# Size Composition, Age Composition, and Growth of Chilipepper, *Sebastes goodei*, and Bocaccio, *S. paucispinis*, From the 1977 Rockfish Survey

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## Introduction

Rockfish of the genus *Sebastes* are a significant component of commercial and sport fisheries off the U.S. Pacific coast. Landings of rockfish have heretofore been reported only by two categories, "*Sebastes alutus*" and "other rockfish" (Gunderson[1]). Consequently, the management of rockfish resources, including over 60 species, has been based on these two taxonomic groupings.

The differences in growth rate, age and size at maturity, and maximum size among the species included in the "other rockfish" category are substantial (Phillips, 1964; Chen, 1971; Westrheim and Harling, 1975), indicating that responsible management of these species demands their separation into more homogeneous groupings on the basis of population biology characteristics. One of the main objectives of the 1977 rockfish survey was to gather such information on the major species included in the "other rockfish" category. Presented here are the results of an investigation of growth, size composition, and age composition of two species important in commercial and sport fisheries off California: Chilipepper, *S. goodei*, and bocaccio, *S. paucispinis*.

## Materials and Methods

During the 1977 rockfish survey, the following length frequency and age-length data were collected from demersal trawl samples of chilipepper and bocaccio between lat. 34°09′ and 46°16′N and within the bottom depth interval of 50-200 fathoms (91-366 m):

| | Otoliths collected | | | Length frequency observations | | |
|---|---|---|---|---|---|---|
| | No. of | Sex | | No. of | Sex | |
| Species | hauls | M | F | hauls | M | F |
| *S. goodei* | 24 | 958 | 1,194 | 56 | 2,273 | 3,105 |
| *S. paucispinis* | 6 | 199 | 187 | 34 | 726 | 635 |

All lengths were measured as fork length to the nearest centimeter. Otoliths (sagittae) were collected for age determination, having been determined by Six and Horton (1977) to be the best aging structure for *Sebastes*. Random samples were taken for length frequency and otolith collections from hauls with relatively large catches of the target species. Otoliths from each haul were stored separately by sex-centimeter groups in vials with 50 percent ethanol solution. The otoliths were later read by the fish aging unit of the Northwest and Alaska Fisheries Center, National Marine Fisheries Service (NMFS), Seattle, Wash.

Since the main spawning seasons of these two species occur between mid-November and mid-March (Phillips, 1964), the specimens measured during the midsummer 1977 rockfish survey had presumably attained half of their annual growth. Consequently, one-half year was added to the age of all fish aged in this study. This enabled me to compare these data with those of Phillips (1964), who used the technique of back-calculation to derive his age-length relationships. When ages are referred to in the text, however, they will be rounded down (i.e., age 5.5 fish will be referred to as age 5).

Age-length keys were compiled by species and sex in each of the latitude-depth areas where data were collected, as well as for various combinations of these areas. Mean lengths at age, derived from these age-length keys, were used to estimate parameters of the von Bertalanffy growth model:

$$l_t = L_\infty (1 - e^{-k(t-t_0)})$$

where $l_t$ = length at age $t$,
$L_\infty$ = asymptotic length for the species,
$k$ = growth completion rate, and
$t_0$ = theoretical age at zero length.

[1]Gunderson, D. R. 1976. Proceedings of the first rockfish survey workshop. Unpubl. manuscr., 17 p. Northwest and Alaska Fisheries Center, NMFS, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

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*ABSTRACT—Size and age compositions were compiled from length measurements and otolith samples of chilipepper,* Sebastes goodei, *and bocaccio,* S. paucispinis, *from trawl catches off California (lat. 34°09′-40°16′N) during the 1977 rockfish survey. Within each species, similar growth patterns were observed throughout this range. Von Bertalanffy growth parameter estimates, in general, were similar to published values. For both species, females grew faster than males after the mean length at maturity had been reached. Size composition and age composition plots indicated offshore movements of older fish of both species, chilipepper beginning to move into the 100-199 fathom (183-364 m) depth zone rather abruptly between ages 4 and 5, and bocaccio beginning to move out more gradually between ages 3 and 7. Mean size for both sexes of both species increased with latitude. With all areas, depths, and sexes combined, age-class strength of chilipepper was notably weak at age 3 and greatest at age 5, and bocaccio age-class strength was greatest at age 4.*

The method of Fabens (1965) was used for these estimates.

