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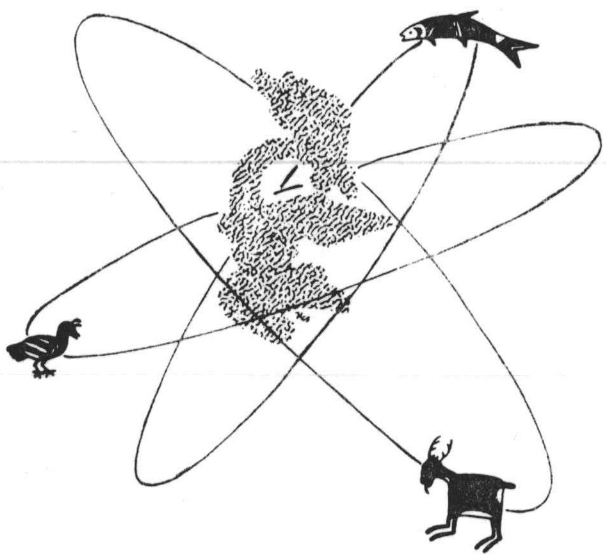

RESEARCH AND DEVELOPMENT SECTION

Oregon Department of Fish and Wildlife

Fish Division

Age, Growth, and Population Trends of Striped Bass,
Morone saxatilis, in Oregon.

Age, Growth, and Population Trends of Striped Bass, *Morone saxatilis*, in Oregon

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ABSTRACT

Lengths of striped bass were back calculated from 2,845 scales collected from the Coos, Umpqua, and Coquille rivers, Oregon, between 1946 and 1973. Average lengths of males and females were calculated from age 1 through a maximum age of 17. Both sexes grew at the same rate until age 4 when females increased at a faster rate. Deviations in calendar-year growth were calculated from 1934-68 in Coos River, 1940-69 in the Umpqua River, and 1958-68 in the Coquille River. The Coos and Coquille populations experienced wide annual fluctuations in growth with depressions following dominant year classes. The growth of Umpqua River striped bass was above average in the early 1940's but fluctuated from year class dominance in the 1960's. Average back-calculated lengths in the three rivers ranked among the largest published. Annuli formed from late March to late July. The von Bertalanffy growth equation was fitted to summations of the mean annual increments for sexes separate and combined from the three populations. Predicted asymtotic lengths ranged from 101.7 to 116.7 centimeters which were reasonably close to empirical measurements. The weight-fork length relationship (r = 0.98) from 2,357 measurements was: $w = 7.869 \times 10^{-6} l^{3.1070}$ with weight in kilograms and length in centimeters. Regressions fitted to an index of population size indicated the Coos River population has declined 1.8%/year; whereas, the Umpqua River population increased 17.2%/year, the Coquille River population 6.6%/year, and the Siuslaw River population 15.8%/year. Management implications of the age and growth parameters and significance of trends in the striped bass populations are discussed.

INTRODUCTION

The striped bass, *Morone saxatilis* (Walbaum), is a popular estuarine sport fish and was formerly landed in commercial gill-net fisheries in the Siuslaw, Smith, Umpqua, Coos, and Coquille rivers in southwestern Oregon. The commercial harvest was eliminated by legislative action following the 1975 season. Prior to closure, commercial landings of striped bass from the five rivers ranged between 5,950 to 113,660 kg since 1931.

The striped bass populations in Oregon originated from a release of only 435 yearlings transported by train from Navesink and Shrewsbury rivers, New Jersey, and liberated into San Francisco Bay, California, in 1879 and 1882 (Scolfield 1931; Nichols 1966). The bass were first documented in Oregon when two were landed by a commercial fisherman in Coos Bay in 1914 (Morgan and Gerlach 1950). Since 1914, striped bass populations have become established in four other estuaries in Oregon including Smith River, a tributary of Umpqua River. The Siuslaw River (44° 00'N, 124° 07'W) apparently sustains the northernmost population of striped bass on the West Coast, although occasional specimens have been reported in the Columbia River (Oreg. Fish Comm. 1948) and as far north as Barkley Sound, British Columbia (Forrester et al. 1972).

The only published life history notes on Oregon striped bass are those of Morgan and Gerlach (1950) for the Coos River population. In 1955, the Fish Commission of Oregon1/ initiated a study to further analyze the life history

1/ *Merged with the Wildlife Commission into a single Department of Fish and Wildlife in 1975.*

of Oregon striped bass. Primary emphasis was placed on monitoring the age composition of the commercial catch through scale analyses. The present study on the age and growth of striped bass is largely based on scales collected from the Coos, Umpqua, and Coquille rivers between 1955 and 1974. Additional scales were added from those collected by Morgan and Gerlach, from a sport fishing survey on the Umpqua River in 1972, and two samples taken from seine hauls in Coos River.

Previous striped bass growth studies have been based on age and size at capture (Pearson 1938; Morgan and Gerlach 1950; Tiller 1950; Vladykov and Wallace 1952) and back-calculated lengths based on the body-scale relationship (Scofield 1931; Robinson 1960; Mansueti 1961). Merriman (1941) used a combination of these two methods.

Description of the Areas

Striped bass are normally confined to the brackish and tidally-influenced fresh water in the five rivers supporting populations in southern Oregon (Fig. 1). The fish rarely migrate upstream beyond the estuaries, except in the Umpqua River where they have been taken 75 km above tidal influence at Kellogg. Unconfirmed reports from anglers indicate striped bass have been landed at the town of Umpqua, 122 km above tidewater.[2/]

Coos Bay is the largest estuary supporting striped bass in Oregon, with a surface area of 5,010 ha at mean high water (Oregon Division of State Lands 1973). Two large tributaries, the Coos and Millicoma rivers, fork 8.9 km east of the bay. Above the forks, tidewater extends upstream about 18 km in each river. Various features of the bay and its tributaries were illustrated and described by Morgan and Gerlach (1950).

The Umpqua River estuary contains 2,764 ha, including Smith River estuary, and extends upstream 43.6 km. Smith River empties into the Umpqua River 18.5 km above the mouth and has a tidal reach of 38.6 km. The Umpqua River drains from the Cascade Mountains in contrast to the other rivers which originate in the Coast Range Mountains of Oregon.

The Coquille River estuary is much smaller than the Coos and Umpqua systems. The estuary covers 752 ha and has a long, narrow tidal reach 66 km from the mouth. The Coquille River is the southernmost area supporting striped bass populations in Oregon, emptying into the Pacific Ocean 27 km south of Coos Bay.

The Siuslaw River estuary is larger (908 ha) than the Coquille River estuary, but tidewater extends upstream a shorter distance (35 km). The population of striped bass is apparently small and erratic compared to the other rivers. Lack of sufficient scale samples prevented comparisons of the age and growth of Siuslaw River striped bass with those in the Coos, Umpqua, and Coquille rivers. However, data on the commercial catch and licensed gear were examined to analyze trends in the population.

2/ *Pers. comm. on July 21, 1978, from Jerry Bauer, Oregon Department of Fish and Wildlife, Roseburg, Oregon.*

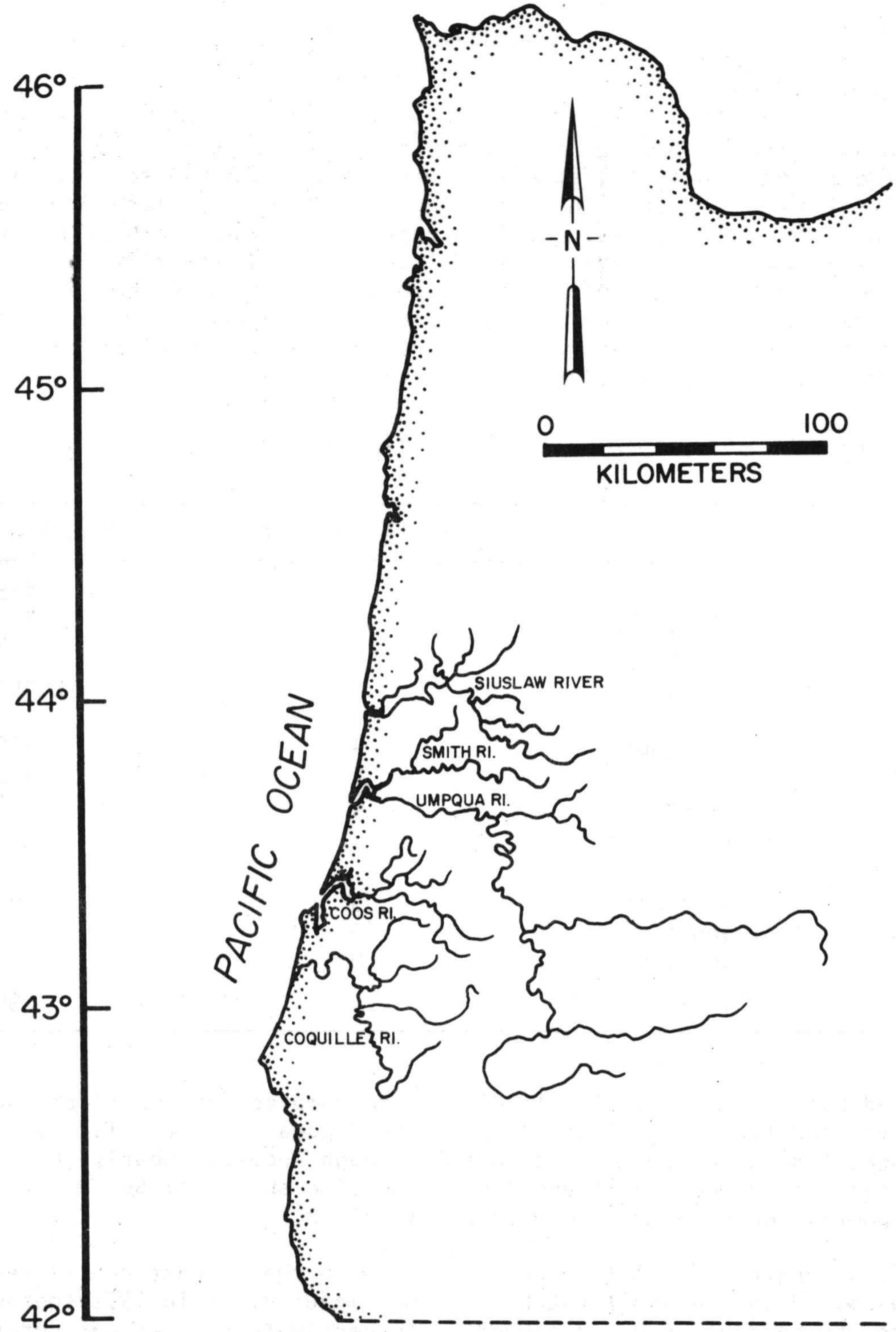

Fig. 1. Rivers sustaining striped bass in Oregon.

METHODS

Scale Samples

Scale samples were obtained from 2,845 striped bass from a variety of sources between 1946 and 1973 (Table 1). The majority (2,440 scales) was from commercially-gillnetted fish. The remaining samples were collected by sport gear (hook and line, 382 scales) and fish captured in small-mesh seines (23 scales). Scale samples from the commercial catch were originally collected for age composition analysis and had been subsampled using Ketchen's (1950) method. We selected scales from these samples to represent a broad range of ages and calendar years. Of the 2,845 striped bass sampled in the three rivers, 1,492 were males, 903 were females, and 513 were unsexed fish.

Table 1. Frequency of striped bass scale collections by river and gear, 1946-1973.

River	Gear	Years sampled	Total scales
Coos	Gill net	9	1,819
	Sport	3	210
	Seine	1	23
	Total		2,052
Umpqua	Gill net	4	525
	Sport	2	172
	Seine	0	0
	Total		697
Coquille	Gill net	5	96
	Sport	0	0
	Seine	0	0
	Total		96

Striped bass from commercial landings were sampled from April through June on Coos River and from May through June on the Umpqua and Coquille rivers. Most angler-caught fish were sampled from April through August. Nearly 90% of the fish were sampled between April and June. The time span from September through March was poorly represented in our sample (Table 2).

The fork lengths of all fish were measured to the nearest centimeter except 147 examined in the sport catch from the Umpqua River in 1972 that were measured to the nearest inch and converted to centimeters. Sex was determined by gonadal examination when the fish were eviscerated at the buying stations. Fish left in the round were sexed by manual expression of ripe or partially ripe eggs or milt from mature bass. Sport-caught bass were sexed in a similar manner. The sex of the fish sampled was not recorded for some years, especially in the earlier collections. Since there were obvious differences in growth rates between males and females greater than 4 years old, we did not include

Table 2. Distribution of the scale sample by time of collection ($\frac{1}{2}$-mo intervals).

Time period		Sample size	Time period		Sample size
January	1-15	0	July	1-15	118
January	16-31	0	July	16-31	53
February	1-15	0	August	1-15	10
February	16-28	0	August	16-31	7
March	1-15	4	September	1-15	65
March	16-31	24	September	16-30	0
April	1-15	334	October	1-15	0
April	16-30	496	October	16-31	1
May	1-15	396	November	1-15	0
May	16-31	833	November	16-30	2
June	1-15	388	December	1-15	2
June	16-30	112	December	16-31	0

any fish of unknown sex older than age 4 in our samples. However, fish of unknown sex age 4 and younger were included in calculations of the scale radius-body length relationship, calendar-year growth deviations, and brood-year growth deviations.

Several scales were collected from the left side of each fish above the lateral line and below the origin of the second dorsal fin. According to Tiller (1950), this area yields the most symmetrical scales. The area also corresponded to that used by Scofield (1931), Merriman (1941), Robinson (1960), and Mansueti (1961). Key scales were not used in the analysis.

Aging Procedures

The scales were placed between two heavy glass plates and projected at a magnification of 13.75X. Two scale readers independently selected the clearest scale from each group and determined the age by counting annular rings. Disagreements were settled by a third reader. Fish taken in the spring were assigned a virtual annulus if the terminal annulus was not yet apparent at the edge of the scale. Scofield (1931) and Merriman (1941) have validated this aging technique.

The term "year class" designates the progeny of a given calendar year of spawning; whereas, "age group" refers to fish of specific ages without reference to the year class.

Scale Measurements

A strip of paper was placed on the scale image and oriented from the focus to the center anterior edge. The locations of the focus, annuli, and scale margin were marked on the paper strip along the scale radius.

Annular rings were more prominently displayed in the antero-lateral and postero-lateral angles on scales of large fish. Therefore, only those rings that could be traced around the scale from the lateral fields were judged as valid annuli. The annuli were measured to the nearest millimeter to determine body length-scale length relationship and to back calculate growth. All scale measurements were performed by the senior author.

Pertinent data from each fish were key punched and processed using a modified version of Chadwick's (1966) computer program. Because of a programming limitation on the number of allowable year classes (40), 13 fish collected from Coos River in 1973 were excluded from back-calculated lengths; although, the scales were used in the body length-scale radius relationship.

Age-Length Relationships

Age-length relationships were expressed using a von Bertalanffy growth curve fitted to age and length data (successive summations of the mean annual increments) by the least squares method (Allen 1966). The von Bertalanffy growth curve is described by the equation

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

where l_t is the length at age t, L_∞ the asymptotic length, K the Brody growth coefficient, and t_0 the hypothetical age at length zero (Ricker 1975).

The instantaneous growth rates of striped bass between sexes and rivers were compared using semi-logarithmic plots of dl/dt against t from the equation

$$dl/dt = KL_\infty e^{-K(t - t_0)}$$

$$\text{(i.e. in log form, } \ln dl/dt = \ln K + \ln L_\infty + Kt_0 - Kt\text{)}$$

(Sandeman 1969).

Weight Samples

Fork lengths to the nearest centimeter and corresponding round weights to the nearest tenth pound were available from 2,357 samples collected from the Coos, Umpqua, and Coquille rivers from 1946 through 1969. The sample contained 937 males, 539 females, and 881 fish of unknown sex. Fish in the sample ranged from 18 through 125 cm and from 0.05 to 26.5 kg after converting all weights into metric units. The logarithmic transformations of the equation $w = al^b$ were fitted using the geometrical mean functional regressions for ungrouped data (Ricker 1973) to determine weight-length relationships where w is weight in kg, l is fork length in cm, and a and b are constants.

Population Analysis

Year class dominance and trends in the striped bass populations were analyzed from commercial catch and licensing records published by Cleaver (1951) and Smith (1956), and unpublished data from Fish Commission of Oregon files. The catch per licensed net (C/L) of the annual landings (kg) was derived by combining drift gill nets and set nets licensed in each river. The time series used in the analysis of population trends was 45 yr in Coos River (1931-1975), 42 yr in the Umpqua River (1934-1975), 36 yr in the Coquille River (1940-1975), and 30 yr in the Siuslaw River (1946-1975).

A larger proportion of drift gill nets was licensed in the 1930's and 1940's before the rivers were closed to salmon fishing.[3/] The two types of gear were combined since there were no records on the proportionate landings by gear type. We were unable to use catch per effort data because no records were available in earlier years. However, the catch/net data were assumed to be suitable indices of the population size in each river. Koo (1970) employed a similar procedure in analyzing trends in striped bass populations on the Atlantic Coast.

The catch/licensed net data were transformed to natural logarithms and detrended to portray dominant year classes using the regression

$$\ln N(t) = a + bt$$

where $N(t)$ is the population index (C/L), t is time, and a and b are regression coefficients. The slope (b) of the regression $\ln N(t)$ on t, when significantly different from zero, indicated whether the populations have increased or decreased through the time series. The slope also provided an estimate of the annual relative rate of change, $e^b - 1$ (Van Winkle et al. 1979).

RESULTS

Body Length-Scale Length Relationship

Enlarged scale radius and body fork length, plotted on a scatter diagram, approached a straight line (Fig. 2). The linear regression was FL = 3.7477 + 0.5495 SR, where FL = fork length in centimeters and SR = enlarged scale radius in millimeters. The correlation coefficient was $r = 0.976$. The linear regression indicates scale lengths and body lengths increase proportionately from 4 cm to at least 124 cm.

The Y intercept of the extrapolated regression line (3.75 cm) theoretically represents the body length at the time of scale formation. The smallest fish appearing in the body-scale length relationship was 4 cm FL and had

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3/ *The Coos and Umpqua rivers (including Smith River) were closed to commercial salmon fishing after 1946 (Cleaver 1951). Commercial salmon fisheries in the Coquille and Siuslaw rivers were closed after 1956.*

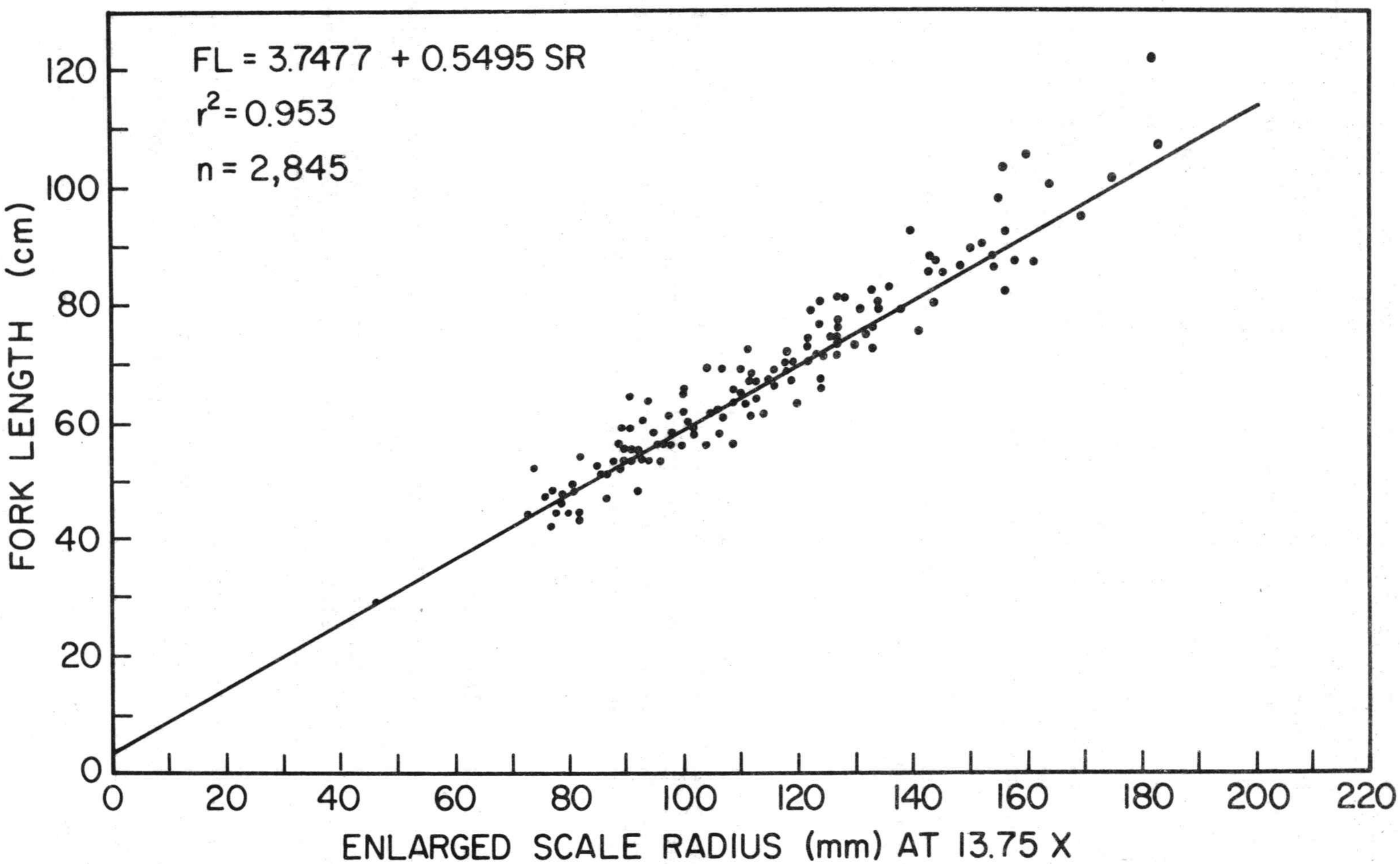

Fig. 2. Relationship between anterior scale radius and fork body length of male and female striped bass collected from the Coos, Umpqua, and Coquille rivers between 1946 and 1973. Points represent a random sample of 5% of the total sample.

well-developed scales. Mansueti (1958) found that scales first appeared on juvenile striped bass at about 1.9 cm. The Y intercept value is obviously artificial and probably does not represent the length at scale formation as was concluded in similar studies (Scolfield 1931; Robinson 1960; and Mansueti 1961) and discussed by Hile (1970). All back-calculated lengths were adjusted for the fork length intercept.

