REGIONAL VARIATIONS IN THE GROWTH AND AGE COMPOSITION OF NORTHERN ANCHOVY, *ENGRAULIS MORDAX*

R. H. PARRISH,[1] D. L. MALLICOATE,[1] AND K. F. MAIS[2]

ABSTRACT

Data from the Sea Survey Program conducted by the California Department of Fish and Game were analyzed to describe regional variations in growth and age composition of northern anchovy, *Engraulis mordax*. Juvenile growth appeared to be greater at higher latitudes and in the offshore portion of the Southern California Bight. Adult growth was less variable; however, there were statistically significant differences between regions. In addition, the growth rate for the southern stock was markedly lower than that of the central stock. This difference in growth rates was used to characterize the area of overlap between the two stocks. Age composition varied with depth of water and geographical location within the Southern California Bight and with latitude. Young-of-the-year and yearling fish were found in larger proportions in shallow water and in the southern and inshore areas of the Southern California Bight. Age compositions of northern anchovies sampled in the California and Mexican purse seine fisheries were compared with those of the Sea Survey Program. This comparison suggests that the present California area restrictions, which exclude the fishery from the nearshore area, greatly reduces the number of young fish in the catch.

The purpose of this study is to describe regional variations in growth and age composition of the northern anchovy, *Engraulis mordax*. Data for the study were taken by the Sea Survey Program of the California Department of Fish and Game. Mais (1974) described this program and analyzed the data for the most common species taken in the survey. This report is an extension of Mais' work and focuses on geographical variations in age composition and growth rates and on depth variations in age composition.

Meristic and morphometric (McHugh 1951) and electrophoretic (Vrooman et al. 1981) studies on the stock structure of the northern anchovy suggest that there are three stocks (northern, central, and southern) and that the boundaries between the stocks occur in central California and central Baja California. There is also recent evidence (Parrish[3]) of a fourth stock which spawns in the fall in central California and in the northern and offshore areas of the Southern California Bight.

Mais (1974) showed that the southern stock of northern anchovies was smaller at age than the central stock. In addition, northern anchovies are known to be larger off central California than off southern California (Collins 1969; Mais 1974; Mallicoate and Parrish 1981), and they are larger in the offshore areas of the Southern California Bight than in the inshore areas (Mais 1974). These differences could be due to varying growth rates between regions, varying seasonality of spawning, varying age compositions, size-specific migration, or a combination of these factors.

Tagging experiments have shown that northern anchovies move from southern California to central California, from central California to southern California, and from southern California to Ensenada, Mexico; there is a northerly movement in summer and a southerly movement in winter (Haugen et al. 1969). Mais (1974) found northern anchovies to be distributed more offshore in some years and more inshore in other years, and he found them concentrated closer to shore and in the northern part of the Southern California Bight during the fall months. Mais (1974) suggested that northern anchovies begin an offshore and southeastward movement in late winter, which coincides with the onset of major spawning activity. These movements of anchovy may affect the measurement of growth rates and age compositions within the different regions.

METHODS

The data used in the study were taken from north-

[1]Southwest Fisheries Center Pacific Fisheries Environmental Group, National Marine Fisheries Service, NOAA, P.O. Box 831, Monterey, CA 93942.

[2]California Department of Fish and Game, 1301 West 12th Street, Long Beach, CA 90813.

[3]Parrish, R. H. 1983 Evidence for a fall spawning anchovy stock. Paper presented at 1983 CalCOFI Conference.

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ern anchovies caught by midwater trawl. The gear and sampling procedures are described by Mais (1974). The data set covers the period 1966-1983 and consists of 101 cruises. Twenty-three cruises extended north of Point Conception, 77 cruises occurred in southern California and northern Baja California, and 8 cruises extended into southern Baja California. Several cruises extended into more than one region. There were a total of 4,166 trawl hauls, of which 3,017 contained anchovies. Standard lengths were normally taken from about 25 anchovies in each trawl haul in which they occurred; otoliths, for aging, were usually taken from a subsample of up to 10 fish. A total of 60,082 northern anchovies were measured, of which 20,772 were aged by California Department of Fish and Game personnel with methods developed by Collins and Spratt (1969).

For purposes of determining age composition and growth rates of northern anchovies, it was assumed that February was the birth month of all fish sampled. Anchovies off California and Baja California have a peak in spawning in February-March; however, some spawning does occur all year (Ahlstrom 1966). The age determinations used in this report are, of course, not accurate to the month. They are based on the number of annuli, the seasonality of annuli formation, an assumed February birth month, and the month the fish were caught. Annuli formation occurs in May in California (Collins and Spratt 1969). A 1-yr-old anchovy would therefore be an anchovy caught in February with no annuli on its otoliths. A 1½-yr-old anchovy would be a fish with one annuli which was caught in August. An anchovy born in February would be 15 mo old when its first annuli was formed. An anchovy spawned in September would be 8 mo old if it formed its first annuli in its first May and 20 mo old if it formed its first annuli in its second May.

Differences in growth between geographical regions were compared by linear regression analyses which included anchovies of 1½ yr of age and older. Evaluation of the relationship between age composition and water depth in the area of capture was made by grouping the samples into depth strata. The strata were established partially on the number of observations.

To determine growth rates, the data were processed with a computer program (Mallicoate and Parrish 1981) which calculates and plots the mean length, standard deviation of length, and length range by age and month. The program also tabulated the number of observations by age and month; these data were used for determining age composition.

Our preliminary analysis of the sea survey data showed an alongshore cline in the mean length of northern anchovies (Fig. 1). It also revealed a bias in the selection of fish to be aged. Aged fish were generally larger at all latitudes than were the unaged fish. This bias is apparently due to a consistent tendency for samplers to pick larger anchovies for the subsample which was aged. Anchovies < 100 mm SL were particularly susceptible to not being selected for aging (Table 1). On checking with the field biologists who took the data, we found a second source of bias which occurred only in trawl hauls of exclusively small fish. When trawl hauls were considered by the sampler to be "obviously" all young-of-the-year fish, there was a tendency not to take otoliths for age determination. These sampling biases affect the analyses of age composition presented in this report but do not affect the growth analyses.

TABLE 1.—Two types of length bias in sampling northern anchovies in the Sea Survey Program.