Length frequency observations, weighted by catch per unit effort (numbers/kilometer) and expanded to the total estimated population size, were plotted for various combinations of latitude-depth areas. Final groupings of latitude-depth areas were made by considering characteristics of growth curves and size composition for each of the areas. Data from areas showing similar characteristics were grouped, as were data from areas with few observations. Age compositions for the final geographic groupings were estimated by applying the appropriate size composition data to the final age-length keys.

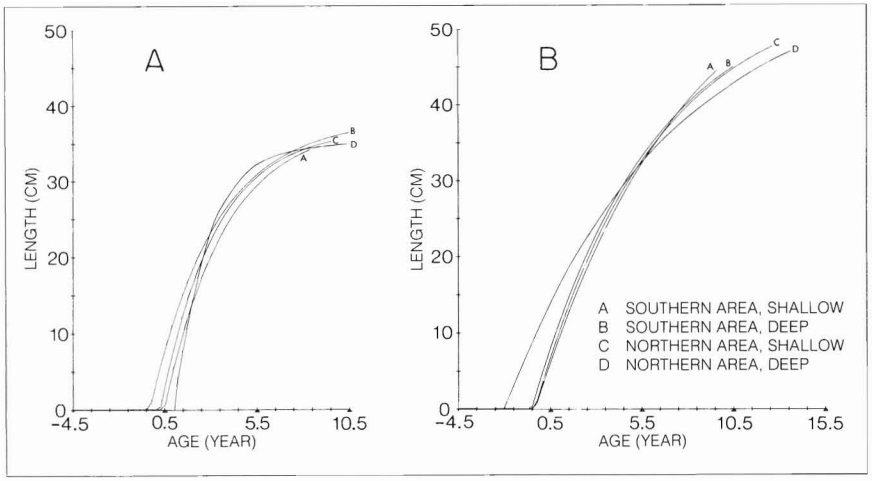


Figure 1.— Von Bertalanffy growth curves for chilipepper males (A) and females (B) from the four latitude-depth strata. Latitude divisions are 34°09′-37°07′N (southern) and 37°07′-40°16′N (northern), and depth zones are 50-99 fathoms (91-181 m) and 100-199 fathoms (182-364 m).

## Results

### Growth

Within sexes, growth curves and mean lengths at age were similar among all latitude-depth groupings of chilipepper (Fig. 1), although males and females showed quite different growth patterns. Growth curves and mean lengths at age were less uniform for the various groupings of bocaccio but only a relatively small number of observations was available from any of the individual latitude-depth areas. As with chilipepper, male and female bocaccio exhibited different growth patterns.

On the basis of the above considerations, all age-length data were pooled for each sex of each species and growth parameters were estimated by fitting the mean length at age data to the von Bertalanffy equation. Best fits for both species usually resulted from using mean lengths at age derived from more than five observations and omission of the youngest age class present (where the mean length at age is biased due to incomplete recruitment). Mean length at age (Tables 1 and 2), growth parameters (Table 3), and growth curve plots (Fig. 2, 3) are presented for both species.

**Table 1.—Number of readable otoliths examined, mean length at age, and standard deviation for chilipepper.**

| Males | | | | Females | | | |
|---|---|---|---|---|---|---|---|
| Age | $N$ | $\bar{L}$ | $s$ | Age | $N$ | $\bar{L}$ | $s$ |
| 1.5 | 22 | 16.9 | 0.8 | 1.5 | 20 | 17.0 | 0.6 |
| 2.5 | 135 | 21.4 | 1.7 | 2.5 | 166 | 21.8 | 1.7 |
| 3.5 | 50 | 24.8 | 2.2 | 3.5 | 89 | 25.2 | 2.5 |
| 4.5 | 166 | 30.3 | 1.8 | 4.5 | 144 | 31.8 | 3.2 |
| 5.5 | 173 | 31.5 | 1.6 | 5.5 | 178 | 34.6 | 2.7 |
| 6.5 | 114 | 33.1 | 1.8 | 6.5 | 112 | 37.5 | 2.9 |
| 7.5 | 109 | 34.6 | 1.8 | 7.5 | 137 | 40.9 | 2.6 |
| 8.5 | 113 | 35.4 | 1.7 | 8.5 | 121 | 42.9 | 2.2 |
| 9.5 | 42 | 36.7 | 3.6 | 9.5 | 82 | 44.9 | 2.6 |
| 10.5 | 21 | 36.3 | 1.1 | 10.5 | 58 | 46.7 | 2.6 |
| 11.5 | 9 | 37.9 | 0.8 | 11.5 | 38 | 48.3 | 2.6 |
| 12.5 | 4 | 36.5 | 2.6 | 12.5 | 29 | 48.2 | 1.7 |
| — | — | — | — | 13.5 | 13 | 48.3 | 2.1 |
| — | — | — | — | 14.5 | 6 | 49.2 | 1.7 |
| — | — | — | — | 15.5 | 1 | 50.0 | — |