We were concerned that age 1 and 2 back-calculated body lengths predicted from this regression equation would be inaccurate since very few age 1 and 2 striped bass were used to compute the regression equation. We were extending our regression equation beyond the range of values used to compute the equation; a dangerous and dubious statistical practice. Computed and observed lengths at these ages were similar, however, and suggested that our equation accurately predicted body lengths at those ages. For example, the mean scale radius measured to age 1 for all fish was approximately 20 mm, yielding a predicted mean body length of 14.7 cm. Very few fish were collected having actual scale radii at capture of 20 mm, but one fish with a scale radius of 21 mm was 14 cm fork length at capture while another fish with a scale radius of 18 mm was 16 cm fork length at capture. Three fish with fork lengths of 18 cm had scale radii measuring 27-31 mm.

Age and Calculated Growth

Length frequencies of unsexed and sexed striped bass grouped by 5 cm intervals and corresponding age groups showed a broad range in length for each age group and considerable overlap at successive ages (Table 3). The overlapping sizes and ages suggest considerable variation exists in growth rates of striped bass.

Back-calculated lengths to each annulus were computed for individual fish from the Coos, Umpqua, and Coquille populations. The computed lengths were averaged for each age at capture and year of life. Weighted grand mean lengths then gave an estimate of the absolute size at the end of each year of life. Growth increments of individual fish were also averaged to obtain mean annual growth increments between successive years of life. The successive summations of these mean annual increments gave a second description of growth rates of male and female striped bass. Successive summations of mean annual growth increments generally yield smoother curves, in conformity with actual growth in different years of life, and are less influenced by small sample sizes in older age groups. The lengths derived from the successive increments are used throughout the remainder of this report.

Coos River

Mean back-calculated lengths of Coos River striped bass were based upon 998 males and 587 females collected from 1949 through 1972 (Tables 4 and 5). Ages 1 through 17 were included in the calculations, although ages 3 through 14 for males and ages 4 through 14 for females comprised the bulk of the samples.

Males and females exhibited similar growth rates through the first 3 years of life; thereafter, females grew at a faster rate than males (Fig. 3). By age 14, females were 8.8 cm larger than males and at age 17, the differential

Table 3. Length frequencies by age groups of male, female, and unsexed (U) striped bass (Coos, Umpqua, and Coquille rivers combined).

Fork length class interval (cm)	Number of annuli 0	1			2			3			4			5		6		7	
	U	M	F	U	M	F	U	M	F	U	M	F	U	M	F	M	F	M	F
0-4	1																		
5-9	12																		
10-14				4															
15-19				16															
20-24			1	89			3												
25-29		1		23	7	3	28												
30-34					13	3	55	1		12		1							
35-39					3	1	4	16		22									
40-44								56	10	24		1	2						
45-49								76	2	8	13	3	65						
50-54								14	1	2	171	57	111	4	1				
55-59											104	64	30	75	27	5			
60-64											39	7	1	90	23	56	11	8	
65-69											1		1	15	35	40	56	74	11
70-74														8	7	15	48	78	55
75-79														1		2	9	26	75
80-84																		8	23
85-89																		3	7
90-94																			2
95-99																			
100-104																			
105-109																			
110-114																			
115-119																			
120-124																			
Totals	13	1	1	132	23	12	90	163	13	68	328	133	210	193	193	118	124	197	173
Mean lengths[a]	5.2	26.0	23.0	22.1	31.2	31.0	30.4	44.8	43.5	39.6	54.6	54.6	51.3	60.6	62.4	65.0	69.1	71.2	75.9

[a] *Mean fork lengths calculated from ungrouped length frequencies.*

(continued)

Table 3. Length frequencies by age groups of male, female, and unsexed (U) striped bass (Coos, Umpqua, and Coquille rivers combined).

Fork length class interval (cm)	Number of annuli																			
	8		9		10		11		12		13		14		15		16		17	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
0-4																				
5-9																				
10-14																				
15-19																				
20-24																				
25-29																				
30-34																				
35-39																				
40-44																				
45-49																				
50-54																				
55-59																				
60-64	1																			
65-69	6		6	1	1															
70-74	20	4	27		10	1	1													
75-79	20	7	37	2	30	2	1		1											
80-84	7	15	18	11	49	12	9		1				1							
85-89	3	14	15	11	23	21	10	4	16	1	2		3							
90-94		1	7	9	12	12	6	10	8	3	6	1	5	1	1					
95-99						12	3	11	2	6	7	5	6	3	2		1			
100-104						4		4	1	12	2	10	3	6	3	3	2	1		
105-109										1	1	2	1	5	3	3	1	2	3	1
110-114														4		4	1	2	1	2
115-119														1		1		1		1
120-124																				4
Totals	57	41	110	34	125	64	30	29	29	23	18	18	19	20	9	11	5	6	4	8
Mean lengths[a]	75.3	82.1	78.2	85.0	81.5	89.1	86.6	95.0	89.1	99.3	94.9	101.1	94.7	104.5	101.3	107.7	103.8	110.3	108.8	117.3

[a]*Mean fork lengths calculated from ungrouped length frequencies.*

Table 4. Calculated lengths of male Coos River striped bass collected from 1949 through 1972.

Age at capture	No. of fish	Mean fork length at capture (cm)	Mean back calculated fork length at each year of life (cm) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1	26.0	12.1																
2	7	32.3	15.0	29.5															
3	70	45.4	15.2	30.1	44.8														
4	215	53.5	13.6	29.0	42.7	53.3													
5	159	60.0	14.0	28.5	42.3	51.8	59.8												
6	31	66.8	14.8	29.7	42.5	51.9	59.9	66.4											
7	181	70.4	14.5	29.8	41.8	50.8	58.5	64.9	70.3										
8	47	73.7	14.4	29.5	42.4	51.2	58.1	63.9	69.0	73.5									
9	98	76.8	14.2	28.1	41.0	50.3	56.8	62.6	68.1	72.7	76.8								
10	107	80.4	14.6	28.2	39.7	49.1	56.7	62.4	68.0	72.9	76.8	80.3							
11	20	84.0	13.7	26.5	38.8	48.7	56.2	62.4	67.7	72.9	77.1	80.6	83.9						
12	23	88.0	14.3	28.3	41.3	51.0	59.3	65.7	71.4	75.6	79.3	82.6	85.4	88.0					
13	12	92.7	14.1	28.7	42.9	52.8	60.4	66.9	72.2	76.7	80.7	84.4	87.5	90.1	92.7				
14	16	93.1	14.8	29.4	42.1	51.6	59.5	66.5	71.7	76.0	79.9	83.0	85.9	88.4	90.8	93.1			
15	5	101.0	14.9	29.8	43.2	54.1	62.1	68.2	73.3	78.2	82.8	86.5	89.9	93.4	96.0	98.7	101.0		
16	2	101.0	13.5	27.3	43.4	51.4	59.2	65.5	71.3	76.2	81.4	86.0	89.2	92.4	94.7	97.0	99.3	101.0	
17	4	108.8	15.2	31.4	47.3	58.0	66.6	72.9	78.9	83.7	87.7	91.6	95.4	97.8	100.4	102.8	105.0	107.0	108.8
Mean length			14.2	29.0	42.0	51.4	58.4	64.1	69.4	73.6	77.6	81.6	86.3	89.7	93.2	95.9	102.2	105.0	108.8
Increment of mean			14.2	14.8	13.0	9.4	7.0	5.7	5.3	4.2	4.0	4.0	4.7	3.4	3.5	2.7	6.3	2.8	3.8
Mean annual increment			14.3	14.7	13.0	9.6	7.6	6.1	4.8	4.7	4.0	3.5	3.1	2.6	2.5	2.4	2.3	1.9	1.8
Summation of the mean increments			14.3	29.0	42.0	51.6	59.2	65.3	70.1	74.8	78.8	82.3	85.4	88.0	90.5	92.9	95.2	97.1	98.9
Number of fish		998	998	997	990	920	705	546	515	334	287	189	82	62	39	27	11	6	4

Table 5. Calculated lengths of female Coos River striped bass collected from 1949 through 1972.

Age at capture	No. of fish	Mean fork length at capture (cm)	Mean back calculated fork length at each year of life (cm) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1	23.0	11.6																
2	6	30.2	13.0	26.6															
3	7	42.9	13.0	27.1	41.3														
4	107	54.4	13.9	29.2	42.7	53.4													
5	135	62.4	14.1	28.6	42.4	53.0	62.0												
6	23	71.7	14.4	29.7	43.5	55.1	63.9	71.2											
7	147	75.0	14.8	30.6	43.3	53.5	62.5	69.1	75.0										
8	26	80.7	14.5	28.4	42.0	53.1	61.9	69.6	75.3	80.3									
9	28	83.5	14.6	28.7	41.8	51.8	59.9	67.1	73.3	78.7	83.2								
10	41	85.7	14.9	28.2	40.6	50.6	59.4	66.0	72.4	77.8	82.0	85.6							
11	13	93.1	14.9	28.6	41.6	52.2	61.8	69.0	75.3	80.9	85.6	89.6	93.1						
12	10	97.8	14.5	28.9	43.0	54.0	64.7	72.7	78.1	83.1	87.1	90.9	94.5	97.8					
13	11	100.5	15.0	29.4	43.5	55.7	64.9	72.7	78.4	83.5	87.7	91.6	94.9	97.6	100.5				
14	14	105.3	14.7	28.8	40.8	51.9	62.0	70.5	76.9	82.2	87.5	92.5	96.4	99.8	102.6	105.3			
15	8	109.3	16.0	30.2	44.2	55.8	66.1	73.7	79.9	85.2	90.0	94.4	98.2	101.7	104.5	106.9	109.2		
16	4	110.8	14.7	28.4	43.2	56.2	65.8	73.1	78.3	83.6	88.7	94.3	97.5	100.9	103.6	106.1	108.5	110:7	
17	6	117.5	15.3	28.8	42.6	53.3	62.8	71.4	78.2	84.3	89.2	94.8	99.4	103.4	107.0	110.3	113.1	115.5	117.5
Mean length			14.4	29.2	42.6	53.1	62.1	69.2	75.1	80.5	85.0	89.6	95.8	99.7	103.1	106.7	110.4	113.6	117.5
Increment of mean			14.4	14.8	13.4	10.5	9.0	7.1	5.9	5.4	4.5	4.6	6.2	3.9	3.4	3.6	3.7	3.2	3.9
Mean annual increment			14.4	14.8	13.3	10.6	9.1	7.1	6.0	5.3	4.5	4.1	3.6	3.3	2.9	2.7	2.5	2.3	2.0
Summation of the mean increments			14.4	29.2	42.5	53.1	62.2	69.3	75.3	80.6	85.1	89.2	92.8	96.1	99.0	101.7	104.2	106.5	108.5
Number of fish		587	587	586	580	573	466	331	308	161	135	107	66	53	43	32	18	10	6

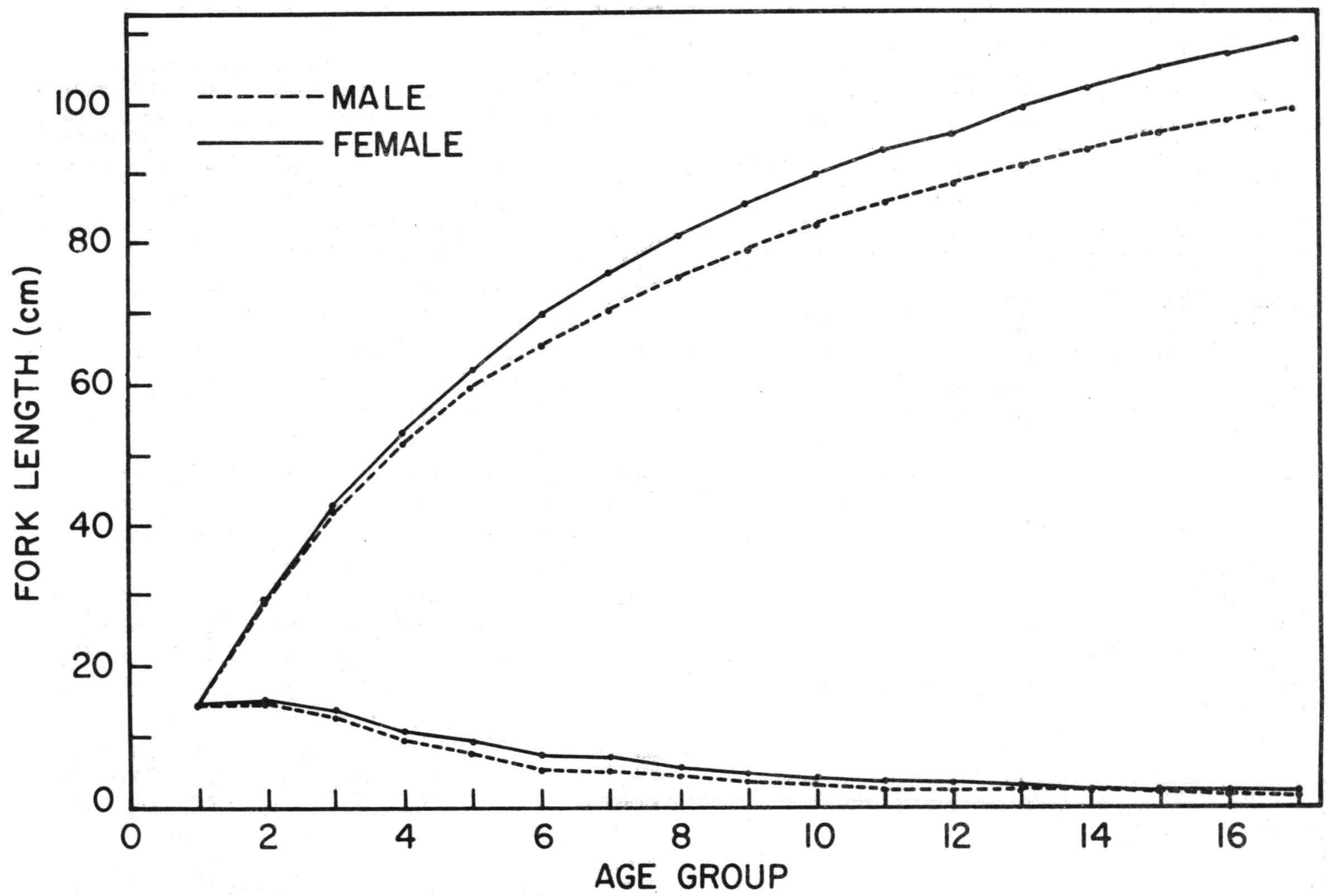

Fig. 3. Growth of male and female striped bass collected from 1949 through 1972, Coos River, Oregon. Upper lines show growth based on the successive summations of the mean increments, and the lower lines show the mean increments of growth.

size between the sexes increased to about 10 cm although the sample size was small. The largest annual growth of both sexes occurred in the second year of life (14.7 cm for males and 14.8 cm for females). Thereafter, the mean annual incremental growth steadily declined to 1.8 cm for males and 2.0 cm for females in the 17th year of life. In contrast, growth in the first year of life was 14.3 cm and 14.4 cm for males and females, respectively, which was nearly as large as that calculated for the second year's growth.

The average back-calculated length of Coos River striped bass at age 4 in the present study was larger than reported by Morgan and Gerlach (1950) from samples taken in 1949-50 (51.9 cm vs. 48.3 cm). Morgan and Gerlach's data were based on mean measured fork lengths taken in size-selective gill nets and therefore may not be directly comparable to our back-calculated lengths. Back-calculated lengths with the sexes combined from the 1945 and 1946 year classes in Morgan and Gerlach's samples were 52.0 cm (1945 year class) and 52.7 cm (1946 year class). These lengths were slightly larger than the long-term average size of age-4 striped bass in Coos River (51.9 cm).

Umpqua River

Samples of 368 male and 292 female striped bass were used to back calculate the growth of the Umpqua River population (Tables 6 and 7). The growth of Umpqua River bass was based on scales collected in the sport fishery and commercial gill-net fishery from 1946 through 1972. Samples from the sport fishery comprised 20% of the males and 32% of the females. Lengths were back calculated from age 1 through age 16 for males and age 1 through 17 for females.

No age 1 bass were captured but the calculated mean lengths at age 1 were similar to those calculated for the Coos Bay population, i.e. males averaged 14.5 cm and females averaged 14.6 cm at the formation of the first annulus. Growth rates were similar during the first 3 years of life (Fig. 4); thereafter, female lengths increased faster than males. Females were 3.9 cm larger than males at age 14. The annual growth was greatest in the first and second years of life. At age 2, the mean length of males was 15.1 cm compared to 14.6 cm for females. Beyond age 2, the mean annual growth increments progressively declined to 1.8 cm for males at age 16 and 2.4 cm at age 17 for females, although sample sizes were poorly represented in the oldest age groups.

Coquille River

Sample sizes of Coquille River striped bass were small compared to those collected from the Coos and Umpqua populations. Only 63 males and 24 females were available to back calculate growth of the Coquille River population (Tables 8 and 9). Age groups 3 through 13 were represented in the male sample with the exception of age 7 fish; whereas, ages 3 through 11 were included in the female group from 1957 through 1971.

The data from back-calculated lengths indicate that males experienced a slightly larger mean annual growth than females during the 2nd and 3rd years of life (Fig. 5). However, the data were too fragmentary to draw any firm conclusions on differential growth between the sexes in the early age groups.

Table 6. Calculated lengths of male Umpqua River striped bass collected from 1946 through 1972.

Age at capture	No. of fish	Mean fork length at capture (cm)	Mean back calculated fork length at each year of life (cm) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	—	—															
2	16	30.7	14.2	29.7														
3	78	43.7	14.2	29.5	42.8													
4	85	55.5	14.2	30.3	44.4	54.8												
5	31	62.9	15.2	30.6	44.4	54.1	62.4											
6	84	64.1	13.9	27.5	40.4	49.9	57.5	63.8										
7	16	79.6	15.6	31.2	45.7	56.4	66.0	73.5	79.1									
8	8	84.5	15.3	31.5	45.6	56.5	65.8	74.0	79.8	84.2								
9	10	89.5	15.1	32.1	46.9	57.8	66.1	74.4	80.6	85.7	89.5							
10	14	90.0	15.2	29.8	42.8	54.1	63.2	70.6	77.1	82.7	86.7	89.9						
11	7	91.3	14.7	28.9	41.8	53.5	62.0	69.7	75.8	80.9	84.9	88.2	91.3					
12	4	96.0	14.4	28.4	43.3	53.7	62.7	70.9	77.3	82.4	86.5	90.1	93.2	96.0				
13	5	100.2	16.4	31.7	45.0	55.1	64.6	72.7	78.5	83.4	87.9	91.6	94.9	97.6	100.2			
14	3	103.3	15.5	31.7	44.5	56.2	65.6	73.5	79.2	84.6	89.4	93.4	96.4	99.1	101.4	103.3		
15	4	101.8	15.9	30.3	43.9	54.6	64.0	71.1	76.8	81.3	85.0	88.5	91.7	94.3	96.9	99.5	101.8	
16	3	105.7	14.5	28.4	41.9	52.6	62.0	69.7	76.1	81.9	86.4	90.5	93.7	96.7	99.5	101.8	103.9	105.7
Mean length			14.4	29.6	43.1	53.4	61.1	67.8	78.3	83.2	87.1	90.0	93.2	96.7	99.4	101.3	102.7	105.7
Increment of mean			14.4	15.2	13.5	10.3	7.7	6.7	10.5	4.9	3.9	2.9	3.2	3.5	2.7	1.9	1.4	3.0
Mean annual increment			14.5	15.1	13.6	10.2	8.4	7.0	6.0	5.1	4.1	3.5	3.1	2.8	2.6	2.3	2.2	1.8
Summation of the mean increments			14.5	29.6	43.2	53.4	61.8	68.8	74.8	79.9	84.0	87.5	90.6	93.4	96.0	98.3	100.5	102.3
Number of fish	368		368	368	352	274	189	158	74	58	50	40	26	19	15	10	7	3

Table 7. Calculated lengths of female Umpqua River striped bass collected from 1946 through 1972.