Standard length (mm)	No. fish measured	No. fish measured in hauls sampled for otoliths	No. otolith samples	[1]Bias 1	[2]Bias 2
<70	2,174	1,275	460	0.59	0.36
70-80	2,366	1,939	684	0.82	0.35
80-90	4,667	4,241	1,667	0.91	0.39
90-100	7,077	6,367	2,498	0.90	0.39
100-110	8,988	7,875	2,997	0.88	0.38
110-120	12,058	10,834	4,164	0.90	0.38
120-130	11,744	10,462	4,215	0.89	0.40
130-140	7,390	6,456	2,748	0.87	0.43
140+	3,619	3,036	1,339	0.84	0.44
Total	60,082	52,484	20,772		

[1]Bias 1 is the decision to sample for otoliths (i.e., the proportion of fish in trawl hauls which were sampled for otoliths).

[2]Bias 2 is the selection of larger fish by the sampler (i.e., the proportion of fish in trawl hauls, which were sampled for otoliths, for which otolith samples were taken).

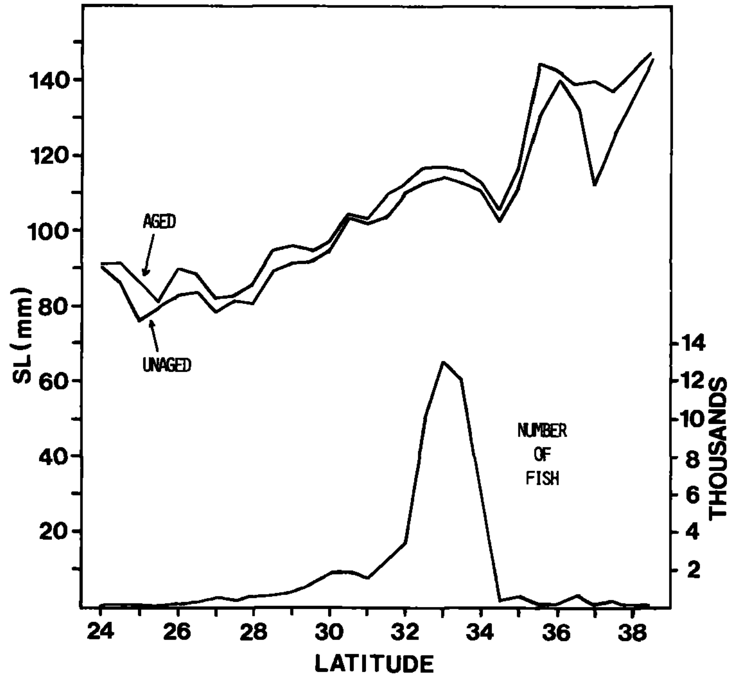

FIGURE 1.—Mean length of aged and unaged northern anchovies and the number of anchovies by half degree of latitude.

The data were inadequate to calculate growth curves or age composition on the one-half degree of latitude interval used in Figure 1; therefore, geographical regions were selected based partially on the number of observations. For example, the southern and central Baja California and central California areas, which had fewer samples, were more widely spaced than the southern California and northern Baja California areas. Nearly all of the anchovy samples taken south of lat. 32°N or north of lat. 34°N were taken within one-half degree of the coast. The lat. 32°-34°N area included a large amount of samples taken further than one-half degree from the coast. This area, the Southern California Bight, contains numerous islands and basins; we, therefore, divided it into regions which approximate the natural basins described in Emery (1954) (Fig. 2).

RESULTS

Growth

Earlier studies on northern anchovies from British Columbia (Pike 1951), northern California (Waldvogel 1977), central California (Clark and Phillips 1952), and southern California (Spratt 1975) showed considerable variation in their growth (Fig. 3A). Anchovies in British Columbia, lat. 49°N, and northern California, lat. 41°N, are of the northern stock (Vrooman et al. 1981) and have a summer spawning season. Anchovies in southern California, lat. 33°N, are of the central stock, whereas those in central California, lat. 36°N, are considered to be a mixture of northern and central stocks (Vrooman et al. 1981); anchovies in both southern and central California have a late winter (February-April) spawning season (Parrish footnote 3). Anchovies in British Columbia were the fastest growing of all the four areas in their first year of life, whereas anchovies in northern California were the slowest. Anchovies in central and southern California showed similar growth rates after their first year of life; however, the growth rate of anchovies in central California was greater than the growth rate of those in southern California in their first year.

Our study shows that the growth of anchovies has a distinct geographical pattern. Anchovies sampled in the Central California region (CC) and the offshore area of the Southern California Bight [i.e., San Nicolas (SN) and Tanner and Cortez Banks (TCB) regions] have the fastest juvenile growth (Fig. 3). Anchovies in these areas attain an average length of 120 mm before they are 1½ yr old. In the inshore areas of the Southern California Bight and in Baja California there is a continuous decline in the growth rate associated with decreasing latitude (Figs. 3, 4). Anchovies reach a mean length of 120 mm at about age 2 in the Santa Barbara Channel region (SBC)