**Table 2.—Number of readable otoliths examined, mean length at age, and standard deviation for bocaccio.**

| Males | | | | Females | | | |
|---|---|---|---|---|---|---|---|
| Age | $N$ | $\bar{L}$ | $s$ | Age | $N$ | $\bar{L}$ | $s$ |
| 2.5 | 2 | 34.5 | 2.1 | 2.5 | 5 | 33.4 | 1.7 |
| 3.5 | 23 | 38.2 | 3.8 | 3.5 | 18 | 39.1 | 4.1 |
| 4.5 | 41 | 42.0 | 3.0 | 4.5 | 37 | 43.1 | 2.8 |
| 5.5 | 45 | 44.2 | 3.6 | 5.5 | 30 | 45.5 | 3.8 |
| 6.5 | 22 | 47.8 | 4.7 | 6.5 | 31 | 51.4 | 5.4 |
| 7.5 | 22 | 56.3 | 3.5 | 7.5 | 26 | 57.9 | 4.5 |
| 8.5 | 18 | 58.1 | 3.6 | 8.5 | 19 | 63.4 | 3.3 |
| 9.5 | 20 | 58.9 | 2.9 | 9.5 | 10 | 66.4 | 3.6 |
| 10.5 | 5 | 63.2 | 3.5 | 10.5 | 6 | 65.5 | 3.7 |
| 11.5 | 1 | 58.0 | — | 11.5 | 2 | 66.5 | 2.1 |
| — | — | — | — | 12.5 | 1 | 68.0 | — |
| — | — | — | — | 13.5 | 2 | 73.0 | 1.4 |

**Table 3.—Von Bertalanffy growth model parameter estimates for chilipepper and bocaccio as derived from selected mean length at age data collected during the 1977 rockfish survey.**

| | Range in age and length (of selected data) | | | | | |
|---|---|---|---|---|---|---|
| Species | Age (yr) | Length (cm) | $L_\infty$ | $k$ | $t_0$ | SD |
| *S. goodei* | | | | | | |
| Males | 2.5-11.5 | 18-48 | 38.66 | 0.30 | −0.15 | 0.71 |
| Females | 2.5-14.5 | 17-53 | 53.19 | 0.18 | −0.43 | 0.88 |
| *S. paucispinis* | | | | | | |
| Males | 3.5-9.5 | 32-64 | 76.58 | 0.13 | −1.81 | 2.47 |
| Females | 2.5-10.5 | 31-71 | 87.76 | 0.11 | −1.73 | 2.60 |

### Size and Age Composition

The size composition for both species differed considerably above and below 100 fathoms with the smaller size classes attaining their highest relative abundance inside 100 fathoms (183 m). Latitudinal differences, although somewhat less distinct than depth differences, generally took the form of larger fish in more northern waters. Final groupings separated size composition data latitudinally at lat. 37°07′N and bathymetrically at 100 fathoms (183 m) for both species, forming four final latitude-depth areas. Plots of length frequency data for these final