Age at capture	No. of fish	Mean fork length at capture (cm)	Mean back calculated fork length at each year of life (cm) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0	—	—																
2	6	31.8	14.8	31.0															
3	4	41.8	14.2	29.1	41.8														
4	20	53.8	14.4	29.5	42.5	52.9													
5	55	62.1	14.3	29.7	42.6	52.7	61.3												
6	100	68.4	14.2	27.5	40.4	51.4	60.4	67.8											
7	22	81.5	15.4	31.6	45.9	57.8	67.7	75.3	80.8										
8	12	85.2	15.7	31.9	46.1	57.6	67.0	74.7	80.8	84.9									
9	5	92.0	15.2	32.8	47.9	60.5	70.0	78.1	83.7	88.1	92.0								
10	20	95.5	16.1	31.8	46.4	57.7	67.9	76.0	82.5	88.1	92.3	95.4							
11	15	96.8	14.1	29.0	43.5	55.2	65.3	73.6	80.1	85.6	90.1	93.5	96.5						
12	13	100.5	15.0	29.6	44.3	55.4	64.7	72.9	79.3	84.4	89.0	93.6	97.2	100.3					
13	7	102.0	14.1	27.5	41.1	52.7	61.5	70.6	77.1	83.5	88.4	92.4	96.4	99.4	102.0				
14	6	102.7	14.5	28.1	41.7	52.7	62.6	70.3	76.4	81.8	86.7	90.1	94.0	97.0	100.0	102.5			
15	3	103.7	14.1	28.3	41.4	52.0	62.3	71.1	77.0	82.2	86.7	90.7	93.3	96.7	99.5	101.5	103.7		
16	2	109.5	14.5	28.6	40.9	52.7	62.5	70.5	77.2	82.4	86.7	91.6	94.9	98.5	101.6	104.1	107.2	109.5	
17	2	116.5	13.4	27.3	41.2	52.2	61.2	69.7	75.9	83.7	88.8	93.0	97.2	101.2	104.7	107.9	111.3	114.1	116.5
Mean length			14.6	29.2	42.6	53.6	62.9	71.0	80.2	85.4	89.9	93.5	96.1	99.1	101.2	103.3	106.9	111.8	116.5
Increment of mean			14.6	14.6	13.4	11.0	9.3	8.1	9.2	5.2	4.5	3.6	2.6	3.0	2.1	2.1	3.6	4.9	4.7
Mean annual increment			14.6	14.6	13.4	11.0	9.2	7.7	6.1	5.3	4.5	3.7	3.5	3.2	2.9	2.5	2.8	2.5	2.4
Summation of the mean increments			14.6	29.2	42.6	53.6	62.8	70.5	76.6	81.9	86.4	90.1	93.6	96.8	99.7	102.2	105.0	107.5	109.9
Number of fish	292		292	292	286	282	262	207	107	85	73	68	48	33	20	13	7	4	2

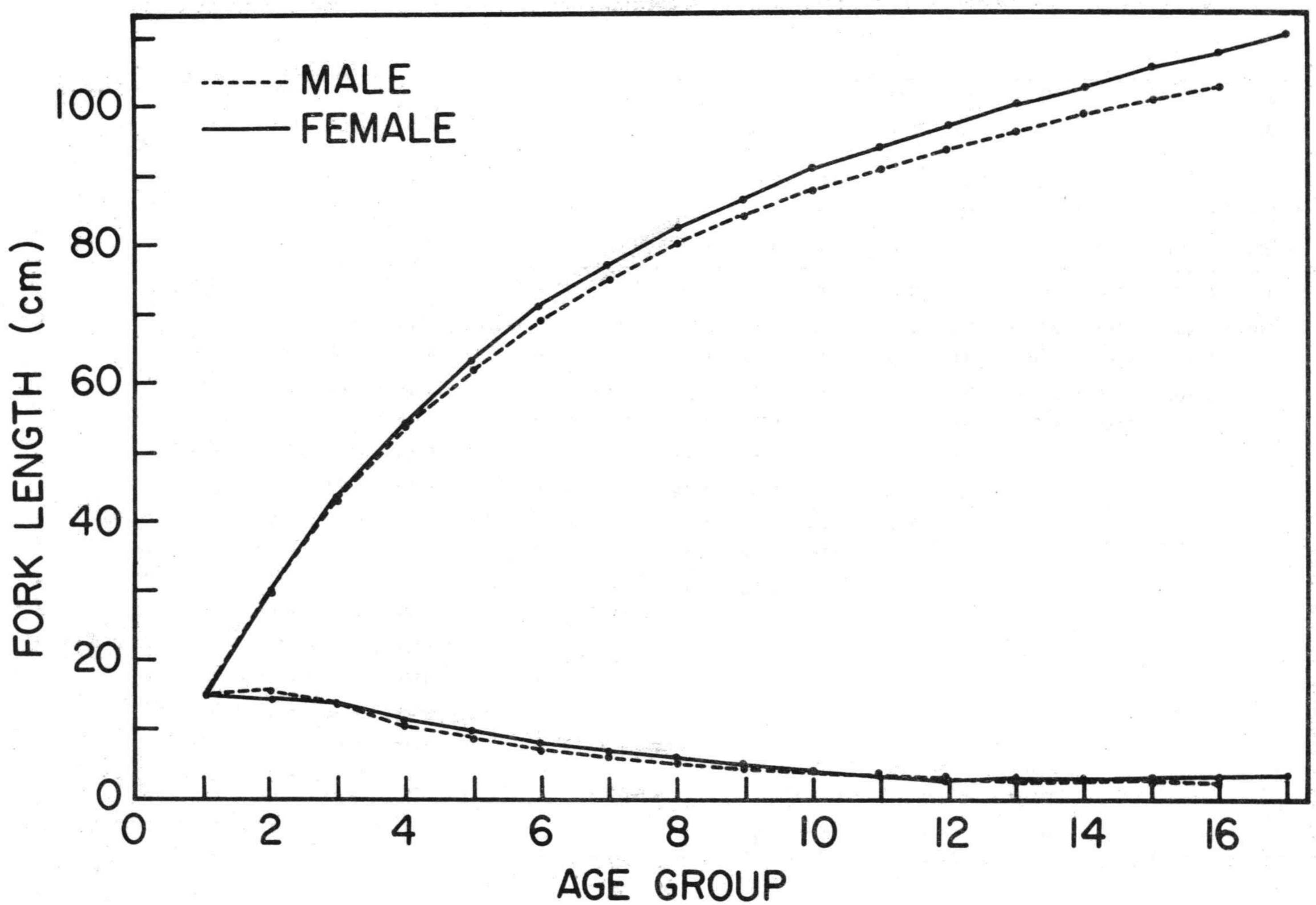

Fig. 4. Growth of male and female striped bass collected from 1946 through 1972, Umpqua River, Oregon. Upper lines show growth based on the successive summations of the mean increments, and the lower lines show the mean increments of growth.

Table 8. Calculated lengths of male Coquille River striped bass collected from 1957 through 1971.

Age at capture	No. of fish	Mean fork length at capture (cm)	Mean back calculated fork length at each year of life (cm)												
			1	2	3	4	5	6	7	8	9	10	11	12	13
1	0	—	—												
2	0	—	—	—											
3	15	47.6	14.4	31.1	46.7										
4	28	60.2	14.7	31.8	47.1	59.6									
5	3	71.3	15.7	33.8	48.5	61.1	70.3								
6	3	73.3	14.4	30.8	46.2	58.1	66.6	73.3							
7	0	—	—	—	—	—	—	—	—						
8	2	78.0	13.7	33.0	45.5	54.4	61.5	67.8	73.3	78.0					
9	2	89.5	14.3	31.6	46.4	58.3	67.8	76.1	81.7	85.6	89.5				
10	4	83.0	14.7	31.4	43.6	53.6	61.2	68.3	72.9	76.3	79.9	83.0			
11	3	93.0	15.5	32.7	47.0	57.7	67.4	75.3	80.6	84.7	87.9	90.9	93.0		
12	2	87.0	15.9	31.1	47.3	56.2	63.5	69.5	74.3	77.6	80.5	82.7	84.8	87.0	
13	1	96.0	12.8	27.8	42.7	52.5	60.3	67.4	73.9	78.5	81.7	85.6	88.9	92.8	96.0
Mean length			14.7	31.6	46.7	58.4	65.2	71.4	76.2	80.0	83.7	85.6	89.6	88.9	96.0
Increment of mean			14.7	16.9	15.1	11.7	6.8	6.2	4.8	3.8	3.7	1.9	4.0	—	7.1
Mean annual increment			14.7	17.0	15.0	11.7	8.5	7.1	5.2	3.9	3.4	3.0	2.3	2.8	3.2
Summation of the mean increments			14.7	31.7	46.7	58.4	66.9	74.0	79.2	83.1	86.5	89.5	91.8	94.6	97.8
Number of fish		63	63	63	63	48	20	17	14	14	12	10	6	3	1

Table 9. Calculated lengths of female Coquille River striped bass collected from 1957 through 1971.

Age at capture	No. of fish	Mean fork length at capture (cm)	Mean back calculated fork length at each year of life (cm)										
			1	2	3	4	5	6	7	8	9	10	11
1	0	—	—										
2	0	—	—	—									
3	2	49.0	14.9	32.7	48.4								
4	6	60.2	14.9	30.3	46.2	59.4							
5	3	67.0	12.5	30.0	44.8	57.2	66.7						
6	1	79.0	14.6	30.3	44.9	57.3	69.3	77.9					
7	4	77.3	14.9	29.5	42.4	54.0	63.9	71.7	77.3				
8	3	82.0	13.8	29.6	42.3	53.5	64.0	71.5	77.4	82.0			
9	1	92.0	17.1	31.6	43.8	56.0	64.1	74.0	81.0	85.6	91.4		
10	3	91.3	16.7	30.5	44.2	55.8	65.6	74.0	79.6	83.8	87.6	91.3	
11	1	94.0	16.5	34.3	47.6	58.8	69.0	74.6	79.2	83.8	86.9	90.4	94.0
Mean length			14.8	30.5	44.7	56.6	65.4	73.1	78.3	83.4	88.2	91.1	94.0
Increment of mean			14.8	15.7	14.2	11.9	8.8	7.7	5.2	5.1	4.8	2.9	2.9
Mean annual increment			14.8	15.7	14.3	12.2	9.9	7.9	5.7	4.5	4.0	3.8	3.6
Summation of the mean increments			14.8	30.5	44.8	57.0	66.9	74.8	80.5	85.0	89.0	92.8	96.4
Number of fish		24	24	24	24	22	16	13	12	8	5	4	1

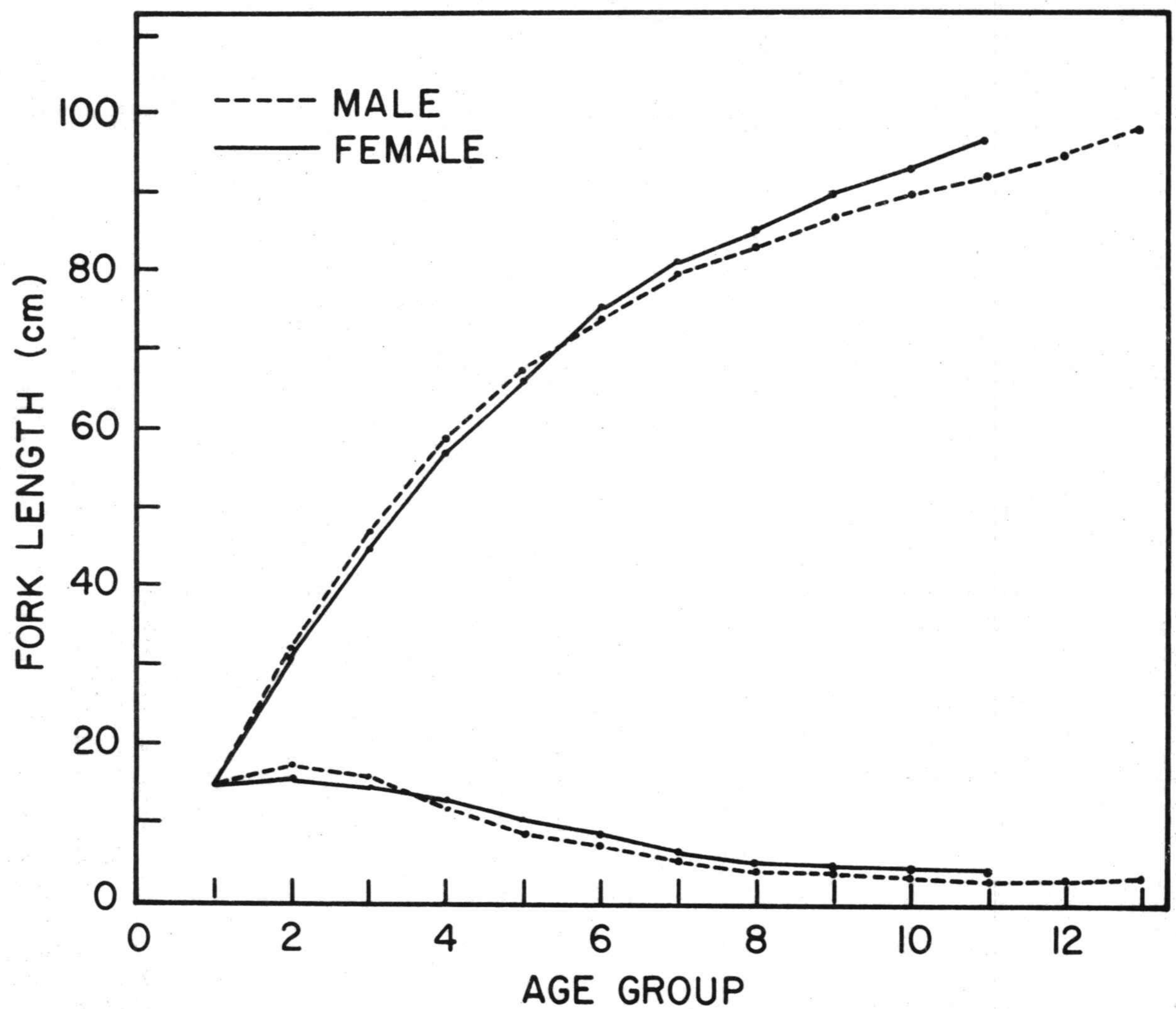

Fig. 5. Growth of male and female striped bass collected from 1975 through 1971, Coquille River, Oregon. Upper lines show growth based on the successive summations of the mean increments, and the lower lines show the mean increments of growth.

Overall, the growth of Coquille River striped bass appeared greater within each age group than either Coos or Umpqua populations. At age 1, Coquille River males averaged 14.7 cm and females 14.8 cm. Both sexes experienced their largest growth at age 2 when the mean increment for males was 17.0 cm compared to 15.7 cm for females. Age 3 males increased 15.0 cm; whereas, females grew 14.3 cm. Thereafter, females grew at a faster rate than males (Fig. 5), similar to the Coos and Umpqua striped bass populations.

The validity of the back-calculated growth of Coquille River striped bass was enhanced by the similarity between measured average lengths at capture and the calculated average lengths in each age group with sufficiently representative samples. Most of the Coquille River samples were collected in late spring following the onset of new growth beyond the last annulus. This would tend to increase the measured average lengths for each group compared to the averages calculated at annulus formation. A comparison between age groups indicates the actual mean lengths were generally slightly larger than calculated lengths for any selected age in the male and female groups (Tables 8 and 9), particularly in the younger age classes where growth was more rapid.

Gill Net Selection

Gill nets can be selective for certain sizes of striped bass (Mansueti 1961; Trent and Hassler 1968). In 1972, representative samples of striped bass were obtained from commercial drift nets (minimum 6 to 6-3/4 in stretch mesh) and from sport anglers on the Umpqua River. We compared the mean back-calculated fork lengths to determine differences in lengths by sex in six age groups. In the analysis, it was assumed the sport-caught fish were randomly collected in relation to length above the 16-in minimum size limit.

The results indicate that the growth rate from gillnetted striped bass was the same as that estimated from sport-caught striped bass (Table 10). An unweighted analysis of variance of cell means (Snedecor and Cochran 1967) was significant between gears at the 95% significance level only for age 2 females.

Table 10. Mean back calculated fork lengths (cm) of six age groups of striped bass taken in drift gill nets and by anglers in 1972 in the Umpqua River (sample size in parentheses).

Age group	Males: Drift nets	Males: Anglers	Males: Difference	Females: Drift nets	Females: Anglers	Females: Difference
1	14.3 (95)	14.3 (65)	0.0	14.4 (117)	14.2 (80)	-0.2
2	28.7 (95)	28.6 (65)	-0.1	29.0 (117)	27.9 (80)	-1.1
3	41.2 (95)	41.4 (65)	+0.2	42.0 (117)	41.1 (80)	-0.9
4	50.4 (90)	51.2 (55)	+0.8	52.4 (117)	52.0 (76)	-0.4
5	57.8 (70)	58.1 (33)	+0.3	61.0 (114)	61.5 (63)	+0.5
6	64.0 (61)	64.7 (26)	+0.7	68.4 (76)	69.7 (53)	+1.3

Since no regular differences in growth rates between gears were apparent in this analysis, we concluded that the collecting gear did not significantly alter the back-calculated growth estimates.

Fluctuations in Growth

Calendar-year growth

Annual deviations from the mean growth rate were calculated for striped bass from the Coos, Umpqua, and Coquille rivers. The technique employed computing a relative percentage change, between successive years, of the unweighted sum of the mean growth increments for the age groups common to both years. These relative changes were then adjusted to a deviation from the long-term average by subtracting their mean. This technique is described in detail by Hile (1941, pp. 249-256). A characteristic of this technique is that a different number of age groups are usually available for making the computations in different calendar years. In general, the more recent the year under consideration the greater the number of age groups involved in the determination. Calendar-year deviations based on few age groups are influenced by year class differences and, in the case of older age groups, sensitive to rounding and measuring errors.

Time spans included in our analysis were: Coos River, 1934-1968; Umpqua River, 1940-1969; and Coquille River, 1958-1968. Annual growth deviations were calculated for each sex separately and for the sexes combined. However, since the deviations were similar for the sexes, the combined results were used in analyzing differences within and between the populations in each river.

Coos River. The striped bass population in Coos River has experienced wide annual fluctuations in growth (Fig. 6). Growth during the 35-yr period was highest in 1936 when the increment was 12.0% above average. Thereafter, there was a general downward trend, culminating in a record low of 14.3% below normal in 1942. After 1942, annual growth increments increased with some oscillations until a secondary peak of 9.6% above normal was reached in 1958. Growth declined once more following the 1958 peak, terminating in a low of 4.9% below normal in 1961. The trend in annual growth has been generally upward from 1961 to 1968. Growth was basically below normal during the 1940's and early 1960's in Coos River.

Coquille River. Annual fluctuations in the growth of Coquille River striped bass closely paralleled the Coos River population during the 11-yr interval from 1958-1968 (Fig. 6). In 1958, growth was 11.6% above normal followed by a precipitous decline to 9.9% below normal in 1961 coinciding with a similar decline in growth in the Coos River population. After 1963, the Coquille River bass exhibited a rising trend in growth, reaching 4.0% above normal in 1968. The similarity in annual fluctuations of growth in the Coos and Coquille rivers suggests a common causal factor influenced striped bass populations in these two systems.

