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GROWTH OF ADULT STRIPED BASS IN THE SACRAMENTO-SAN JOAQUIN ESTUARY [1]

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Adult striped bass, *Morone saxatilis,* growth in the Sacramento-San Joaqin Estuary was described well by the von Bertalanffy growth equation. After age 3, females grew more rapidly than males and by age 6 they were as large as 7-yr-old males. The size bass attain as adults appeared to be affected by their growth rate as young-of-the-year. An average 2 cm decrease in adult mean length was associated with an 18% decrease in young bass growth rate commencing in 1970. Annual mean growth in 1971 was substantially higher than for any other year and was associated with abundant forage in San Francisco and San Pablo bays.

INTRODUCTION

Adult striped bass, *Morone saxatilis,* growth in the Sacramento-San Joaquin Estuary from 1969–1978 was studied to identify possible factors affecting growth rates. Documentation of such resource requirements is a prerequisite for rational fishery management decisions. Previous striped bass growth studies (Scofield 1931, Robinson 1960, Miller and Orsi 1969) demonstrated a significant ($P < 0.05$) increase in mean length for age groups 3 to 7 between the 1920's and 1950's. Robinson (1960) suggested this size increase may have been due to decreased competition resulting from a decline in the striped bass population over this period as indicated by a decreasing trend in catch per unit effort (Chadwick 1962). The size that bass attain as adults might also be influenced by their growth when immature (Merriman 1941, Tiller 1943).

Robinson (1960) observed fluctuations among annual growth increments for 1952 to 1956, but did not have sufficient data to determine either the causes or the significance of these fluctuations.

Specific objectives of my study were to: (i) describe the present age-length relationship of adult striped bass in the estuary, (ii) determine if the size attained as adults is affected by their growth as young-of-the-year, and (iii) determine if fluctuations in annual growth increments are associated with fluctuation in adult bass and/or forage abundance.

A mark-recapture study begun in 1969 to estimate adult striped bass abundance has provided age-length data for fish 3 yr and older during spring, summer, and fall. Annual tow net and midwater trawl surveys in the estuary (Stevens 1977*a*) provided data to calculate growth of young striped bass and to estimate forage abundance.

MATERIALS AND METHODS

Striped bass were captured each year (1969–1978) during their spring spawning migration (mid-March to mid-June). The primary objectives of this work was to capture legal sized [$\geq$ 40.6 cm total length (TL), $\cong$ 38 cm fork length (FL) bass for tagging; therefore, my growth study only includes bass $\geq$38 cm FL.

[1] Accepted for publication December 1980.

Fish were captured in wire fyke traps (Hallock, Fry, and LaFaunce 1957) in the Sacramento River near Clarksburg and with drift gill nets (stretched mesh sizes: 10.2 cm to 14.0 cm) in the San Joaquin River near Antioch. In 1977 and 1978 fish were captured in the San Joaquin River only. A creel census in the San Francisco Bay area during summer and fall (1969–1977) provided additional monthly samples. Sex and fork length (to the nearest centimetre) were recorded for all fish from which scale samples were collected for aging. During spring, fish were classified as male if milt was extruded when abdominal pressure was applied; if milt did not flow the fish were classified as female. During summer and fall sex was determined by dissection.

Scales were taken midway between the spinous dorsal fin and the lateral line and independently read by two individuals using binocular dissecting microscopes at 30X magnification. Scofield (1931) demonstrated the validity of using scale samples from striped bass to determine age. Scale growth appears as fairly evenly spaced arched circuli lying between numerous radii (Figure 1). Most annuli are very distinct, appearing as thick ridges continuous around the anterior