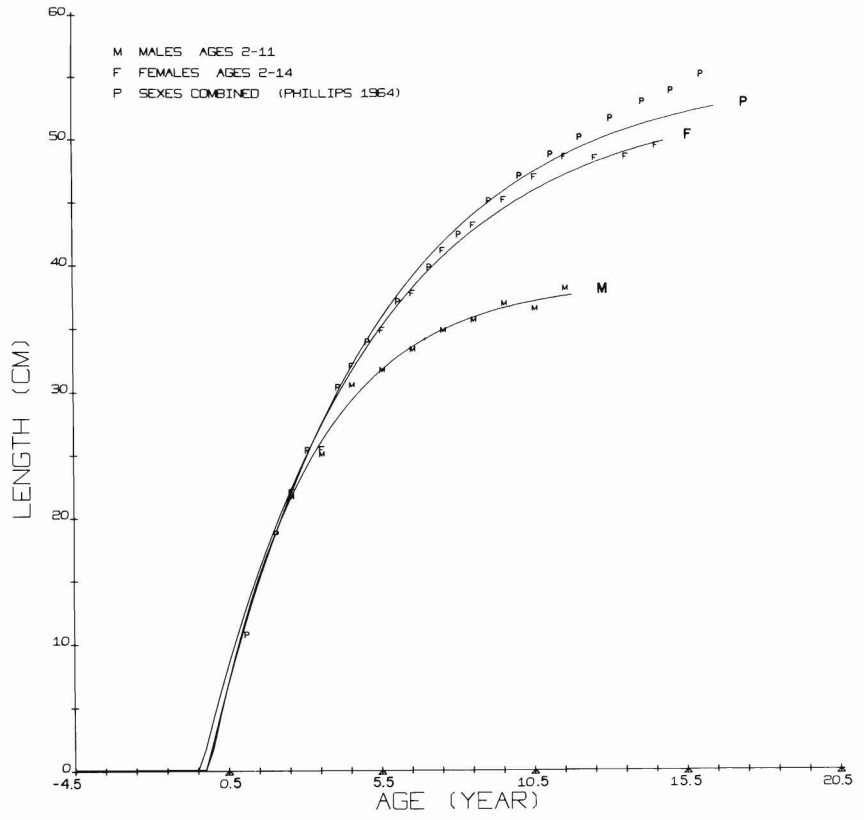


Figure 2.—Von Bertalanffy growth curves for chilipepper and mean lengths at age used to fit the curves (small symbols). (M) males from entire 1977 survey area (fork length), (F) females from entire 1977 survey area (fork length), and (P) sexes combined from Phillips (1964) (total length).

areas are presented for chilipepper (Fig. 4) and bocaccio (Fig. 5) by sex and with sexes combined. Age composition data for these same areas are presented in Figures 6-8 (chilipepper) and Figures 9-11 (bocaccio).

## Discussion

Age-length keys compiled for male and female chilipepper (Table 1) showed similar mean lengths at age for both sexes through age 3. Females exhibited much faster growth from age 4 onward. The size at which the growth patterns diverge is about 30 cm. This divergence occurs near the onset of maturation for males, since Gunderson et al. (1980) found mean size at maturity to be 26.1 cm for males and 37.0 cm for females.

Some adjustments in the growth curves were needed to facilitate comparison with results from Phillips (1964). The half-year increments added to the ages of chilipepper from the 1977 survey were effectively removed by calculating mean lengths at last birthday via the von Bertalanffy equation. This was done for each sex and averaged to provide estimated mean lengths at last birthday for a mixed-sex sample. Mean total lengths at age from Phillips were converted to fork length by the following relationship provided by W. H. Lenarz (pers. commun.): FL(mm) = −3.139944 + 0.949641 TL(mm). The resultant mean lengths at age from Phillips could then be compared with

