition of exploited and unexploited populations, age of maturity, and the influence of local and large-scale environmental conditions on recruitment. The biological significance of differences in growth and other population parameters between areas within the region are also worthy of attention. Investigation of specific fishing practices of the fleet and the effects of fishing on these populations are a priority that should be addressed through a mandatory logbook program.

Until practical and accurate stock assessment methods are developed for nearshore rockfish species, we recommend that habitat protection, monitoring of fishing effort and location, low GHLs aimed at distributing effort, and maintenance of biological time-series data be used to ensure sustainable management of the resource. In particular, fishery monitoring should focus on age and sex composition of populations, which can indirectly indicate potential successful recruitment.

## LITERATURE CITED

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