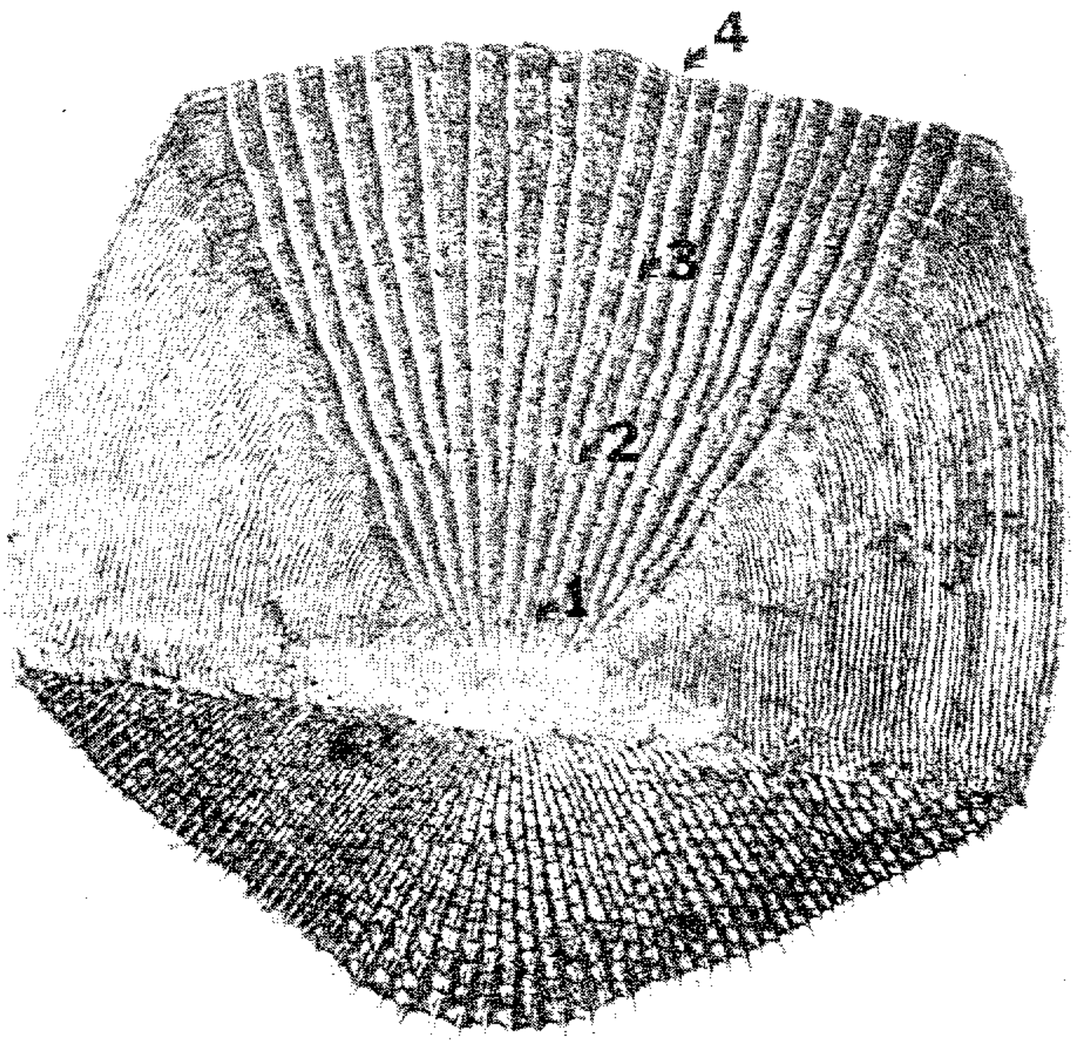

FIGURE 1. Scale from a 4-yr-old striped bass collected in the spring of 1979 from the Sacramento-San Joaquin Estuary. Marks not labeled are false annuli. *Photograph by Tom Taylor.*

and lateral fields. Annuli tend to bend inward at the base of the lateral field "crossing over" circuli. Since annuli are not visible until normal growth resumes in spring or early summer the scales collected in the spring were assumed to have an annulus at the margin even if one was not detected.

Identification of false or extra annuli is often difficult. False annuli may cover only half the scale, the circuli comprising them are often curved instead of straight, and their spacing is usually irregular. There is an orderly decrease in spacing between true annuli as the fish age.

Among older fish, the annuli become compacted toward the margin making individual annuli very hard to detect. Hence, while ages up to 7 or 8 yr can be readily determined, the incidence of age disagreements between readers increases to over 50% in older bass and ages may be underestimated. The oldest age that we estimated from reading more than 125,000 scales was 19 yr; however, recovery in 1977 of a bass tagged 17 yr earlier when it was 6 or 7-yr-old reveals that bass live to at least age 23.

Average growth from age 3 to 12 was estimated for males and females separately by fitting the mean fork lengths ($\overline{FL}$) observed each spring to the von Bertalanffy growth equation (Ricker 1975) using the least squares computation (Abramson 1971). Bass over 12-yr-old were not included because samples were too small.

Average seasonal growth (May to November) for each sex was estimated for ages 3 to 8. The procedure was: (i) each year determine the mean length of each sex-age group during each month of this period, and (ii) calculate linear regressions of mean lengths on month for each age group. The regression coefficients were estimates of average seasonal growth rates. Monthly samples usually were small for bass over 8-yr-old so seasonal growth rate was not estimated for those fish.

Inspection of age-length data (Tables 1 and 2) suggested that average lengths were smaller for some year classes than for others at all ages; therefore, analysis of variance tests were used to determine if significant differences occurred among mean lengths of individual year classes at the various ages. Student-Newman-Keuls tests, *a posteriori* stepwise range test (Sokal and Rohlf 1969), were used to determine which groups were significantly different. This analysis demonstrated a clear distinction between year classes 1965–1969 and 1970–1975 for both sexes. Therefore, for each age group (3 to 7) grand mean fork lengths were calculated for sexes combined from the mean lengths of the 1965–1969 and the 1970–1975 year classes. Grand mean lengths were used in linear regressions on age to determine if growth rates differed for these two sets of year classes as adults or if the differences observed were solely due to differences in growth in younger stages.

The hypothesis that growth rates of immature striped bass affect the size attained as adults was tested by correlating the annual spring lengths of individual adult age groups with growth rates (mm/day) estimated from July to October for the same year classes as young-of-the-year (Table 3).