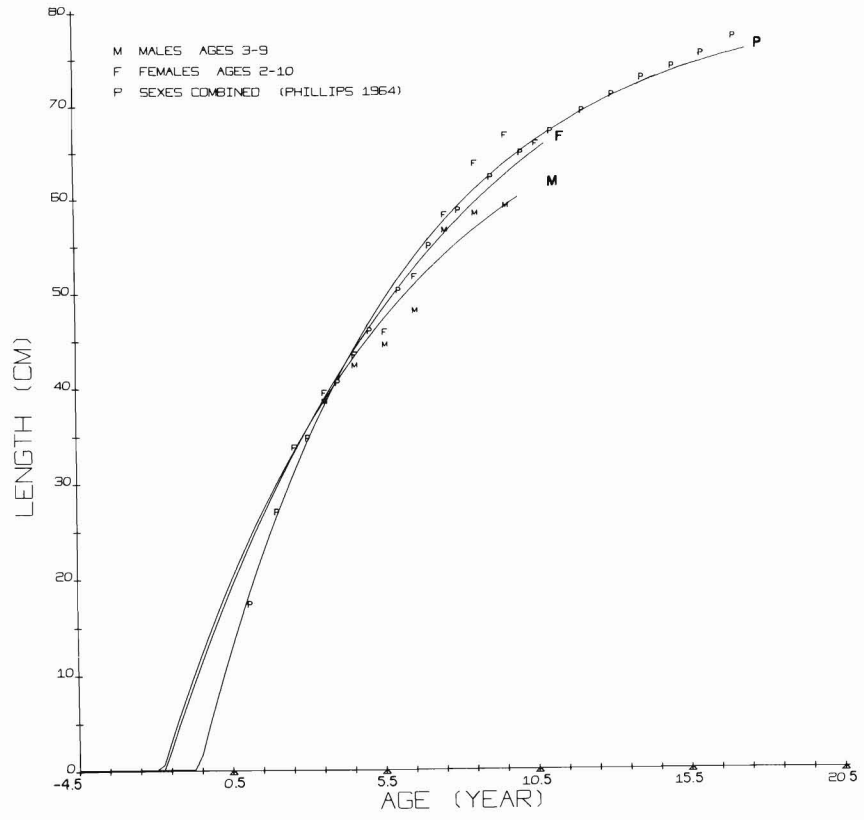


Figure 3.—Von Bertalanffy growth curves for bocaccio and mean lengths at age used to fit the curves (small symbols). (M) males from entire 1977 survey area (fork length), (F) females from entire 1977 survey area (fork length), and (P) sexes combined from Phillips (1964) (total length).

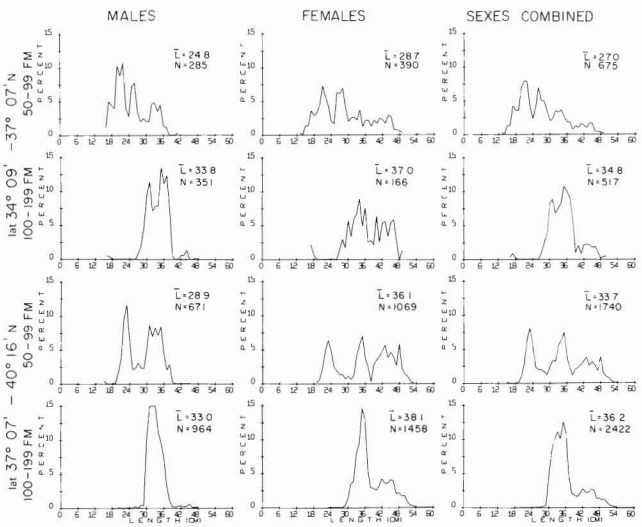


Figure 4.—Expanded size composition of chilipepper for the four final latitude-depth areas including mean length ($\bar{L}$) and number of length frequency observations upon which the estimates are based (N).

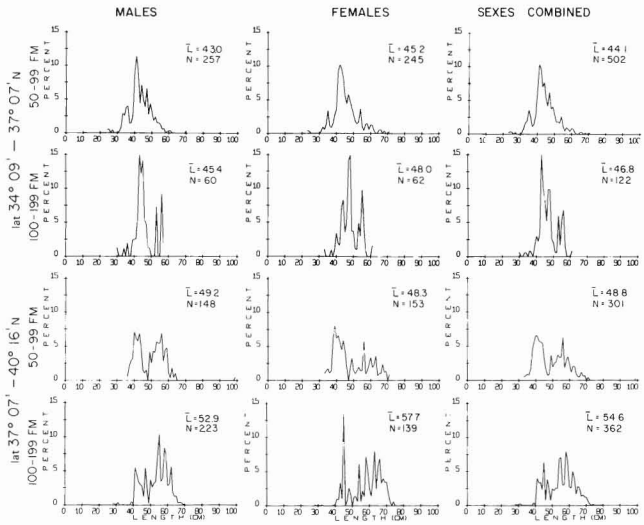


Figure 5.—Expanded size composition of bocaccio for the four final latitude-depth areas including mean lengths ($\bar{L}$) and number of length frequency observations upon which the estimates are based (N).