Umpqua River. Growth of Umpqua River striped bass was above average from 1940 through 1945, based on single-age group samples, and remained below average from 1954 through 1969 (Fig. 7). No data were available to determine percentage deviations in the mean annual growth increments during the 1946-1953 time period. The highest growth occurred in 1940 when the increment was 30.4% above average followed by a sharp decline to 7.5% above average in 1942. In 1943, growth increased to 28.6% above normal and then fell once more to 6.0% above average by 1945. By 1954, growth was 0.8% below normal and subsequently plunged to 11.3%

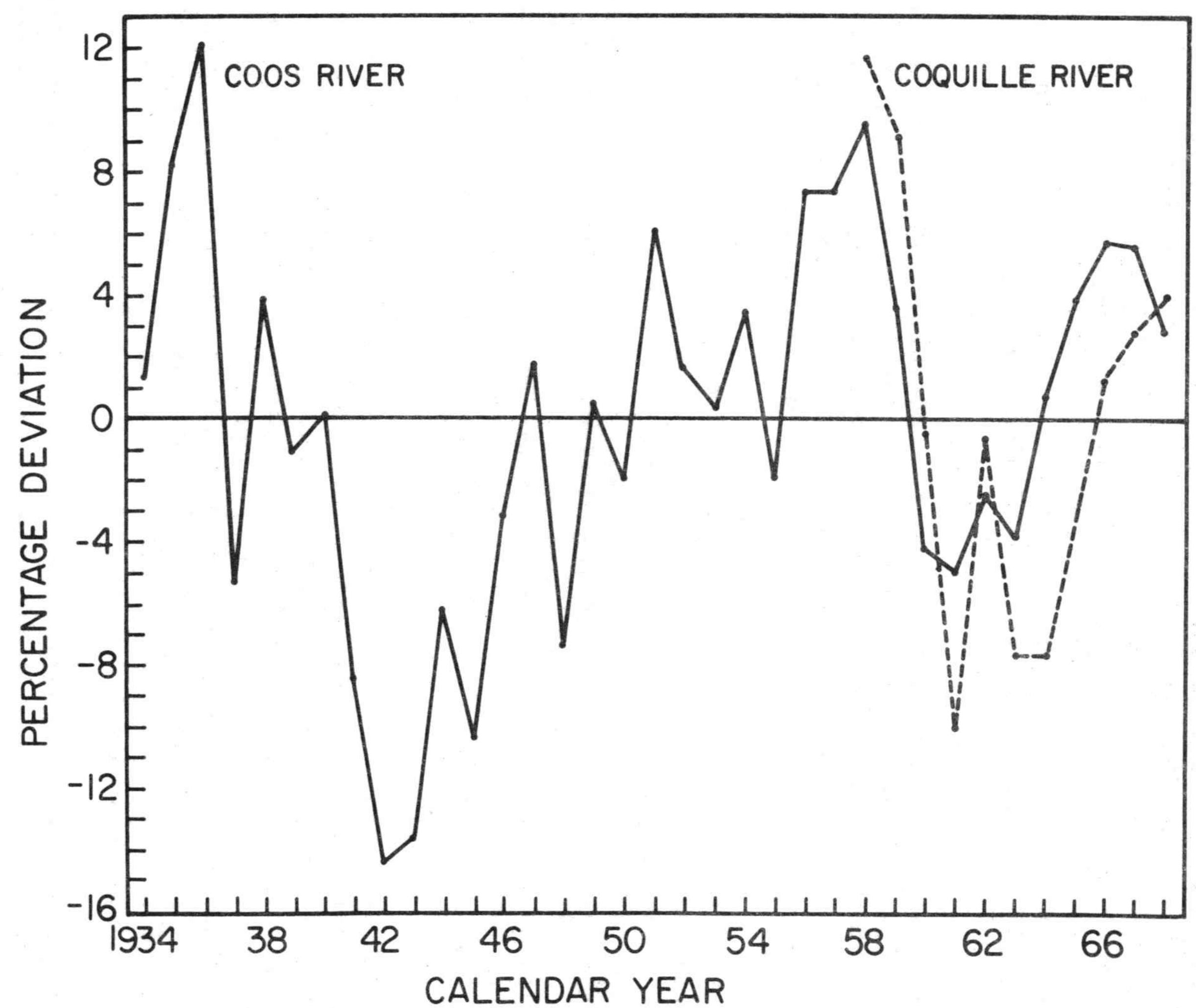

Fig. 6. Percentage deviation from the mean annual growth increment of striped bass, 1934 through 1968, Coos and Coquille rivers. Sexes combined.

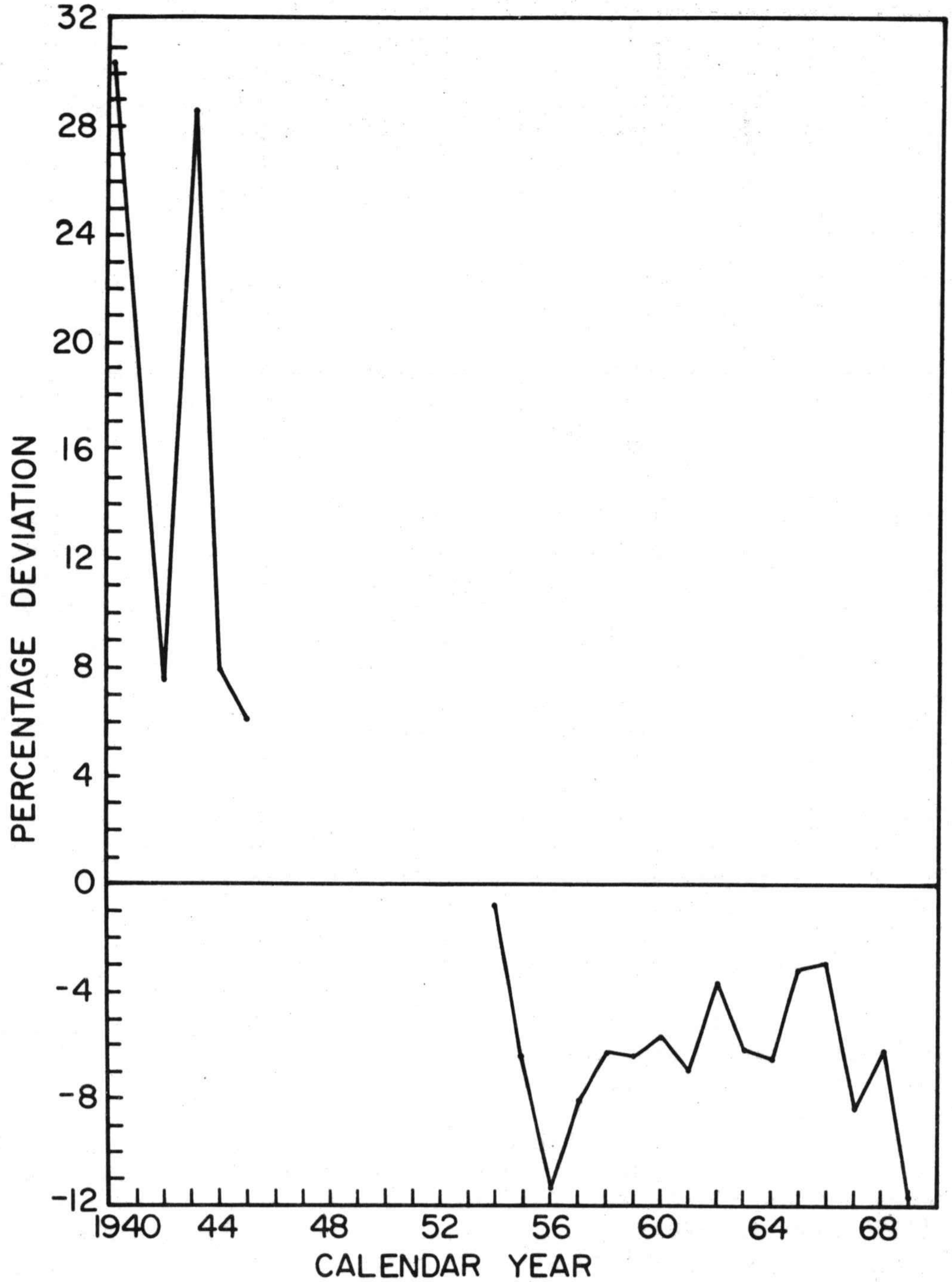

Fig. 7. Percentage deviation from the mean annual growth increment of striped bass, 1940 through 1969, Umpqua River. Sexes combined.

below normal in 1956. Thereafter, annual growth exhibited a generally rising trend with minor fluctuations through 1966, reaching 3.0% below average. After 1966, annual growth declined to an all-time low of 11.7% below normal in 1969. The sharp decline in growth in 1940 coincided with a similar decline in the Coos Bay population (Fig. 6). However, there seemed to be little relationship between annual fluctuations in growth in the Umpqua River population compared to the Coos and Coquille populations from 1954 through 1968.

Year-class growth

Growth histories of individual year classes of male and female striped bass were plotted to compare changes in growth over the years in the Coos and Umpqua rivers. Year classes with two or more fish were included in the analyses. The lengths were based on the successive summations of the mean annual increments of each year class. Year classes and sample numbers within many year classes were too sporadic to analyze growth histories of Coquille River striped bass.

Coos River. There was a general downward trend in growth of year classes in the 1930's and 1940's in Coos River, which was particularly evident in the female population (Figs. 8 and 9). In contrast, growth of 1-year-old striped bass was remarkably uniform in male and female segments of the Coos River population. The 1950, 1955, 1963, and 1966 year classes of males were larger than most other year classes at comparable ages. Males in the 1940, 1941, and 1942 year classes exhibited poorer growth than any of the other year classes illustrated. Relatively poor growth also occurred among males in the 1954 and 1959 year classes.

Among female striped bass, the 1934 year class was larger at any given age than most following year classes. Others exhibiting good growth were the 1957, 1964, and 1968 year classes. The 1940, 1941, and 1942 year classes were smaller at any given age than preceding and subsequent year classes similar to the growth of males. Female striped bass also experienced relatively poor growth within the 1951 and 1960 year classes.

Since some year classes were poorly represented in earlier periods and some year classes were absent for males or females elsewhere in the 37-yr interim from 1932 through 1968, we combined sexes and divided the growth data into 4 parts: 1932 through 1939 (8 yr), 1940 through 1949 (10 yr), 1950 through 1959 (10 yr), and 1960 through 1968 (9 yr). The general pattern of growth was consistently better during the first period (1932-1939) and poorest in the second period (1940-1949)(Fig. 10). Growth in the third and fourth periods (1950-1959 and 1960-1968) tended to be intermediate, although the 1960-1968 year classes exhibited slightly better growth until age 10. At age 10, growth of year classes in the second, third, and fourth periods converged and remained essentially the same thereafter. However, few samples were represented in age 10 or older age groups from 1960 through 1968.

The results indicate there has been a definite change in growth of striped bass in Coos River following the 1930's. Depressed growth in the latter periods has been particularly evident among the older age groups in the population, i.e., after about age 6 compared to year classes in the 1932 through 1939 period.

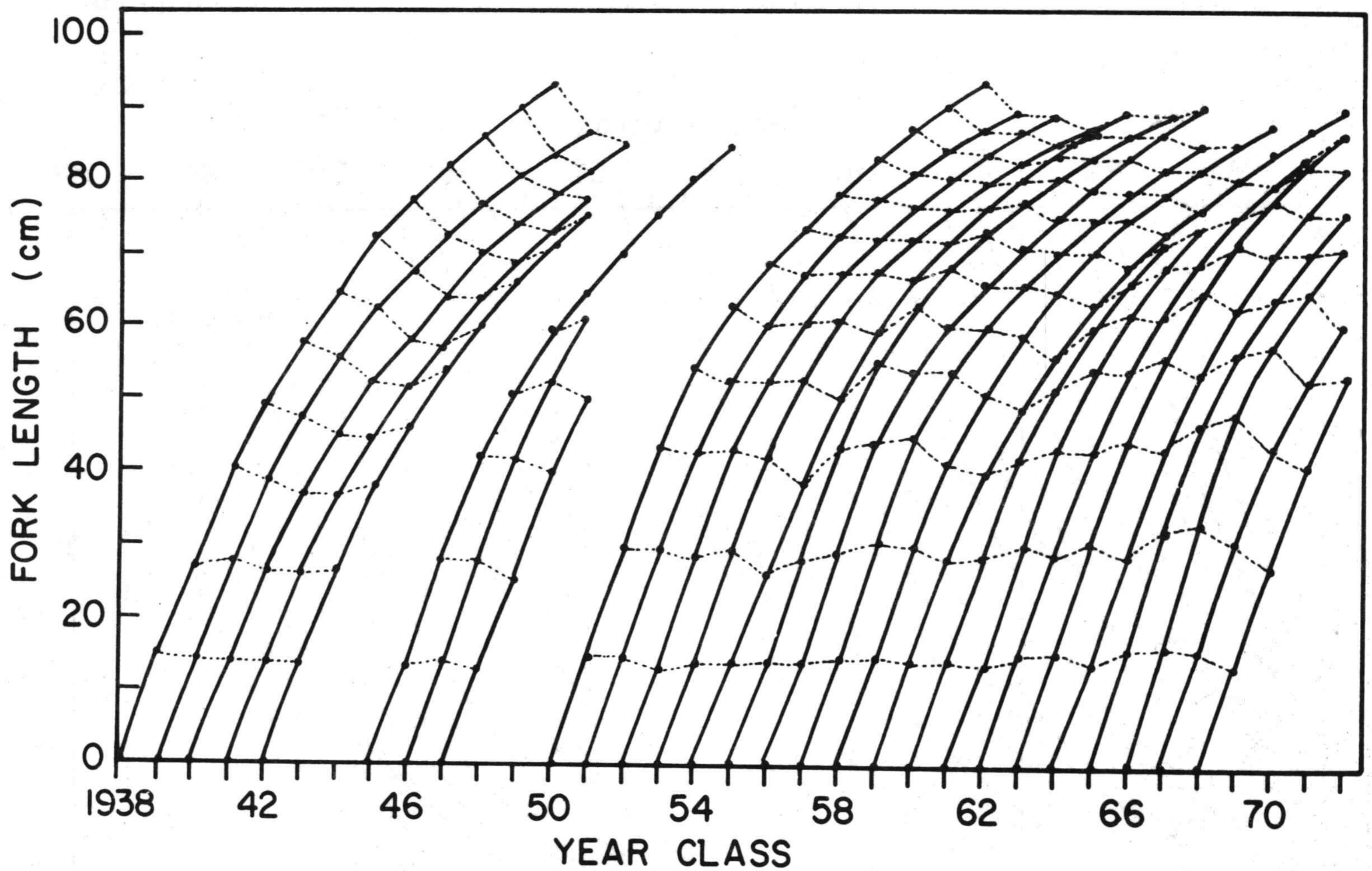

Fig. 8. Growth histories of the different year classes of male striped bass from Coos River, Oregon. Growth based on successive summations of the mean increments. Lengths at corresponding years of life are connected by dotted lines.

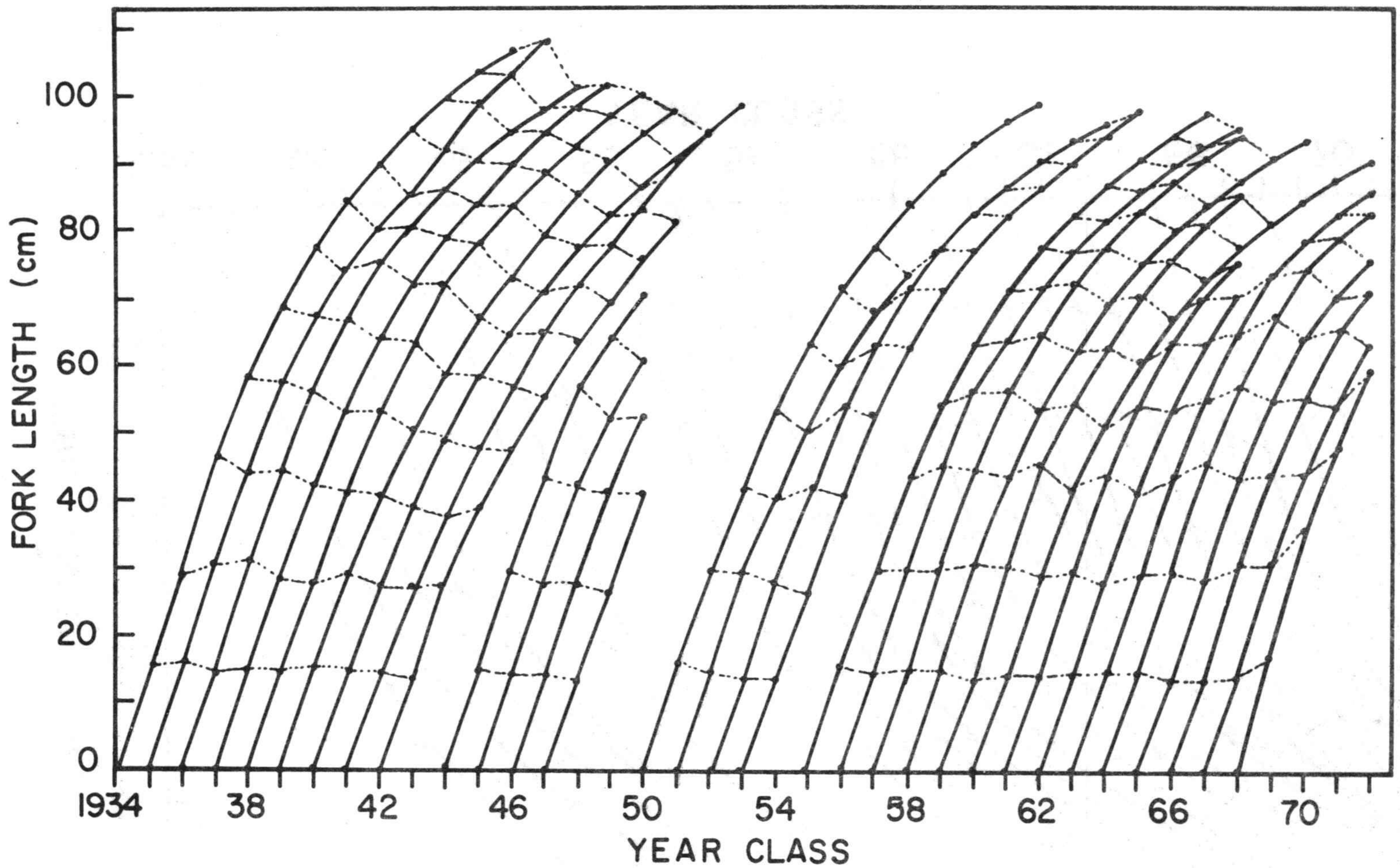

Fig. 9. Growth histories of the different year classes of female striped bass from Coos River, Oregon. Growth based on successive summations of the mean increments. Lengths at corresponding years of life connected by dotted lines.

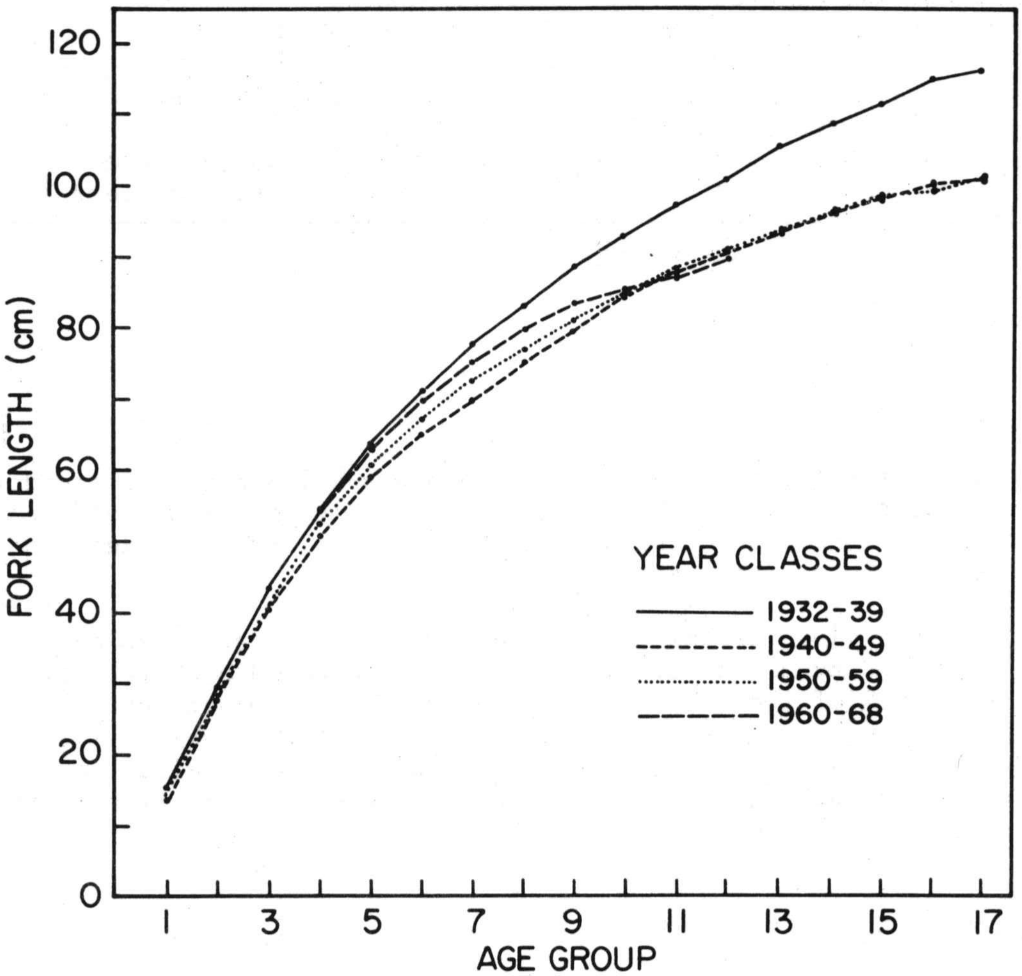

Fig. 10. Growth of Coos Bay striped bass grouped by year classes. Sexes combined.

Umpqua River. Growth histories of male and female striped bass in the Umpqua River from the 1954 through 1969 and 1953 through 1969 year classes, respectively, were plotted to examine trends in the population (Fig. 11). Growth of 1-year-old fish was reasonably constant similar to the Coos River population. Beyond age 1, growth became more irregular among males and females. The 1954 and 1966 year classes grew more slowly than other year classes at comparable ages. Among males, the 1961 and 1965 year classes were larger at the same ages than most other year classes; whereas, females displayed better growth in the 1953, 1962, and 1963 year classes.