TABLE 1. Mean Fork Lengths (cm) ± SD for Male Striped Bass Tagged During Spring in the Sacramento-San Joaquin Estuary.[a]

	Age						
Year	*3*[b]	*4*	*5*	*6*	*7*	*8*	*9*
1969	43.6(971)	50.5±5.5(3054)	58.2±5.8(1949)	64.8±5.2(1566)	70.8±6.0(805)	75.8±5.3(577)	79.1±5.1(423)
	YC = 1966	YC = 1965	YC = 1964	YC = 1963	YC = 1962	YC = 1961	YC = 1960
1970	44.5(986)	50.8±4.8(1692)	58.7±5.2(685)	64.6±5.1(338)	70.1±5.1(295)	75.2±4.8(141)	78.5±4.2(82)
	YC = 1967						
1971	43.1(1105)	50.5±5.0(3069)	58.3±5.2(1123)	65.2±5.2(368)	70.4±4.5(206)	74.2±4.5(229)	77.8±4.6(116)
	YC = 1968						
1972	43.6(1568)	51.7±4.8(4113)	59.9±5.2(2264)	66.8±4.9(718)	71.8±4.8(419)	75.4±4.0(291)	79.0±4.5(264)
	YC = 1969						
1973	42.5(1116)	51.8±4.8(5090)	59.0±5.5(1500)	66.2±5.1(995)	71.5±5.0(380)	75.6±5.1(289)	78.0±5.2(220)
	YC = 1970						
1974	42.1(1737)	49.5±4.9(3648)	59.0±5.7(1559)	65.5±6.0(482)	71.4±5.4(374)	76.3±4.7(163)	79.2±5.8(109)
	YC = 1971						
1975	42.4(885)	49.4±4.7(2832)	56.1±6.4(619)	65.5±6.3(342)	70.6±6.1(121)	75.2±4.8(101)	78.0±4.5(51)
	YC = 1972						
1976	42.8(1269)	49.8±4.4(3008)	56.4±5.5(1477)	63.0±6.6(408)	70.4±5.5(251)	74.4±4.9(116)	78.4±4.6(90)
	YC = 1973						
1977	42.6(1067)	50.1±4.3(1901)	56.4±5.5(456)	63.6±6.0(221)	68.8±5.8(81)	73.9±6.5(43)	
	YC = 1974						
1978	42.2(1307)	49.6±4.4(1603)	56.4±5.1(420)	63.4±6.1(125)	69.9±5.5(56)		
	YC = 1975						

[a] Sample sizes in parentheses; year classes (YC) follow diagonals.
[b] Lengths biased high for age group 3 (see text).

TABLE 2. Mean Fork Lengths (cm) ± SD for Female Striped Bass Tagged During Spring in the Sacramento-San Joaquin Estuary.[a]

	Age					
Year	4	5	6	7	8	9
1969	54.2±6.2(716)	63.6±5.3(1674)	70.2±5.5(1400)	75.8±6.1(573)	81.0±6.4(352)	85.8±6.5(277)
	YC = 1965	YC = 1964	YC = 1963	YC = 1962	YC = 1961	YC = 1960
1970	55.3±4.9(323)	64.2±4.9(821)	69.3±5.2(485)	75.2±5.4(329)	80.2±5.6(142)	84.2±5.2(80)
	YC = 1966					
1971	55.9±5.7(571)	63.9±5.3(658)	70.8±5.1(380)	76.6±5.5(204)	79.8±5.4(121)	83.2±4.5(51)
	YC = 1967					
1972	56.0±7.3(649)	65.5±4.6(2686)	72.6±5.0(841)	78.3±4.8(464)	82.2±4.5(221)	85.0±5.1(175)
	YC = 1968					
1973	55.3±6.0(593)	65.2±5.0(1303)	72.2±4.5(1416)	78.0±4.7(363)	82.5±5.2(162)	85.8±5.7(138)
	YC = 1969					
1974	52.4±6.2(508)	64.6±5.1(1602)	71.7±5.4(680)	78.0±5.1(495)	83.0±5.1(143)	86.7±6.1(92)
	YC = 1970					
1975	51.5±5.6(461)	62.7±6.2(597)	72.1±4.9(718)	77.0±5.2(195)	81.7±5.4(146)	85.2±5.3(51)
	YC = 1971					
1976	51.3±5.2(387)	62.7±5.4(1058)	70.0±5.9(449)	77.4±4.6(349)	82.2±5.2(107)	86.8±5.5(62)
	YC = 1972					
1977	52.9±5.4(190)	62.3±5.1(348)	70.3±4.7(237)	76.2±5.9(86)	82.2±5.5(47)	
	YC = 1973					
1978	54.1±4.7(141)	62.5±5.5(229)	69.8±5.3(138)	75.5±6.0(59)		
	YC = 1974					

[a] Sample sizes in parentheses; year classes (YC) follow diagonals.

TABLE 3. Growth Rate Estimates for Young-of-the-Year Striped Bass in the Sacramento-San Joaquin Estuary.[a]

Year class	*Estimated date that bass reach 25.4 mm*	*Date*	*Mean fork length (mm)*	*Growth increment (mm)*	*Growth rate (mm/day)*
1967	7/28	10/20	82.9	57.5	0.68
1968	7/7	10/11	87.8	62.4	0.64
1969	7/25	10/22	84.9	59.5	0.66
1970	7/1	10/18	88.2	62.8	0.58
1971	7/23	10/13	79.1	53.7	0.58
1972	7/6	10/17	82.7	57.3	0.55
1973	7/26	10/16	80.2	54.8	0.49
1974	—	—	—	—	—
1975	7/9	10/16	74.2	48.8	0.49

[a] Growth rates based on observed length of young bass captured in annual summer and fall tow net surveys (Chadwick, Stevens, and Miller 1977; Miller unpubl. data).