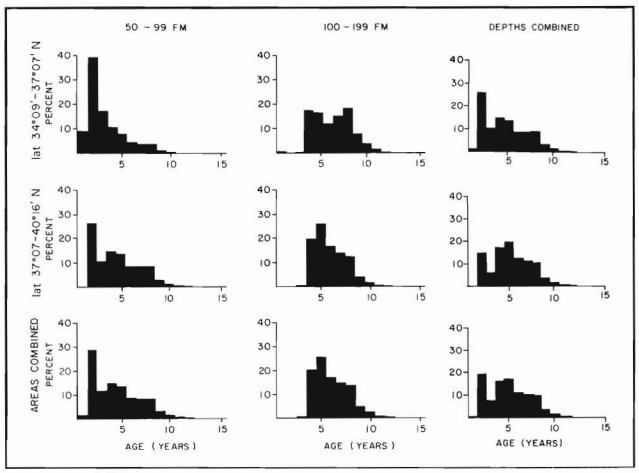


Figure 6.—Percent age composition for chilipepper males for the four latitude-depth strata and combinations thereof.

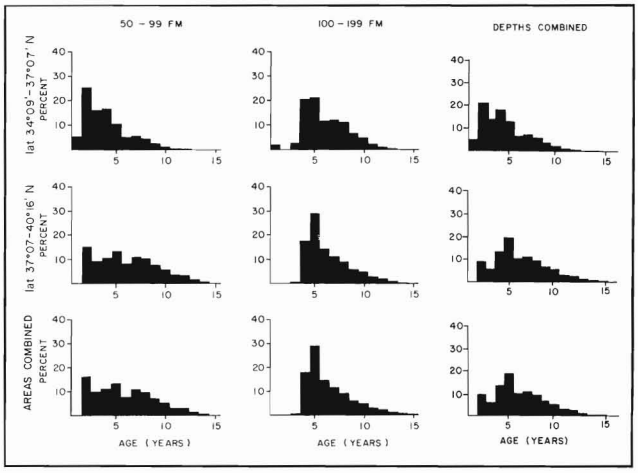


Figure 7.—Percent age composition for chilipepper females for the four latitude-depth strata and combinations thereof.

mean lengths at last birthday from the simulated mixed-sex sample of 1977 chilipepper.

For chilipepper aged 1 and 2 years, mean lengths at age from Phillips' data were 1.9 and 1.2 cm less, respectively, than those from the 1977 survey. Agreement was close (within 0.6 cm) for ages 3-7. For fish aged 9-15, Phillips' mean lengths were greater than those from this survey by an increasing margin of 2.4 to 6.6 cm. The discrepancy at ages 1 and 2 is likely due to Phillips' use of back-calculation (and the associated bias caused by Lee's phenomenon) for nearly all observations in these age classes. The difference in sizes at older ages may be due to Phillips' use of scales, although he did not feel he had missed any outer rings. The similarity between the growth curves of Phillips (sexes combined) and that of female chilipepper from this survey (Fig. 2) suggests another reason. If Phillips used a sampling scheme of length-stratified sampling without regard to sex, the larger size classes would have been composed of an increasing proportion of females, producing an upward bias in the right-hand side of his curve.

The growth curves for male and female chilipepper (Fig. 2) show a distinct difference in growth patterns. Females reach a much greater maximum length ($L_\infty$) but the rate at

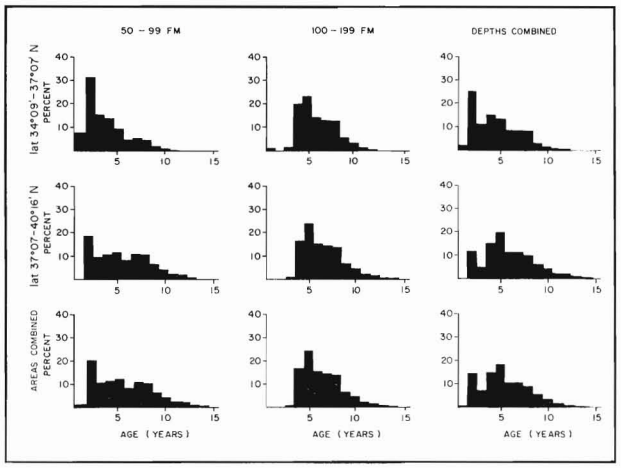


Figure 8.—Percent age composition for chilipepper, sexes combined, for the four latitude-depth strata and combinations thereof.