During the 17-yr interim (1953-69), Umpqua River striped bass exhibited a general rising trend in growth at specific ages until the mid 1960's followed by a period of depressed growth beginning with the 1966 year class. Since a limited number of year classes was sampled following the 1966 year class, it is difficult to predict if slower growth will persist or return to levels attained prior to 1966 in the Umpqua River.

Seasonal Growth

Annulus formation

The percentage of striped bass with a new annulus was determined from 2,845 scale samples. The samples were heavily weighted with scales collected from commercial landings in the spring. All rivers, years, sexes, and ages were combined into a single sample.

Semimonthly plots of the percentages of fish showing a new annulus suggest annulus formation began in late March and was completed by late July (Fig. 12). By late June, 50% of the striped bass have formed a new annulus. Since the annulus was not evident until new growth resumed, the actual formation occurred slightly earlier in the spring. The new annulus was more discernable on the fast-growing, younger age groups than on the slower-growing fish in the oldest age groups.

Progression of annual growth

The progression of growth partially through the annual season is plotted in Fig. 13 for Coos River striped bass using Hile's (1941) method. The data indicate that growth was relatively insignificant during April and May. At the end of May, only about 4% of the expected annual growth was completed; however, the percentages rapidly increased from June through August and began leveling off once more in September. Approximately 50% of the seasonal growth was completed by the end of July. Insufficient samples in the fall and winter months prevented further analysis of growth through the full seasonal cycle. However, by September 15, the expected annual growth was 80% complete, leaving about 20% to occur until the next annuli formed in the spring.

The annual cycle of growth among striped bass in Coos River was similar to that reported in California (Scofield 1931). Immature and mature bass in California exhibited a 7-mo period of growth (April through October) followed

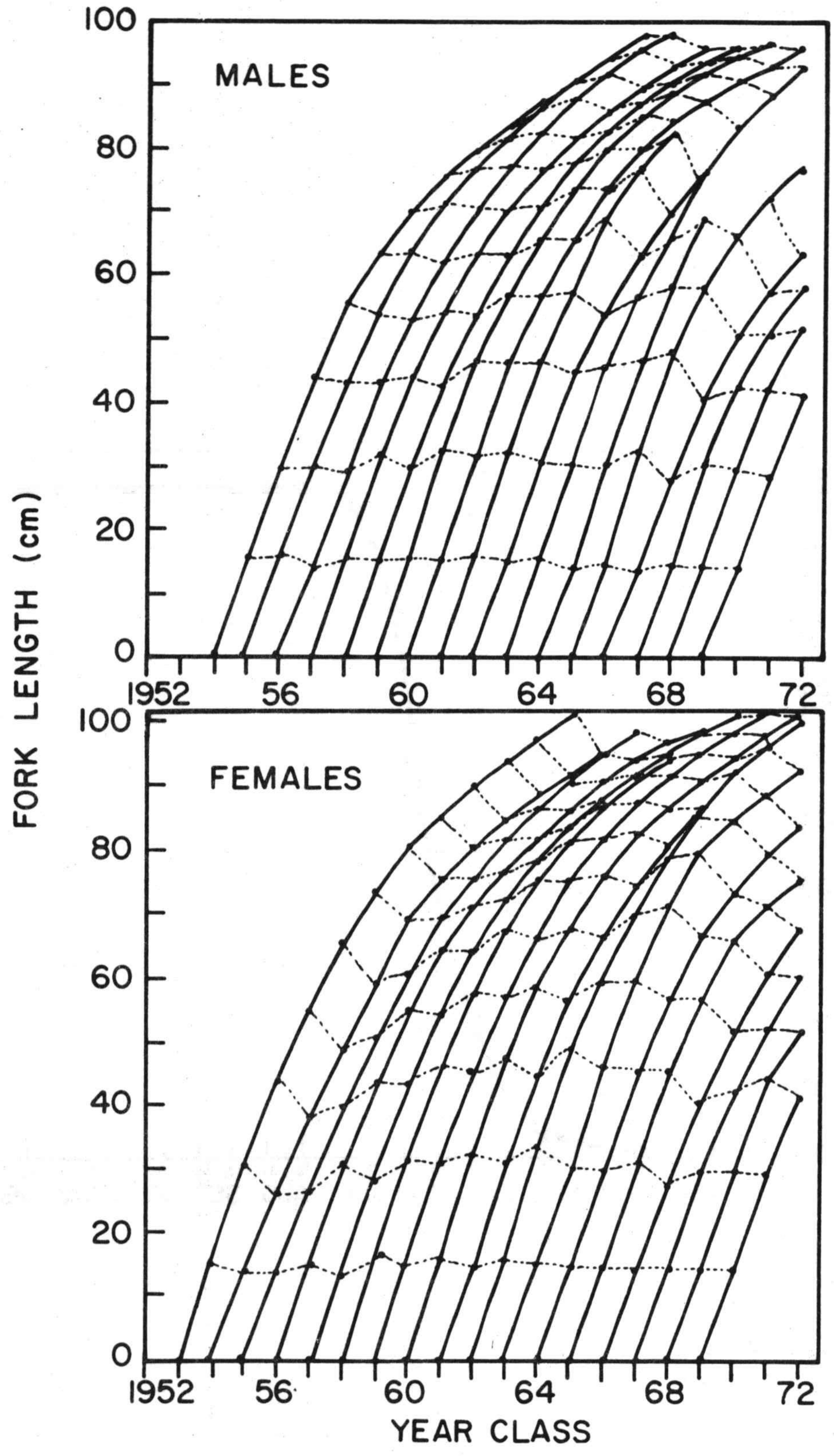

Fig. 11. Growth histories of the different year classes of striped bass from Umpqua River, Oregon. Growth based on successive summations of the mean increments. Lengths at corresponding years of life connected by dotted lines.

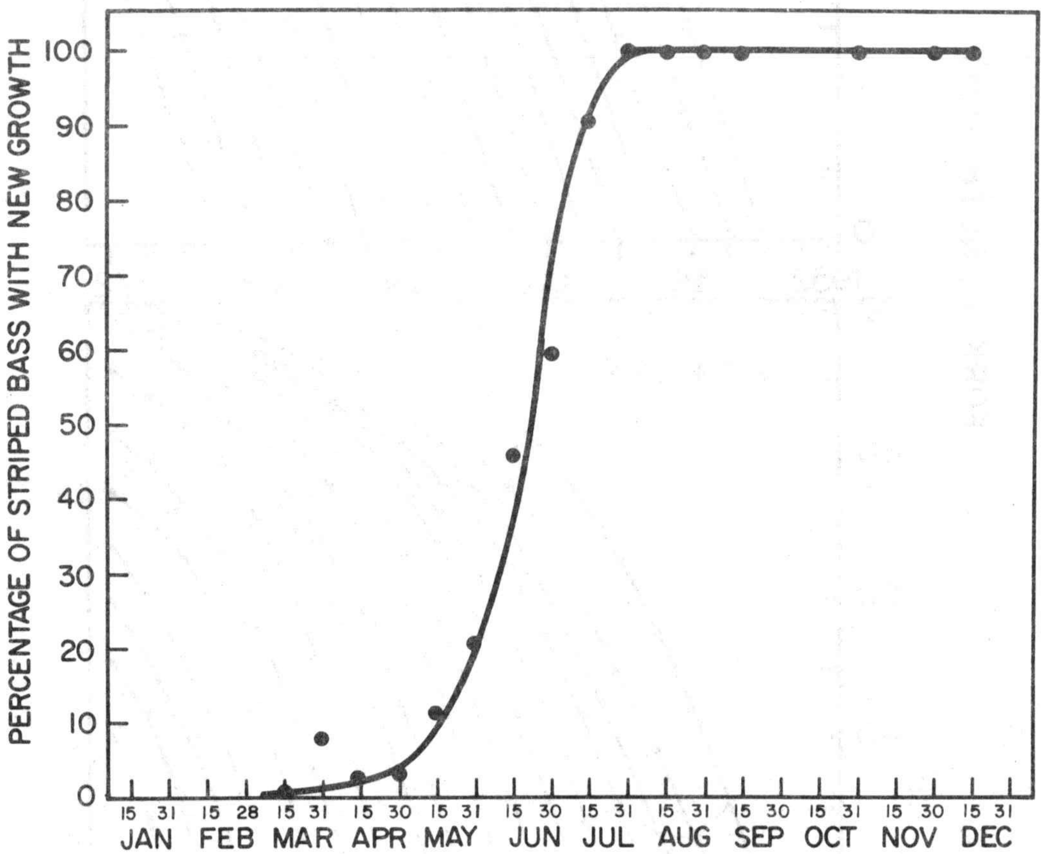

Fig. 12. Percentage of striped bass with new growth; rivers, years, sexes, and ages combined. Freehand curve.

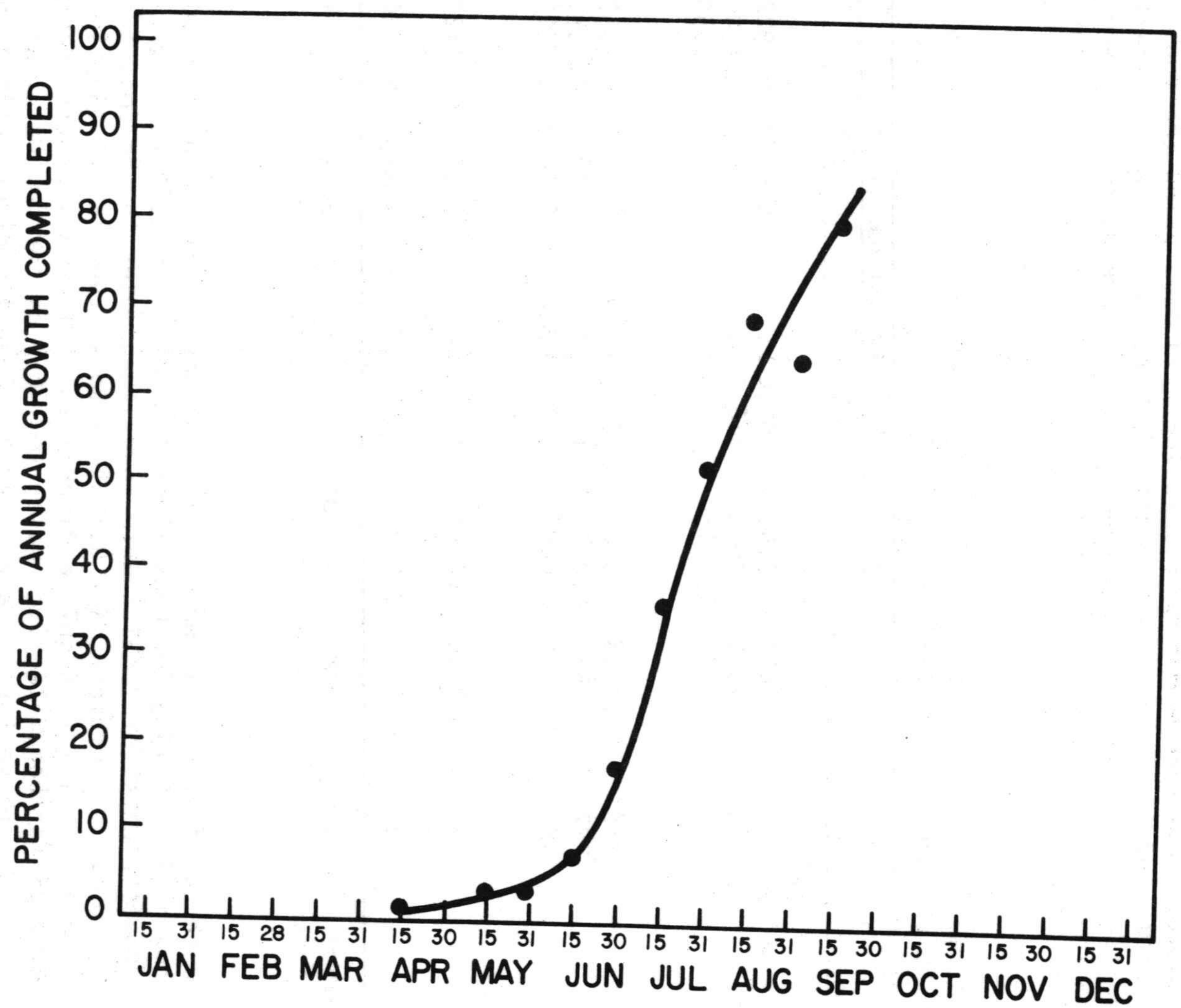

Fig. 13. Percentage of annual growth completed by Coos River striped bass; sexes, years, and ages combined. Freehand curve.

by a 5-mo period of dormancy (November through March). In Coos River, the onset of spring growth appeared to be about 2 mo later than for California striped bass.

Age-Length Relationship

Parameters were calculated to determine the theoretical growth of Coos, Umpqua, and Coquille striped bass from back-calculated data using the von Bertalanffy growth model. The von Bertalanffy equation was fitted to growth data obtained from the summation of the mean annual increments for each sex and sexes combined, except for Coquille River females where data were scanty (Table 11).

Table 11. Variables calculated for the von Bertalanffy growth equations of striped bass by sex and river system.

River and sex	Sample	Variable with 95% confidence limits[a]		
		K	L_∞	*t*
Coos River				
Males	998	0.1631 ± 0.0142	103.6 ± 2.7	-0.0272 ± 0.1922
Females	587	0.1505 ± 0.0092	116.1 ± 2.3	0.0515 ± 0.1306
Combined	2,039	0.1554 ± 0.0118	109.4 ± 2.6	0.0297 ± 0.1650
Umpqua River				
Males	368	0.1708 ± 0.0087	108.3 ± 1.7	0.1102 ± 0.1032
Females	292	0.1533 ± 0.0100	116.7 ± 2.5	0.0812 ± 0.1390
Combined	697	0.1585 ± 0.0097	113.5 ± 2.2	0.0839 ± 0.1305
Coquille River				
Males	63	0.2260 ± 0.0161	101.7 ± 2.2	0.3062 ± 0.1120
Females	24	— —	— —	— —
Combined	96	0.2141 ± 0.0140	104.0 ± 2.1	0.3192 ± 0.1020

[a] *The confidence limits are approximations since they were calculated from the summation of the mean annual increments which was assumed to have zero variance.*

Brody growth coefficients (*K*) were similar between rivers, and sexes within the rivers, ranging from 0.1505 for Coos River females and 0.2260 for Coquille River males. Coefficients for females were lower than males in the Coos and Umpqua rivers. For sexes combined, $K = 0.1554$ in Coos River, $K = 0.1585$ in Umpqua River, and $K = 0.2141$ in Coquille River (Table 11). Asymptotic lengths ranged from 101.7 cm for Coquille River males to 116.7 cm for Umpqua River females. However, growth variables calculated for Coquille River striped bass are preliminary estimates since they were based upon a relatively small sample and included few younger or older age groups. The calculated asymtotic lengths of male and female striped bass indicated they reached similar maximum sizes in the Coos and Umpqua rivers (Coos males, 103.6 cm; females, 116.1 cm; and Umpqua males, 108.3 cm; females, 116.7 cm). Fork lengths calculated from the von Bertalanffy equations closely agreed with empirical data obtained from the summations of the mean growth increments (Table 12).

Table 12. Comparison of empirical fork lengths of striped bass with lengths calculated from von Bertalanffy growth equations by sex and river system.

	Empirical fork lengths (cm)[a]					Calculated fork lengths (cm)				
	Coos R.		Umpqua R.		Coquille R.	Coos R.		Umpqua R.		Coquille R.
Age	M	F	M	F	M	M	F	M	F	M
1	14.3	14.4	14.5	14.6	14.7	16.0	15.4	15.3	15.3	14.8
2	29.0	29.2	29.6	29.2	31.7	29.2	29.5	29.9	29.7	32.4
3	42.0	42.5	43.2	42.6	46.7	40.4	41.6	42.2	42.1	46.4
4	51.6	53.1	53.4	53.6	58.4	49.9	52.0	52.6	52.7	57.6
5	59.2	62.2	61.8	62.8	66.9	58.0	61.0	61.3	61.8	66.5
6	65.3	69.3	68.8	70.5	74.0	64.8	68.7	68.7	69.6	73.6
7	70.1	75.3	74.8	76.6	79.2	70.7	75.3	74.9	76.3	79.3
8	74.8	80.6	79.9	81.9	83.1	75.6	81.0	80.2	82.0	83.8
9	78.8	85.1	84.0	86.4	86.5	79.8	85.9	84.6	87.0	87.4
10	82.3	89.2	87.5	90.1	89.5	83.4	90.1	88.3	91.2	90.3
11	85.4	92.8	90.6	93.6	91.8	86.4	93.8	91.4	94.8	92.6
12	88.0	96.1	93.4	96.8	94.6	89.0	96.9	94.1	97.9	94.5
13	90.5	99.0	96.0	99.7	97.8	91.2	99.6	96.3	100.6	95.9
14	92.9	101.7	98.3	102.2	—	93.1	101.9	98.2	102.9	—
15	95.2	104.2	100.5	105.0	—	94.7	103.9	99.8	104.8	—
16	97.1	106.5	102.3	107.2	—	96.0	105.6	101.1	106.5	—
17	98.9	108.5	—	109.9	—	97.2	107.0	—	108.0	—

[a] *Empirical fork lengths from the summation of the mean growth increments.*

A more generalized picture of the growth of striped bass in each river was obtained from the summations of the mean increments of the sexes combined. From a management standpoint, it is normally difficult to manage the sexes separately within any given river system; therefore, growth curves of combined sexes may prove more useful. Growth curves derived from the combined sexes were intermediate to curves of males and females separately beyond about age 4. The von Bertalanffy growth curves are plotted in Fig. 14 for the sexes combined in the Coos, Umpqua, and Coquille rivers. The growth equations of the striped bass populations are

Coos River: $l_t = 109.4\ (1 - e^{-0.1554(t - 0.0297)})$

Umpqua River: $l_t = 113.5\ (1 - e^{-0.1585(t - 0.0839)})$

Coquille River: $l_t = 104.0\ (1 - e^{-0.2141(t - 0.3192)})$

The relative rate of approach (K) to maximum length (L_∞) was lowest for Coos River striped bass ($K = 0.1554$) and highest in the Coquille River population ($K = 0.2141$).

The comparatively rapid rate of change in length increments and relatively fast rate of approach to L_∞ for Coquille River males is portrayed in Fig. 15. In contrast, the rates of approach to L_∞ were similar for males and females in the Coos and Umpqua rivers. Analysis of covariance indicated there was no significant difference in the instantaneous growth rates of males in the Coos and Umpqua rivers ($F_{1,30} = 0.69$), but instantaneous growth rates were significantly different ($P < 0.005$) between males in the Coos and Umpqua rivers compared with males in the Coquille River. Analysis of covariance of the instantaneous growth rates between sexes revealed no significant differences in either the slope ($F_{1,30} = 0.18$) or intercept ($F_{1,31} = 1.98$) in Coos River. Similarly, no significant differences were found in the slope ($F_{1,30} = 0.05$) or intercept ($F_{1,31} = 0.42$) between sexes in the Umpqua River.

A comparison of the three populations with the sexes combined demonstrated the similarity of instantaneous growth rates among Coos and Umpqua striped bass compared with those in the Coquille River (Fig. 16). Analysis of covariance of instantaneous growth rates revealed highly significant differences ($P < 0.005$) between striped bass in the Coos and Coquille rivers ($F_{1,26} = 17.28$) and Umpqua and Coquille rivers ($F_{1,26} = 13.48$). The instantaneous growth rates of the Coos and Umpqua populations were not significantly different ($F_{1,30} = 0.28$) at the 5% level of significance. However, the comparisons between populations were partially biased by a larger proportion of males in the Coquille River sample since males approached asymptotic lengths at a faster rate than females.

Weight-Length Relationship

Weight-fork length relationships were calculated separately for 937 males, 539 females, and 2,357 striped bass with the sexes combined. Striped bass from the Coos, Umpqua, and Coquille rivers were represented in the samples, ranging in length from 18 to 125 cm.