Annual growth increments were calculated for each age group 3 to 8 from spring data (i.e., 1974 growth increment for 4-yr-olds = age 5 $\overline{FL}$ in 1975 − age 4 $\overline{FL}$ in 1974). Observed mean lengths for 3-yr-old bass were biased high since in spring about half the 3-yr-old population were shorter than the 38 cm FL minimum tagging length. Therefore, growth increment estimates for age 3 bass are biased low, but still are useful as an annual index of growth. Lengths for age 3 females were assumed to equal lengths observed for age 3 males because few age 3 females were captured. They do not undertake a spawning migration until they are 4 or 5-yr-old (Chadwick 1967). Back calculated lengths demonstrate that male and female striped bass are essentially the same length up to age 3 (Scofield 1931, Robinson 1960).

I examined fluctuations in the annual growth increments for evidence that they may have resulted from variations in forage availability or intraspecific competition. For this analysis, the mean of the annual growth increments for ages 3 to 8 were calculated for each year for each sex; the average for male and female bass was then used as an estimate of the annual mean growth of adult striped bass. Abundance estimates for two important forage species, northern anchovy, *Engraulis mordax,* and shiner perch, *Cymatogaster aggregata* (Thomas 1967) were available from midwater trawl surveys during August, September, and October from 1969 to 1973. Two measures of adult bass abundance were used to examine intraspecific effects. One abundance index was calculated from commercial passenger fishing boat catches (Stevens 1977*b*); the other abundance index consists of Petersen population estimates (Stevens 1977*a*).

RESULTS

Von Bertalanffy Growth Equation

Growth of adult striped bass collected from 1969–1976 in the Sacramento-San Joaquin Estuary was described well by the von Bertalanffy growth equation (Figure 2). Correlation coefficients (r) between observed and predicted lengths from the von Bertalanffy equation were 0.998 for males and 0.996 for females. Male bass grew from about 40 cm at age 3 to about 86 cm at age 12; while female bass grew from about 40 cm at age 3 to about 96 cm at age 12. Hence, females grew more rapidly than males and by age 6 ($\overline{FL}$ = 70.7 cm) were as large as 7-yr-old males ($\overline{FL}$ = 70.6 cm).

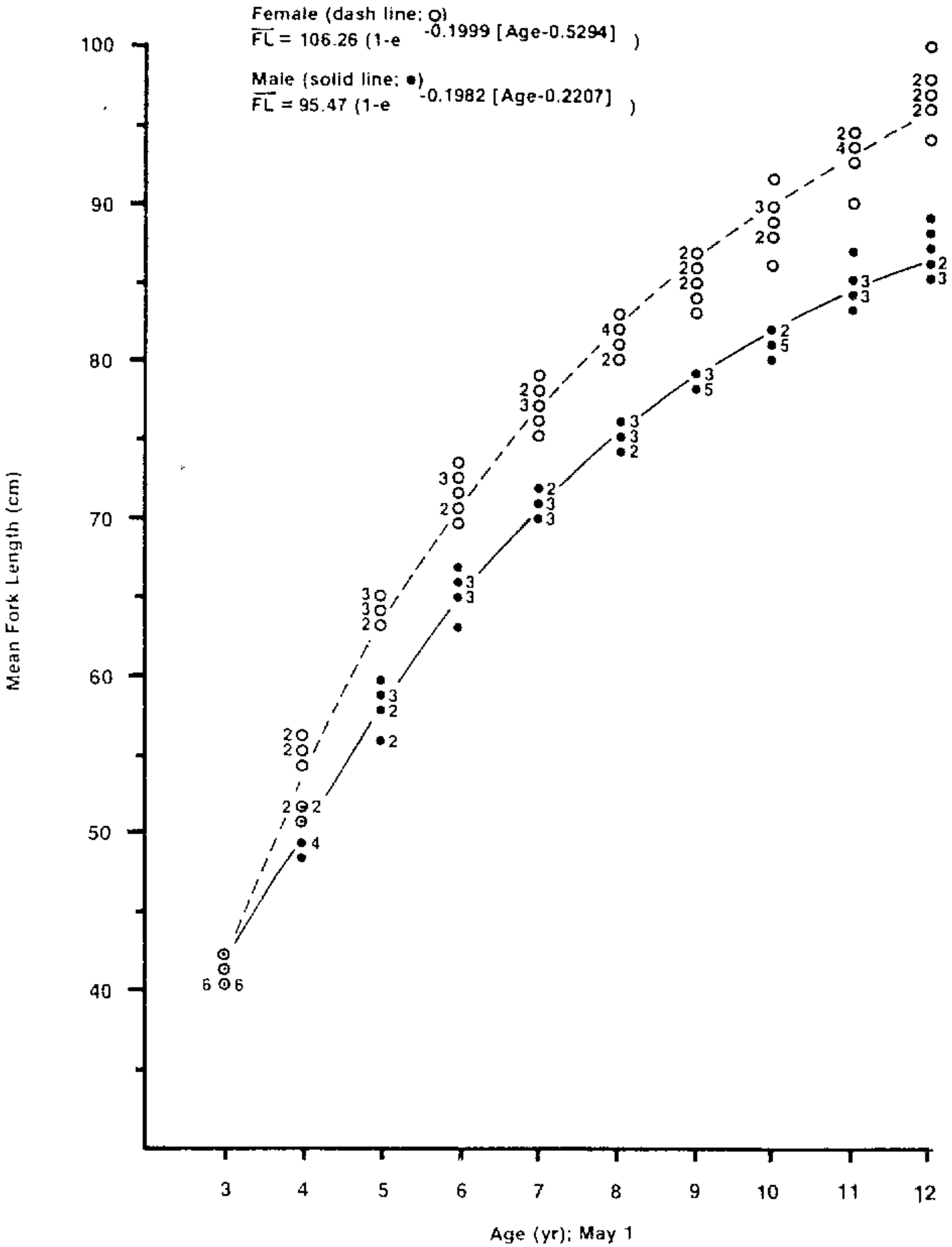

FIGURE 2. Von Bertalanffy growth curves for striped bass sampled during spring (1969–1976) in the Sacramento-San Joaquin Estuary. Equations were calculated from annual mean lengths. Numbers next to data points indicate number of overlapping points.