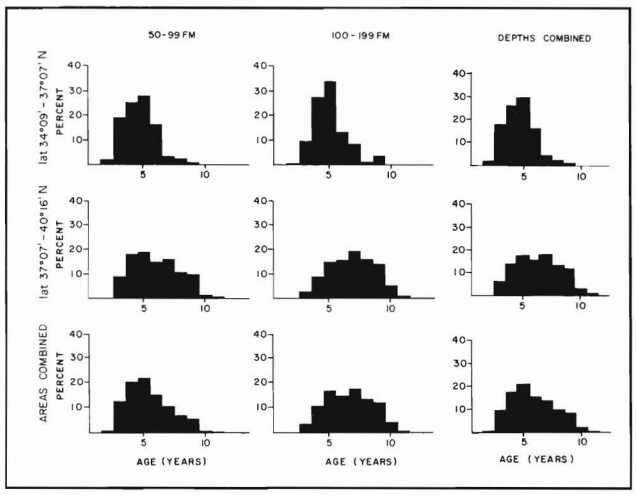


Figure 9.—Percent age composition for bocaccio males for the four latitude-depth strata and combinations thereof.

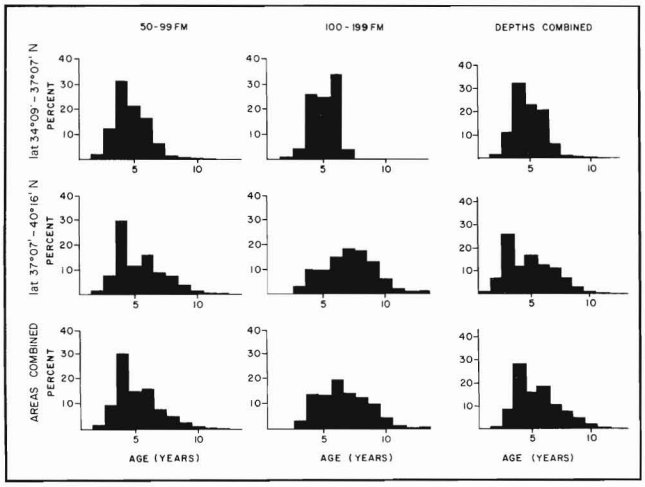


Figure 10.—Percent age composition for bocaccio females for the four latitude-depth strata and combinations thereof.

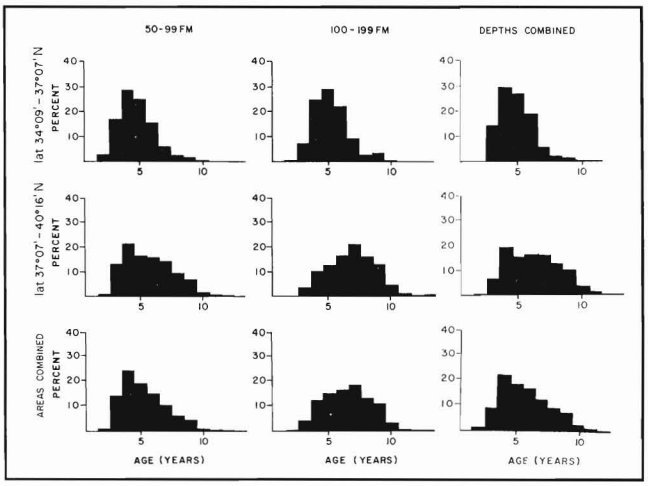


Figure 11.—Percent age composition for bocaccio, sexes combined, for the four latitude-depth strata and combinations thereof.

which that length is approached ($k$) is much less than for males. Parameter estimates for the von Bertalanffy growth model (Table 3) cannot be compared directly with Phillips' results because sexes were not separated in that work, and Phillips' parameters refer to fish measured in terms of total length. However, the growth completion rate constant ($k$) and maximum length ($L_\infty$) found by Phillips for sexes combined were 0.18 and 55.3 cm, respectively, which are similar to those found for females in this investigation.

Size composition plots (Fig. 4) for chilipepper showed that smaller fish (<25 cm) were found almost exclusively inside 100 fathoms (183 m). Upper ranges of length appeared similar for each sex, regardless of depth or latitudinal groupings. Mean lengths generally increased with latitude.