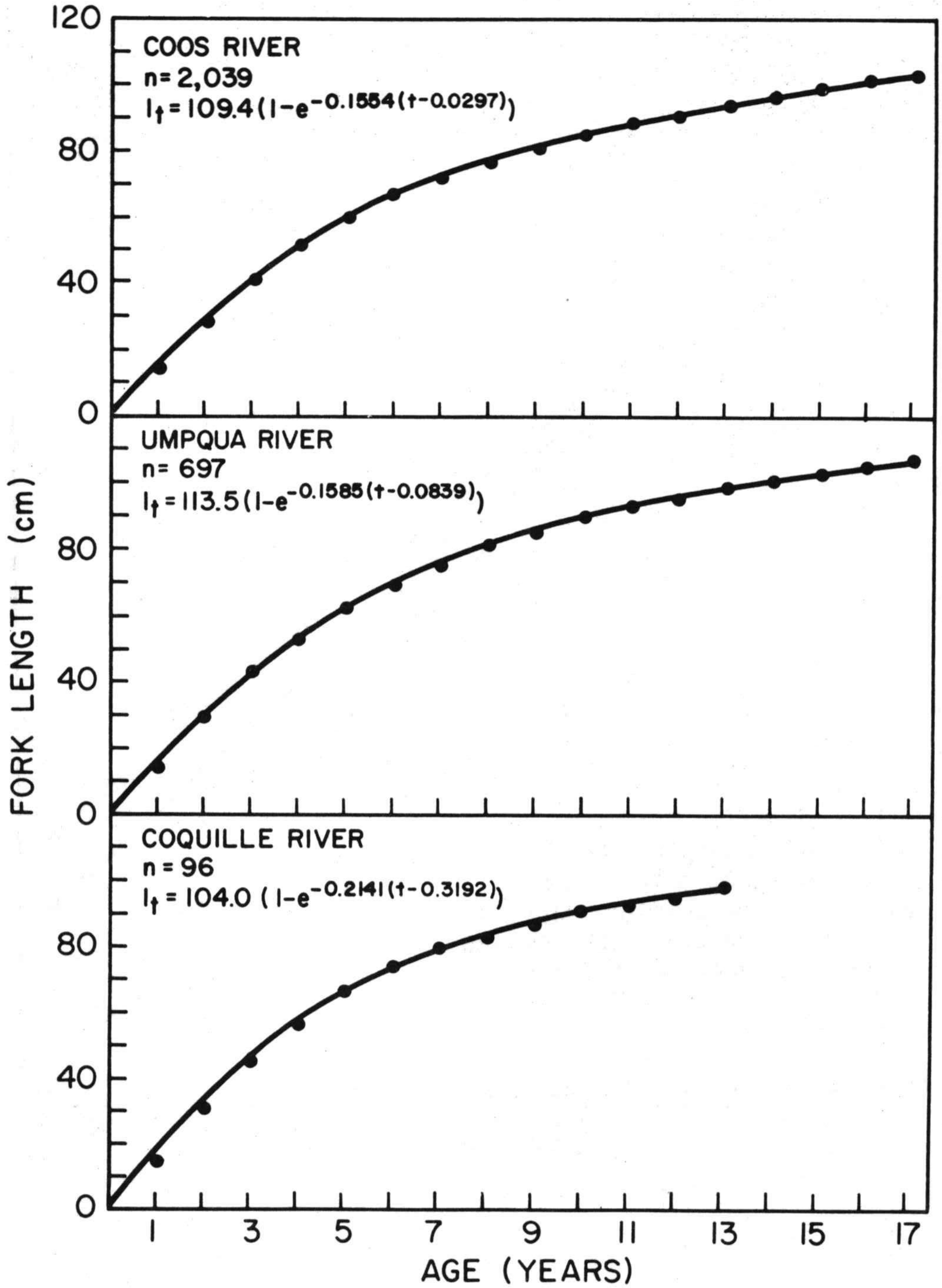

Fig. 14. Growth curves of Coos, Umpqua, and Coquille river striped bass fitted by the von Bertalanffy equation. Empirical plots from the summation of the mean growth increments. Sexes combined.

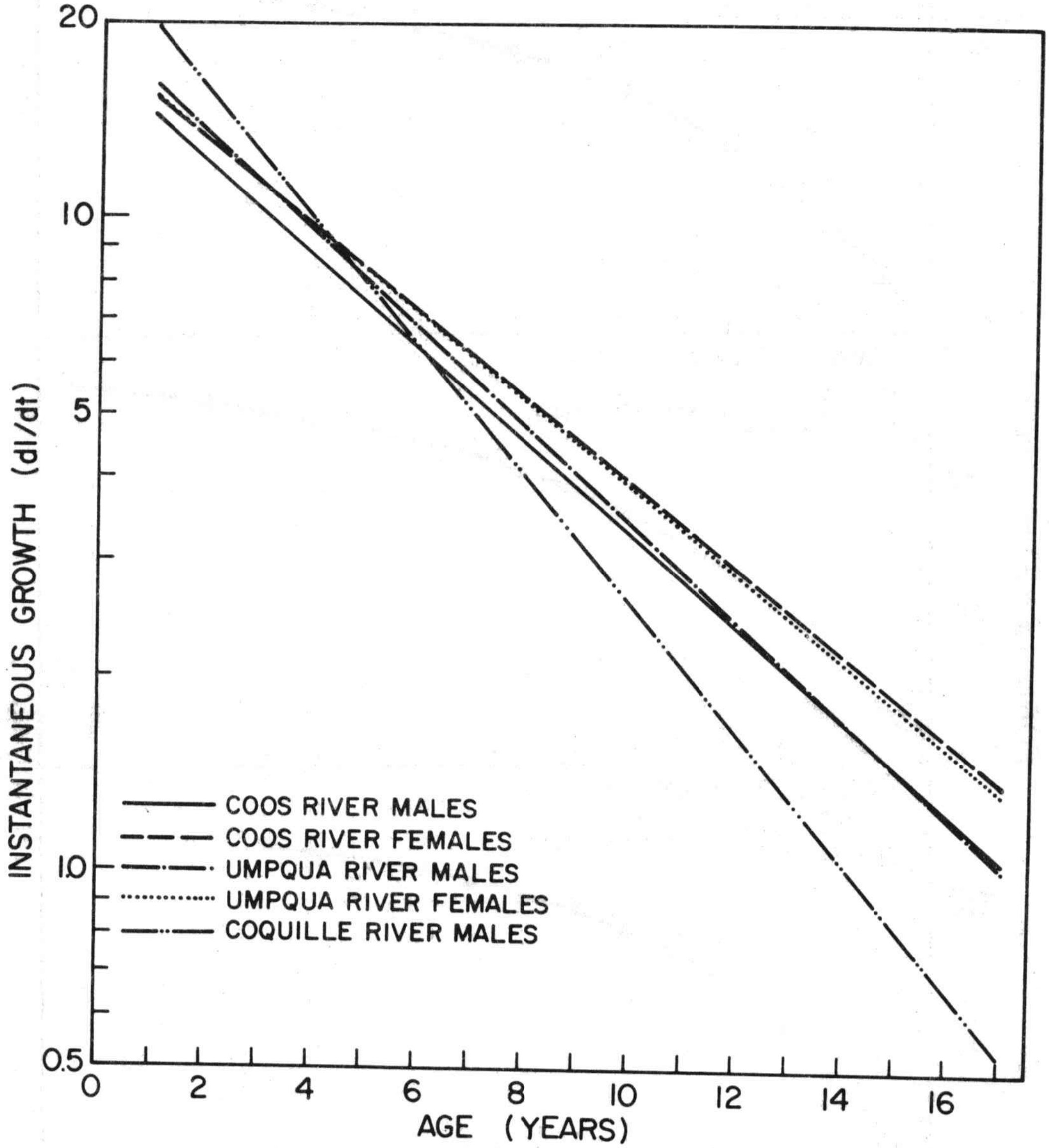

Fig. 15. Instantaneous growth rates of male and female striped bass from the Coos, Umpqua, and Coquille rivers.

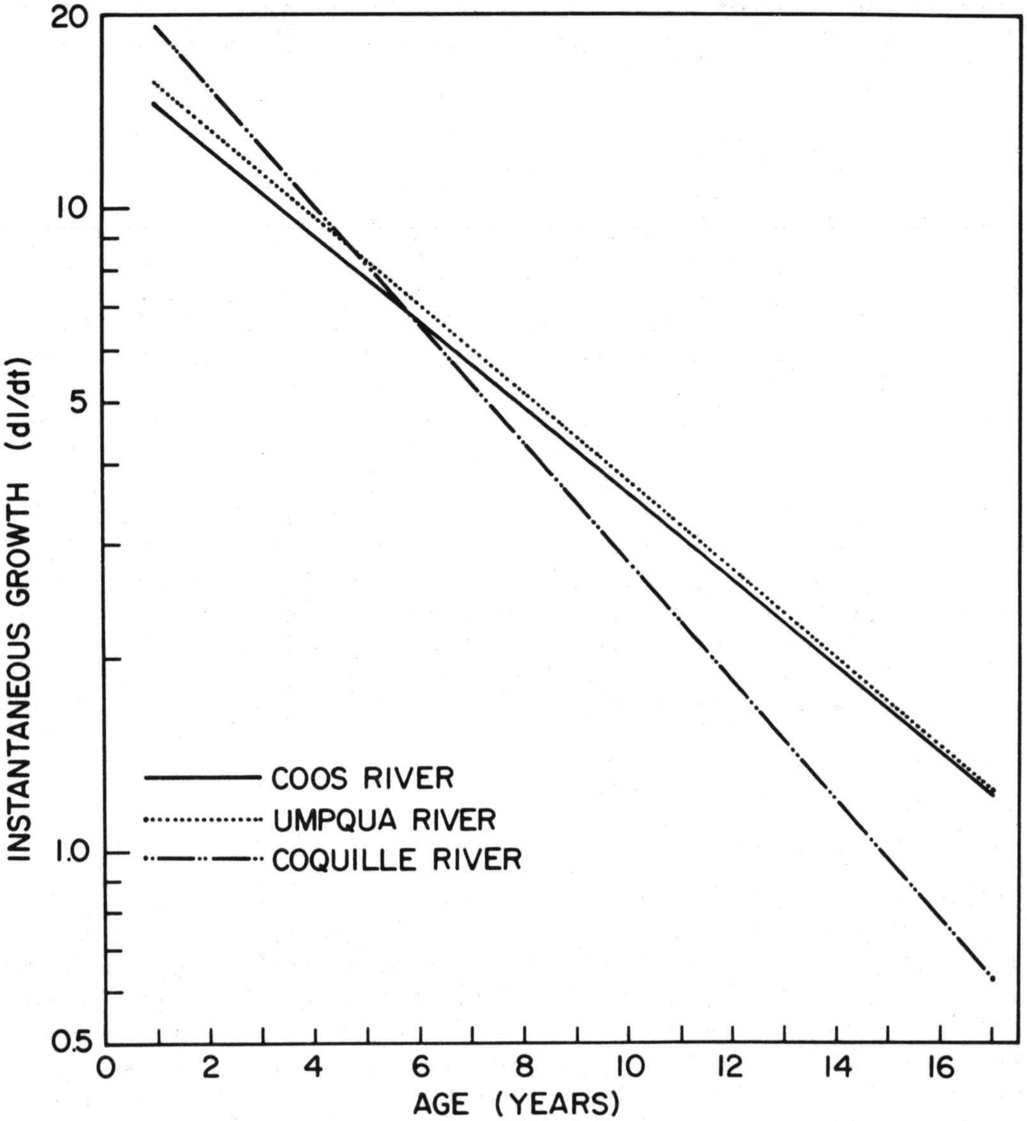

Fig. 16. Instantaneous growth rates of striped bass from the Coos, Umpqua, and Coquille rivers. Sexes combined.

The geometric mean functional regressions were similar with the three groups displaying allometric growth. The relationship for males was $w = 8.851 \times 10^{-6} l^{3.0759}$ (r = 0.980; S.E. = 0.0199) compared with $w = 8.136 \times 10^{-6} l^{3.1045}$ (r = 0.985; S.E. = 0.0234) for females. The combined weight-length relationship was $w = 7.869 \times 10^{-6} l^{3.1070}$ (r = 0.980; S.E. = 0.0129) where w is weight in kg and l is fork length in cm (Fig. 17). From these regressions, a 70-cm striped bass would weigh 4.2 kg if a male, and 4.4 kg if a female. However, considerable variability can occur in the weight of females, and to a lesser degree males, depending upon the stages of gonadal development during the season (Vladykov and Wallis 1952).

Regional Growth Comparisons

The back-calculated fork lengths (sexes combined) of striped bass at the end of each year of life indicate those in the Coos, Umpqua, and Coquille rivers rank among the largest measured in the nation (Table 13). With the lengths placed in descending order at age 4, Coquille River striped bass ranked the highest of any region, averaging 57.1 cm. Calculated lengths in the three Oregon rivers ranked among the top four and were similar to those reported by Scruggs (1957) and Stevens (1957) for the land-locked population in the Santee-Cooper system, South Carolina.

Irregularities in the growth rates among the older age groups within regions were probably due to higher proportions of females in the samples compared to younger age groups. Differences between regions were possibly caused by sample size, size selective fishing gear, aging errors, methods in calculating average lengths (mean measured fork lengths versus back-calculated fork lengths), or variable environmental influences on growth. However, the overall growth between the various populations was similar from the third through the ninth year of life.

Population Trends

Continuous trends in commercial landings and licensed gear were available from 1931 to 1975 when the commercial fishery for striped bass was closed (Table 14). Although striped bass first appeared in the commercial catch in 1914 in Coos River, they apparently spread to adjoining rivers in subsequent years. The first recorded landings occurred in 1934 in the Umpqua River, 1940 in the Coquille River, and 1946 in the Siuslaw River. Unfortunately, there are no records of the catch of striped bass in Coos River between 1914 and 1930; but the population was firmly entrenched in the estuary when landing records commenced in 1931. Long-term trends in the statistical data along with biological data on age composition and growth provided valuable tools in analyzing the status of the striped bass populations.

The slope of the regression line fitted to the index of population size (C/L) indicated the striped bass biomass has slowly declined in Coos River since 1931 (Fig. 18). The slope of -0.0182 is significantly less than 0.0 ($t = -3.569$ w/43 d.f.; $P < 0.001$), suggesting an average annual relative rate of decrease of 1.8%/yr ($CL_{95} \pm 1.0\%$) for the stock.

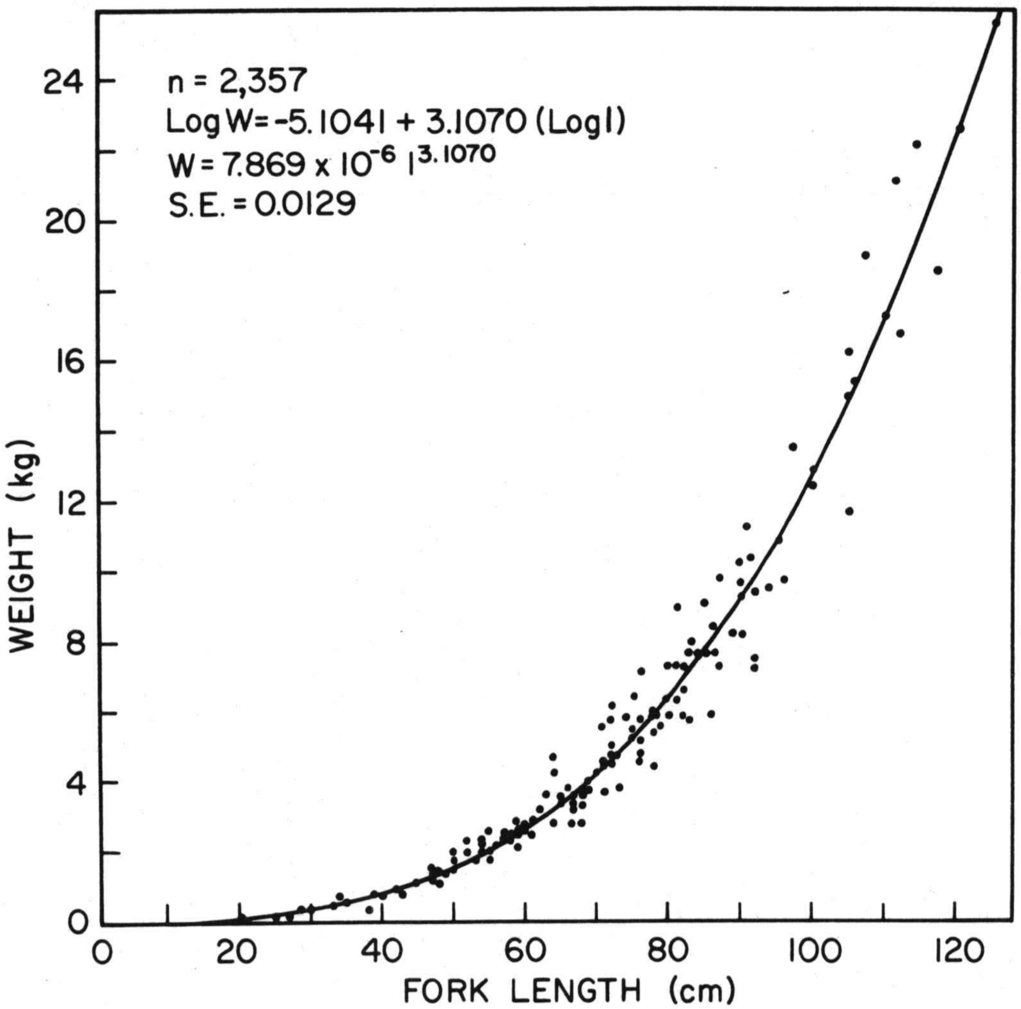

Fig. 17. Weight-length relationship of striped bass. Geometric mean functional regression. Points represent a random sample of 5% of the total sample.

Table 13. Regional comparison of growth of striped bass, sexes combined.

Region [a]	Fork length (cm) by age group																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Oregon (Coquille R.) (Present study)	14.5	30.7	45.5	57.1	65.3	72.1	77.2	81.2	85.0	87.1	90.2	88.9	96.0	--	--	--	--
South Carolina (Stevens 1957)[b]	20.3	37.6	47.2	54.6	61.5	68.1	72.1	--	--	--	--	--	--	--	--	--	--
Oregon (Umpqua R.) (Present study)	14.5	29.3	42.9	53.5	62.1	69.6	79.4	84.5	88.8	92.2	95.1	98.2	100.5	102.5	104.8	109.2	116.5
South Carolina (Scruggs 1957)[b]	17.0	35.6	46.5	52.8	59.9	65.5	71.9	77.2	82.6	--	--	--	--	--	--	--	--
Oregon (Coos R.) (Present study)	14.0	28.4	41.7	51.9	59.9	66.1	71.5	75.8	80.0	84.5	90.5	94.3	98.4	101.8	107.2	110.4	114.0
California (Robinson 1960)	10.4	24.9	38.9	49.8	58.2	65.3	70.9	75.9	82.0	--	--	--	--	--	--	--	--
North Carolina (Trent and Hassler 1968)	--	35.6	44.5	48.9	52.3	57.7	62.2	65.2	76.8	74.2	76.2	96.5	90.2	--	--	--	--
Oregon (Coos R.) (Morgan and Gerlach 1950)	--	--	36.8	48.3	57.7	63.5	69.3	73.2	76.2	--	--	--	--	--	--	--	--
Maryland (Pearson 1938)	10.2	25.4	38.1	47.0	--	--	--	--	--	--	--	--	--	--	--	--	--
California (Scofield 1931)	10.6	24.9	37.1	45.3	52.9	58.8	64.6	--	--	--	--	--	--	--	--	--	--
Maryland (Mansueti 1961)	13.0	29.5	38.5	45.0	52.8	62.0	71.4	76.8	84.3	88.8	92.1	100.6	98.3	104.4	--	--	--
New England States (Merriman 1941)	12.5	23.5	36.5	45.0	53.0	61.0	68.5	75.0	82.0	--	--	--	--	--	--	--	--

[a] *Regions are ranked by decreasing size of age-4 striped bass.*

[b] *Total lengths converted to fork lengths by a conversion factor of 0.93 (Mansueti 1961).*

Table 14. Commercial catch, licensed nets, and catch/licensed net of striped bass in the Coos, Umpqua, Coquille, and Siuslaw rivers, 1931-1975.

