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ERRATUM

Abramson, Norman J., Estimating the number of angling license purchasers, vol. 48, no. 4, pp. 253-255.

The expression following the equal sign on line 3, page 254 should read

$$N - \frac{N(N-1)}{n(n-1)} x_2 \quad \text{rather than} \quad \frac{N(N-1)}{n(n-1)} x_2 .$$

The author is indebted to Maurice I. Gershenson, California Division of Labor Statistics and Research, for noting this error.

ANNUAL ABUNDANCE OF YOUNG STRIPED BASS, *ROCCUS SAXATILIS*, IN THE SACRAMENTO-SAN JOAQUIN DELTA, CALIFORNIA[1]

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INTRODUCTION

A reliable index of striped bass spawning success would serve two important management purposes. First, it would enable us to determine if recruitment is directly related to spawning success. If it is, we could predict important changes in the fishery three years in advance.

Second, it would give insight into environmental factors responsible for good and poor year-classes. Besides increasing our understanding of the bass population, this knowledge might be used to improve recruitment by modifying water development plans in the Sacramento-San Joaquin Delta under the State Water Resources Development System.

Fyke net samples provided the earliest information on young bass distribution (Hatton, 1940). They were not promising for estimating abundance, and subsequent sampling of eggs and larvae with plankton nets also had important limitations (Calhoun and Woodhull, 1948; Calhoun, Woodhull, and Johnson, 1950).

An exploratory survey with tow nets in the early summer of 1947 (Calhoun and Woodhull, 1948) found bass about an inch long distributed throughout the lower Sacramento-San Joaquin River system except in the Sacramento River above Isleton. This suggested the best index of spawning success would be the abundance of bass about an inch long, measured by tow netting.

In 1948 and 1949 extensive tow net surveys were made to measure the relative abundance of young bass in the Delta between Rio Vista and Pittsburg (Erkkila *et al.*, 1950). In 1951, the actual size of the young bass population was estimated twice during the summer (Calhoun, 1953). Since 1953, the Department has made more limited surveys annually.

This paper reports results of these annual surveys for 1953 through 1962. It also reports results of two types of studies to evaluate their accuracy. First, more intensive surveys (Delta-wide surveys), exploratory tow net sampling, and beach seining were used to learn if annual surveys accurately measured abundance throughout the nursery grounds, and throughout the time when young bass were vulnerable to the tow net. Second, the net's size selectivity, the vertical and horizontal distribution of young bass, the effects of tidal stage on catch, and the

[1] Submitted for publication September 1963. This work was performed as part of Dingell-Johnson Project California F-9-R, "A Study of Sturgeon and Striped Bass," supported by Federal Aid to Fish Restoration funds.

relationship between water transparency and net efficiency were examined to determine how accurately tow netting measures abundance in the immediate water mass being sampled.

DESCRIPTION OF STUDY AREA

California's only large striped bass population inhabits the estuary of the Sacramento-San Joaquin River system (Figure 1) and adjacent coastal waters. Tidal movement dominates the estuary, with flow reversal occurring in summer up to Courtland on the Sacramento River and above Mossdale on the San Joaquin River. However, the Delta is essentially fresh water, with salinities seldom exceeding 1,000 ppm chlorides a few miles above the confluence of the two rivers. Downstream, salinity increases rapidly, sometimes approaching 90 percent of seawater in San Pablo Bay in late summer

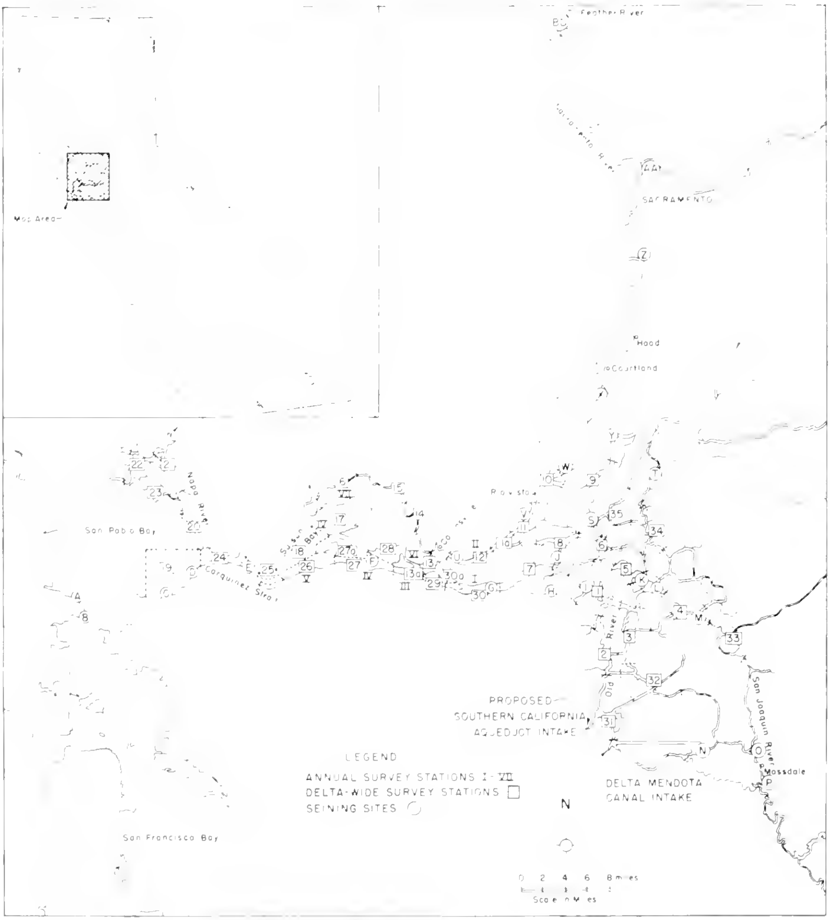

FIGURE 1. The study area showing tow net and seining stations and areas represented by Delta-wide survey stations.

Waters throughout the Delta are turbid, with Secchi disk readings seldom over a foot, except in the Sacramento River above Rio Vista. In the bays west of Pittsburg the water is clearer.

METHODS

Description of Nets

Most sampling was with a tow net mounted on skis, as described by Calhoun (1953). The net cone was made of ½-inch stretched mesh #6 medium-laid cotton webbing, and nylon bobbinet with openings approximately 0.1 inches in diameter (Pattern No. 281, Marion Textiles, Inc., New York). A 9-foot cone of cotton webbing was attached directly to the frame, and a 7-foot nylon bobbinet cone was sewed to the cotton webbing, so that the cotton webbing formed a 2-foot fyke inside the bobbinet. The overall length of the net was approximately 14 feet. A quart Mason jar was tied in the apex of the bobbinet cone.

Size selectivity, vertical distribution, and some horizontal distribution measurements were determined with modified nets. In measuring size selectivity, the bobbinet of the standard net was replaced with bobbinet having holes approximately 0.04 inches in diameter (Pattern 1400, Marion Textiles).

In measuring vertical distribution, we used circular nets, 3 feet in diameter. These had an 8-foot cone of the same cotton webbing joined to a 6½-foot cone of No. 281 bobbinet to form a 2-foot fyke inside the bobbinet. One of these nets was mounted on skis to measure horizontal distribution during 1961.

Fishing Procedures

The standard net was towed from the 28-foot research boat *Striper*, on a ¼-inch steel cable passing from a winch amidship through a block suspended from an "A" frame at the stern (Figure 2).

All samples were taken towing into the current at 1,000 rpm engine speed giving a velocity through the water of approximately 2.7 feet per second. Calhoun found this an efficient speed (Calhoun and Warren, 1949).

Fishing depth was estimated from the length of cable released. The relationship between fishing depth and cable length was established by measuring cable deflection angle, and from readings made with Moeller Chemical Sounding Tubes suspended by rubber stoppers inside an aluminum tubing capsule attached to the net frame.

Three circular nets were fished simultaneously to measure vertical distribution. Each was attached with a swivel safety hook to a swivel clamped on the towing cable. A 2-foot-square wooden kite weighted with concrete blocks was attached to the end of the cable to depress it, so less cable was needed to fish a given depth. The nets could be retrieved so rapidly that the difference between fishing times of the top and bottom nets was less than 5 percent.

Lateral distribution of small bass in various channels was measured during 1961 with a circular net mounted on skis, towed from a 40 hp outboard skiff.

FIGURE 2. Tow net being pulled aboard *Striper* at end of a tow. *Photograph by William Heubach, July 1962.*

Annual Survey Procedures

In 1953, stations were selected in the lower San Joaquin River (I), and in the Sacramento River several miles above and below the mouth of the San Joaquin River (II and III); in 1954, two stations were added in Suisun Bay (IV and V) (Figure 1). We believed these stations represented the area inhabited by almost 90 percent of the estimated young bass population in early July 1951 (Calhoun, 1953).

These localities were sampled during the week of minus tides (water height at low tide at Golden Gate, San Francisco, below mean sea level) closest to the time that young bass at Antioch reached a mean length of 1-inch. This was to compensate for annual variations in spawning time and growth rate. Stations were sampled in numerical order—one station a day—on successive days. Fifteen 15-minute samples were taken at each station during the minus ebb tide. At the start of each tow, 185 feet of cable was released and it was retrieved during odd-minute intervals, thus all depths to about 30 feet were sampled equally.

Procedures were changed in 1957. Stations III, IV, and V were dropped, and stations were selected in Spoonbill Slough (VI) and Montezuma Slough (VII) (Figure 1). The same minus tides were sampled, but each station was sampled on three different days with five, 15-minute tows per day. Stations I and II were sampled during ebb tides on days 1, 3, and 5, and 2, 4, and 6, respectively. Stations VI and VII were sampled during flood tides on days 1, 3, and 5, and 2, 4, and 6, respectively. Sampling started $2\frac{1}{2}$, 2, $\frac{1}{2}$, and 1 hour after slack water at Stations I, II, VI, and VII, respectively, and subsequent samples were taken at ½-hour intervals, so any correlation between catch and tidal stage would not bias the results. Only 100 feet of cable were released at Station VI; it was shortened to 75 and 50 feet after 5 and 10 minutes, since the water was considerably shallower there. Other procedures remained the same.

Delta-wide Survey Procedures

Thirty stations (Stations 1-30, Figure 1) were selected to sample the area between upper San Pablo Bay and Isleton on the Sacramento River and Mossdale on the San Joaquin River as extensively as could be done in 5 days with one boat. Three 10-minute samples were taken at each station every other week. Days of least tidal fluctuation were sampled to minimize any biases associated with tidal stage. Sampling was conducted from the time substantial numbers of bass over 0.7 inches long appeared until the mean bass size approached 2 inches.

Previous work indicated most bass were in the top 10 feet of water (U. S. Dept. of Interior, 1957); hence, towing procedures were designed to sample equally all depths to 12 feet. This was done by releasing 100 feet of cable at the start of each tow, and retrieving 25 feet at 3-minute intervals. Data collected in 1960 showed the vertical distribution of bass was not constant, so in 1961 towing procedures were modified to sample all depths equally. We released enough cable to reach the bottom at the start of towing and pulled in 25 feet at appropriate intervals. Selected stations had a 30-foot maximum depth, since deeper water could not be sampled with available gear. During 1961, one tow at each station was made in the old manner each period, so a ratio of catches by the new method (diagonal tows) to the old method (surface tows) could be calculated.

In 1961, Stations 9, 19, 21, 22, and 24 were abandoned, because few fish had been caught there, and five stations (31-35) were added to cover the San Joaquin Delta more thoroughly. In 1962, Stations 20, 23, and 32 were abandoned so Stations 11a, 13a, 27a, and 30a could be added to increase sampling in areas of greatest water volume.

Seine Survey Procedures

Seine collections were made with a 100- by 6-foot, ¾-inch stretched mesh beach seine during October or November 1956-1959. Sites were selected wherever suitable beaches were found from western San Pablo Bay to the mouth of the Feather River on the Sacramento River and about 10 miles above Mossdale on the San Joaquin River (Stations A-BB, Figure 1). Up to three hauls were made at each station.

Procedures Used to Evaluate Accuracy of Local Abundance Estimates

The minimum size selectivity of the standard tow net was measured by comparing lengths of bass caught in the standard net with lengths of bass caught in the net with the Pattern 1400 bobbinet cod end.

We measured vertical distribution at several localities having water depths of approximately 30 feet, by fishing the three circular nets simultaneously at 5, 15, and 25 feet.