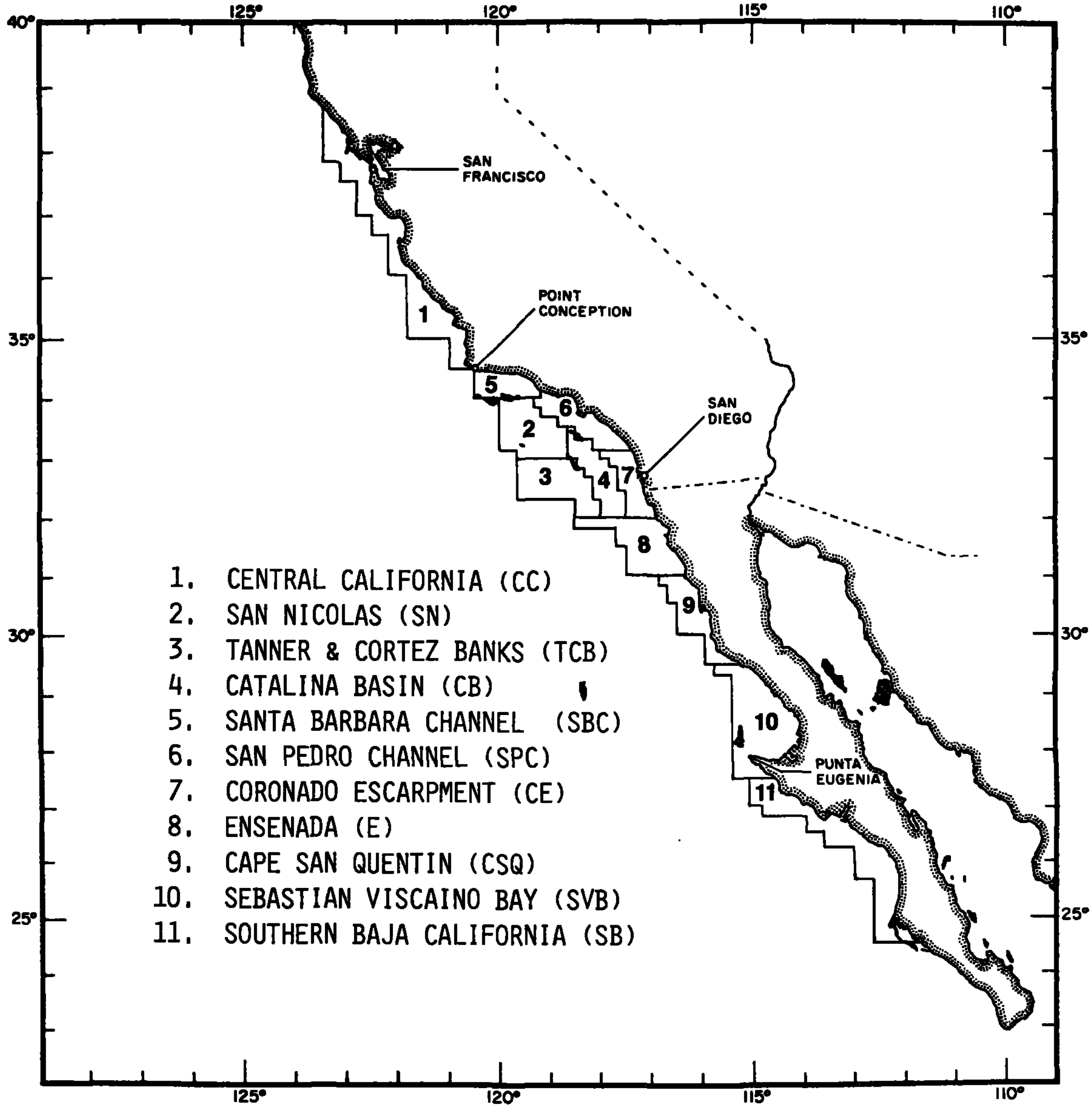

FIGURE 2.—Geographical regions for which the growth and age composition of northern anchovies were determined.

and in the remaining offshore region, Catalina Basin (CB). In the San Pedro Channel (SPC), Coronado Escarpment (CE), and Ensenada (E) regions anchovies reach 120 mm at about age 3. In the Cape San Quentin (CSQ) and Sebastian Viscaino Bay (SVB) regions anchovies reach 120 mm at about age 4 or later.

The Cape San Quentin (CSQ), Sebastian Viscaino Bay (SVB), and Southern Baja California (SB) regions include anchovies from both the central and southern stocks, and there are marked differences in their growth (Fig. 4). Anchovies from the southern stock appear to reach an asymptotic mean size of about 92 mm, whereas those from the central stock continue to grow throughout their lives. Note the occurrences of 2- to 4-yr-old fish with monthly mean lengths of about 92 mm (Fig. 4 CSQ, SVB, SB). Assuming that stocks can be identified by size at age, the Cape San Quentin region appears to be dominated by the central stock; however, the

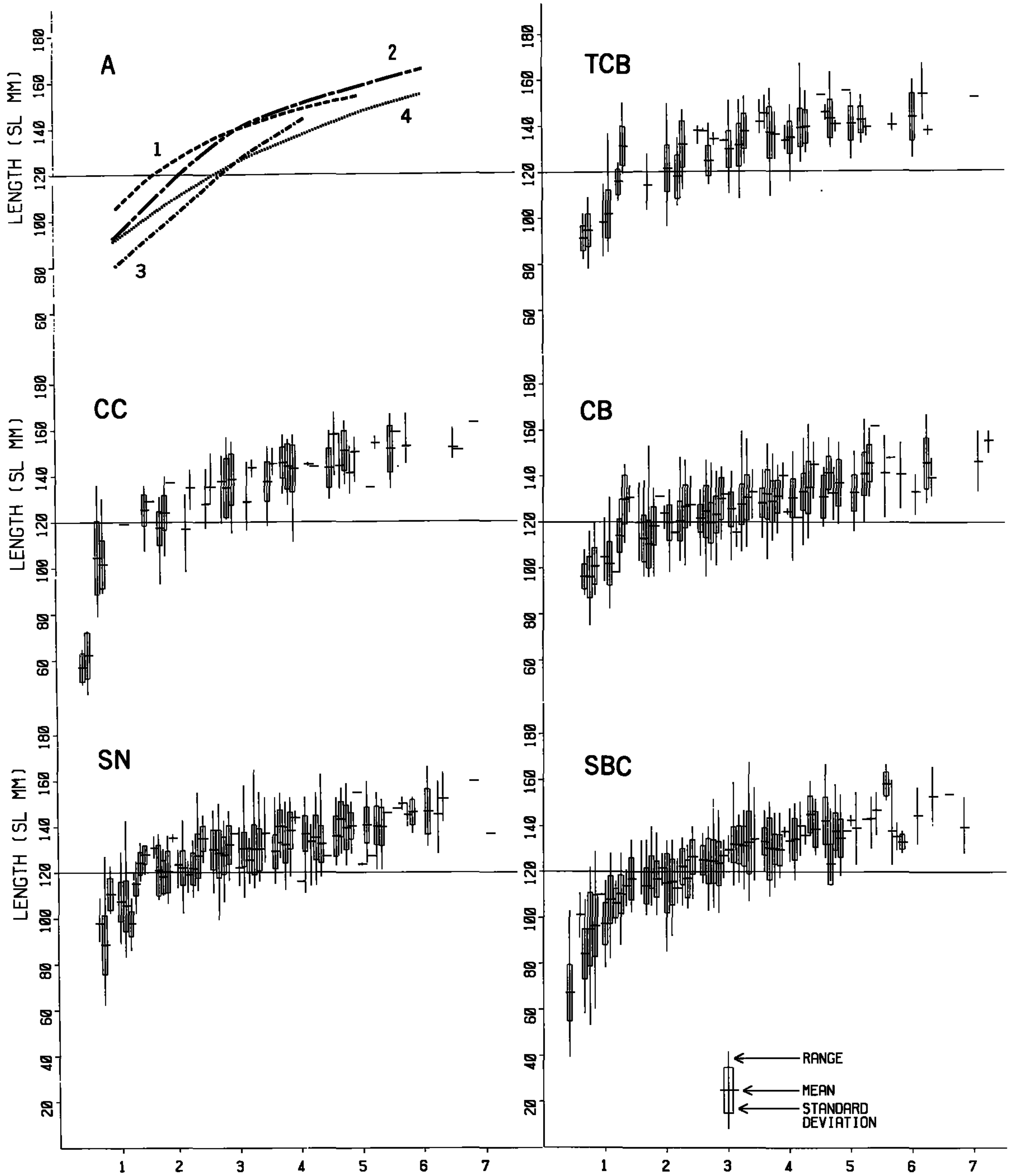

FIGURE 3.—Age-length relationships of northern anchovies taken in A. Earlier studies 1) British Columbia (Pike 1951), 2) Central California (Clark and Phillips 1952), 3) Northern California (Waldvogel 1977), and 4) Southern California (Spratt 1975), CC, Central California; SN, San Nicolas; TCB, Tanner and Cortez Banks; CB, Catalina Basin; SBC, Santa Barbara Channel.