	Coos River			Umpqua River			Coquille River			Siuslaw River		
Year	Catch (kg)	No. Nets	C/L	Catch (kg)	No. Nets	C/L	Catch (kg)	No. Nets	C/L	Catch (kg)	No. Nets	C/L
1931	8187	75	109.2	0	147	0.0	0	56	0.0	0	106	0.0
32	7981	(60)[a]	133.0	0	(130)[a]	0.0	0	(68)[a]	0.0	0	(131)[a]	0.0
33	9615	44	218.5	0	114	0.0	0	81	0.0	0	156	0.0
34	11663	51	228.7	28	108	0.3	0	115	0.0	0	127	0.0
35	12518	58	215.8	0	137	0.0	0	131	0.0	0	122	0.0
36	13270	93	142.7	0	157	0.0	0	110	0.0	0	124	0.0
37	14868	98	151.7	24	162	0.2	0	106	0.0	0	131	0.0
38	19269	97	198.6	9	163	0.1	0	136	0.0	0	121	0.0
39	29543	106	278.7	49	182	0.3	0	143	0.0	0	88	0.0
1940	34155	119	287.0	0	193	0.0	41	157	0.3	0	105	0.0
41	29978	94	318.9	2359	137	17.2	1193	129	9.2	0	84	0.0
42	22922	80	286.5	906	137	6.6	860	129	6.7	0	49	0.0
43	27315	109	250.6	1152	140	8.2	582	109	5.3	0	51	0.0
44	40631	139	292.3	1816	132	13.8	465	93	5.0	0	61	0.0
45	104880	217	483.3	8433	147	57.4	342	71	4.8	0	82	0.0
46	80024	335	238.9	7398	165	44.8	386	74	5.2	32	113	0.3
47	39651	279	142.1	1286	184	7.0	686	60	11.4	0	107	0.0
48	42841	200	214.2	2767	137	20.2	374	64	5.8	0	109	0.0
49	10620	150	70.8	484	119	4.1	122	47	2.6	0	70	0.0
1950	16058	132	121.7	479	118	4.1	78	41	1.9	20	71	0.3
51	11329	97	116.8	1340	108	12.4	56	47	1.2	20	64	0.3
52	6457	84	76.9	1502	107	14.0	94	57	1.6	0	56	0.0
53	11540	64	180.3	1338	102	13.1	1722	46	37.4	0	39	0.0
54	8619	60	143.7	873	111	7.9	668	11	60.7	0	20	0.0
55	10153	67	151.5	1152	91	12.7	1038	11	94.4	0	26	0.0
56	12563	50	251.3	2545	70	36.4	153	1	153.0	0	23	0.0
57	3663	52	70.4	1989	38	52.3	176	9	19.6	124	30	4.1
58	4082	46	88.7	4226	52	81.3	1617	23	70.3	77	23	3.3
59	4380	38	115.3	4330	52	83.3	360	25	14.4	138	29	4.8
1960	5514	31	177.9	6966	51	136.6	390	13	30.0	135	23	5.9
61	6446	36	179.1	9237	59	156.6	240	23	10.4	193	23	8.4
62	10284	47	218.8	12990	81	160.4	913	49	18.6	78	22	3.5
63	20494[b]	68	301.4	10018	64	156.5	635	42	15.1	59	13	4.5
64	12353	71	174.0	8168	56	145.9	220	24	9.2	352	20	17.6
65	13314	88	151.3	5363	45	119.2	86	6	14.3	46	20	2.3
66	14496	69	210.1	6987	60	116.5	290	23	12.6	127	16	7.9
67	6329	47	134.7	7403	68	108.9	496	27	18.4	128	13	9.8
68	4471	47	95.1	7556	63	119.9	226	10	22.6	0	4	0.0
69	8318	48	173.3	8837	66	133.9	349	12	29.1	0	5	0.0
1970	6134	42	146.0	16090	66	243.8	179	6	29.8	299	7	42.7
71	4075	51	79.9	25547	72	354.8	244	8	30.5	563	9	62.6
72	5160	53	97.4	19091	52	367.1	0	0	0.0	333	5	66.6
73	3991	73	54.7	13235	66	200.5	202	18	11.2	496	42	11.8
74	3785	57	66.4	12070	(58)[c]	208.1	0	0	0.0	89	32	2.8
75	1826	(28)[c]	65.2	6069	(28)[c]	216.8	180	(12)[c]	15.0	60	(9)[c]	6.7

[a] *Calculated effort estimated by linear interpolation between the preceding and following year.*

[b] *Includes 731 kg landed from set lines (Breuser 1964).*

[c] *Fishermen were not required to purchase drift net licenses in 1974 and set net licenses in 1975. Numbers were estimated from set net site registrations and fishermen counts.*

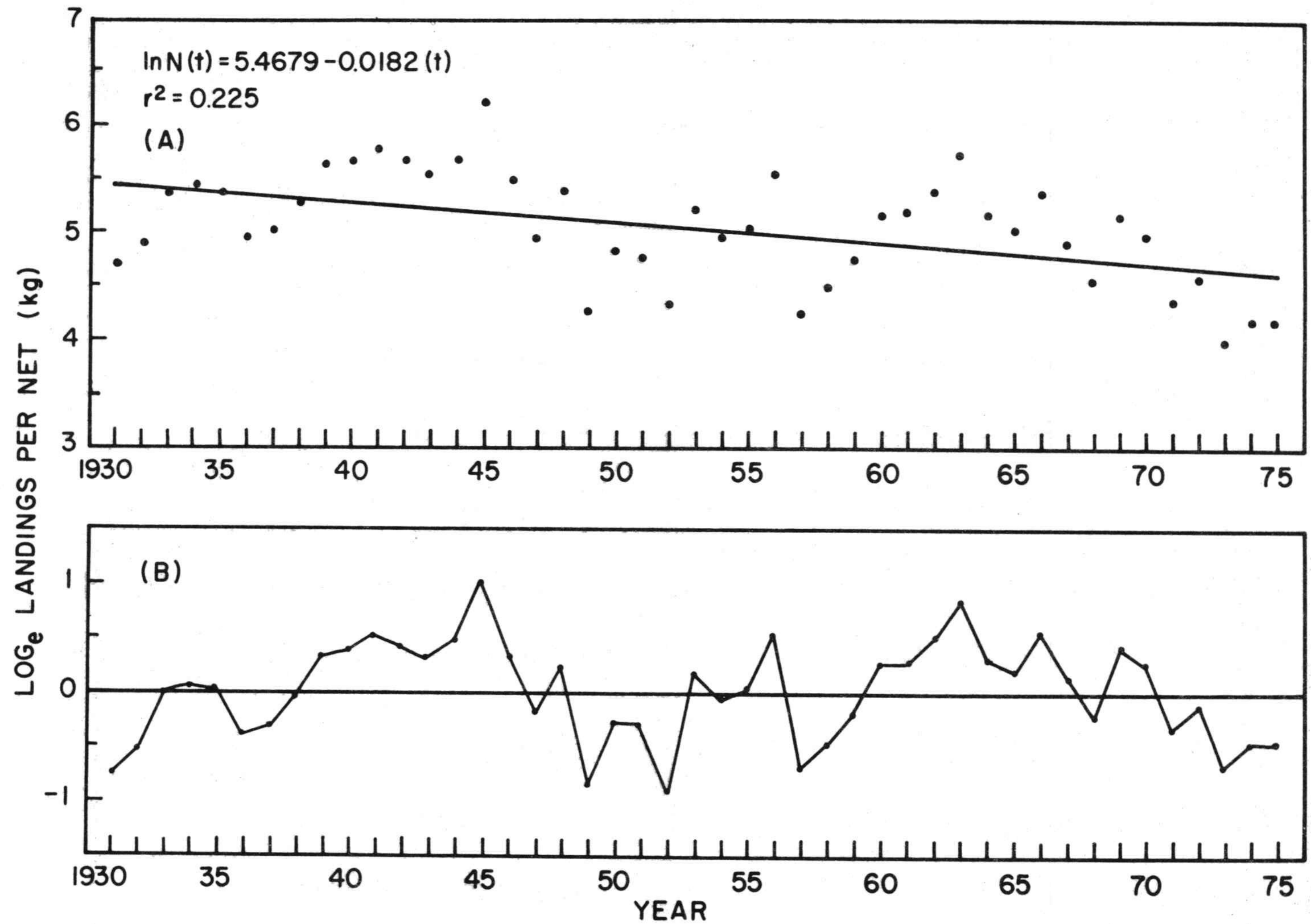

Fig. 18. Commercial landings of Coos River striped bass per licensed net: (A) linear trend of the 45-yr time series; and (B) plot of the detrended residuals from regression.

In contrast to Coos River, the populations of striped bass in the Umpqua, Coquille, and Siuslaw rivers have significantly increased ($P < 0.005$) since the first recorded catches in each river. The rate of population growth was greatest in the Umpqua River with a slope of 0.1585 (Fig. 19). The average annual relative rate of increase was 17.2%/yr (CL_{95} ± 3.1%) since 1934. The rate of increase was somewhat slower for the Coquille River striped bass population, averaging 6.6%/yr (CL_{95} ± 4.1%) since 1940 based on a slope of 0.0639 (Fig. 20). The rate of increase of biomass in the Siuslaw River ($b = 0.1470$) since 1946 was similar to the trend in the Umpqua River (Fig. 21). The Siuslaw River population has increased at an average annual rate of 15.8%/yr (CL_{95} ± 6.1%) according to the ln C/L time series. Although the annual rates of increase were similar in the Umpqua and Siuslaw rivers, the average biomass in the Umpqua River was nearly seven times larger as measured by the C/L data in the time series.

Slopes of the regression lines for ln C/L and ln C (catch) plotted against time were examined by analysis of covariance to determine if the licensed commercial gear affected the population trends in each river. There were no significant differences in the regressions for the Coos ($F_{1,86} = 3.78$), Umpqua ($F_{1,74} = 1.83$), or Siuslaw ($F_{1,36} = 3.93$) rivers at the 95% level of confidence. In the Coquille River time series, the slope for ln C/L was significantly greater ($P = 0.005$) than for ln C ($F_{1,64} = 8.49$), suggesting the increased trend in catch was partly influenced by the gear rather than changes in the biomass of the population.

The relatively rapid rate of increase of abundance in the Umpqua, Coquille, and Siuslaw rivers suggests these bass populations have remained in a logistic phase of growth with no evidence of reaching an asymtotic level as was apparent for the Coos River population. The striped bass population in Coos River has probably stabilized within the long-term carrying capacity of the environment compared with the more recently established populations in the Umpqua, Coquille, and Siuslaw rivers.

Dominant year classes

Dominant year classes are a characteristic feature of striped bass populations (Merriman 1941; Raney 1952; Vladykov and Wallace 1952; Tiller 1950; Clark 1933; Koo 1970; Grant et al. 1971). Although year class dominance has long been known, the causes of periodic increases in striped bass populations remain obscure. Dominance in Oregon's striped bass populations was examined from published data on the age composition of commercial landings and plots of the detrended time series (residuals) from regressions of ln C/L on t.

Coos River. Based on age composition data, dominant year classes occurred in Coos River in 1940 (Morgan and Gerlach 1950) and in 1958 (Breuser 1964). The 1940 year class was probably the largest produced in the history of striped bass in the system. The influence of the dominant 1940 and 1958 year classes on the commercial catch is portrayed in the plot of the detrended time series (Fig. 18), offset 5 yr (1945 and 1963, respectively) when the year classes were recruited to the nets. The peak catch evident in 1956 was possibly due to above-average recruitment of juvenile bass in 1951.

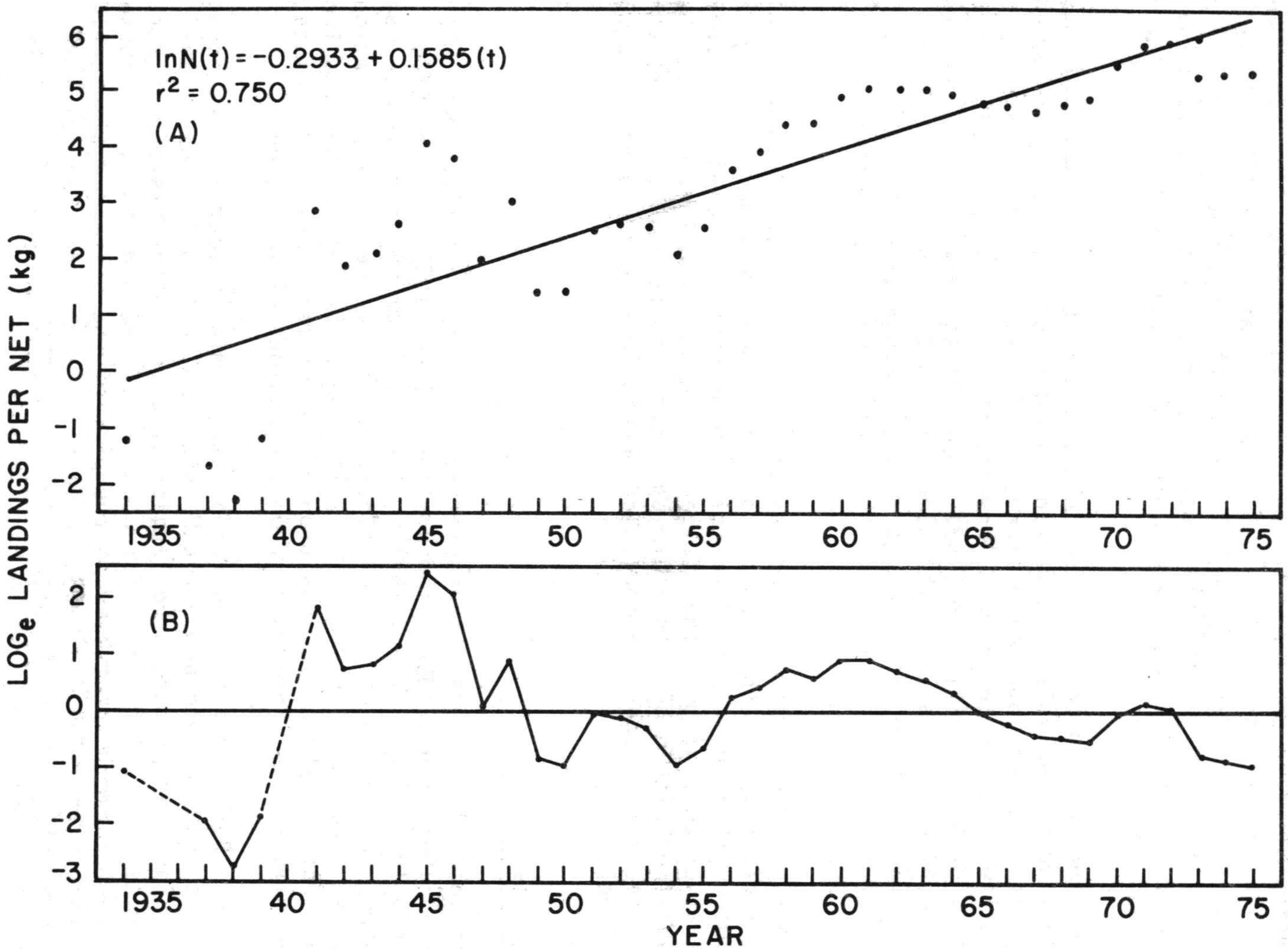

Fig. 19. Commercial landings of Umpqua River striped bass per licensed net: (A) linear trend of the 42-yr time series; and (B) plot of the detrended residuals from regression.

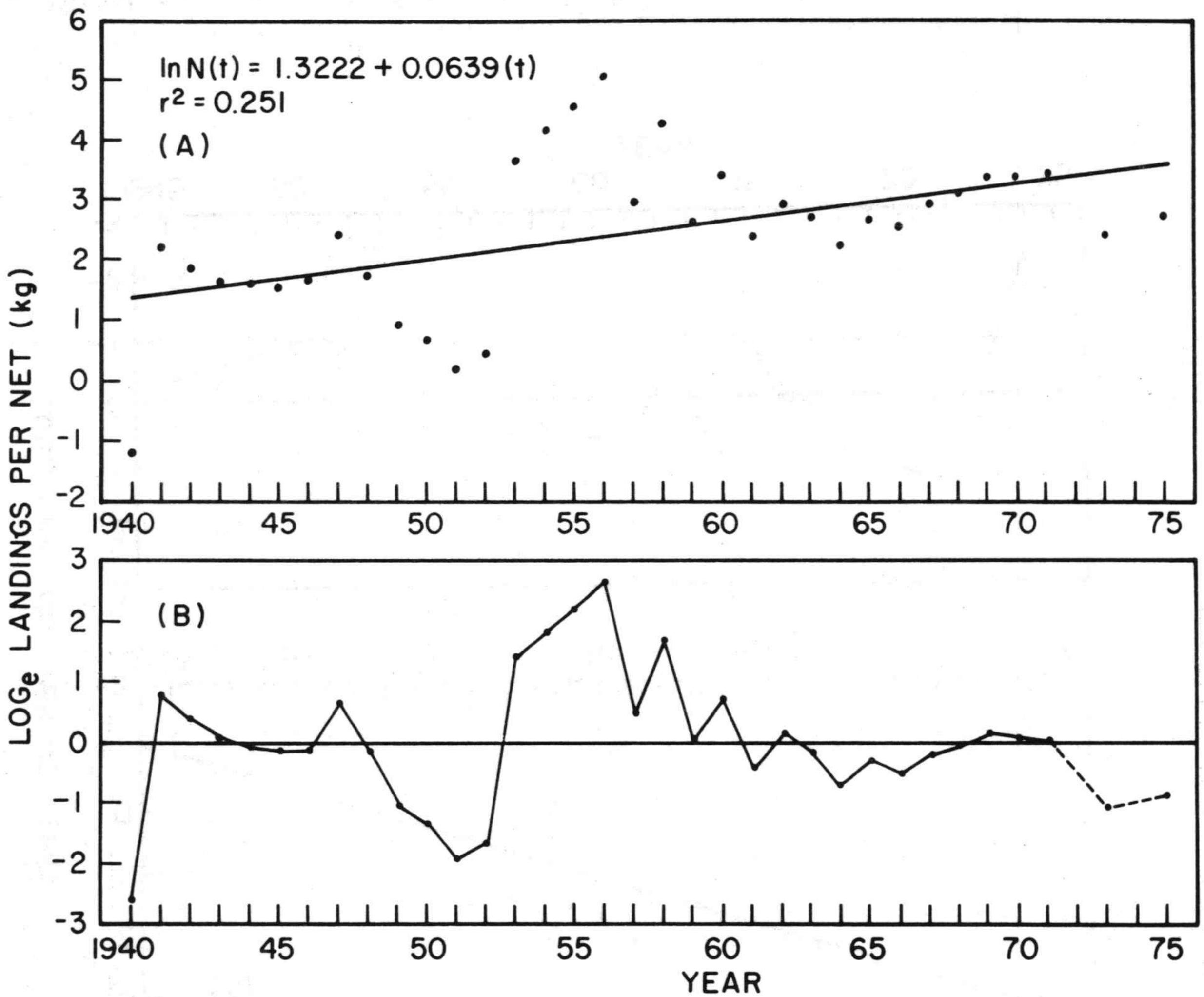

Fig. 20. Commercial landings of Coquille River striped bass per licensed net: (A) linear trend of the 36-yr time series; and (B) plot of the detrended residuals from regression.

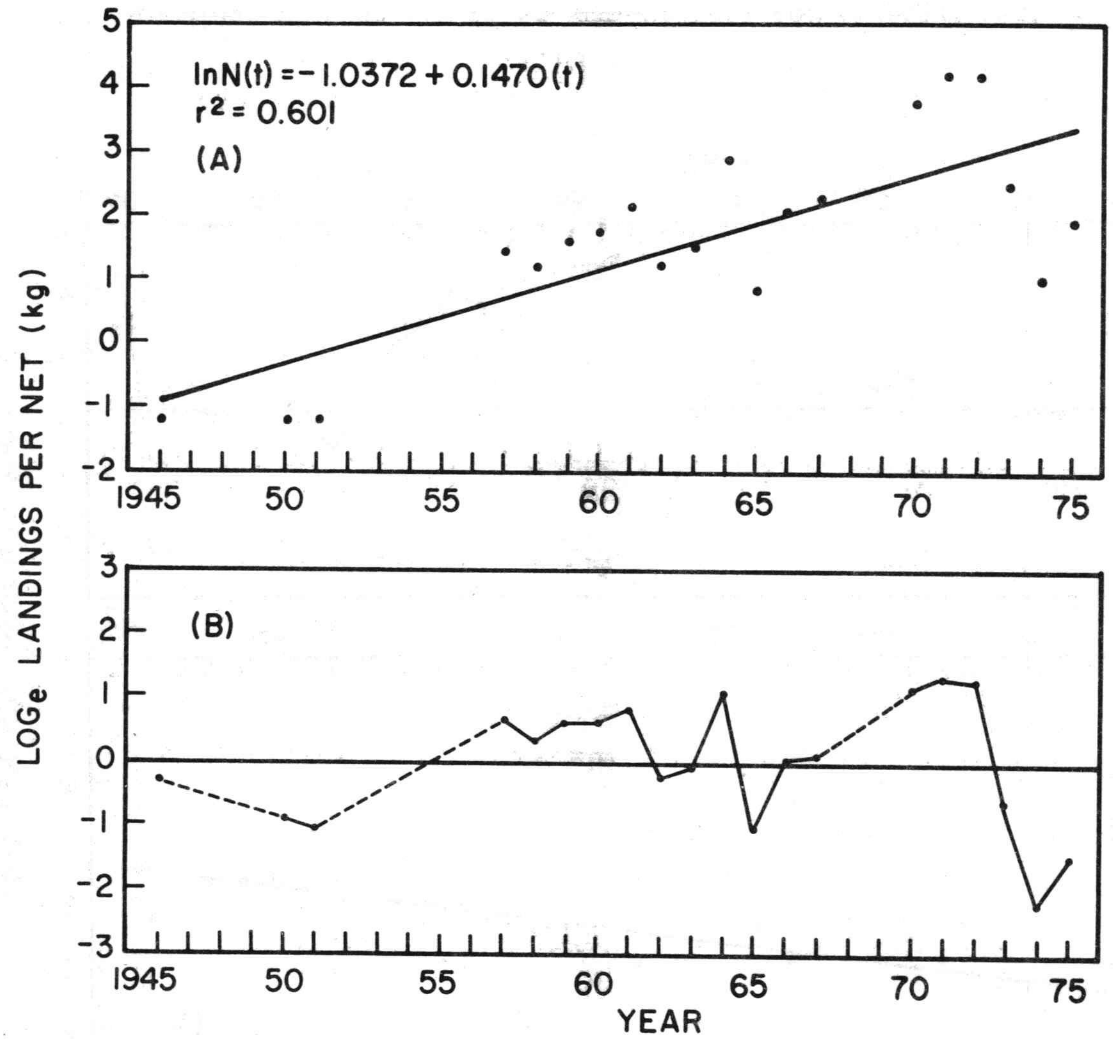

Fig. 21. Commercial landings of Siuslaw River striped bass per licensed net: (A) linear trend of the 30-yr time series; and (B) plot of the detrended residuals from regression.