Age composition plots (Fig. 6-8) again show the trend of younger chilipepper inside 100 fathoms (183 m) beginning to appear in significant quantities in deeper water as 4 and 5 year olds. The time of movement into deeper water corresponds closely with ages extrapolated from mean size at maturity (Gunderson et al., 1980). The proportion of older fish is greater in deeper waters but the range of ages is usually similar, regardless of depth. The differences in age composition between northern and southern areas are not as

clear as the differences between depth zones. Young fish constitute a greater proportion of the population in the southern area than they do in the northern area, while the opposite is true of the older age-classes. Because of the dissimilarities between depth zones and latitudinal areas, age composition (population size at each age) was estimated by sex for each latitude-depth stratum and then combined to obtain the age composition data for areas, sexes, and depths combined (Fig. 8).

Notable features of the total age composition for chilipepper include the weak representation of 3-year-old fish and the high relative abundance of 4- and 5-year-old fish in all areas. A further characteristic of these estimates is that abundance tends to taper off systematically between ages 7 and 14.

Mean lengths at age for male and female bocaccio were found to be very similar through age 5 (Table 2). Females began to noticeably outgrow males around age 6 (Fig. 3). As with chilipepper, the size at the point at which the growth curves of male and female bocaccio diverge corresponds closely with the size at maturity for males (44.8 cm) reported by Gunderson et al. (1980).

For comparison with data from Phillips (1964), bocaccio mean lengths were standardized as they were for chilipepper. The total length to fork length conversion used for bocaccio (Lenarz, pers. commun.) was: FL(mm) = 2.016508 + 0.956098 TL(mm). Mean lengths for the first three observed age classes in the 1977 survey (ages 2, 3, and 4) were 4.0, 2.6, and 1.9 cm longer, respectively, than those from Phillips' study. Fish aged 5 and 6 years agreed more closely with Phillips' data, exceeding his mean lengths at these ages by 1.5 and 1.4 cm, respectively. Agreement was very close (within 0.6 cm) for ages 7 through 13. The discrepancy at ages 2-4 is again likely due to Phillips' use of back-calculation and the associated Lee's phenomenon bias. This might also be the cause of the smaller differences seen at ages 5 and 6.

Mean lengths at age from this study generally exceeded those found by Westrheim and Harling (1975) by considerable margins. However, survey areas of the two studies were widely separated.

The range of lengths at each age appeared to be much broader for bocaccio than for chilipepper. When examining this phenomenon, there did not appear to be any distinct modes in the length distributions of most of the age classes. This appeared to be indirect evidence of a protracted spawning period for this species and was substantiated further by observations of maturity stages. Maturity observations made in July and early August showed about half of bocaccio females to be sexually inactive, but quite a significant proportion (24 percent) were either approaching spawning (visible embryos) or recently spent. Another 24 percent were either maturing or recently fertilized (Gunderson et al., 1980). These results are somewhat contradictory to the bimodal spawning pattern, with modes in November and March, found by Moser (1967) for bocaccio off southern California and seem to indicate that the spawning period is more protracted than previously suggested.

Size composition data for bocaccio (Fig. 5) indicate that the smallest size classes have their highest relative abundance inside 100 fathoms (183 m). Upper size ranges did not vary by depth, but larger fish were found in the northern area than in the southern area. Mean lengths increased with depth and with latitude.

Age composition plots for bocaccio (Fig. 9-11) further indicate that smaller, younger fish attain their highest relative abundance in shallow waters. Age distributions for the shallower areas are noticeably skewed toward the younger ages, while those for the deeper waters appear more normal. This indicates that there is a distinct tendency for fish to move to deeper water as they become older. The left side of the plots for 100-199 fathoms (183-364 m) depths show a more gradual increase for bocaccio than for chilipepper, indicating a more prolonged period of movement from shallow to deep water.

In all areas, bocaccio younger than age 3 were rare, and age 3 fish appeared to be incompletely recruited. Age 5 males and age 4 females were the most abundant year classes in shallow water in both latitudinal areas. In deeper water, age 5 males and age 6 females were most abundant in the southern area, whereas in the northern area, age 7 fish of both sexes predominated. When all areas and sexes were combined, relative abundance peaked at age 4 and declined very regularly through age 11.


## Acknowledgments

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