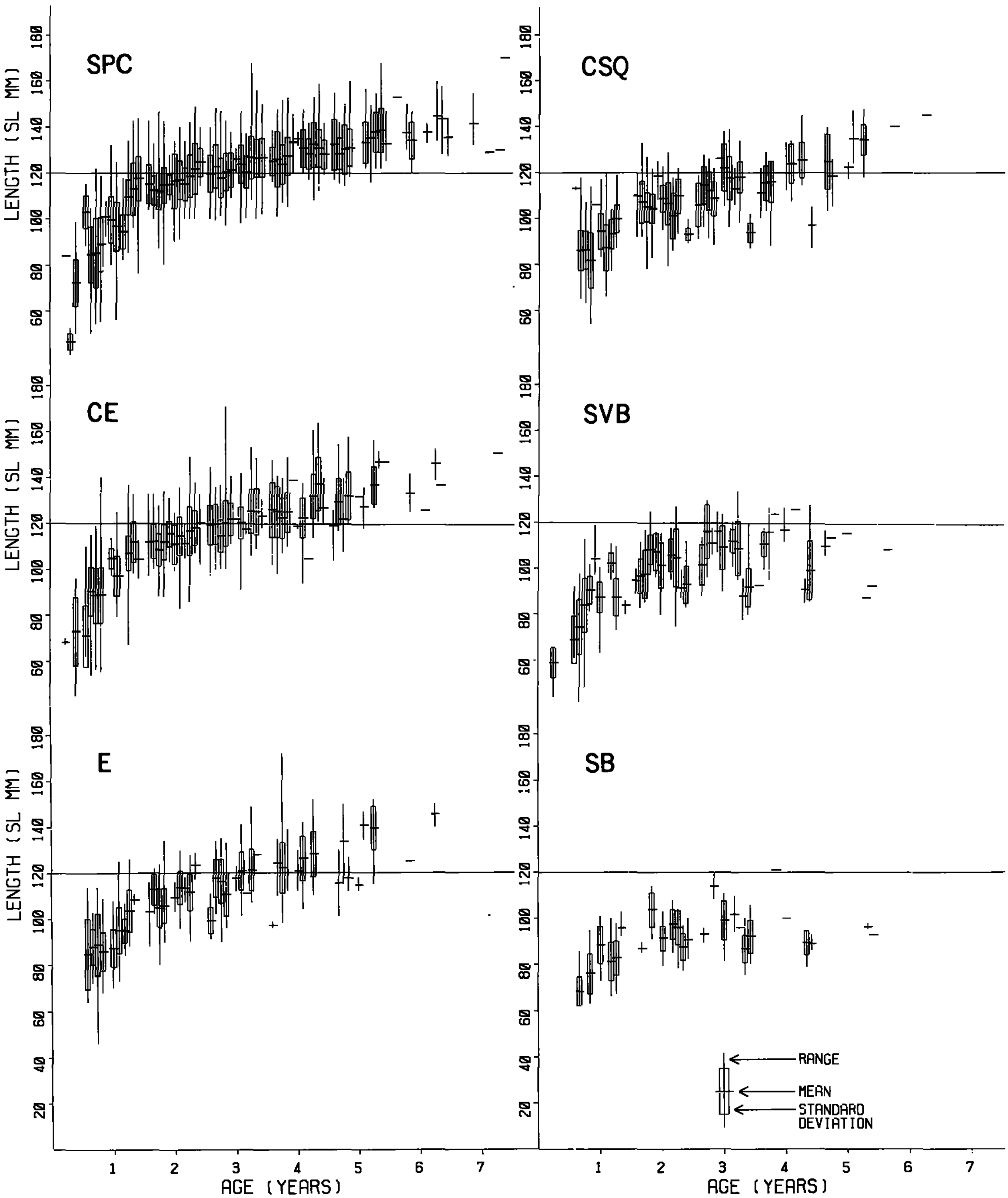

FIGURE 4.—Age-length relationships of northern anchovies taken in SPC, San Pedro Channel; CE, Coronado Escarpment; E, Ensenada; CSQ, Cape San Quentin; SVB, Sebastian Viscaino Bay; and SB, Southern Baja California.

southern stock does extend into this region. The most northerly trawl sample which could be identified, by size at age, as southern stock was a June 1971 sample taken at lat. 30.3°N. Southern and central stock anchovies broadly overlap in the Sebastian Viscaino Bay region; however, the region is occupied principally by the southern stock in the summer and by the central stock in the fall and winter. The Southern Baja California region is dominated by the southern stock; however, central stock anchovies, as identified by size at age, were taken as far south as lat. 26.5°N in November 1967. The fact that the central stock is the farthest south in winter and the southern stock the farthest north in summer suggests that the separation of the stocks is aided by different environmental preferences, possibly temperature.

The Central California region is an area of overlap between the northern and central anchovy stocks. In addition, as previously mentioned (Parrish footnote 3), a fall spawning stock may occur in central California and the offshore areas of the Southern California Bight. Vrooman et al. (1981) did not have any samples south of Monterey in central California or from the offshore and northern areas of the Southern California Bight. Samples from these areas may consist of a mixture of different stocks with different spawning seasons. Our assumption of a February birth month in these areas must therefore be evaluated.