The slow downward trend in the Coos River population may be related to the declining but persistent influence of the dominant 1940 year class through much of the time series. We suspect the population will oscillate above and below a zero slope depending upon the intensity and frequency of future dominant year classes in Coos River, providing there are no long-term changes in the environment.

Umpqua River. The 1966 year class dominated the catch of striped bass in the Umpqua River in the early 1970's (Mullen 1972) based on the age composition of the catch. We have scant data on dominant year classes prior to 1966, but peaks in the detrended time series of ln C/L indicate relatively strong year classes occurred in 1940 and the mid 1950's assuming a 5-yr lag between the year classes and peak commercial catches (Fig. 19). The appearance of dominant year classes in the Umpqua River has been superimposed on the long-term upward trend in the population, particularly the strong 1966 year class.

Coquille River. Lack of sufficient scale samples prevented any definitive analysis of dominant year classes in the Coquille River based on the age composition of the commercial catch. However, the plot of the detrended time series of ln C/L since 1940 indicates the 1951 year class was dominant assuming a 5-yr lag in recruitment to the commercial nets in 1956 (Fig. 20).

The strong 1951 year class coincides with the relatively large recruitment apparent in Coos River the same year. There was no evidence of dominant year classes in the Coquille River in 1958 similar to Coos River or in 1966 compared with the Umpqua River. There was a modest increase in C/L in the early 1970's in the Coquille River possibly associated with above-average recruitment in the mid 1960's, although the relationships are not pronounced in the time series.

Siuslaw River. Commercial landings of striped bass have been small and erratic in the Siuslaw River since the first recorded catch in 1946. The population has exhibited a general upward trend with a peak catch occurring in 1971 in the detrended time series (Fig. 21). This peak may have been associated with above-average production from the 1966 year class assuming a 5-yr lag before recruitment to the nets. If so, the peak would coincide with the strong 1966 year class produced in the Umpqua River. A secondary peak catch also occurred in 1964 that may be related to the strong 1958 year class in Coos River, although in this instance the offset between production and recruitment to the commercial gear would be 6 yr rather than 5 yr. The exact relationship between year class strengths and catches in the Siuslaw was obscured by a lack of data on the age composition of the commercial landings during the time series.

DISCUSSION

Dominant year classes had a profound effect on the growth of striped bass. The decline in growth following the onset of the dominant year classes are illustrated in Fig. 6 for Coos River and Fig. 7 for the Umpqua River population. Following 1940, there was a rapid depression in growth of Coos River bass as shown by the below average deviations from the mean annual growth increments that persisted for about 3 yr (1941-43). A similar, though less severe, depression in growth occurred for 3 yr following the strong 1958 year class (1959-61).

Growth of striped bass in the Umpqua River exhibited a downward trend in 1967-69 following the strong 1966 year class. Growth increments of bass were much higher in the early 1940's compared to the 1954-68 period in the Umpqua River. Commercial landings of striped bass commenced in 1934 when only 28 kg were harvested. The high growth rates in the earlier years in the Umpqua system probably reflect the lack of competition for the available food resources in the estuary when the population began to increase. Causes of growth suppression in the Coquille River striped bass population are obscure because of a lack of long-term age and growth data. Suppressed growth of the population occurred from 1959 through 1961 (Fig. 6) which suggests the 1958 year class was large. However, a strong 1958 year class was not evident in the detrended time series plotted in Fig. 20. The 1958 year class was possibly stronger in the Coquille River than indicated by the ln C/L data based upon the steep decline in the annual growth increments after 1958.

Robinson (1960) examined percentage deviations from the mean annual growth of striped bass in California from 1952 through 1956 and found similar annual fluctuations in growth. The average calculated deviations ranged from -9.5% to +5.3% during the 5-yr period. In comparison, annual deviations in growth ranged from -14.3% to +12.0% during a 37-yr period in Coos River (1934-68) and from -11.7% to +30.4% between 1940 and 1969 in the Umpqua River. Negative correlations of growth rates with year class abundance have been reported for walleyes (*Stizostedion vitreum*) by Carlander and Whitney (1961) and striped bass (Austin and Hickey 1978; Tiller 1950), consistent with the general thesis that growth rate declines as the population density increases.

The strong relationship between population densities and differences in sizes at specific ages within and between age classes may prove useful in predicting strengths and weaknesses of individual year classes in Oregon rivers. For instance, Austin and Hickey (1978) found that the modal length of bass in their third year of life was a reliable index of the abundance of that year class.

Back-calculated lengths of striped bass showed little evidence of Lee's phenomenon, i.e. back-calculated lengths from older fish less than those calculated from younger fish. According to Ricker (1969), Lee's phenomenon can occur because of technical problems in the back-calculation technique, from biased sampling of fish in the population, and from selective mortality. A large proportion of the scale samples analyzed in this study came from commercial gill-net landings. Gill nets are selective for certain sizes of fish in a narrow range of lengths. Possible size-selective mortality from gill-net selection of the larger, faster-growing siblings in the population or from differing catchabilities of different sizes (ages) of striped bass played no appreciable role in biasing the back-calculated lengths of striped bass. The absence of Lee's phenomenon in the back-calculated lengths indicates fishing was not intensive on the populations. Since striped bass were primarily caught in gill nets incidental to the primary American shad (*Alosa sapidissima*) commercial fishery, it is unlikely that the commercial fishery exerted any lasting influence on back-calculated lengths. Additional evidence of low fishing mortality on the stocks was provided by a tagging study on the Umpqua River population in 1972-73 (Mullen 1974) that indicated exploitation rates were 8-9% in the commercial fishery. Morgan and Gerlach (1950) estimated about 19% of the commercially available population were taken by gill nets from Coos River in 1950, indicating exploitation rates were also relatively light on this population.

Striped bass are long-lived and displayed a steadily declining growth rate after the second year of life in the Coos, Umpqua, and Coquille populations. Asymptotic lengths predicted from the von Bertalanffy growth equation ranged from 101.7 to 108.3 cm for males and 116.1 to 116.7 cm for females. The theoretical maximum lengths were reasonably close to empirical measurements taken over several years in the three rivers (males, 113 cm; females, 125 cm). Considerable variability in asymptotic lengths can be expected due to the influence of dominant year classes on growth rates in the population. The maximum sizes attained by striped bass in Oregon rivers rank among the largest measured in the nation. Mansueti (1961) reported a male measuring 37.2 in (94.5 cm) in Maryland which was apparently one of the largest on record on the East Coast. Chapoton and Sykes (1961) reported maximum lengths of unsexed striped bass ranging from 45.0 to 48.8 in (114-124 cm) captured in a haul-seine fishery devoted to capturing large fish off North Carolina from 1955 to 1958. In California, striped bass older than 10 yr were relatively rare (Scofield 1931; Robinson 1960).

Although age and growth statistics of striped bass were limited to age 17 and younger, older bass are known to occur in Oregon rivers. The oldest known record came from a bass tagged in Coos River on May 26, 1951, and recovered in a set net near the same locality on June 6, 1968, after being at liberty 6,221 days. When tagged, the fish measured 91 cm F.L. but no sex or scale samples were taken. However, the size at tagging and assuming the fish was a female since they normally live longer than males, indicates the bass was 10 years old when tagged (1941 year class) and therefore 27 years old when recaptured in 1968. The tagged fish weighed 18.6 kg dressed, but no length measurement was taken.

The weight-length relationship of combined sexes calculated for Oregon striped bass using the geometric mean functional regression was similar to those calculated using ordinary regression techniques for other populations of bass (Clark 1938; Merriman 1941; Robinson 1960). According to Ricker (1973), the GM functional regression should be used to avoid bias when predicting weights from lengths or lengths from weights. The ordinary regression of log w on log l of the sexes combined was 3.0433 compared to 3.1070 for the GM regression for a difference of 0.0637. The difference was greater than the standard error of 0.0129 for the regressions, indicating the two regressions were significantly different.

Our study suggests that striped bass populations in Oregon were subjected to strong, widely-spaced year class dominance that influenced growth and abundance of fish recruited to the fishery. The persistence and spacing of dominant year classes has affected the recruitment and subsequent catch in each river. Year class dominance and failures are probably magnified in Oregon striped bass populations by harsher environmental factors at the extreme northern limit of their distribution on the West Coast.

Recruitment in Oregon's striped bass populations appears to be a function of density-dependent and density independent mechanisms. We hypothesize that year class dominance in Oregon populations was independent of harvests and most likely related to low parent stock densities followed by one or more favorable environmental factors enhancing survival of eggs or juveniles. If true, the mechanisms regulating the populations are alternately density-dependent with increasing prerecruitment mortality associated with increasing population density (compensatory mortality) and density-independent when stocks are small. The persistence of dominant year classes imparts some stability in the populations and the chance occurrence of favorable environmental factors increasing survival once the stocks decline tends to promote wide-spaced dominance.

That relatively low spawning stock densities have usually produced the dominant year classes are illustrated in the detrended time series of ln C/L on *t* for each river, with a lag of approximately 5-6 yr until the year classes were fully recruited to the commercial nets (Figs. 18-21). Recruitment per parent was evidently quite high at low spawning stock densities in each striped bass population. Studies of other striped bass populations have also demonstrated that recruitment per parent was often high at low spawning stock densities (Raney 1952; Vladykov and Wallace 1952; Chadwick 1969; Koo 1970).

Chadwick (1969) speculated that the reproduction curve for striped bass in California has a steep left limb, maximum recruitment at a stock density below the equilibrium stock (where recruitment equals parent stock in the absence of fishing mortality), and steep sloping right limb partly due to cannibalism in a Ricker (1954) stock-recruitment model. We suspect that Oregon's striped bass populations behave in a similar fashion, except that compensatory mortality among prerecruits on the right limb of the curve may be partly a function of intraspecific competition for food rather than cannibalism. Cannibalism does not appear to be an important factor controlling recruitment in Oregon since young bass have been absent in the stomach contents examined from older bass (Morgan and Gerlach 1950; Oreg. Dep. Fish Wildl., unpub. data), although further analysis is needed, particularly when dominant year classes occur. The possibility of compensatory mortality through intraspecific competition for food at high stock densities is evident in the declining trends in the annual growth increments. Whether compensatory mortality is actually linked with declining trends in growth when dominant year classes appear in the populations remains unanswered.

The coincidence of dominant year classes in certain years such as 1940, 1951, 1958, and 1966 in several of Oregon's striped bass populations suggests a common causal link between the periodicities and general area-wide environmental factors enhancing survival. However, additional research is needed on the ecology and population dynamics of striped bass to define the primary mechanisms influencing recruitment.

Management Implications

Sport harvests of striped bass in Oregon are governed by a combination of size and bag limits. A minimum legal size limit of 16 in (40.6 cm) total length is imposed which translates into about 38.1 cm fork length. In 1978, the daily bag limit was reduced from five to three fish. No seasonal restrictions are imposed and angling is permitted during darkness.

The 16-in size limit delays recruitment until the fish are about 3 years old, protecting age 1 and 2 bass which double their length each year. The results of this study indicate the regulation on size limits still accomplishes its intent. The regulation permitting night fishing should be retained to increase the harvest of striped bass. In contrast, the reduced daily bag limit of three fish appears to have no biological justification. The reduced bag limit was ostensively imposed to rebuild the stocks following closure of the commercial fisheries after 1975.

Differences in the observed growth rates and deviations in calendar year growth corroborate previous findings based on tagging data that distinct stocks exist within each river system (Morgan and Gerlach 1950; Mullen 1974). Regulations governing the harvest of striped bass stocks in one river system should have little or no effect on adjacent populations in Oregon.

There appears to be little biological justification for outlawing the incidental catch of striped bass in commercial shad fishing gear. The striped bass populations have maintained healthy proportions of large, older-age groups while exploited by combined sport and commercial fishermen up to 1976. The presence of older age groups in the population is indicative of relatively low exploitation rates by the combined fisheries. The age and growth data presented in this study corroborate the low exploitation rates obtained from independent tagging studies in the Coos and Umpqua rivers by Morgan and Gerlach (1950) and Mullen (1974). The increasing trends in biomass of about 7% to 17%/yr in the Coquille, Umpqua, and Siuslaw rivers also indicate the fisheries have not materially reduced the striped bass populations over a period of 30 to 42 years of exploitation. The slight declining trend evident in the Coos River striped bass population ($\sim$2%/yr) over a span of 45 yr was probably influenced by the exceptionally strong 1940 year class early in the time series rather than to any persistent trends in overfishing or declining productivity of the estuary.

Strong year classes of striped bass tend to be irregular and widely spaced in Oregon rivers. Dominant year classes temporarily elevate catches, then gradually decline for a number of years as natural and fishing mortality exact a toll on the population in the absence of strong recruitment in succeeding generations, apparently through density-dependent mechanisms. The aperiodic cyclic process eventually triggers another strong year class when the parent stock density subsides below a critical threshold. Unfortunately, the public often views the natural phenomenon as a sign that striped bass populations are destined for oblivion as the dominant year class fades and consequently exert considerable pressure to eliminate fisheries and impose more stringent regulations. Fisheries managers need to recognize the underlying principles governing striped bass populations. Recruitment per parent can be very high at low spawning stock densities, provided suitable environmental conditions exist to enhance survival of the progeny and the habitat has not deteriorated in the meantime.

To maintain healthy striped bass populations, managers need to ensure sensitive estuarine habitats supporting the stocks are properly protected from adverse encroachments. Estuaries are an essential feature of the environment of most striped bass stocks (Talbot 1966) and this is particularly true in Oregon. However, detailed studies are needed to define specific critical habitats and environmental features required by Oregon's striped bass populations.

Age and growth data should be collected from Oregon's striped bass populations in the future. The data provide an effective means of charting long-term trends in the age composition and growth, isolating dominant year classes, and judging the effectiveness of regulations governing the harvest. Statistically-valid estimates of fishing and natural mortality rates are needed for each striped bass population which, with age and growth data, would permit rational management schemes to obtain optimum yields. Additional studies on the ecological relationships of striped bass in estuarine systems, particularly juveniles, are required to effectively protect Oregon's striped bass populations.

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LITERATURE CITED

Allen, K. R. 1966. A method of fitting growth curves of the von Bertalanffy type to observed data. J. Fish. Res. Board Can. 23(2):163-179.

Austin, H. M. and C. R. Hickey, Jr. 1978. Predicting abundance of striped bass, *Morone saxatilis*, in New York waters from modal lengths. Nat. Oceanic Atmos. Adm. (U.S.), Fish. Bull. 76(2):467-473.

Breuser, R. N. 1964. The 1963 commercial shad and striped bass fisheries in southwestern Oregon rivers. Fish Comm. Oreg. Proc. Rep. 45 p. Mimeo.

Carlander, D. C. and R. H. Whitney. 1961. Age and growth of walleyes in Clear Lake, Iowa, 1935-1957. Trans. Am. Fish. Soc. 90(2):130-138.

Chadwick, H. K. 1966. Age and growth program, Univac 1107, Fortran IV. Trans. Am. Fish. Soc. 95(2):229-230.

__________. 1969. An evaluation of striped bass angling regulations based on an equilibrium yield model. Calif. Fish Game 55(1):12-19.

Chapoton, R. B. and J. E. Sykes. 1961. Atlantic coast migration of large striped bass as evidenced by fisheries and tagging. Trans. Am. Fish. Soc. 90(1):13-20.

Clark, G. H. 1933. Fluctuations in the abundance of striped bass (*Roccus lineatus*) in California. Calif. Div. Fish Game, Fish. Bull. 39. 20 p.

__________. 1939. Weight and age determination of striped bass. Calif. Fish Game 24(2):176-177.

Cleaver, F. C. 1951. Fisheries statistics of Oregon. Fish Comm. Oreg. Contrib. No. 16. 176 p.

Forrester, C. R., A. E. Peden, and R. M. Wilson. 1972. First records of the striped bass, *Morone saxatilis*, in British Columbia waters. J. Fish. Res. Board Can. 29(3):337-339.

Grant, C. G., V. G. Burrell, Jr., and W. H. Kriete, Jr. 1971. Age composition and magnitude of striped bass winter gill-net catches in the Rappahannock River, 1967-1970. V. Inst. Mar. Sci. Contrib. 399:659-667.

Hile, R. 1941. Age and growth of the rock bass, *Ambloplites rupestris* (Rafinesque), in Nebish Lake, Wisconsin. Trans. Wis. Acad. Sci., Arts and Lett., Vol. 33:189-337.

__________. 1970. Body-scale relation and calculation of growth in fishes. Trans. Am. Fish. Soc. 99(3):468-474.

Ketchen, K. S. 1950. Stratified subsampling for determining age distributions. Trans. Am. Fish. Soc. 79:205-212.

Koo, T. S. Y. 1970. The striped bass fishery in the Atlantic states. Chesapeake Sci. 11(2):73-93.

Mansueti, R. J. 1958. Eggs, larvae and young of the striped bass, *Roccus saxatilis*. M. Dep. Res. and Educ., Contrib. 112:1-35.

__________. 1961. Age, growth, and movements of the striped bass, *Roccus saxatilis* taken in size selective fishing gear in Maryland. Chesapeake Sci. 2(1-2):9-36.

Merriman, D. 1941. Studies on the striped bass (*Roccus saxatilis*) of the Atlantic Coast. U.S., Fish Wildl. Serv., Fish. Bull. 35. 77 p.

Morgan, A. R. and A. R. Gerlach. 1950. Striped bass studies on Coos Bay, Oregon in 1949 and 1950. Oreg. Fish Comm., Contrib. 14: 31 p.

Mullen, R. E. 1972. Ecology of shad and striped bass in coastal rivers and estuaries. Fish Comm. Oreg. Ann. Rep. July 1, 1971 to June 30, 1972. 31 p.

__________. 1974. Tagging of striped bass in the Umpqua River, 1971-73. Fish Comm. Oreg., Coastal Rivers Invest. Inf. Rep. 74-7. 25 p. Mimeo.

Nichols, P. R. 1966. The striped bass. U.S. Fish Wildl. Serv., Bur. Comm. Fish. Fish. Leafl. 592. 6 p.

Oregon Division of State Lands. 1973. Oregon estuaries. Div. St. Lands, Oreg. Booklet.

Oregon Fish Commission. 1948. Striped bass in Columbia River. Fish Comm. Oreg. Res. Briefs 1(2): p. 32.

Pearson, J. C. 1938. The life history of the striped bass, or rockfish, *Roccus saxatilis* (Walbaum). U.S., Bur. Fish. Bull. 49(28):825-851.

Raney, E. C. 1952. The life history of the striped bass, *Roccus saxatilis* (Walbaum). Bull. Bingham Oceanogr. Collect., 14(1):5-97.

Ricker, W. E. 1954. Stock and recruitment. J. Fish. Res. Board Can. 11(5): 559-623.

__________. 1969. Effects of size-selective mortality and sampling bias on estimates of growth, mortality, production, and yield. J. Fish. Res. Board Can. 26(3):479-541.

__________. 1973. Linear regressions in fishery research. J. Fish. Res. Board Can. 30(3):409-434.

__________. 1975. Computation and interpretation of biological statistics of fish populations. Fish. Res. Board Can., Bull. 191: 382 p.

Robinson, J. B. 1960. The age and growth of striped bass (*Roccus saxatilis*) in California. Calif. Fish Game 46(3):279-290.

Sandeman, E. J. 1969. Age determination and growth rate of redfish, *Sebastes* sp., from selected areas around Newfoundland. Int. Comm. Northwest Atl. Fish. Res. Bull. 6:79-106.

Scofield, E. C. 1931. The striped bass of California (*Roccus lineatus*). Calif. Div. Fish Game, Fish. Bull. 29. 84 p.

Scruggs, G. D., Jr. 1957. Reproduction of resident striped bass in Santee-Cooper Reservoir, South Carolina. Trans. Am. Fish. Soc. 85 [1955]:144-159.

Smith, H. S. 1956. Fisheries statistics of Oregon 1950-1953. Fish Comm. Oreg. Contrib. No. 22. 33 p.

Snedecor, G. W. and W. G. Cochran. 1967. Statistical methods. 6th ed. Iowa State Univ. Press. Ames, Iowa. 593 p.

Stevens, R. E. 1957. The striped bass of the Santee-Cooper Reservoir. South Carolina Wildl. Resources Dep. Rep. 21 p. Mimeo.

Talbot, G. B. 1966. Estuarine environmental requirements and limiting factors for striped bass. Pages 37-49 *in* A symposium on estuarine fisheries. Am. Fish. Soc. Spec. Publ. No. 3 154 p.

Tiller, R. E. 1950. A five-year study of the striped bass fishery of Maryland, based on analyses of the scales. Chesapeake Biol. Lab., Publ. 85. 30 p.

Trent, L. and W. W. Hassler. 1968. Gill net selection, migration, size and age composition, sex ratio, harvest efficiency, and management of striped bass in the Roanoke River, North Carolina. Chesapeake Sci. 9(4):217-232.

Van Winkle, W., B. L. Kirk, and B. W. Rust. 1979. Periodicities in Atlantic Coast striped bass (*Morone saxatilis*) commercial fisheries data. J. Fish. Res. Board Can. 36(1):54-62.

Vladykov, V. D. and D. H. Wallace. 1952. Studies of the striped bass, *Roccus saxatilis* (Walbaum), with special reference to the Chesapeake Bay region during 1936-1938. Bull. Bingham Oceanogr. Collect., 14(1):132-177.