Between 1957 and 1959, we measured horizontal distribution by comparing catches next to shore and at mid-river on alternate tows. Shore tows were in water less than 10 feet deep with 75 feet of cable, so the net rode on the bottom except at Stations I and 5, where the water was 20 to 30 feet deep adjacent to shore. Mid-river tows were taken following annual survey procedures. In 1961, comparisons were made by simultaneously taking a sample next to shore with the small tow net pulled by a skiff and a sample at mid-river using the procedure designed to measure vertical distribution. The mean catch of the three nets fished in mid-river was compared with the catch near shore.

Statistical Methods

Catches were analyzed with standard statistical procedures. In most experiments variables were analyzed by factorial design analysis of variance, which requires normally distributed measurements. It was impossible to determine the type of distribution of sample catches, since the population sampled was constantly changing because of tidal movement and fish behavior. However, trawl net catches generally have some type of contagious distribution, so the logarithms of the catches, or the catches plus one in samples with zero catches, are suitable for most statistical analyses (Gulland, 1956). Logarithmic transformations have been used commonly in other similar studies (Winsor and Clarke, 1940; Silliman, 1946; and Bagenal, 1958), and I used them in all analyses.

For the annual surveys, simple aggregate indices of abundance were calculated by dividing the sum of the mean catches per tow at several stations during a given year by the sum of the mean catches per tow at those stations during the base year. This gives each station an importance proportional to the magnitude of its catch. This is preferable to other ways of calculating indices, since the fraction of the population present at each station cannot be estimated.

A simple aggregate index was also calculated for the Delta-wide surveys. In addition, a weighted index was calculated by multiplying the catch at each station by the water volume represented by the station (Appendix A). These volumes were determined by setting boundaries midway between stations or at a distance of 2.5 miles from stations on the area's periphery and estimating the water volume present at mean half-tide to the nearest 1,000 acre-feet.

Striped bass were measured to the nearest 0.1-inch, fork length.

RESULTS

Annual Surveys

1953-1956 Surveys

Catches during 1953 and 1954 were considerably greater than those during 1955 and 1956, and catches were generally greatest at Stations I and II (Table 1).

The 1954-1956 results were analyzed by analysis of variance to test the hypothesis that these stations sampled the population adequately. The 1953 results were not included, since only three stations were sampled. I assumed the first tow each day was made at the same tidal stage, and the other tows followed at equal time intervals. Thus, the

TABLE 1

Summary of Striped Bass Catches Made During Annual Surveys

Station		Date									
		7/26-28 1953	6/28-7/2 1954	7/4-8 1955	7/19-23 1956	7/13-16 1957	7/26-8/1 1958	6/20-25 1959	7/6-11 1960	6/26-7/1 1961	7/1-6 1962
I	Catch/tow	85.0	117.1	73.5	48.9	*23.9	37.6	13.1	42.1	157.8	*277.8
	Mean length†	1.0	1.0	1.1	1.0	1.2	1.1	1.5	1.3	1.1	0.9
II	Catch/tow	110.7	96.2	35.5	21.3	*27.3	17.9	9.3	117.3	235.6	417.9
	Mean length	1.0	1.0	1.0	1.0	1.3	1.3	1.4	1.2	0.9	1.1
III	Catch/tow	64.5	57.0	4.9	20.5						
	Mean length	1.1	1.1	1.0	1.3						
IV	Catch/tow		51.3	5.8	30.3						
	Mean length		1.2	1.2	1.5						
V	Catch/tow		6.7	10.9	9.7						
	Mean length		1.3	1.2	1.4						
VI	Catch/tow					*58.9	54.7	30.7	129.1	362.1	*462.8
	Mean length					1.1	1.0	1.3	1.1	0.9	1.0
VII	Catch/tow					*50.5	116.9	10.0	19.6	87.5	*235.5
	Mean length					1.4	1.2	1.6	1.7	1.3	1.1

* Sampling limited to two days and 10 samples.
† Fork length in inches.

catches of any given tow were indicative of a certain time during the tide. The first order interactions, year x time and time x station, were not significantly different at the 95 percent level from the second order interaction, so the three were combined to estimate sampling error (Table 2).

TABLE 2

Analysis of Variance of 1954-1956 Tow Net Surveys

Variable	*Degrees of Freedom*	*Sum of Squares*	*Mean Square*
Year	2	4.252	2.126
Station	4	8.281	2.070
Time	14	0.949	0.068
Year x station	8	2.485	0.311
Error	196	6.618	0.034
Total	224	22.585	

Three important results of this analysis are: (i) differences among yearly catches are highly significant ($F = 62.53$ with $F_{.01} = 4.70$); (ii) differences among mean catches at the stations are highly significant ($F = 60.88$ with $F_{.01} = 3.85$), clearly indicating an unequal distribution of bass in the area sampled; (iii) the year x station interaction is significant ($F = 9.15$ with $F_{.01} \cong 2.85$), indicating significant annual differences in geographical distribution.

To test the hypothesis that these stations sampled the population in many miles of river due to fish being carried by the relatively fast-moving water during minus ebb tides, the relationship between the catches at Stations I, II, III, and V was examined. Float studies

(Calif. Div. of Water Resources, 1952) indicated that water moves from Station III to Station V in approximately 3 hours. Hence, early catches at Station III should be similar to late catches at Station V. Such a relationship was evident only in 1956 (Table 3). Catches at Stations I and II also failed to show a relationship to those at Station III.

TABLE 3

Total Catches of Striped Bass at Stations III and V During Comparable Periods of Sampling

	Station III Tows 1-5	*Station V Tows 10-15*
1954	230	67
1955	9	104
1956	91	81

1957-1962 Surveys

Boat breakdowns prevented 1 day of sampling at each station in 1957 and 1 day at three stations in 1962. The 1959 results are aberrant because the survey was 2 weeks late. This occurred because young bass reached a 1-inch mean length a month earlier than in any other year.

Annual catches were relatively low from 1957 through 1959 and then increased sharply to a 10-year high in 1962 (Table 1).

Appreciable variations in catches on different days at the same station have occurred during some years (Table 4).

TABLE 4

Variability in Catch of Striped Bass at Station I During Annual Surveys

	Mean catch per tow		
Year	*Series I*	*Series II*	*Series III*
1957	33.6	14.2	
1958	43.8	37.8	31.2
1959	14.0	17.0	8.2
1960	50.8	37.4	38.0
1961	160.2	219.6	93.6
1962	350.2		205.2

Indices of Abundance

The only measure of abundance possible for all years is an index of abundance at Stations I and II (Table 5, Annual survey A), since these were the only stations sampled every year. Broader based indices were calculated for 1957 through 1962 from catches at Stations I, II, VI, and VII (Table 5, Annual survey B), and for 1954 through 1956 from catches at Stations I through V (Table 5, Annual survey C); 1960 is the base year used for the first two indices. The last index was calculated using 1954 as a base and multiplying each annual abundance index by 1.34 to put them on the same scale as the other indices.

The indices agree closely with each other. They show a decline in abundance from a 1953-54 peak to a low in 1959, and then a sharp increase through 1962, with abundance being greatest in 1961 and 1962.

TABLE 5

Indices of Annual Abundance of Striped Bass Fry in the Sacramento-San Joaquin Delta [1]

Index	*1953*	*1954*	*1955*	*1956*	*1957*	*1958*	*1959*	*1960*	*1961*	*1962*
					Year					
Annual survey A [2]	1.23	1.34	0.68	0.14	0.32	0.35	0.14	1.00	2.47	4.36
Annual survey B [3]					0.48	0.67	0.19	1.00	2.19	4.12
Annual survey C [4]		1.34	0.54	0.54						
Delta-wide survey A [5]							0.49	1.00	1.40	3.20
Delta-wide survey B [6]							0.38	1.00	1.04	2.60
Delta-wide survey C [7]							0.44	1.00	1.20	3.34
Delta-wide survey D [8]									1.00	2.42

[1] Underlining indicates best estimates of relative abundance.
[2] Sum of mean catches per tow at Stations I and II divided by the 1960 sum.
[3] Sum of mean catches per tow at stations I, II, VI, and VII divided by the 1960 sum.
[4] Sum of the mean catches per tow at Stations I, II, III, IV, and V, divided by 1954 sum, and multiplied by 1.34 to equate it to other indices.
[5] Total number of bass collected at Stations 1-30 during three surveys when more than 70 percent of all bass were between 0.7 and 2.0 inches long, adjusted for annual differences in survey procedures, and divided by 1960 total.
[6] Similar to Delta-wide survey A except that catch at each station was multiplied by the thousands of acre feet of water present at the station and stations with "a" suffixes included in 1962 in addition to stations 1-30.
[7] Similar to Delta-wide survey B except that catches during four surveys were included (Survey No. 1 excluded in 1961) and only 1.0-1.4 inch bass were included, except during first survey, when those larger than that were included, and fourth survey, when those smaller than that were included.
[8] Similar to Delta-wide survey B but includes stations 31, 33, 34, and 35, and excludes stations 9, and 19-24.

Delta-wide Surveys

Length Composition of Catch

Four Delta-wide surveys were made annually in 1959, 1960, and 1962, and five were made in 1961 (Table 6). The 1960, 1961, 1962 catches

TABLE 6

Summary of Striped Bass Catches During Delta-wide Surveys *

Year	*First survey*	*Second survey*	*Third survey*	*Fourth survey*	*Fifth survey*
1959					
Date	6/13-18	6/27-7/1	7/11-15	7/25-29	
Total catch	556	824	640	272	
Percentage 0.7-2.0 inches	91	72	70	66	
Mean length †	1.1	1.1	1.5	1.9	
1960					
Date	6/16-20	6/30-7/4	7/13-18	7/28-8/1	
Total catch	1,737	1,329	758	280	
Percentage 0.7-2.0 inches	82	89	85	55	
Mean length †	0.8	1.1	1.5	2.1	
1961					
Date	6/5-9	6/19-23	7/4-10	7/17-21	7/31-8/3
Total catch	1,061	3,736	4,428	1,152	335
Percentage 0.7-2.0 inches	55	81	82	91	64
Mean length †	0.7	0.8	1.0	1.4	1.9
1962					
Date	6/26-29	7/8-12	7/23-27	8/6-10	
Total catch	10,814	8,099	3,103	733	
Percentage 0.7-2.0 inches	85	96	88	64	
Mean length †	0.9	1.2	1.5	1.9	

* Catches are not comparable in all years due to changes in survey procedures and stations described in text.
† Fork length in inches.

showed similar patterns, with mean length increasing from 0.8 or 0.9 inches to about 2 inches over a period of four surveys. The bulk of the catch was made during the first three of these surveys, when over 80 percent of the bass were 0.7 to 2.0 inches long. In 1959, bass were larger during the first survey and the size range was greater, and only about 70 percent of the catch was in the 0.8 to 2.0-inch range, except during the first period.

Length frequency distributions of the catches are not as similar as the means (Figure 3). Three modes progress through the fishery in 1959, while there were two modes in 1960 and 1961, and only one in 1962. The modes probably indicate either periodicity in spawning or periodicity in survival. The modes on successive surveys generally coincided during 1959 and 1960, and the modes at 0.7 inches coincided in 1961.

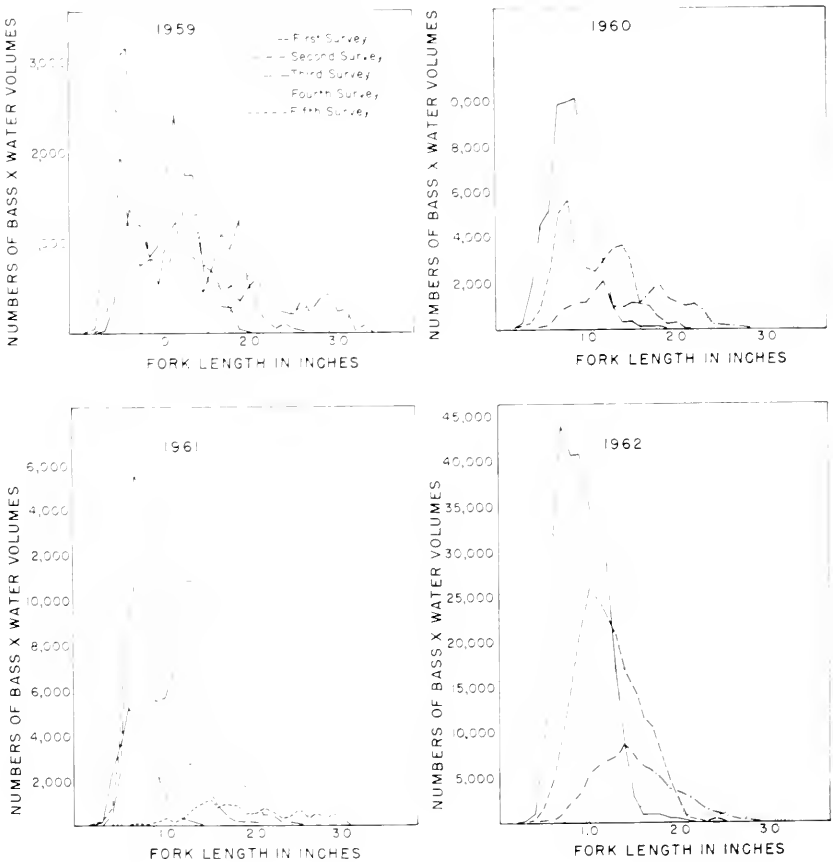

FIGURE 3. Length frequencies of striped bass caught during Delta-wide surveys.