Regression Analysis

Growth in length of anchovies in the size range sampled by the Sea Survey Program (i.e., 40-180 mm SL) can be divided into two phases. The early, juvenile phase extends until the fish are about 1 yr old. Methot (1981) found that in the Southern California Bight juvenile growth averages about 9 mm/mo, and it is at a maximum when the fish are between 40 and 50 mm SL. The second, adult phase extends from a little over 1 yr old until death. Growth during this phase is more than an order of magnitude less than the early phase (i.e., 0.48-0.69 mm/mo). Examination of the age-length relationships (Figs. 3, 4) in the central stock shows that growth in the adult phase is essentially linear. Therefore, we used linear regressions to compare growth of anchovies from different regions. These analyses included only fish of 1½ yr of age and older. This model has several advantages for comparing the growth during the two phases described above. By limiting the model to the linear segment of the age-length relationships, the slopes of the regressions can be used to compare the regional variations in growth rate during the adult phase. Another advantage is that the expected length at 1½ yr of age can be used to compare regional variation in growth during the juvenile phase.

Juvenile Growth

In the area occupied by the central stock, growth during the juvenile phase shows considerable variation among regions. There were significant differences in growth to age 1½. Fastest growth occurred in the north, and the slowest was in the south (Table 2, Fig. 5). Mean standard length at 1½ yr of age was 123.6 mm in the Central California region, 113.4 mm in the San Pedro Channel region, and 103.6 mm in the Cape San Quentin region. The three southernmost Baja California regions contain mixtures of the central and southern stocks; therefore, data from these regions were divided into central and southern stock sets, based on length and month, for the analyses. In contrast to those of the central stock, anchovies of the southern stock attain only 91.8 mm by age 1½. Within the Southern California Bight there is also an inshore-offshore gradient, with faster juvenile growth in the offshore regions and slower growth in the inshore regions (i.e., lengths at age 1½ in the Coronado Escarpment, Catalina Basin, and Tanner and Cortez Banks regions were 110.5, 116.4, and 119.2 mm respectively).

An analysis of covariance showed that the differences in size at age 1½ are not significantly different (α = 0.01) in two pairs of regions. The San Nicolas region (120.4 mm at age 1½) and the Tanner and Cortez Banks region (119.2 mm) are the first pair, and the Catalina Basin region (116.4 mm) and the Santa Barbara Channel region (116.2 mm) are the second pair. In all other pairs of regions, size at age 1½ is significantly different at the α = 0.0001 level.

Adult Growth

The regressions demonstrate that growth during the adult phase is relatively constant between the different regions occupied by the central stock, with slopes varying from a low of about 6 mm/yr to a high of about 8 mm/yr (Table 2). In contrast, anchovies of the southern stock have essentially no adult growth after age 1½ (i.e., slope = 0.07 mm/yr).

Although the differences in adult growth between regions is not large, there are statistically significant differences (Table 3). The San Nicolas region and the Tanner and Cortez Banks region have adult growth

TABLE 2.—Regression parameters and statistics for the relationship between age and length of northern anchovies older than 1½ yr: Central California (CC), San Nicolas (SN), Tanner-Cortez Banks (TCB), San Nicolas combined with Tanner-Cortez Banks (SN+TCB), Catalina Basin (CB), Santa Barbara Channel (SBC), Catalina Basin combined with Santa Barbara Channel (CB+SBC), San Pedro Channel (SPC), Coronado Escarpment (CE), Ensenada (E), Cape San Quentin (CSQ), *Sebastian Viscaino* Bay and Southern Baja California, central stock only (SVB+SB), and Southern Baja California, southern stock only (S).

Area	Mean age (Yr)	Mean length (SL mm)	Length at age 1½ (SL mm)	Adult growth (mm/yr)	*r*	SD of length at age 1½	SD of adult growth	*N*
				Central Stock				
CC	3.4	138.4	123.6	7.75	0.702	1.563	0.431	335
SN	3.3	131.1	120.4	5.97	0.613	0.713	0.205	1,410
TCB	3.2	130.8	119.2	6.69	0.623	0.975	0.286	860
SN+TCB	3.3	131.0	120.0	6.23	0.616	0.577	0.167	2,270
CB	3.1	126.7	116.4	6.29	0.582	0.633	0.192	2,092
SBC	2.9	125.6	116.2	6.83	0.636	0.689	0.224	1,374
CB+SBC	3.0	126.3	116.4	6.50	0.606	0.465	0.145	3,466
SPC	2.8	121.3	113.4	6.07	0.575	0.435	0.146	3,497
CE	2.7	118.7	110.5	6.89	0.569	0.666	0.235	1,798
E	2.8	116.5	106.2	8.08	0.636	0.944	0.321	934
CSQ	2.5	111.1	103.6	7.54	0.649	0.776	0.291	923
SVB+SB	2.4	106.4	101.1	5.76	0.443	1.571	0.618	358
				Southern Stock				
S[1]	2.9	91.9	91.8	0.07	0.009	1.274	0.421	335

[1]Combined from three areas: CSQ, SVB, and SB.

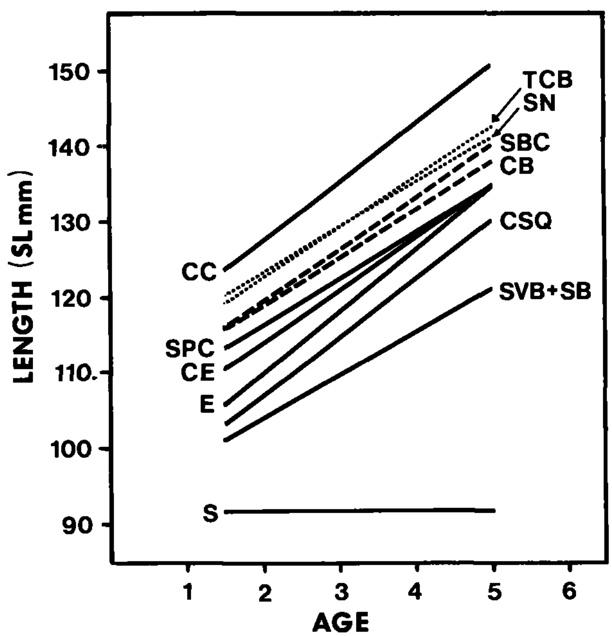

FIGURE 5.—Linear regressions showing the expected length at age (Table 1) of northern anchovies taken in CC, Central California; SN, San Nicolas; TCB, Tanner and Cortez Banks; CB, Catalina Basin; SBC, Santa Barbara Channel; SPC, San Pedro Channel; CE, Coronado Escarpment; E, Ensenada; CSQ, Cape San Quentin; SVB+SB, Sebastian Viscaino Bay and Southern Baja California, central stock only; and S, Southern Baja California, southern stock only.

patterns which are not statistically different (α = 0.01), and since the two regions are adjacent we have considered them together. Also there is no significant difference (α = 0.01) in adult growth in the Catalina Basin and the Santa Barbara Channel regions, but since these regions are geographically separated we have retained them as separate regions. The relatively large standard deviations of the regression slopes (Table 2) for fish from the Central California and the Sebastian Viscaino Bay and the Southern Baja California regions may indicate that these regions are the most likely to have mixtures of more than one stock.