Seasonal Growth

Growth varied seasonally. Length increased from May to November and then, except for 3 to 5-yr-old females, showed little or no increase until the following May (Table 4). Three to 5-yr-old females had a mean length increase of 2.3 cm from November to May which is about 0.46 cm/month and about one-third as fast as the summer-fall growth rate (1.46 cm/month) for these fish. No data were available to determine if 3 to 5-yr-old females grew constantly throughout winter at this low rate. An inconsistency is that among age 4 to 8 males and 7 to 8 females the mean fork length in November is larger than the mean fork length for the next age group the following May.

TABLE 4. Seasonal Growth of Striped Bass (1969–1977) in the Sacramento-San Joaquin Estuary. Lengths are Monthly Grand Means; Growth Rates (cm/month) are Given as Regression Coefficients (b) ± Standard Errors (SE).

	Age					
Males	*3*	*4*	*5*	*6*	*7*	*8*
May	40.2 *	50.5	58.0	65.0	70.6	75.1
June	43.5	53.7	61.9	68.4	74.7	77.9
July	44.5	53.9	63.4	69.9	74.8	79.2
Aug	47.0	56.7	64.5	70.1	75.1	78.6
Sept	49.1	58.0	64.7	70.1	75.1	79.1
Oct	50.3	58.4	65.2	70.8	75.6	79.1
Nov	50.5	58.7	65.5	72.6	76.3	79.9
b	1.75	1.36	1.09	0.99	0.69	0.66
SE	0.17	0.19	0.25	0.21	0.23	0.19
Females						
May	40.2 *	53.9	63.8	72.1	77.0	81.6
June	43.8	54.7	64.0	73.3	78.2	82.0
July	45.1	56.2	66.9	74.2	79.6	84.2
Aug	47.0	59.2	68.4	74.9	80.4	84.6
Sept	49.8	60.5	68.6	75.2	80.4	84.9
Oct	50.9	61.0	69.4	75.5	81.3	85.6
Nov	51.3	61.4	70.1	77.1	82.1	85.8
b	1.86	1.41	1.12	0.73	0.80	0.67
SE	0.17	0.16	0.15	0.07	0.08	0.09

* Average of the modal fork lengths for males captured in fyke traps (1969–1976).

Annual Size Variations

Significant differences ($P < 0.001$) among spring mean lengths of striped bass (sexes combined) at the same age were found for age groups 4 to 7. *A posteriori* comparisons demonstrated that the 1970 and latter year classes were significantly smaller ($P < 0.01$) at all ages than the 1965–1969 year classes, which averaged 2 cm larger over this age range (Tables 1 and 2). However, growth rates over this age range (Figure 3) for the 1965–1969 year classes (7.7 cm/month) were not significantly different from the 1970 and latter year classes (7.4 cm/month).

Reduced first year growth (Table 3) apparently contributed to the reductions in lengths observed for the post-1969 year classes. The average growth rate for the 1970–1975 year classes as young-of-the-year was 0.54 mm/day, 18% lower than the average growth rate estimate of 0.66 mm/day for the 1967–1969 year classes as young-of-the-year. Except for age 4, mean lengths of adults (sexes combined) in spring were significantly correlated with growth rates estimated for the same year classes as young-of-the-year (Table 5). The correlation coefficients tended to increase with age because at ages ≥ 4 the 1975 year class dropped from the analysis and at age 6 the 1973 year class was eliminated. Dropping these year classes improved the correlation coefficients because as adults their lengths were greater than expected from the relation between young growth and adult size for the other year classes.