Geographical Distribution

Appreciable annual variations occurred in the geographical distribution of young bass (Table 7). Distribution was similar in 1959 and

1961, with about 60 percent of the bass in the lower Delta and most of the rest in the San Joaquin Delta. The 1960 distribution was similar, but even more bass were in the lower Delta and fewer in the San Joaquin Delta. The population was generally farther downstream in 1962.

TABLE 7

Relative Distribution of Young Striped Bass in the Sacramento-San Joaquin Delta

	Percentage of Total Catch *			
Stations	*1959*	*1960*	*1961*	*1962* †
San Joaquin Delta				
1, 2 and 3	16	7	12	4
4, 5, 6, and 8	16	8	14	7
Lower Delta				
7 and 30	13	16	13	21
9, 10, 11, and 12 ‡	41	25	32	18
13 and 29	8	37	21	17
Suisun Bay Area				
14, 15, and 16	4	4	5	11
26, 27, and 28	2	2	3	19
17, 18, and 25	1	1	1	3
San Pablo Bay Area				
20 and 23	Trace	0	0	–

* Percentage of total catch weighted by water volume during the three Delta-wide Surveys with over 70 percent of bass between 0.7 and 2.0 inches.
† Stations with "a" suffixes tabulated with station of same number. Part of station 13 included in station 30a.
‡ Station 9 not sampled in 1961 and 1962.

Indices of Abundance

Four indices of abundance were calculated from the Delta-wide surveys (Table 5). Delta-wide survey indices A and B were based on catches during the three surveys each year when over 70 percent of the bass caught were 0.7 to 2.0 inches long (Table 6). Both were adjusted by depth correction factors during 1959 and 1960, and for 1961 because only two diagonal tows were made at most stations that year. The depth correction factors were calculated by grouping similar stations and dividing the sum of the average diagonal tow catches by the sum of the surface tow catches (Table 8). Index A was calculated by dividing the total catch during the three surveys in each year by the 1960 total catch. Index B was calculated by weighing the catch at each station by the appropriate water volume (Appendix A), summing the weighted totals, and dividing each year's total by the 1960 total.

TABLE 8

Comparison of Diagonal Tows and Surface Tows During the First Four 1961 Delta-wide Surveys

	Total catch *		
Stations	*Diagonal tows*	*Surface tows*	*Ratio*
1+2+3	467.5	430	1.1
4+5+6+8	504.5	511	1.0
7+30	162	108	1.5
29	104.5	165	0.6
11	185.5	55	3.4
12	195.5	18	10.9
13	165.5	67	2.5
15+16	135	67	2.0
25+26+27	18.5	22	0.8

* Catches include only fish 0.7-2.0 inches long. Catches from diagonal tows were divided by two, since two diagonal tows and only one surface tow were made at each station.

Delta-wide survey Index C estimates bass fry abundance as they pass through the size interval 1.0 to 1.4 inches. Modal lengths (Figure 3) indicate this interval is approximately equal to bass growth during a 2-week period. Thus, each group would be sampled only once. This index was calculated by using the total catch of 1.0- to 1.4-inch bass, weighted by water volumes, during four surveys (Survey 1 excluded in 1961). In addition, the weighted catches of bass larger than this on the first survey and smaller than this on the fourth survey were included.

Delta-wide survey D was calculated similarly to Index B, but Stations 9 and 19-24 were excluded and Stations 31, 33, 34, and 35 were included.

All three indices show similar trends of increasing abundance during 1959 through 1962.

A weighted index comparable to Index B was calculated for each of five size groups of bass (Table 9). Annual differences are smallest in the largest and smallest groups, and greatest in the middle group.

TABLE 9

Index of Abundance of Various Sizes of Striped Bass

Length group	*1959*	*1960* *	*1961*	*1962*
0.0-0.5	45	100	60	112
0.6-0.9	28	100	84	208
1.0-1.4	41	100	118	328
1.5-1.9	50	100	109	215
2.0+	116	100	57	99

* Base year.

Growth Rates

Distances between modal lengths in subsequent surveys are probably accurate measures of growth for 2-week periods. The distances between pronounced modes in tenths of inches are: 1959—0.5, 0.6, 0.7; 1960—0.4, 0.4, 0.6; 1961—0.4, 0.6; 1962—0.3, 0.4 (Figure 3).

Exploratory Tow Net Sampling

Considerable exploratory tow netting was done between 1954 and 1958. Most sampling in areas covered later by the Delta-wide surveys contributed nothing additional to our knowledge of young bass distribution. However, sampling in the Sacramento River above Rio Vista, in San Pablo Bay, and in the Napa River and adjacent sloughs contributed substantially.

On August 7 and 8, 1957, eight tow net samples were taken at scattered locations from the south end of Steamboat Slough (Station W) to the mouth of the Feather River. The only bass was collected near Station X. At the same time, seine collections caught 13 bass at Station W in two hauls, 18 at Station AA in three hauls, and 3 at Station BB in one haul.

On July 7, 1958, no bass were caught in five tow net samples between Stations W and AA.

On July 17, 1957, one bass was caught in six tow net collections in the Napa River between the mouth and Napa.

The Napa River was sampled on three occasions in 1958. On June 19, 26 bass were caught in four samples between the mouth and Station 21. On June 26, 429 bass were caught in eight samples in the river and adjacent sloughs in the general area covered by Stations 20-23. On July 22, 227 bass were caught in seven samples in this area and three in the main river between Station 21 and Napa.

The only sampling in San Pablo Bay consisted of 12 tow net hauls on June 25, 1958 at scattered localities throughout the Bay. Only nine bass were taken in the eastern part of the Bay. In contrast, the remainder of the catch was composed of Sacramento smelt, *Spirinchus thaleichthys*, 7; smelt, *Hypomesus* spp., 110; anchovy, *Engraulis mordax*, 1,157; splittail, *Pogonichthys macrolepidotus*, 24; threespine stickleback, *Gasterosteus aculeatus*, 3; unknown goby, 208.

Seine Surveys

Fall seine surveys collected young bass in appreciable numbers from eastern San Pablo Bay to Ryde on the Sacramento River and Mossdale on the San Joaquin River (Table 10).

TABLE 10

Catches of Young-of-the-Year Striped Bass Made in Fall Seine Collections

		Number of young-of-the-year striped bass per seine haul			
Station	*Location*	*1956*	*1957*	*1958*	*1959*
A	San Pablo Bay at China Camp		0	0	0
B	San Pablo Bay at Pt. San Pedro		0	0	0
C	San Pablo Bay at Pt. Wilson		5	4	0
D	San Pablo Bay at Rodeo	19	9	53	1
E	Carquinez Strait at Port Costa	76	80	10	3
F	Sacramento R. at Middle Grounds	53	16	7	101
G	San Joaquin R. at Antioch	300	20	133	6
H	Taylor Slough	–	5	1	2
I	Sand Mound Slough at Piper Slough	–	–	50	3
J	Fishermen's Cut		0	0	1
K	San Joaquin R. at Medford Island	550	82	129	172
L	San Joaquin R. at Headreach Island	600	22	37	10
M	San Joaquin R. at Roberts Island	200	128	82	436
N	Salmon Slough at Doughty Cut	8	3	14	3
O	San Joaquin R. ½ mi. below Mossdale	8	2	–	–
P	San Joaquin R. 1 mi. above Mossdale	–	86	1	2
Q	San Joaquin R. 3 mi. above Mossdale	–	–	0	–
R	San Joaquin R. 10 mi. above Mossdale	–	–	3	–
S	Mokelumne R. at Highway 12	62	12	1	2
T	South Fork Mokelumne R. above Hog Slough	2	7	1	1
U	Sacramento R. at Sherman Island	77	38	82	3
V	Sacramento R. below Rio Vista	90	163	51	10
W	Steamboat Slough, south end	15	17	12	1
X	Steamboat Slough, north end	–	44	7	4
Y	Sacramento R. at Ryde	25	13	23	5
Z	Sacramento R. above Freeport	5	7	2	3
AA	Sacramento R. at American R.	5	0	1	+
BB	Sacramento R. at Feather R.	2	–	15	0

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Accuracy of Measurement of Local Abundance

Size Selectivity

Ratios of bass catches in the standard-mesh net to those in the fine-mesh net during two pairs of tows at Station 14 and three pairs at Station 1 indicated the standard net's efficiency increases sharply as bass size increases from 0.5 to 0.7 inches and reaches 100 percent at approximately 0.8 inches (Table 11). This is supported by the fact that of 42 bass fry gilled in the standard bobbinet during 1958, the percentages of 0.6-, 0.7-, and 0.8-inch fry were 12, 76, and 12, respectively.

TABLE 11

Comparison of the Lengths of Striped Bass Fry Caught in Standard Tow Net and Tow Net with Small Mesh Cod End

Length [*]	*Standard Net*	*Small Cod End Net*	*Ratio*
0.2	0	63	0.00
0.3	4	151	0.03
0.4	14	102	0.14
0.5	36	198	0.18
0.6	175	326	0.54
0.7	283	346	0.82
0.8	150	128	1.17
0.9	36	39	0.92
1.0	3	6	
1.1	0	5	
1.2	1	0	
1.3	1	0	—
1.4	0	1	—

[*] Fork length in inches.

Striped bass become less vulnerable to the net as they grow, presumably because of increased swimming ability. The limit of vulnerability is about 3.5 inches, since virtually no larger ones were caught, even though they occurred in the areas sampled. However, no satisfactory method was found to measure accurately the decline in vulnerability. During the Delta-wide surveys, annual modal length varied from 0.7 to 0.9 inches and the catch of larger fish generally declined sharply (Figure 3). This resulted from a combination of mortality and declining vulnerability, and no facts are available to measure the contribution of each. However, the small catch of bass longer than 2 inches (11.4 percent of the catch in 1959, and half or less of this in other years) suggested the net was quite inefficient for bass of this size.

Vertical Distribution

During 1960 and 1961, vertical distribution was sampled at nine localities (Tables 12 and 13). In the western part of the Delta (Stations 7-30), bass were generally concentrated near the bottom, while in the eastern part (Stations 1-5) they were more evenly distributed, with greatest concentration frequently near the surface.

Bass showed a general tendency to raise off the bottom during flood tides. This was more pronounced and general in the western localities. This tendency was particularly pronounced and closely correlated with tidal stage at Station 12 in both 1960 (Figure 4) and 1961.

TABLE 12

Vertical Distribution of Striped Bass During Ebb Tides

			Mean catches per tow at various depths below surface †		
Station	*Date*	*Number of tows*	*5 feet*	*15 feet*	*25 feet*
15	6/14/60	10	4.2	17.1 **	15.0
14a	7/25/60	10	2.1	8.3	14.1 **
12	6/15/61	7	1.6	15.7	20.5 **
12	7/23/60	10	1.4	16.9	65.1 **
12	7/27/61	7	0	18.5	70.8 **
12	8/ 2/60	5	8.2	12.0	94.6 **
30	6/27/60	10	16.5	32.5 **	24.0
7	6/16/61	7	0.4	23.5	28.3 **
7	7/13/61	7	2.6	34.5	104.8 **
5	6/14/61	7	38.8 **	25.2	9.0
5	7/12/61	7	19.8	32.1 **	29.1
1	6/24/60	10	29.5	33.5 **	13.9
1	7/21/60	10	13.3 **	7.0	3.2
3	6/13/61	7	38.4 **	21.2	7.3
3	7/11/61	7	21.8	81.6 **	23.5

† In this and subsequent tables, single asterisks denote differences significant at 95 percent levels and double asterisks denote differences significant at 99 percent levels.