There was no significant difference (α = 0.01) between growth of adults in the best growth regions (Ensenada, Cape San Quentin, and Central California). The difference between the Coronado Escarpment and the Santa Barbara Channel regions is not significant at the α = 0.1 level nor are the differences between the Catalina Basin, combined San Nicolas-Tanner and Cortez Banks, San Pedro Channel, and combined Sebastian Viscaino Bay and Southern Baja California regions.

Tanner and Cortez Banks, and Catalina Basin) differ from the other regions in that they are dominated by fish 3 yr and older (Fig. 6A, Table 4). Central California and Tanner and Cortez Banks also have substantial percentages of young-of-the-year fish, whereas the other two regions do not.

Anchovies in the three inshore regions of the Southern California Bight (Santa Barbara Channel, San Pedro Channel, and the Coronado Escarpment) have very similar age compositions (Fig. 6B, Table 4). One- and two-yr-old fish are the most numerous in these three regions. Young-of-the-year and 3 yr-olds are slightly less abundant than 1- and 2-yr-olds, and there are fewer older fish in the samples.

Baja California is characterized by a dominance of young fish (Fig. 6C, Table 4). The age compositions in the Ensenada, Cape San Quentin, and Sebastian Viscaino Bay regions are very similar; young-of-the-year and 1-yr-old fish are the most abundant, and there is rapid decrease in the abundance of fish with increasing age. Anchovies in southern Baja California are principally from the southern stock. The age composition in this region shows a preponderance of 1-yr-olds, and like the other Baja California regions there are few fish of age 4 or older.

TABLE 3.—Significance levels for differences in growth of adult northern anchovies from different geographical regions: Ensenada (E), Central California (CC), Cape San Quentin (CSQ), Coronado Escarpment (CE), Santa Barbara Channel (SBC), Tanner and Cortez Banks (TCB), Catalina Basin (CB), San Nicolas combined with Tanner and Cortez Banks (SN+TCB), San Pedro Channel (SPC), San Nicolas (SN), Sebastian Viscaino Bay and Southern Baja California, central stock only (SVB+SB), and Southern Baja California, southern stock only (S). Geographic areas are arranged in order from largest to smallest slopes.

Area	E	CC	CSQ	CE	SBC	TCB	CB	SN+TCB	SPC	SN	SVB+SB	S
E	—											
CC	0.5573	—										
CSQ	0.2217	0.6517	—									
CE	0.0019	0.0514	0.0754	—								
SBC	0.0015	0.0477	0.0629	0.9422	—							
TCB	0.0013	0.0331	0.0384	0.6516	0.6951	—						
CB	0.0000	0.0000	0.0000	0.0605	0.0628	0.2400	—					
SN + TCB	0.0000	0.0003	0.0002	0.0283	0.0280	0.0000	0.8141	—				
SPC	0.0000	0.0000	0.0000	0.0015	0.0033	0.0465	0.3560	0.4659	—			
SN	0.0000	0.0000	0.0000	0.0042	0.0042	0.0367	0.2547	0.3234	0.6902	—		
SBV + SB	0.0000	0.0085	0.0051	0.0826	0.0952	0.1616	0.3943	0.4372	0.6048	0.7379	—	
S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	—

Age Composition by Area

Geographical variation in age composition is one factor which could influence the observed variation in mean size of anchovies in the various regions; therefore, age composition was calculated for each of the regions used earlier (Fig. 2). Few anchovies < 60 mm SL occur in the data, and it appears that young-of-the-year fish are apparently not susceptible to capture by the midwater trawl gear used in the sea survey until they are about 6 mo old.

Central California and the three offshore regions within the Southern California Bight (San Nicolas,

Age Composition by Depth Strata

Anchovies primarily live within the upper mixed layer; they occur in the surface layer over the continental shelf and over deepwater regions. Mais (1974) showed that the average size of anchovies sampled in offshore areas was greater than that of anchovies sampled near the coast. The percentage of trawl hauls containing anchovies was quite constant in areas with different water depths, varying

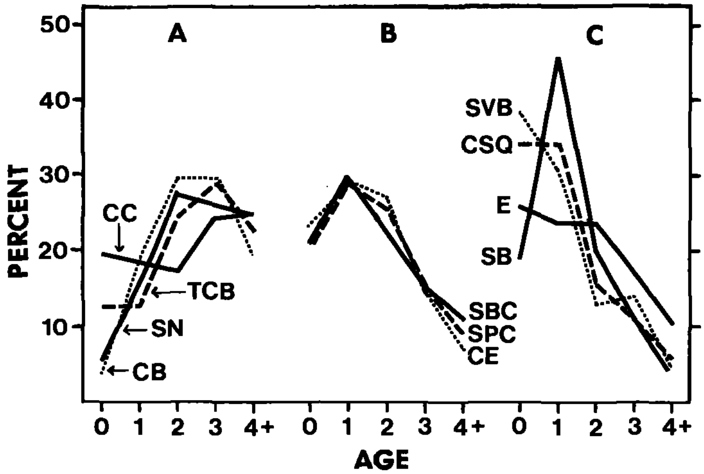

FIGURE 6.—Age composition of northern anchovies taken in the following geographical regions: A. Central California and offshore areas of the Southern California Bight; Central California (CC), San Nicolas (SN), Tanner and Cortez Banks (TCB), and Catalina Basin (CB); B. Inshore areas of the Southern California Bight; Santa Barbara Channel (SBC), San Pedro Channel (SPC), and Coronado Escarpment (CE); C. Baja California; Ensenada (E), Cape San Quentin (CSQ), Sebastian Viscaino Bay (SVB), and Southern Baja California (SB).

TABLE 4.—Percentage age composition of northern anchovies by geographical region: Central California (CC), San Nicolas (SN), Tanner-Cortez Banks (TCB), Catalina Basin (CB), Santa Barbara Channel (SBC), San Pedro Channel (SPC), Coronado Escarpment (CE), Ensenada (E), Cape San Quentin (CSQ) Sebastian Viscaino Bay (SVB), Southern Baja California (SB).