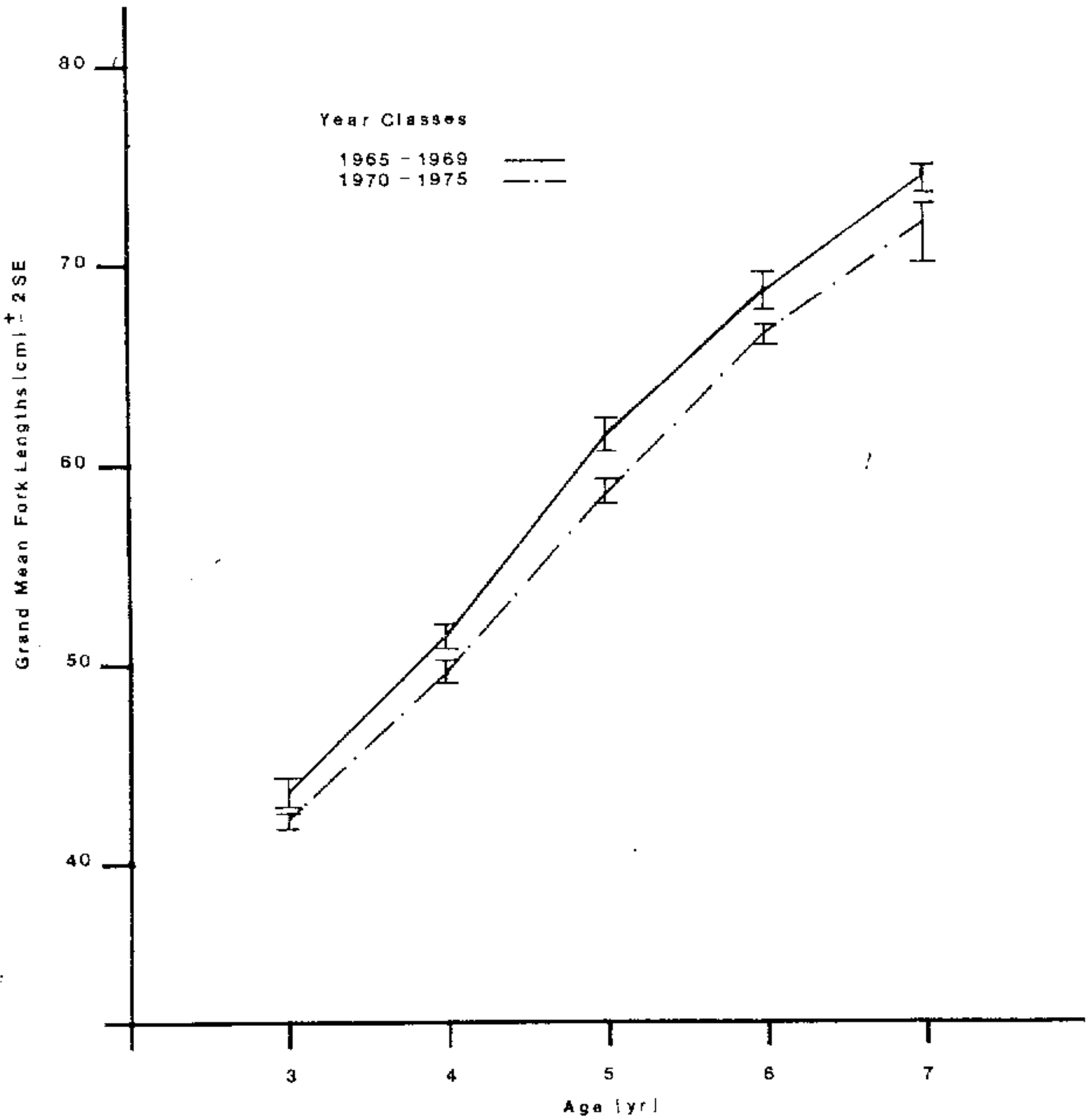

FIGURE 3. Growth of striped bass sampled during spring in the Sacramento-San Joaquin Estuary from the 1965–1969 and 1970–1975 year classes. Sexes combined.

TABLE 5. Growth Rates of Young-of-the-Year Striped Bass (July–October) and Mean Lengths, Sexes Combined, Attained in Spring During Subsequent Years of Adult Life (r = Correlation Coefficient).

	Young bass growth rate	Spring fork length (cm)				
Year class	(mm/day)	Age 3 R=0.76*	Age 4 r=0.72	Age 5 r=0.93**	Age 6 r=0.97**	Age 7 r=0.95*
1967	0.68	44.5	51.3	63.0	69.7	75.1
1968	0.64	43.1	52.2	61.9	69.2	74.5
1969	0.66	43.6	52.2	61.8	70.0	74.5
1970	0.58	42.5	49.8	59.3	66.6	72.6
1971	0.58	42.1	49.7	59.0	67.0	71.5
1972	0.55	42.4	50.0	58.9	66.5	
1973	0.49	42.8	50.3	58.5		
1974		42.6	49.9			
1975	0.49	42.2				

* = $P < 0.05$
** = $P < 0.01$

The mean of the annual growth increments from 1969 to 1977 for male bass decreased from 7.3 cm for 4-yr-olds to 3.0 cm for 8-yr-olds (Table 6), while the mean annual growth increment for females over the same ages decreased from 9.9 cm to 3.8 cm. The mean of the annual growth increments during a given year for ages 3 to 8 (annual mean growth) varied from 5.2 cm to 7.2 cm for males and 6.4 cm to 8.2 cm for females. However, variations in annual mean growth from 1969 to 1977 were significantly correlated for males and females ($r = 0.90$; $P < 0.01$).

TABLE 6. Annual Growth Increments (cm) of Striped Bass in the Sacramento-San Joaquin Estuary.

	Males									
	Year									
Age	*1969*	*1970*	*1971*	*1972*	*1973*	*1974*	*1975*	*1976*	*1977*	*Mean*
3*	7.2	6.0	8.6	8.2	7.0	7.3	7.4	7.3	7.0	7.3
4	8.2	7.5	9.4	7.3	7.2	6.6	7.0	6.6	6.3	7.3
5	6.4	6.5	8.5	6.3	6.5	6.5	6.9	7.2	7.0	6.9
6	5.3	5.8	6.6	4.7	5.2	5.1	4.9	5.8	6.3	5.5
7	4.4	4.1	5.0	3.8	4.8	3.8	3.8	3.5	(4.2) +	4.2
8	2.7	2.6	4.8	2.6	3.6	1.7	3.2	(3.0) +	(3.0) +	3.0
Annual mean	5.7	5.4	7.2	5.5	5.7	5.2	5.5	5.6	5.6	5.7
Age	*Females*									*Mean*
3*	11.7	11.4	12.9	11.7	9.9	9.4	8.9	10.1	11.5	10.8
4	10.0	8.6	9.6	9.2	9.3	10.3	11.2	11.0	9.6	9.9
5	5.7	6.6	8.7	6.7	6.5	7.5	7.3	7.6	7.5	7.1
6	5.0	7.3	7.5	5.4	5.8	5.3	5.3	6.2	5.2	5.9
7	4.4	4.6	5.6	4.2	5.0	3.7	5.2	4.8	(4.7) +	4.7
8	3.2	3.0	5.2	3.6	4.2	2.2	5.1	(3.8) +	(3.8) +	3.8
Annual mean	6.7	6.9	8.2	6.8	6.8	6.4	7.2	7.2	7.0	7.0