TABLE 13

Vertical Distribution of Striped Bass During Flood Tides

			Mean catches per tow at various depths below surface		
Station	*Date*	*Number of tows*	*5 feet*	*15 feet*	*25 feet*
16	7/20/61	7	1.0	0.7	7.8 **
14a	7/25/60	5	2.4	10.0	11.4 **
12	6/15/61	7	0.9	21.8 **	12.9
12	7/23/60	5	2.8	14.4	34.5 **
12	7/27/61	7	0.6	14.8	64.0 **
12	8/ 2/60	10	2.4	38.9 **	24.9
30	6/27/60	5	9.2	23.0	32.0 **
7	6/16/61	7	6.7	42.0	45.4 **
7	7/13/61	7	10.0	27.8	68.0 **
5	6/14/61	5	27.5 *	15.4	2.8
5	7/12/61	7	23.5	45.2 **	24.1
1	6/24/60	5	28.8	16.8	18.4
1	7/21/60	5	6.6 **	1.0	2.5
3	6/13/61	7	50.5 **	36.5	17.8
3	7/11/61	7	14.7	23.1	28.2 **

TABLE 14

Mean Lengths of Striped Bass Caught at Different Depths

		Mean lengths at various depths		
Station	*Date*	*5 feet*	*15 feet*	*25 feet*
15	6/14/60	0.8	0.8	0.7
14a	7/25/60	1.8	1.7	1.7
12	6/15/61	0.6	0.7	0.6
12	7/23/60	1.9	1.5	1.6
12	7/27/61	1.9	1.6	1.8
12	8/ 2/60	2.4	2.1	2.0
30	6/27/60	1.0	1.1	1.1
7	6/16/61	0.7	0.7	0.8
7	7/13/61	1.2	1.1	1.1
5	6/14/60	0.7	0.8	0.7
5	7/12/61	1.0	1.0	1.0
1	6/24/60	0.9	1.0	1.0
1	7/21/60	1.4	1.4	1.5
3	6/13/61	0.7	0.7	0.7
3	7/11/61	0.9	0.9	0.9

Mean length of bass and depth were not correlated except at Station 12, where fish near the surface were larger late in the season (Table 14).

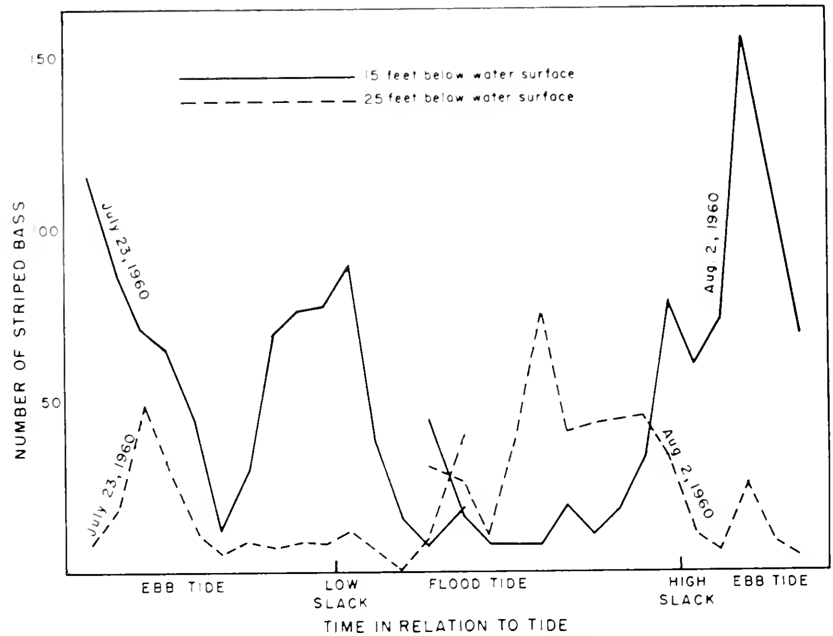

FIGURE 4. Relationship between striped bass tow net catches at different depths and tidal stage.

Horizontal Distribution

Horizontal distribution was measured between 1957 and 1961 (Tables 15 and 16).

Huge concentrations of small bass were found along the shore in the western Delta. As they grew, their distribution became more even, and in several instances significantly more of the larger bass were caught at mid-river.

Bass were more evenly distributed at Stations 1, 3, and 5, but some mid-river catches were significantly greater at Stations 3 and 5.

Variations Due to Tidal Stage

Evidence of significant vertical distribution variations related to tide was presented earlier. A comparison of the ratios of bass caught near shore to bass caught in mid-river during ebb tides with comparable ratios during flood tides (Table 17) indicates that differences were not consistent, even though they were sometimes great.

TABLE 15

Horizontal Distribution of Striped Bass During Ebb Tides

			Mean catches per tow					
		Number of tows	*Bass to 0.8 inches*		*Bass 0.9-1.4 inches*		*Bass 1.5 inches or more*	
Station	*Date*		*Near shore*	*Mid-river*	*Near shore*	*Mid-river*	*Near shore*	*Mid-river*
16	6/28/57	7	461 **	115	34	26	0	0
16	6/20/58	8	68 **	12	20 **	5	0	0
16	7/3/58	8	157 **	34	38 **	6	3 **	—
16	8/1/58	8	24 *	6	49	71	2	35 **
16	7/20/61	7	0	0	2	—	18 **	0
14a	7/22/59	8	0	0	3	9 *	6	27 **
111	7/27/57	7	0	0	0	0	5	8
30	7/26/57	7	0	0	0	0	4	11
30	7/13/58	7	14	12	4	8	0	0
30	7/16/58	8	23	18	5	8	0	0
30	7/24/58	8	28 *	10	20 **	6	4	2
12	6/15/61	6	282 **	12	7 **	1	0	0
12	7/27/61	7	6 **	—	11	9	1	21 **
7	6/16/61	5	225 **	11	25 **	4	0	
7	7/13/61	7	10	7	8	34 *	1	7 **
1	6/23/60	8	27	13	14	21	—	—
3	7/11/61	7	14	19	11	19	—	1
5	6/14/61	6	8	21 *	2	4	0	0
5	7/12/61	7	4	7 *	8	18 **	1	2 *

TABLE 16

Horizontal Distribution of Striped Bass During Flood Tides

			Mean catches per tow					
		Number of tows	*Bass to 0.8 inches*		*Bass 0.9-1.4 inches*		*Bass 1.5 inches or more*	
Station	*Date*		*Near shore*	*Mid-river*	*Near shore*	*Mid-river*	*Near shore*	*Mid-river*
16	6/20/58	4	31 *	15	21	7	0	0
16	7/3/58	4	127	29	41	8	0	0
16	7/20/61	6	6	0	6 *	1	18	9
14a	7/22/59	4	0	0	5	3	18	13
30	7/13/58	4	35 *	9	15 *	4	0	0
30	7/16/58	4	14	19	9	9	0	0
12	6/15/61	7	350 **	11	10 **	1	0	0
12	7/27/61	7	7 **	—	11	11	5	25 **
7	6/16/61	7	145 **	25	18	6	0	0
1	6/23/60	4	18	5	32 *	11	—	—
3	7/11/61	7	6	8	7	12 *	—	1
5	6/14/61	7	5	13 **	1	3 *	0	0
5	7/12/61	7	7	6	1	23 **	1	2

However, mid-river catches made on comparable tows before and following slack tide were greater on ebb tides more often than on flood tides (Table 18). Most differences were not statistically significant, but because of small samples the analysis of variance test was not very sensitive in most cases. On the other hand, the equal division of significantly larger catches between ebb and flood tides, and the lack of consistent pronounced differences at any location suggest there was no general difference in catches at different tidal stages.

TABLE 17

Ratios of Striped Bass Catch Near Shore to Catch in Mid-River During Ebb and Flood Tides

		Bass to 0.8 inches		*Bass 0.9–1.4 inches*		*Bass 1.5 or more inches*	
Date	*Station*	*Ebb*	*Flood*	*Ebb*	*Flood*	*Ebb*	*Flood*
6/20/58	16	5.6	2.3	4.0	3.0	–	–
7/3/58	16	4.6	4.1	6.3	5.1	–	–
7/22/59	14a		–	0.3	1.6	0.2	1.4
7/13/58	30	1.2	3.9	0.5	3.8	–	–
7/16/58	30	1.3	0.7	0.6	1.0		
6/15/61	12	23.5	31.8	7.0	10.0	–	
7/27/61	12	20.7	36.8	1.2	1.0	0.04	0.4
6/16/61	7	20.5	5.8	6.3	3.0	–	–
6/23/60	1	2.1	3.6	0.7	2.9		–
7/11/61	3	0.7	0.8	0.6	0.6		–
6/11/61	5	0.3	0.4	0.5	0.3		–
7/12/61	5	0.6	1.2	0.4	0.04		–

TABLE 18

Catches of Striped Bass During Ebb and Flood Tides

			Mean catch per tow	
Station	*Date*	*No. pairs of tows*	*Ebb*	*Flood*
16	6/20/58	4	15	22
16	6/27/57	6	174	151
16	7/3/58	4	52	39
16	7/20/61	7	+	9 **
14a	7/22/59	4	35	23
14a	7/25/60	5	30	24
V1	6/26/57	5	195	215
V1	7/24/57	6	16	13
12	6/15/61	7	38	36
12	7/23/60	5	65	52
12	7/27/61	7	89	109
12	8/2/60	5	115	77
30	6/27/60	5	75	64
30	7/3/58	4	15	13
30	7/16/58	4	19	28
30	7/25/57	5	8	4
30	8/7/56	5	11	13
7	6/16/61	7	52	94 *
7	7/13/61	7	142	106
5	6/14/61	7	73 **	46
5	7/12/61	7	81	93
1	6/23/60	4	28 **	16
1	6/24/60	5	56	64
1	7/21/60	5	13 **	10
3	6/13/61	7	67	105 **
3	7/11/61	7	127 **	66

Relationship of Efficiency to Water Transparency

Trawl net efficiency is generally closely related to water transparency, so tow net efficiency should be similarly related. Unfortunately, no method has been found to measure this, since there is no way of obtaining an absolute measure of bass abundance in any area, or of holding abundance constant and observing the effect of varying water transparency on catches.

Most areas inhabited by young bass are quite turbid, with turbidity declining somewhat as summer progresses. For example, Secchi disk readings at 27 stations between June 19 and 23, 1961 varied from 3 to 17 inches and averaged 11.2 inches, while on July 31 to August 3 they varied from 7 to 31 inches and averaged 13.3 inches. Changes were generally small and increases exceeded 5 inches at only five stations.

During the June 19-23 period, total catches gave no indication of relationship to turbidity at stations with Secchi disk readings less than 13 inches (Figure 5). Where readings were over 13 inches, low catches probably reflected scarcity rather than decreased net efficiency, since five of these stations were at the area's western periphery, and the two stations closest to these had readings of 3 and 11 and catches of 3 and 4. Catches were uniformly low from July 31-August 3, so they could not be related to turbidity.

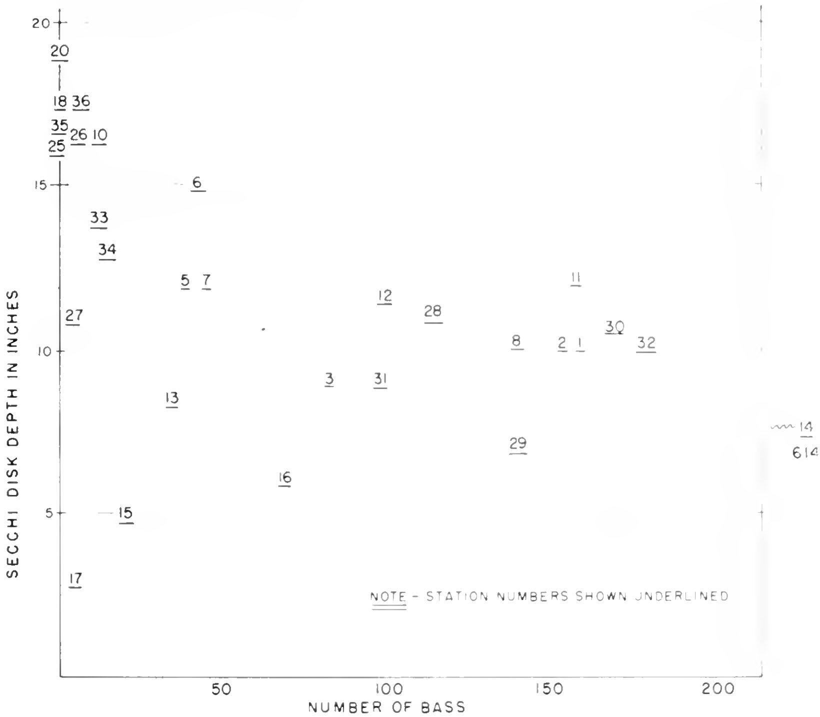

FIGURE 5. Relationship between striped bass tow net catches and water transparency during June 19-23, 1961 Delta-wide survey.