	Age							
Area	0	I	II	III	IV	V	VI+	No. fish
CC	19.3	17.2	14.7	23.9	17.7	5.7	1.6	436
SN	5.6	15.5	27.7	26.0	15.9	7.4	2.0	1,721
TCB	12.6	12.6	24.3	28.3	13.6	6.5	2.1	1,136
CB	3.7	18.7	29.2	29.2	12.8	5.2	1.1	2,538
SBC	21.8	29.6	22.2	15.2	8.2	2.4	0.6	1,989
SPC	21.6	28.6	25.4	15.6	6.3	1.9	0.5	5,439
CE	23.5	28.1	26.9	14.6	5.4	1.3	0.2	2,965
E	25.8	23.6	23.4	17.1	7.6	2.3	0.2	1,464
CSQ	33.8	33.7	15.5	11.2	4.4	1.2	0.1	1,779
SVB	38.1	30.8	12.8	13.5	4.5	0.3	—	896
SB	18.8	45.7	19.6	11.5	3.7	0.7	—	409

between 64 and 77% (Table 5). This is probably influenced by the fact that trawling (in the upper 30 m) was carried out normally in areas where fish schools had already been detected by depth recorder or sonar.

In southern California (lat. 32°-34°N) young-of-the-year anchovies comprise more than one-half of the anchovies sampled in the 5-25 fathom-depth stratum (Table 6A). One- and two-yr-olds comprise more than one-half of the anchovies in the 26-50, 51-150, 151-300, and 301-500 fathom strata. The most abundant age group in the 26-50 stratum is age 1; there are essentially equal numbers of age 1 and age 2 anchovies in the 51-150 and 151-300 strata; 2-yr-olds are the most abundant age group in the 301-500 stratum; and 3-yr-olds are the most abundant age group in the 701+ stratum. Age groups 3-6+ each show an increasing percentage with increasing depth. Collectively they comprise about 11% of the 5-25 stratum, 31% of the 51-150 stratum, and 51% of the 701+ stratum. The same general pattern occurs in northern Baja California (lat. 29.5°-32°N); however, the percentage of young fish declines more

TABLE 5.—Percentage of midwater trawl hauls taking northern anchovies by depth strata. Trawl hauls were normally within 30 meters of the surface.

Depth (fm)	Total sets	% sets with anchovies
5-25	704	75
26-50	828	69
51-150	554	69
151-300	546	76
301-500	752	77
501-700	437	73
701+	345	64
Total	4,166	72

TABLE 6.—Age composition (%) of northern anchovies taken in shallow and deep-water areas (depth in fathoms).

A

Age	Depth:	Lat. 32°-34°N						
		5-25	26-50	51-150	151-300	301-500	501-700	701+
0		56.5	26.3	16.9	7.8	5.5	3.0	6.5
I		20.6	29.5	26.5	27.4	25.8	17.9	15.5
II		12.5	24.1	26.0	27.9	30.6	32.0	26.8
III		7.0	12.3	20.1	22.8	22.7	28.2	27.1
IV		2.5	5.8	6.8	9.1	10.5	13.3	15.3
V		0.8	1.5	3.2	3.6	3.8	4.9	7.2
VI+		0.2	0.5	0.6	1.4	1.1	0.6	1.7
n		1,579	1,492	1,102	2,199	3,704	2,091	1,086

B

Age	Depth:	Lat. 29.5°-32°N			
		5-25	26-50	51-150	151+
0		56.1	36.8	21.0	8.9
I		23.1	40.4	28.5	28.8
II		12.3	10.8	24.2	26.9
III		6.2	7.8	14.2	23.3
IV		1.9	3.6	9.4	8.7
V		0.3	0.6	2.5	3.0
VI+		—	—	0.2	0.3
n		935	619	480	1,189

C Aug.-Dec.

Age	Depth:	Lat. 29.5°-32°N				Lat. 32°-34°N			
		5-25	26-50	51-150	151+	5-25	26-50	51-150	151-300
0		62.8	52.6	38.7	24.9	66.2	37.8	26.4	16.0
I		18.2	32.3	29.2	43.0	15.6	29.0	24.7	21.0
II		11.7	10.6	19.9	24.4	12.1	22.5	25.8	32.4
III		5.7	4.0	8.2	6.4	5.0	8.6	16.1	21.2
IV		1.6	0.5	4.1	1.2	0.9	2.0	5.1	8.3
V		—	—	0.7	—	0.2	0.1	1.8	0.9
VI+		—	—	—	—	—	—	—	0.2
n		806	378	267	405	1,286	1,013	546	990

slowly with increasing depth there than in southern California (Table 6B). In both southern California and northern Baja California, there is a direct relationship between average age and depth of water in which fish were caught. In the period August-December when smaller (< 60 mm) anchovies can be caught by midwater trawls, there is a greater dominance of young-of-the-year fish in the shallower water (Table 6C). In the northern Baja California area, 63% of the 5-25 stratum and 53% of the 25-50 stratum were young-of-the-year fish. In southern California the corresponding percentages were 66 and 38.

Sea Survey - Fishery Comparisons

The purse seine fleets which harvest anchovies operate primarily out of San Pedro, California, and Ensenada, Mexico. The age composition of anchovies in the San Pedro fishery (Mallicoate and Parrish 1981) contains a smaller proportion of age 0 and age 1 fish than does the sea survey data for the San Pedro Channel region. We only had 2 years of age composition data for the Ensenada fishery available to us (Sunada and Silva 1980), but this limited information shows the same dominance of younger anchovies as in the sea survey data for this region. The San Pedro fishery had several regulations which reduced the numbers of young fish in the catch. These included a 5-in minimum size limit and a series of area closures which prevent the fleet from fishing in nearshore areas. The Ensenada fishery did not have regulations which influenced the age composition of the catch.

To evaluate the effects of the area closures and size limit on the San Pedro fishery, we broke the sea survey data into depth classifications, < 50 fathoms and $\geq$ 50 fathoms. The > 50 fathom classification was intended to approximate the area of the fishery (i.e., the coastal strip is excluded). In this area the age composition of anchovies taken by the Sea Survey Program is very close to that taken by the fishery; conversely, the age composition of the fishery is unlike that taken in areas < 50 fathoms (Fig. 7). The California fishery no longer has a 5-in size limit; however, the closure of the nearshore area appears to be the dominant factor in reducing the catch of young anchovies.