* Biased low (see text).
+ Growth increment not available for this year; therefore, the mean increment for the age group was used in calculating the annual mean increment for this year.

For all ages, except age 4 females, the largest annual growth increments occurred from spring 1971 to spring 1972 (Table 6). That year estimated average annual mean growth for sexes combined exceeded the average for all other years by 1.5 cm.

Effects of Forage Abundance and Intraspecific Competition

The higher average annual mean growth in 1971 corresponded to the largest forage abundance indices observed for anchovies and shiner perch in San Francisco and San Pablo bays (Figure 4). The 1971 abundance indices for anchovies and shiner perch were 48% and 38% greater, respectively, than the mean abundance indices for 1969, 1970, 1972, and 1973, during which essentially no variation was observed in annual mean growth for striped bass.

There was no obvious relationship between bass growth and either Stevens' (1977*b*) striped bass abundance indices or Petersen population estimates (Bailey 1951) for adult bass (Figure 4). While peak growth occurred when abundance was moderately low, growth increments coinciding with lower abundance measurements were equivalent to growth increments measured at some of the highest abundance estimates.

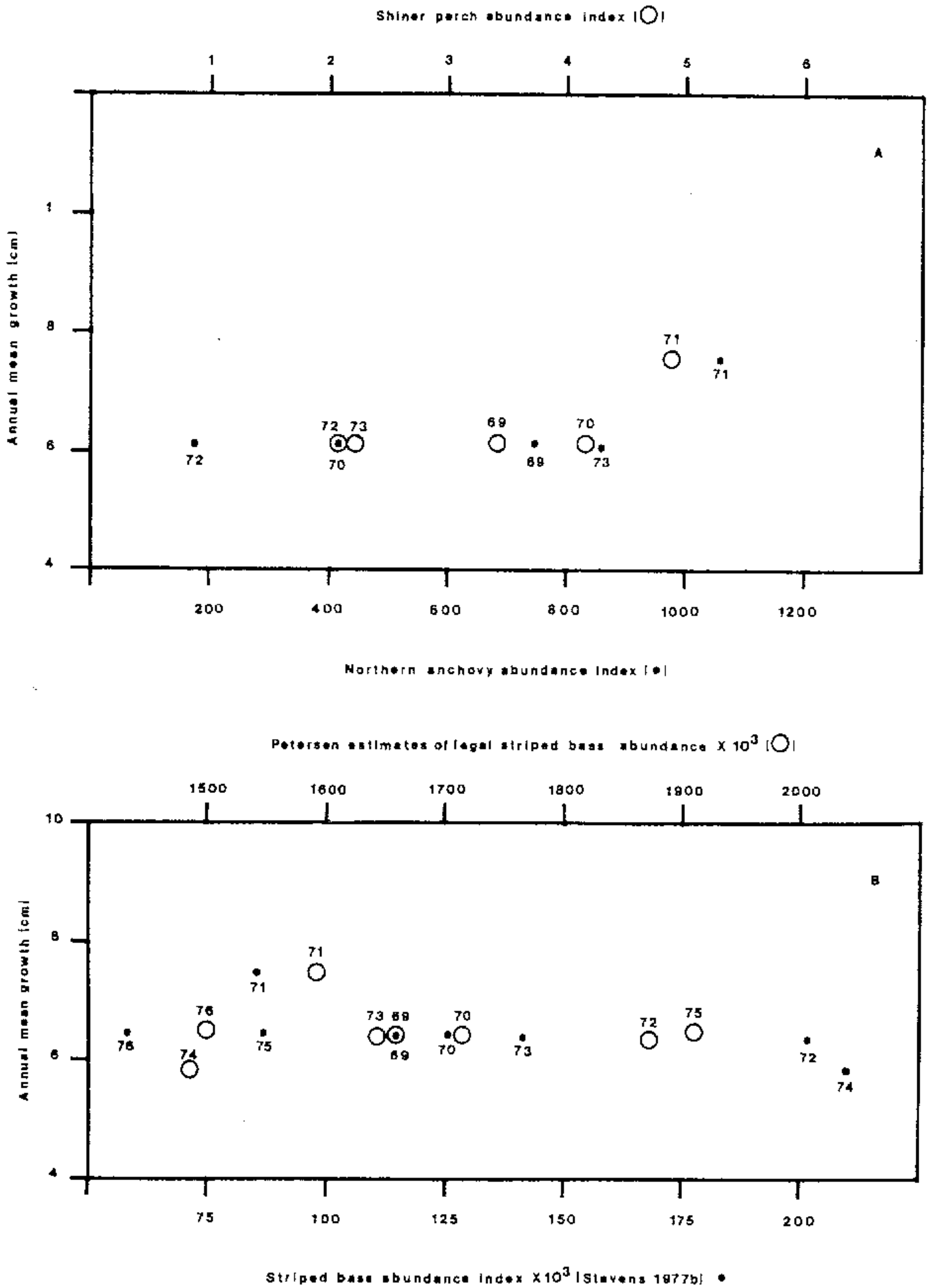

FIGURE 4. Adult striped bass annual mean growth vs. forage abundance estimates in San Francisco and San Pablo bays and adult striped bass abundance estimates.