DISCUSSION

Evaluation of Indices

Accuracy of Measurements of Local Abundance

The tow net's size selectivity limited the size range of bass caught efficiently. The lower limit of the size range is clearly defined as 0.7-0.8 inches. The upper limit is not clearly defined, but apparently bass over 2.0 inches are sampled inefficiently.

Vertical distribution measurements showed that previous sampling results in Old River, which indicated 70 to 92 percent of all bass were in the top 10 feet of water (U.S. Dept. of Interior, 1957), are not universally applicable. However, those results were qualitatively similar to ours at Stations 1-5.

The varying vertical distribution of young bass is a potential source of bias, but it can be overcome by sampling all depths equally. The fact that diagonal tow catches in the Delta-wide surveys were as much as 10 times the surface tow catches (Table 8) illustrates this bias' potential importance.

The uneven horizontal distribution presents a more serious problem than does vertical distribution, since it is impractical to eliminate this bias by sampling all portions of the cross-sectional area equally. It causes estimates of abundance to be biased downwards in the areas where concentrations occur near shore. However, this bias' importance is minimized, since it occurs when the bass are relatively small, since it does not occur in all areas, and since the shallow shelf next to shore constitutes only 2 to 4 percent of the river's cross-sectional area. I estimated the error it causes by assuming bass abundances in waters less than and more than 10 feet deep were uniformly equal to concentrations indicated by shore and mid-river samples. The average underestimate was about 15 percent for bass 0.7 inches and larger on the 4 days when the greatest concentrations were near shore at Stations 7, 12, and 16. The range of the underestimates was 6 to 37 percent.

There do not appear to be any biases associated with tidal stage.

The importance of differences in water transparency is not fully known. However, general high turbidity throughout the area, the lack of correlation between catch and turbidity, and the occasional good catches at Stations 10, 18, and 26, where turbidity was lower, suggest it was not serious in the area covered by the Delta-wide surveys.

Thus, while several factors bias catches, I believe tow net samples give reasonably accurate measures of local abundance of 0.7- to 2.0-inch bass, so long as all water depths are sampled equally.

Relationship of Water Movement to Young Bass Movement

The basic premise in planning the annual surveys was an hypothesis that bass abundance in a few areas would reflect abundance over a wide area, because water moving past any locality during a large ebb tide would carry bass from a considerable distance upstream past that locality. This hypothesis was based on measurements showing water moved as much as 13 miles during large ebb tides (Calif. Div. of Water Resources, 1952). While it is evident that water flow greatly affects the movement and distribution of young striped bass, several sources of information indicate this hypothesis should be modified.

The large concentrations of young bass found along shorelines and near the bottom in some areas clearly demonstrate that bass have considerable control over their movement at an early age. While these bass are too small to maintain their position in mid-water during periods of maximum tidal movement, they apparently seek favorable areas during periods of low water velocity, so their movement cannot be assumed to be directly correlated to water flow.

Diurnal catch fluctuations at the Tracy Fish Collection Facility also indicate that young bass have considerable control over their movement. Louver screens there collect fish from water entering the Delta Mendota

Canal. Catches of striped bass are typically much greater at night than during the day (Bates *et al.*, 1960, Figure 15), indicating bass tend to maintain their position during the day and move voluntarily at night.

More recent information indicates water generally moves much less than 13 miles during a tide. For example, a float we placed in the San Joaquin River at the mouth of False River at the beginning of an ebb tide on July 29, 1957 moved a little over 7 miles downstream, and a float we placed in the Sacramento River at Three-Mile Slough about an hour after the start of an ebb tide on July 30, 1957, moved 5½ miles downstream. The tidal variations at the Golden Gate on these dates were +6.1 to −0.5 and +5.5 to −0.1. The Department of Water Resources estimated the maximum tidal movements from the Sacramento River at Stations 13a and 10, and from the San Joaquin River at Station 6 on August 20, 1959 were 8, 6, and 7 miles, respectively (Carl Warner, letter). On that day, tidal variation at the Golden Gate was +5.7 to +0.1. These water movements were at mid-river; movements near the channel's periphery are appreciably less.

Hence, it is not surprising that catches at annual survey stations did not reflect catches at stations farther upstream.

Temporal Distribution of Young Bass

The annual surveys can be biased by differences in temporal distribution even though they are made at approximately the same time in relation to bass size at Antioch. One cause of this is that survey time could vary as much as a week in relation to bass size at Antioch since minus tides occur only every other week. The rapid changes in bass abundance, indicated by differences in daily catches during the 1957-1962 annual surveys and by the differences between successive Delta-wide surveys, indicate this bias is important.

Bias also occurs because successful spawning is not distributed through the season in a similar manner each year. In years such as 1962, when the distribution was unimodal, a single survey during the peak of abundance would sample the population more efficiently than in years such as 1959, when there were several modes.

The Delta-wide surveys minimized this bias by taking several samples each season. Some differences between Delta-wide and annual survey results are partially due to this bias and show its importance. For example, the annual survey indicated the difference in abundance between 1959 and 1962 was about 20 times, while the Delta-wide survey indicated only a sixfold difference.

Geographical Distribution of Young Bass

Annual surveys would measure abundance accurately only if geographical distribution remained the same each year. When analysis of the 1954-1956 surveys showed that geographical distribution varied, the survey stations were changed to try to sample the most densely populated areas to minimize the bias. The surveys and exploratory sampling indicated this could best be done by retaining Stations I and II and selecting additional stations in Spoonbill Slough and Montezuma Slough, where large numbers of bass had been caught regularly. However, the magnitude of geographical distribution variations shown by the Delta-wide surveys (Table 7) indicates that no group of four or five stations can give an accurate indication of annual abundance.

The Delta-wide survey stations used during 1962 did not cover the whole area inhabited by young bass. Young bass probably occurred in the unsampled portions of the southeastern San Joaquin Delta in concentrations about equal to their abundance in the adjacent sampled areas (Erkkila *et al.*, 1950; Calhoun, 1953). However, the water volume there forms only a small fraction of the total volume in the Delta.

The exploratory tow net sampling and the fall seining indicated few young bass occur in the Sacramento River above Station 10. This substantiated earlier findings (Calhoun and Woodhull, 1948), so this omission was probably not important.

The omission of the western part of Carquinez Strait, San Pablo Bay, and the Napa River may have seriously biased the survey results. Appreciable bass concentrations certainly occurred in the Napa River in 1958, but this may have been a fairly unusual occurrence, since virtually no bass were caught there in 1957, 1959, 1960, or 1961. This and the fact that the water volume at the four Napa River stations included in the 1959 and 1960 surveys amounted to less than three percent of the water volume of the area now surveyed indicates omission of these stations probably causes little bias.

Some young bass are present in Carquinez Strait and San Pablo Bay, and the water is relatively clear there, so low net efficiency might cause poor catches. However, the small bass catches there in 1958, when many bass were caught in the Napa River and when many other fish were caught in San Pablo Bay, tends to refute this. We have observed schools of bass in sheltered places along the shore in this area, which may indicate they seek sheltered areas in clear water and are thus unavailable to the tow net. The water volume here is great, so the presence of a few bass could significantly bias the survey. However, I believe the bias is small, since this is certainly the periphery of the bass' range.

Comparison of Annual and Delta-wide Surveys

The three annual survey indices show similar trends, although some appreciable differences in magnitude occur, with Index A having greatest variability. This was to be expected, since it is based on more limited sampling, and it indicates that Indices B and C are superior.

While all Delta-wide survey indices had similar trends, there are appreciable differences in magnitude among indices. The differences in magnitude between Indices A and B reflect annual geographical differences in distribution and the unequal volumes of water at various stations. For example, the difference between 1960 and 1961 is due primarily to the fact that 28 percent of the 1960 catch was made at stations with water volumes over 60,000 acre-feet, while 42 percent of the 1961 catch was made at these stations. These variations indicate that weighing by volume is necessary, and that Index A is unsatisfactory.

Theoretically, Index C should be superior to Index B, since biases due to temporal variations in annual distribution would be less. The size range 1.0 to 1.4 inches has additional advantages in that the net had close to maximum efficiency in this range and few bass were either larger during the first survey or smaller during the last survey.

However, survey C was not as good as survey B, because the catches in the limited size range were affected more by chance variation than was the total catch. This is exemplified by differences in the relative abundance within different size groups (Table 9). Annual variations in growth and mortality rates would also tend to make Index B more accurate. Therefore, Index B is superior for 1959-1962 and Index D should be used in the future, since its stations cover the Delta better.

For the 1959-1962 period, both the Delta-wide and annual survey indices exhibit similar trends. However, differences in magnitude exceeded 100 percent primarily because of the annual survey's greater biases, but also because of its greater sampling variability, associated with its more limited nature. Therefore, Delta-wide surveys are preferable, not only because of their greater accuracy, but also because they provide additional information on geographical distribution.

The best estimate of relative abundance during the 10-year period can be made by combining "Annual Survey" Index A for 1953-1956, "Annual Survey" Index B for 1957 and 1958, and Delta-wide survey Index B for 1959-1962 (Table 5).

Comparison of Surveys and Catches at Tracy Fish Collection Facility

Fish in the water entering the Delta Mendota Canal are screened out by louvers at the Tracy Fish Collection Facility (Bates *et al.*, 1960). Striped bass catches there should be proportional to the abundance of bass in the sloughs south of the San Joaquin River. Delta-wide survey stations 1, 2, and 3 sampled part of this area and catches there were similar to the relative annual catches at Tracy (Table 19). This supports the accuracy of the Delta-wide surveys.

TABLE 19

Comparison of Relative Annual Abundance of Striped Bass at Stations 1, 2, and 3 with June and July Catches at Tracy Fish Collection Facility

Year	*Weighted catch at Stations 1, 2, 3*	*Ratio to 1959 abundance*	*Tracy*[1] *catch*	*Ratios to 1959 catch*
1959	13,591	1.00	8,860	1.00
1960	15,847	1.17	10,246	1.16
1961	28,333	2.08	15,166	1.71
1962	26,426	1.94	14,032	1.58

[1] To nearest thousand bass.

Causes of Uneven Local Distribution

The causes for the variability in vertical distribution are not obvious. The concentration of fish near the bottom in the western Delta was probably related to the lower water velocities there, since bass have been shown to seek areas of lowered velocity (Kerr, 1953). The upwards movement during flood tide in the western Delta may also have been related to velocities, since velocities are less during flood tides than ebb tides. However, the fact that bass generally remain near the bottom during low slack tide, come up during peak flood tide flows, and then go back down as high slack tide approaches (Figure 4) indicates it is not a simple reaction to velocity.

The differences between the eastern and western Delta are even more difficult to explain. A possible explanation is eastern Delta waters generally carry a heavy load of finely divided plant detritus. This is most dense near the bottom and could either cause bass to avoid this area or cause inaccurate sampling results by clogging the net. However, this hypothesis was discounted by the distribution at Station 7, where there also was a heavy load of plant detritus, and by the lack of any substantial change at eastern Delta stations during slack tide, when virtually all plant detritus settles to the bottom.

Another possible explanation is that water velocities are generally greater in the western Delta. However, again this cannot be a simple reaction to velocity, since there was no common distribution when velocity approaches zero at slack tide.

A reasonable hypothesis for the cause of differences in horizontal distribution between the eastern and western areas is that western areas had shallow shelves with growths of sedges (*Scirpus* sp.) extending into the water, while at eastern stations the banks dropped abruptly to 20 or more feet. The shallow areas near shore would attract fish, since water velocities would be lower, especially where the sedge growths extended into the water.

Causes of Abundance and Distribution Variations

A primary purpose of this work was to relate the abundance and distribution estimates with observations of physical and biological environmental changes, to try to identify conditions controlling spawning success. Physical factors such as salinity (Bishai, 1961), and water currents (Bishai, 1960) have been directly or indirectly related to the survival of pelagic fish eggs and larvae, and light is deleterious to trout eggs (Leitritz, 1959).

A relationship between water temperature and egg and larval bass survival would not be surprising, since striped bass spawning is closely related to water temperatures. Peak spawning usually occurs at temperatures between 60° and 67°F. (Raney, 1952), and spawning frequently ceases during periods of decreasing water temperatures in the Sacramento-San Joaquin River system (Calhoun, Woodhull and Johnson, 1950; Chadwick, 1958; Albrecht, unpublished data).

Air temperature is the only environmental factor previously shown to be related to striped bass abundance. The mean February to May air temperature in Washington, D. C. had a −0.354 correlation with the commercial catch of adult striped bass 2 years later along the Atlantic Coast from 1884-1937 (Merriman, 1941). This correlation is significant at the one percent level. Presumably, air temperature was related to egg or larval survival indirectly through other environmental factors, such as water temperature.