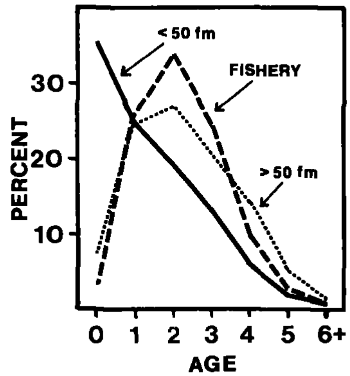

FIGURE 7.—Comparison of the age composition of northern anchovies taken in the San Pedro purse seine fishery with those taken in areas with <50 fathoms and >50 fathoms of water in the midwater trawl Sea Survey Program.

DISCUSSION

Our data show that the growth rate and the age composition of northern anchovies vary geographically. The greatest differences in growth appear to occur during the juvenile stage; growth in adults shows much less regional variation. Juvenile growth is greatest in central California and in the offshore areas of the Southern California Bight. In the inshore regions there is a trend toward reduced juvenile growth from central California to southern Baja California. Average size at age 1½ falls from 123.6 mm to 91.8 mm over this area. Growth in adult anchovies appears to be the greatest in northern California, and it is also relatively high in British Columbia (Pike 1951), central California, and northern Baja California. Adult growth appears to be relatively low in the Southern California Bight; this, however, may be an artifact as this area probably includes resident fish plus slower growing fish which have moved into this region from the south. Age composition showed a large variation among regions, and the pattern of this variation appears to be closely related to the gyral circulation within the Southern California Bight. There is also a strong relationship in age composition to the depth of water at trawl sites. Adult anchovies dominated the catches in the offshore, deepwater regions of the Southern California Bight and in central California. Age also had a strong latitudinal gradient with adult fish dominating in the north and young-of-the-year and yearling fish dominating in the shallow water areas off central and northern Baja California. Adult anchovies appear to be concentrated in areas of the Bight where prevailing currents will result in southerly and inshore larval transport (Parrish et al. 1981). At recruitment, anchovies appear to be heavily concentrated in shallow water, and young fish appear to be concentrated in the nearshore area where they will tend to be advected northward by the southern California gyre.

As will be discussed later, the interpretation of the regional differences in juvenile growth is dependent upon the stock structure in the various regions. Earlier studies (McHugh 1951; Vrooman et al. 1981) showed that the boundary between the southern and central stocks was in the northern Sebastian Viscaino Bay area. This is supported by the present study, and, as previously mentioned, the boundary is further north in the summer and fall and further south in winter and spring. We feel that there is ample evidence that the southern stock had the smallest juvenile growth rate and that growth during the adult phase is minor. Vrooman et al. (1981) suggested that the boundary between the northern and central stocks occurs in the central California area; both northern and central stocks occurred in samples taken at San Francisco (lat. 37°50′N) and Monterey (lat. 36°50′N). Their data might be interpreted to suggest that a fourth stock occurred in the San Francisco and Monterey samples, and in addition it has been suggested (Parrish footnote 3) that this fourth stock spawns during the fall in central California and the offshore areas of the Southern California Bight. Unfortunately the Vrooman et al. (1981) study did not have any samples from the region between Monterey (lat. 36°50′N) and Newport (lat. 33°30′N), nor were there any samples from the offshore areas of the Southern California Bight. It is therefore not presently possible to determine the amount of stock mixture over much of the accepted range of the central stock.

Variation in juvenile growth of northern anchovies in the different regions may be due to genetic factors, differences in the seasonality of spawning, or environmental factors. The northern stock has a relatively short spawning season with a strong peak in July (Richardson 1980). The central stock has a more extended spawning season with a broad peak from February to April, and there is some spawning all year in the central stock region. It is not yet known if the anchovies that spawn in central and southern California during the summer and fall are from the central stock, northern stock, or a possible fall spawning stock. If the anchovies in this region are predominatly from the central stock, the relatively high juvenile growth in central California and the offshore portion of the Bight might be due to a favorable feeding environment. Offshore portions of the Southern California Bight have been shown to have considerably more plankton and nutrients than the inshore portions (Reid et al. 1958; Owen 1980). If the anchovies in the area occupied by the central stock have a large component that are not central stock, the increased juvenile growth could be due to the genetic differences, due to environmental differences, or caused by the assumption of a February birth month. At our "assumed" age of 1½ yr, an anchovy spawned in the fall would be about 6 mo older than the "normal" central stock anchovy. If the growth that occurred during these additional 5 mo was at the normal adult rate (i.e., 0.48-0.69 mm/mo), there would be only a 2-4 mm difference in the size of the two fish. However, the difference in mean length between 1½-yr-old anchovies in the central California and Cape San Quentin regions is 20 mm. If, however, growth during the 5 mo is even one-half of the average juvenile rate (i.e., 9 mm/mo) the difference in size at "1½" yr could be achieved.

CONCLUSION

The interpretation of regional variations in the growth and age composition of northern anchovies in the area between central California and central Baja California and the implications of this study for fisheries management are dependent upon the stock structure of the anchovies in the area.

If a significant proportion of these fish are not from the central stock, this study suggests the following:

1. The observed regional variation in age composition may be the result of mixtures of stocks with different mortality rates.
2. The juvenile growth rate of anchovies in the central stock is lower than that of anchovies from the northern stock(s). The reason for this lower growth rate could be either genetic, environmental, or dependent upon the seasonality of spawning.
3. The southern California and Mexican fisheries are based on different stock mixtures, and thus the interactions between these fisheries would not be as great as they would be if both were based entirely on the same stock.

If essentially all of these anchovies are from the central stock, this study suggests the following:

1. The offshore regions of the Southern California Bight contain a disproportionate share of the adult anchovies; however, recruitment does not occur here to any significant extent.
2. Recruitment occurs largely in shallow water along the coast, and the northern Baja California region has the largest percentage share of young-of-the-year anchovies.
3. Larvae and juveniles recruited from the offshore regions of the Southern California Bight tend to move or be advected south and inshore.
4. The relatively high juvenile growth rates in central California and the offshore regions of the Southern California Bight are due to favorable environmental conditions.
5. As they grow older anchovies tend to move, or be advected, north and offshore.
6. Mixing of adults is not complete; otherwise length at age and age composition would be the same everywhere.
7. Due to the inferred tendency for recruitment to occur in the south, an extensive fishery on the central stock would reduce the proportion of older anchovies and result in fewer older anchovies in the northern and offshore areas.
8. The combination of the large Mexican fishery, which has been associated with a reduction in the proportion of older anchovies (Mais 1982), and the continued closure of the nearshore areas where younger fish are concentrated will severely impact the California fishery.

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