DISCUSSION

The von Bertalanffy growth equation described the general form of adult striped bass growth well but underestimates maximum length. Asymptotic lengths predicted by the equation were 95.5 cm for males and 106.3 cm for females. Mean lengths of the largest bass observed each spring were 101.1 cm for males and 113.4 cm for females. This underestimation probably resulted from restricting the analysis to ages 3 to 12.

Growth occurred primarily between May and November. Comparisons of lengths for various age groups in November with the next older age group in May suggested some winter growth occurred among 3 to 5-yr-old females. In contrast 4 to 7-yr-old male bass lengths in May were consistently smaller than lengths in the previous November. A similar discrepancy was also observed for females at age 6 (fall) and 7 (spring). These discrepancies apparently reflect unresolved sampling biases.

The 1970 and later year classes averaged about 2 cm smaller than the 1965–69 year classes at all ages; however, growth rates from ages 3 to 7 did not significantly differ between these two groups. The size reduction was associated with decreased growth of the same year classes as young-of-the-year which may have been due to reduced food abundance. From 1968 to 1975 young-of-the-year bass growth was significantly correlated ($r = 0.81$, $P < 0.05$) with indices of abundance (J. Orsi, Assoc. Fish. Biol., Calif. Dept. Fish and Game, pers. commun.) of their major food organism, *Neomysis mercedis.* Survival of young bass also has decreased since 1970 due to State and Federal water projects increasing diversions from the striped bass nursery and reducing freshwater flows which disperse young bass through the estuary (Chadwick, Stevens, and Miller 1977). Abundance of *Neomysis* may have been reduced by the same water diversions (Orsi and Knutson 1979). Thus, the water projects may be reducing both survival and growth of striped bass.

Other studies also have demonstrated that size differentials established in young fish are maintained throughout life. Merriman (1941) reported that 2 and 3-yr-old striped bass of the dominant 1934 year class sampled in Connecticut grew at about the same rate but averaged at least 2 cm smaller than members of the 1933 and 1935 year classes at age 3. Therefore, the observed size difference developed early in life. Also, Tiller (1943) reported that larger striped bass yearlings in Chesapeake Bay maintained their size advantage in subsequent years.

Mean lengths of 4 to 7-yr-old striped bass in 1957–58 (Robinson 1960) averaged about 5.6 cm longer than in 1925–28 (Scofield 1931). Robinson suggested this size increase might be a response to decreased intraspecific competition resulting from a decline in striped bass abundance. Appropriate data are not available for the 1920's, but a general decline in fishing success suggests bass abundance declined from the late 1930's to the time of Robinson's study in the mid-1950's (Chadwick 1962). Similarly, McGie and Mullen (1979) reported that growth increments of striped bass in Umpqua River, Oregon, were larger during the early 1940's when the striped bass population was smaller (as indicated by the commercial catch statistics) than the 1954–68 period.

Increases in the size of adult striped bass have also been observed since 1957–58 but were smaller than observed between Scofield's and Robinson's studies.

The average length of ages 4 to 7 increased 1.8 cm from 1957–58 to 1961–65 (Miller and Orsi 1969), and 1.2 cm from 1961–65 to 1969–78. The size increase from 1961–65 to 1969–78 is consistent with the intraspecific competition hypothesis as average adult abundance probably was lower from 1969 to 1978 (Stevens 1977*b*). However, the size increase from 1957–58 to 1961–65 is not consistent with this hypothesis, since bass probably were more abundant from 1961 to 1965 (Stevens 1977*b*). Therefore, other factors apparently also affected these results. The differences observed in the size of the bass since Robinson's study have been within the size range I have attributed to differences in first year growth rates, therefore may have resulted from differences in growth of immature fish.

Robinson (1960) observed fluctuations in annual growth from 1952 to 1956 but did not have sufficient data to explain them. Very little variation occurred among the mean annual growth increments during my study except for 1971 when a substantial increase in growth was observed for almost all ages. This corresponded with the largest forage abundance index observed between 1969 and 1973. I also examined potential effects of intraspecific competition. Although bass abundance did not fluctuate much during my study, the abundance estimate was moderately low in 1971 when the highest growth was observed. However, growth was essentially equal at lower and higher population abundance levels. Possibly the high growth rate in 1971 resulted from the combination of high forage abundance and moderately low bass abundance.

Although growth (Miller and Orsi 1969) and abundance (Stevens 1977*b*) data also are available from 1961 to 1965, I did not use them to analyze effects of intraspecific competition on growth because some of the growth data did not appear reliable. For example the growth increment for age 3 females was unrealistically low in 1963 (3.3 cm) and the increment for age 4 females was unrealistically high in 1964 (15 cm). To resolve specifically how changes in forage abundance and intraspecific competition affect adult striped bass growth more observations are needed.

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