Correlation coefficients for the relationships between young bass abundance and water temperature, water temperature fluctuations, runoff, salinity, and light (sky cover) (Table 20) were not significantly different from 0. However, significant relationships may still exist, since correlation coefficients are quite variable for small samples (Snedecor, 1956). Estimates of bass abundance are not precise, and the most desirable environmental measurements are not available in all cases. Moreover, while one factor may affect egg and larval survival, overall survival is probably controlled by a combination of factors, so a high correlation between one factor and young fish abundance is unlikely (Ricker, 1958).

Spawning stock size is a biological factor which might determine abundance of young. While no marked relationship generally exists between the size of an adult stock and the number of recruits (Beverton and Holt, 1957), Radovich (1962) has shown that the Pacific sardine

TABLE 20

Relationship Between Abundance of Young Striped Bass and Various Environmental Factors

Year	*Abundance of young bass*	*Water temperature*[1]	*Water temperature fluctuations*[2]	*Runoff*[3]	*Salinity*[4]	*Sky cover*[5]
1953	1.23	61.1	11	659	22	158
1954	1.34	64.2	11	640	148	107
1955	0.68	61.8	15	320	112	92
1956	0.44	62.4	10	866	8	127
1957	0.48	63.6	15	503	84	165
1958	0.67	63.9	7	1,749	4	104
1959	0.38	65.3	12	224	326	95
1960	1.00	63.9	18	301	192	134
1961	1.04			259	248	130
1962	2.60				76	131
Correlation coefficient		.24	.04	.09	.13	-.17

[1] Mean April-May water temperature at Contra Costa P.G. & E. Steam Plant, Antioch.
[2] Sum of decreases in mean temperatures between successive days from the day that the mean temperature first reaches 60° F. to the end of May at the Contra Costa Steam Plant.
[3] Total measured flow to the Delta during April, May, and June in ten thousands of acre feet. From Calif. Dept. of Water Resources Water Supervision and Water Flow Bulletins.
[4] Average salinity in parts of chlorides per 100,000 parts of water during June and July at Collinsville on Sacramento River. Measurements taken 1½ hours after high high tide at 4 day intervals. From Calif. Dept. of Water Resources Water Supervision and Water Flow Bulletins.
[5] Sum of daily sunrise-sunset sky cover in 10ths during May at Sacramento Airport. From records of U.S. Dept. of Commerce, Weather Bureau.

(*Sardinops caeruleus*) population fits a model describing the relationship of stock size and environment to production of young.

Available long-term indices of adult bass abundance are based on catch statistics of limited accuracy (Chadwick, 1962), and none of these provides a suitable measure of spawning stock. The best available index of bass spawning stock is angler success in the Delta during the springs of 1959 through 1962 (Albrecht and Chadwick, m.s.). The mean catches per hour there during these springs were 0.118, 0.085, 0.074, and 0.050. These have a definite negative relationship with the index of abundance of young for these years, but the significance of this cannot be judged from so few measurements.

The distribution of young bass might also be affected by environmental conditions. Water flow and salinity are the environmental conditions most likely to affect distribution, since bass eggs and larvae are pelagic and since bass seek fresh water for spawning (Raney, 1952). In the Sacramento-San Joaquin Delta, the effects of water inflow and salinity cannot be differentiated, since they are mutually controlled. For correlation purposes, relative distribution of young bass was measured by both the percentage of the annual survey total catch made at Stations I, II, and VI for the years 1957-1962 and the proportion of the total bass catch taken above the confluence of the Sacramento and San Joaquin rivers during the two extensive 1951 surveys (Calhoun, 1953) and during the 1959-1962 Delta-wide surveys. The correlation coefficients between distribution and runoff and salinity are quite high (Table 21). The correlations with our annual survey distribution are significant at the 10 percent level and 1 percent level, respectively. While evidence based on so few years is not conclusive, it strongly indicates that young bass are farther upstream during years of high salinity and low runoff than in years of low salinity and high runoff. This could reflect either the distance adults migrate upstream to spawn

TABLE 21

Relationship Between Distribution of Young Bass and Salinity at Collinsville and Runoff to Delta

Year	*Proportion of bass catch above confluence of Sacramento and San Joaquin rivers*	*Proportion of Annual Survey total catch caught at Stations I, II, and VI*
1951	81	
1957		68
1958		49
1959	94	84
1960	94	85
1961	91	90
1962	67	83
Correlation with salinity *	+.74	+.76
Correlation with runoff †	—.78	.93

* See Table 20 for salinity measurements. 1951 salinity = 8
† See Table 20 for runoff measurements. 1951 runoff = 502.

or how far eggs and larvae are carried downstream by water currents. Facts necessary to determine the relative role of each are not available.

Relation of Recruitment to Abundance of Young

The second purpose of this study was to determine if recruitment to the fishery is related to abundance of young-of-the-year bass. This has never been measured for any striped bass population. However, good fishing on the Atlantic Coast has been related to dominant year-classes, which have been recognized in their third year by rough quantitative observations (Merriman, 1941). Dominant year-classes have not been recognized in California's striped bass population.

Striped bass enter the fishery as 3-year-olds. Good measurements of annual recruitment are not available. At present, the best measure is the angler catch per hour for 3-year-old bass in the Delta during April and May of 1959 through 1962 (Albrecht and Chadwick, m.s.). This essentially measures the relative abundance of males, since 3-year-old females are immature and do not migrate to the Delta (Chadwick, unpublished data). The respective catches per hour were 0.034, 0.033, 0.016, and 0.016. These would be recruitment indices for the 1956-1959 year-classes. Except for 1958, they parallel the abundance of young indicated by our annual surveys.

While annual recruitment cannot be measured from the total angler catch, the total catch does reflect trends in recruitment. The fall party boat fishery in Carquinez Strait-San Pablo Bay gives the best available measure of overall bass abundance (Chadwick, 1962), and has the added advantage of being largely composed of bass at the end of their third and fourth growing seasons.

The catches per hour there were 0.24, 0.35, 0.23, 0.24, 0.20 for 1957 through 1961. If recruitment is related to the abundance of young bass, these catches per hour should reflect trends indicated by spawning success surveys three or four years earlier and, except for 1957, they do. While these data suggest a direct relationship between bass recruitment and abundance of young during their first summer, the data are so limited I consider this to be a tentative hypothesis.

Growth and Survival

The 2-week growth increments of 0.3 to 0.7 inches are smaller than comparable growth increments of 0.5 to 1.1 inches reported in the Patuxent River (Mansueti, 1958). As a result, Patuxent River bass average over 2 inches long in early July, while bass in the Delta average 1.0 to 1.5 inches long then, despite the fact that peak spawning occurs during May in both places.

Growth increments were greatest in 1959 and smallest in 1962, suggesting that growth may be negatively correlated with abundance.

The relationship between bass size and net efficiency precludes accurate survival estimates from tow net catches. However, the coincidence of modes in our 1959 and 1960 Delta-wide surveys indicates biweekly cycles in spawning time or survival, since surveys were taken at 2-week intervals. Tidal stage is the only environmental factor having an obvious 2-week cycle, so survival or spawning intensity may be related to tidal stage.

The decreasing annual variations in abundance indices as bass size increased from 1-inch to over 2 inches (Table 9) could be caused by density dependent mortality. However, the small annual variations among 0.3- to 0.5-inch bass would not be expected if this were true. Hence, the small annual variations were probably chance similarities among the small catches within the largest and smallest size groups.

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I thank the California Department of Water Resources for calculating water volumes, and the Pacific Gas and Electric Company for providing the water temperature measurements.

SUMMARY

We sampled young-of-the-year striped bass to measure their relative abundance throughout their range in the Sacramento-San Joaquin River system. We did this to obtain a measure of annual abundance which could be used to determine: (i) if spawning success and recruitment are correlated, and (ii) which environmental factors control spawning success.

Sampling was done with a fixed frame tow net, which earlier studies had shown was efficient for sampling young bass. The sampling included: (i) various experiments to determine if the tow netting accurately measured abundance in the immediate area of sampling; (ii) annual surveys consisting of one series of samples at a few stations to try to develop an annual index of abundance; (iii) Delta-wide sur-

veys consisting of repeated sampling at many stations throughout the bass' range to develop an index of abundance suitable for determining if our annual surveys accurately measured abundance; and (iv) limited exploratory tow netting and seining to determine the range of young-of-the-year bass.

Experiments to determine if tow netting accurately measured local abundance showed that it did measure the abundance of 0.7- to 2.0-inch bass reasonably accurately, at least within our Delta-wide survey area. Accuracy requires sampling all depths equally because the vertical distribution of bass is not uniform and is also variable. Variations in horizontal distribution biased sampling of smaller bass in some areas, but this bias appeared to be relatively insignificant. The effects of water transparency were not thoroughly evaluated, but the available evidence indicates it was not a serious problem in the survey area.

The uneven distribution is largely unexplained, but behavioral characteristics partially related to tidal stage and water velocity are important. These behavioral characteristics indicate that even very young bass have considerable control over their distribution and movement.

Our annual and Delta-wide surveys showed important annual geographical and temporal differences in bass distribution, although the Delta-wide surveys showed that most of the population was in the Sacramento and San Joaquin rivers within a few miles of their confluence. Marked changes in abundance at given localities occurred within 2 days, and overall abundance in the Delta changed significantly within 2 weeks.

Biases associated with these differences were the primary cause of substantial errors in our annual survey abundance estimates. These errors tended to magnify annual variations. Delta-wide surveys provided more accurate measures of annual abundance, although they were also somewhat biased, because tow netting and seining showed they did not cover the entire nursery area, and there were biases in the accuracy of local measurements.

Our annual surveys indicated that young bass declined in abundance from a 1953-54 peak to a 1959 low and then increased to a 10-year high in 1962. The Delta-wide surveys showed a similar 1959-1962 trend.

No relationships were detected between young bass abundance and water temperature, water temperature fluctuations, runoff, salinity, light, or spawning stock size. However, the available data are inadequate for a definitive evaluation. The data do show their distribution probably has a relationship to salinity and water runoff to the Delta, with bass being farther upstream in years of greater salinity intrusion and lower runoff.

The results also suggest a direct relationship between abundance of young-of-the-year bass during the summer, and year-class recruitment. They also indicate that growth of young bass is slower here than in the Patuxent River, and is negatively related to abundance.

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APPENDIX A

Water Volumes[1] of Delta Segments Represented by Delta-wide Survey Stations

Station	*1959-61 volume*	*1962 volume*	*Station*	*1959-61 volume*	*1962 volume*
1	23		19	213	
2	15		20	14	
3	15		21	5	
4	11		22	1	
5	21		23	3	
6	40		24	113	
7	56		25	13	
8	22		26	46	
9	5		27	81	60
10	32		27a		19
11	52	35	28	15	
11a		27	29	9	
12	63	53	30	62	52
13	90	43	30a		26
13a		31	31	11	
14	4		32	5	
15	15		33	8	
16	20		34	10	
17	44		35	22	
18	84	70			

[1] Volumes in thousands of acre feet at mean half-tide with an estimated reliability of ± 15 percent. Estimates made by Delta Branch, California Department of Water Resources.

SOME OBSERVATIONS ON FACTORS ASSOCIATED WITH SURVIVAL OF STRIPED BASS EGGS AND LARVAE [1]

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INTRODUCTION

Striped bass, *Roccus saxatilis* (Walbaum), are the primary gamefish inhabiting the Sacramento-San Joaquin Delta. They have flourished there since being introduced from New Jersey in 1879.

The population is now threatened by habitat changes which will result from a planned water development project. Although the specific plan for this project has not been selected yet, it will certainly alter current, salinity, and temperature conditions in a major portion of the present striped bass spawning grounds. Knowledge of the possible effects of these changes on striped bass reproduction is needed to insure adequate consideration for this species in the final project design. This paper reports the results of laboratory experiments conducted during 1962 and 1963 to determine these effects.

In conjunction with these experiments, measurements were made of the diameter, specific gravity, and vertical distribution of developing striped bass eggs. This information could be useful in designing screening apparatus to protect the developing semi-buoyant eggs from water diversion pumps.

This work will also aid in evaluating the feasibility of introducing striped bass into reservoirs, since lack of successful reproduction is believed to be the cause of failure in attempts to establish striped bass populations in freshwater impoundments.

There have been no previous laboratory studies of the factors which may affect striped bass egg and larval survival, but many field observations have yielded pertinent facts.

Actual observation of spawning (Woodhull, 1947; Morgan and Gerlach, 1950), and the collection of recently-spawned, developing eggs (Pearson, 1938; Woodhull, 1947; Calhoun and Woodhull, 1948; Calhoun *et al.*, 1950; Tresselt, 1952; and Rathjen and Miller, 1957) have shown that striped bass spawn in fresh water in a moderate to swift current. Mansueti (1958a) infers that suspension of the semi-buoyant striped bass egg by water current is necessary for its survival. Considering the failure of striped bass to reproduce in freshwater impoundments, this is a logical assumption, but it apparently has not been substantiated by experiments or direct field observations.

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Spawning has never been observed in brackish or salt water. Tresselt (1952) collected developing eggs at salinities up to 2,000 ppm, and we in California have captured newly-hatched bass in brackish waters frequently, but they could have easily drifted into these areas from fresh water. Concerning brackish water spawning, Mansueti (1958a) states, "The production of eggs in brackish waters, of greater density than the eggs, would probably insure floatation, and hence survival, especially in quiet waters." This would also apply to eggs produced in fresh water and carried into brackish water. No previous studies have been made to determine the maximum salinity that will allow egg and larval survival.

Water temperature is the principal factor controlling the time of striped bass spawning (Calhoun *et al.*, 1950; Erkkila *et al.*, 1950; Rathjen and Miller, 1957; and Chadwick, 1958). The minimal temperature at which spawning occurs in most areas is about 58 F. Peak activity occurs at 60-65 F, and declines rapidly thereafter. At these temperatures, 2 days or less are required for hatching.

Striped bass eggs have been incubated successfully at temperatures ranging from 58 F. (Bigelow and Welsh, 1925) to 72 F. (Merriman, 1941).[2] However, no previous attempt has been made to determine temperature tolerance limits, or the effect of temperature fluctuation on egg survival.

Numerous diameter measurements of developing striped bass eggs been made on the Atlantic Coast (Pearson, 1938; Merriman, 1941; Mansueti, 1958a; and Mansueti and Hollis, 1963). Generally, means of approximately 3.5 mm were observed, with a range of 2.4 to 3.95 mm. Smaller eggs (1.32-1.53 mm) were collected from the Blackwater, Transquaking, and Manokin rivers (Mansueti and Hollis, 1963). In California, Woodhull (1947) reported a mean diameter of 3.3 mm for a preserved sample of eggs from the San Joaquin River.

The specific gravity of the striped bass egg has not been measured previously. Pearson (1938) and Mansueti (1958a) both state that the striped bass egg "is slightly heavier than fresh water," suggesting a specific gravity slightly greater than 1.0.

Observations on the depth at which striped bass eggs move in the water are conflicting. Surface and bottom samples, in which there were large numbers of eggs, taken from two stations on the Mattaponi River, Virginia, indicate a greater egg concentration on the surface (Tresselt, 1952). In the Hudson River, New York, Rathjen and Miller (1957) found a subsurface net (18 to 20 feet) was more efficient (1.42 eggs/hour) than a surface net (0.44 eggs/hour) or bottom trawl (0.61 eggs/hour). Hatton (1942) and Woodhull (1947), concerning limited collections in the Sacramento-San Joaquin Delta, report egg concentrations near the bottom.

METHODS

Developing striped bass eggs were collected from the Sacramento and San Joaquin rivers by large-mesh plankton nets (23 meshes/inch) set in the current from an anchored skiff. These nets were 20 inches in diameter, with a cone approximately 4 feet long. A quart Mason jar was attached at the apex of each net.

[2] See Mansueti, 1958a, Table 3, page 10, for a summary of published hatching times of striped bass eggs.

Collected eggs were placed in 5,000 ml round-bottom flasks and incubated under the desired physical conditions. Approximately 100 eggs were placed in each hatching flask. The period from time of collection to the start of the incubation tests varied from 1 to 4 hours.

Tests of the effect of egg suspension were made in fresh water agitated with air to suspend eggs either over a gravel substrate or with no substrate. These were compared with tests in which eggs were allowed to rest on a gravel substrate. In all other tests, eggs were kept suspended by air agitation in water of desired temperature and salinity without any substrate. One observation was made on egg tolerance to sunlight by exposing 100 developing eggs in a 2,500 ml open-top jar to bright sunshine for 5 hours, and retaining a similar shaded control.

Only one attempt was made to keep larval bass alive beyond the absorption of their yolk sac. These fish were fed daily rations of brine shrimp.

All eggs for the laboratory rearing experiments were collected in the temperature range of 61 to 68° F. Acclimatization to the desired temperature was gradual, usually over a period of approximately 30 minutes. Temperature was controlled by placing the hatching flasks in water baths, supplied either with tap water or water recirculated from a Harshaw temperature control unit. The initial 1962 hatching experiments were conducted in the Delta Field Base near Antioch. Diurnal temperature fluctuations in the building resulted in temperature changes of about 10 F. in the water bath. Some 1962 and all 1963 experiments were conducted in the Sacramento Field Station where a temperature control unit was available and temperature fluctuations could be kept under 2 F.

Saline solutions consisted of brackish San Francisco Bay water mixed with fresh American River water. Eggs were transferred directly into the desired saline solution without any acclimatization.

Chloride analyses of the San Francisco Bay water were made by the chemical laboratory of the California Department of Water Resources using the Mohr method. Water samples for oxygen determinations were siphoned from the center of the hatching flasks at the time of the first larva count, and analyzed by the Rideal-Stewart modification of the Winkler Method.

Eggs and larvae were measured using an ocular micrometer in a dissecting microscope.

Egg specific gravity was measured by placing individual eggs in a series of saline solutions of known densities and observing if they floated, remained suspended, or sank. Saline solutions of various densities were prepared using 99.8 percent pure NaCl and distilled water. After the approximate egg specific gravity was determined, a series of NaCl solutions ranging in density from 1.00030 to 1.00065, with intervals of approximately 0.00005, were prepared for the measurements reported here. Individual eggs were assigned the specific gravity value of the solution they were most equal to in density. New solutions were usually prepared for each sample of eggs. Eggs were transferred from one solution to the next on the tip of an eye dropper, using care to avoid contamination of each solution. Eggs with a damaged chorion were not used.

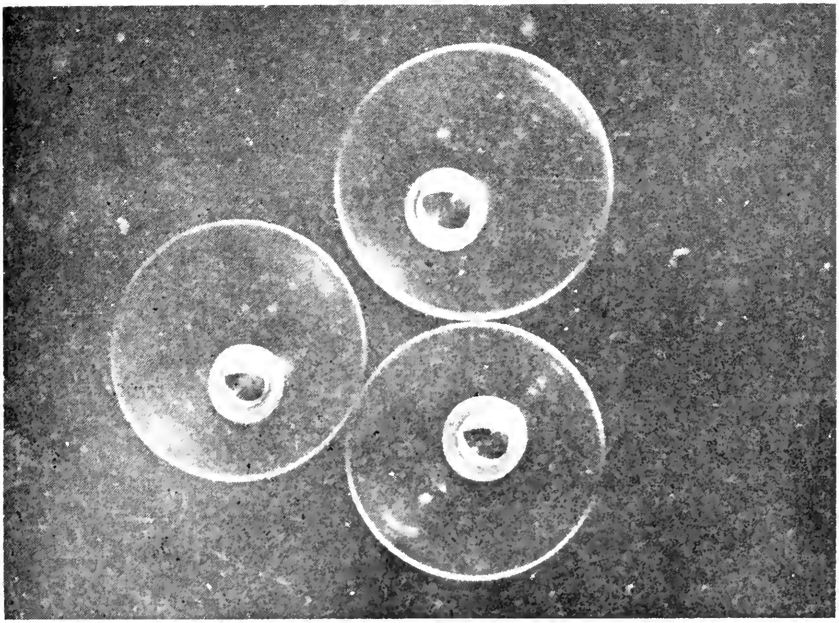

FIGURE 1. Top view, striped bass eggs less than 12 hours old at 64 F. Photograph by William E. Schafer, June 1963.

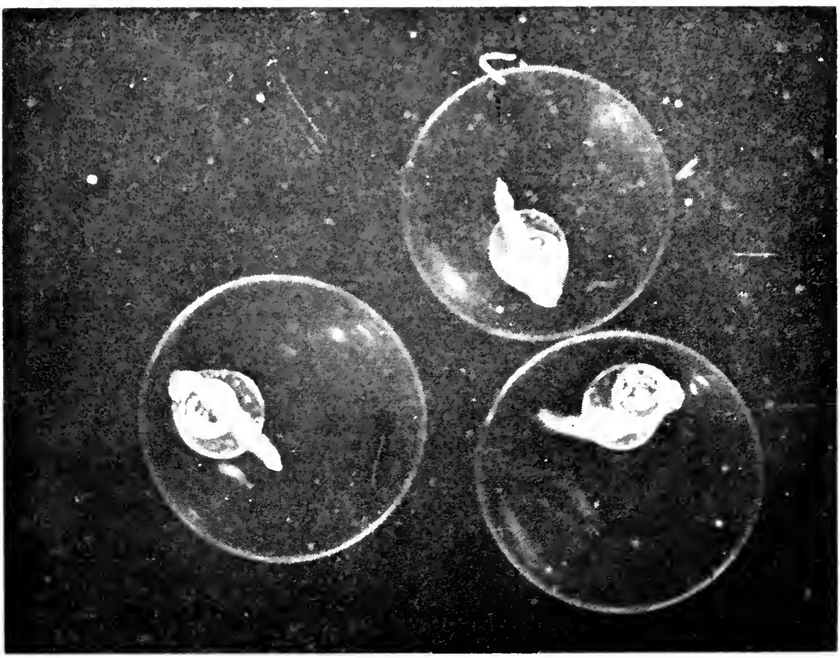

FIGURE 2. Top view, striped bass eggs approximately 36 hours old at 64 F. Photograph by William E. Schafer, June 1963.

FIGURE 3. Striped bass larvae shortly after hatching. *Photograph by William E. Schafer, June 1963.*

Measurements of egg diameter and specific gravity were made in quarter stages of egg development, based upon a hatching time of 48 hours at 62 F. Drawings from Mansueti (1958a) aided in aging the collected eggs.

The vertical distribution of developing bass eggs was studied by fishing three plankton nets simultaneously at different depths and comparing catches. Subsurface nets were fished slightly longer than the surface net, but the number of eggs collected per minute of sampling was determined for each net and employed in calculating egg density at various depths. Net sets ranged from 10 to 20 minutes in duration. Water velocity was recorded with an Ott current meter.

RESULTS

Suspension of Developing Eggs

In all laboratory experiments, eggs kept suspended by air bubble agitation of the water hatched better than those allowed to rest on a substrate (Table 1). Eggs suspended in flasks without any substrate had a mean hatch of 81 percent, and eggs suspended over a gravel substrate had an average hatch of 61 percent. The lower hatch in the latter case may have been due to difficulties encountered in keeping eggs suspended over the gravel substrate. In comparison, no eggs allowed to rest on a gravel substrate without aeration hatched, and only an average of 8 percent of the eggs resting on a gravel substrate with aeration at the surface hatched.

TABLE 1

Survival of Striped Bass Eggs Suspended by Aeration Over No Substrate (NS), Suspended by Aeration Over a Gravel Substrate (SG), Resting on a Gravel Substrate, Aeration at Surface (RG), and Resting on a Gravel Substrate, No Aeration (NA)

Date started	*Condition*	*Water temp. F.°*	*D. O. ppm*	*No. of eggs*	*Time interval (hours)**	*Live larvae (percent)*
5/6/62	NS	62-72	7.7	100	50	92
	"	"	8.4	100	"	93
	"	"	8.3	50	"	58
	RG	"	7.9	100	"	3
	"	"	8.0	100	"	8
	"	"	8.0	50	"	0
	NA	"	7.0	100	"	0
	"	"	6.4	100	"	0
	"	"	7.1	50	"	0
5/6/63	SG	62-64	8.8	100	72	38
	RG	"	7.5	100	"	0
5/9/63	SG	62-64	9.1	88	72	93
	RG	"	8.8	88	"	10
5/14/63	SG	62-64	8.8	100	72	51
	RG	"	9.0	100	"	27

* In this and following tables, hours refer to the time period from the start of the test to the larva count.

The average oxygen content of the flasks in which air was introduced at the surface was only 0.3 ppm lower than in those flasks with the air introduced near the bottom. Water samples for these measurements were siphoned from the center of the hatching flasks, so micro-oxygen deficiencies could have existed in the immediate perimeter of each egg. Also, fine debris settled on the chorion of eggs not in suspension, and could have interfered with the respiration of the developing embryo.

Egg and Larval Salinity Tolerance

Laboratory experiments indicated striped bass eggs can withstand a moderate increase in salinity, and that survival of the resulting larvae is best in water of slight salinity (Table 2).

In 1962, hatches of 63, 89, and 94 percent were obtained in water of high salinity (chlorides 14,100 ppm); however, the resulting larvae reared in this water suffered an almost complete mortality within 48 hours after hatching. Hatches in fresh water controls ranged from 87 to 93 percent, and 5 days after hatching 75 percent still survived.

The second year's results were similar but larval survival was more variable. High hatches were achieved at salinities up to 9,480 ppm of chlorides. Survival was consistently high in water of low salinity (chlorides 920-948 ppm), and relatively good in fresh water and water of moderate salinity (chlorides 4,595-4,740 ppm). Survival in water of higher salinity (chlorides 9,190-9,480 ppm) was good in one of three flasks; however, many of these fish were deformed.

Standard lengths and yolk absorption were similar for larvae developing at the various salinities (Table 3). The yolk sac was over 50 percent absorbed at 6 days, and growth in body length ceased.

TABLE 2

Survival of Striped Bass Eggs and Larvae at Various Salinities

Date started	Chlorides ppm	Water temp. F	D. O. ppm	Number of eggs	Percentage of larvae surviving (hours)			
					40	64	88	160
5-11-62	76	58-65	8.4	120	87			
	7,088	"		120	90			
	11,100	"	7.1	120	94			
5-21-62	Fresh	60-73	7.9	133	93			
	Fresh	"	7.8	99	88	88*	82	71
	11,100	"	7.0	133	63			
	11,100	"	6.9	133	89	26*	2	1
					72	144	216	264
5-6-63	Fresh	62-64	8.5	100	97	83	54	37
	Fresh	"	9.7	100	76	65	41	30
	920	"	7.7	100	100	95	94	94
	920	"	8.8	100	96	78	71	67
	4,595	"	8.5	100	91	69	47	42
	4,595	"	8.5	100	100	59	47	42
	9,190	"	8.1	100	96	10		
	9,190	"	8.2	100	98	70	42	34
5-17-63	Fresh	64	--	100	93	24	2	
	948	"	--	100	95	68	46	
	4,740	"	--	100	92	45	18	
	9,480		--	100	90	56	14	

* Surviving larvae combined.

TABLE 3

Mean Standard Length (s.l.) and Mean Yolk Mass Length (y.l.) in mm of Striped Bass Larvae Reared in Water of Various Salinities at 64° F.

	72 hours			144 hours			216 hours		264 hours	
Chlorides ppm	Larvae	s.l.	y.l.	Larvae	s.l.	y.l.	Larvae	s.l.	Larvae	s.l.
Freshwater	13	5.0	1.1	6	5.9	.5	5	5.7	11	6.0
920	10	4.6	1.0	5	6.0	.6	4	6.0	12	5.8
4,595	9	4.8	1.0	5	5.9	.6	5	5.8	12	6.1
9,190	—	—	—	8	5.6	.6	5*	5.4	17**	5.6

* 3 deformed bass.
** 3 deformed bass.

The tolerance of larval bass to sudden salinity increases was investigated also (Table 4). Three-day-old larvae from eggs hatched in fresh water were transferred to saline solutions of 948 and 4,740 ppm of chlorides. One freshwater control was retained. At the age of approximately 6 days, the larvae in all three solutions were fed brine shrimp daily. Survival was better in saline solutions over a 3-week period; however, brine shrimp survived better in the salt water also, so the more continuous food supply could have enhanced bass survival. Cannibalism was noted at the age of about 2 weeks and it became more prevalent as the bass grew.

TABLE 4

Survival of Striped Bass Larvae when Transferred (T) from Fresh Water to Saline Water

Date started	*No. of eggs per jar*	*Temp. F°.*	*Live larvae (72 hrs.)*	*T, 5/28 (96 hrs.)*	*Live larvae (Days)*** 1	6	23
5/24/63	100	65	97	No T	83	31	9
5/24/63	100	65	99	948 ppm *	90	41	23
5/24/63	100	65	88	4,740 ppm *	86	39	19

* Chlorides.
** Days after transfer from fresh water.

Egg and Larval Temperature Tolerance

The previously described 1962 egg suspension and salinity tolerance experiments indicated 10 F. temperature fluctuations between 58 and 73°F. do not prevent hatching, since an average of 85 percent of the eggs in five fresh water tests hatched (Tables 1 and 2).

Other laboratory experiments indicated eggs and larvae can survive at various constant temperatures ranging from 55 to 75°F. (Table 5). Only 2 of 53 eggs held at 52 F. hatched. At 55 F., a mean hatch of 88 percent was obtained in three flasks, while at 62-64 F., a mean hatch of 85 percent was obtained in six tests. The highest mean hatch, 97 percent, came from three flasks held at 67-69 F. At 75 F., survival at 72 hours was 67 percent, while at 80 F. it was only 7 percent.

TABLE 5

Survival of Striped Bass Eggs and Larvae at Various Water Temperatures

Date started	*Water temp. F.*	*D. O. ppm*	*No. of eggs*	*Live larvae (percent)* *40 hours*	*144 hours*
5/29/62	52	-	53		4
5/29/62	67–69		53	98	83
5/29/62	74–78		53	66	45
				24 hours	*90 hours*
6/7/62	67–69	–	108	97	86
6/7/62	"	–	108	96	74
6/7/62	70–76	–	108	93	76
6/7/62	"	–	108	81	57
				72 hours	*144 hours*
5/6/63	62–64	8.7	100	81	71
5/6/63	"	8.5	100	97	83
5/6/63	"	8.7	100	76	65
5/6/63	80	7.5	100	3	–
5/6/63	"	7.5	100	17	–
5/6/63	"	7.2	100	2	–
5/14/63	62–64	8.8	100	85	51
5/14/63	75	7.6	100	76	11
5/15/63	62–64	8.7	91	78	20
5/15/63	75	8.1	91	71	4
5/17/63	62–64	8.7	100	93	24
5/17/63	75	7.6	100	55	1
6/10/63	55	–	100	90	60
6/10/63	"	–	100	90	30
6/10/63	"	–	100	83	54

Larval mortality occurred sooner at the higher temperatures. This was probably due to faster yolk absorption, and because no provision was made for other nourishment. Yolk absorption at 72 hours in the larvae reared at 75 F. was nearly comparable to yolk absorption in larvae reared at 62-64 F. at 144 hours (Tables 3 and 6). Hence, survival might be similar at these two temperatures if adequate food was available.

TABLE 6

Mean Standard Length and Mean Yolk Length (in mm) of Striped Bass Larvae Reared in Fresh Water of Various Temperatures at 72 Hours

Date started	*Water temp. F.*	*Larvae examined*	*Standard length*	*Yolk length*
6/10/63	55	5	4.4	1.3
5/17/63	64	4	4.7	1.0
5/17/63	75	4	5.0	.8
5/18/63	64	4	4.6	.9
5/18/63	75	5	5.3	.7
5/9/63	64	13	5.0	1.2
5/9/63	80	13	4.9	.5

Egg Tolerance to Sunlight

One observation was made on the effect of sunlight on egg survival. Ninety-three of 100 eggs in an open-top 2,500 ml jar, exposed to 5 hours of bright sunshine, hatched. A control, not exposed to the sunlight, had a 78 percent hatch.

Egg Diameter and Specific Gravity

The diameter and specific gravity of eggs in seven collections were measured (Table 7). Eggs in five collections from the lower San Joaquin River ranged from 3.3 to 4.6 mm in diameter, with means of 3.8 to 4.0 mm. Eggs in two collections from the Sacramento River near Sacramento ranged from 2.5 to 3.8 mm in diameter, with means of 3.2 and 3.3 mm. Egg specific gravity measurements ranged from 1.0003 to 1.00065,[3] with means of approximately 1.0005.

TABLE 7

Diameter and Specific Gravity Measurements of Striped Bass Eggs Collected in the Sacramento and San Joaquin Rivers

Date	Locality	Number of eggs	Diameter (mm)		Specific gravity	
			Range	Mean	Range	Mean
April 17, 1962	San Joaquin River	84	3.4-4.3	3.8	--	--
April 23, 1962	San Joaquin River	25	3.3-4.6	3.9	1.00033*-1.00053	1.00045
April 25, 1962	San Joaquin River	20	3.8-4.2	4.0	1.00042 -1.00065	1.00050
May 7, 1962	San Joaquin River	83	3.3-4.4	3.9	1.00033 -1.00065	1.00051
June 12, 1962	Sacramento River	50	2.7-3.8	3.3	1.00046 -1.00062+**	1.00055
June 13, 1962	Sacramento River	64	2.5-3.6	3.2	1.00042 -1.00062+***	1.00054
May 13, 1963	San Joaquin River	25	3.3-4.1	3.8	1.00033 -1.00053	1.00043

* One egg, 4.6 mm in diameter, had a specific gravity of approximately 1.00006.
** Four eggs sank slowly in a NaCl solution of 1.00062. They were assigned a value of 1.00065 for calculation of the specific gravity mean.
*** Two eggs sank slowly in a NaCl solution of 1.00062. They were assigned a value of 1.00065.

[3] The most dense saline solution used for measuring the Sacramento River collections had a specific gravity of 1.00062. Six eggs sank slowly in this solution and were assigned a specific gravity value of 1.00065 for calculating the mean.

No differences in egg size or specific gravity were noted among quarter stages of egg development. The May 7, 1962 collection provided the best comparison of these measurements (Table 8).

There was an inverse correlation between diameter and specific gravity in the eggs collected from the Sacramento River on June 12 and 13, 1962 (Table 9). This suggests that larger eggs are more buoyant.

TABLE 8

Diameter and Specific Gravity Measurements of 83 Striped Bass Eggs Collected May 7, 1962 from the San Joaquin River Near Antioch

Egg age (hours)	Number of eggs	Diameter (mm) Range	Diameter (mm) Mean	Specific gravity Range	Specific gravity Mean
0-12	20	3.6-4.1	3.9	1.00033-1.00065	1.00051
12-24	21	3.7-4.1	4.0	1.00037-1.00059	1.00047
24-36	22	3.3-4.3	3.9	1.00037-1.00065	1.00051
36-48	20	3.6-4.2	3.9	1.00037-1.00065	1.00053
Totals	83	3.3-4.4	3.9	1.00033-1.00065	1.00051

TABLE 9

Mean Specific Gravity by Egg Diameter of 114 Striped Bass Eggs Collected June 12 and 13, 1962, from the Sacramento River, Sacramento

Egg diameter (mm)	*Number of eggs*	*Mean specific gravity*
2.5	3	1.00064
2.6	0	
2.7	1	1.00065
2.8	3	1.00063
2.9	2	1.00064
3.0	10	1.00057
3.1	11	1.00054
3.2	16	1.00054
3.3	24	1.00054
3.4	16	1.00053
3.5	15	1.00050
3.6	9	1.00050
3.7	3	1.00050
3.8	1	1.00050

Vertical Distribution of Developing Eggs

All observations of the vertical distribution of developing striped bass eggs were made in the San Joaquin River above the Antioch Bridge. Only those sets in which 20 or more eggs were collected are reported here.

Considerable numbers of eggs were observed at all collecting depths at various tidal velocities (Table 10). At surface velocities of 0.6 to 0.9 feet-per-second, eggs were generally collected in larger numbers near the bottom, while at higher velocities distribution was more variable.

TABLE 10

Vertical Distribution of Developing Striped Bass Eggs at Various Tidal Velocities in the San Joaquin River Near Antioch, 1962

Date	Tide	Surface velocity ft./sec.	No. of eggs per 3 nets	Percentage of total by net: Surface 0-5′	Mid-water 10-15′	Bottom 15-25′
5/8	flood	.6	34	24	18	57
5/29	flood	.9	81	25	37	38
5/29	flood	.9	35	28	29	44
4/15	flood	.9	29	81	11	7
5/8	ebb	.9	20	0	26	74
5/5	ebb	1.1	10,661	66	27	7
5/29	flood	1.5	24	39	49	12
5/29	flood	1.6	36	0	83	18
5/29	flood	1.7	25	22	54	25
4/24	ebb	1.8	185	37	59	5
5/29	flood	1.9	77	32	6	62
4/24	ebb	2.0	1,022	38	44	17
5/29	flood	2.1	37	37	48	15
5/8	ebb	2.3	552	73	19	8
5/8	ebb	2.7	1,456	56	23	22
5/8	ebb	2.9	2,065	59	25	16
5/8	ebb	2.9	415	65	31	4

In four consecutive large collections, made at velocities exceeding 2.3 feet-per-second, eggs were more concentrated near the surface. However, in another large collection made at a velocity of 1.1 feet-per-second eggs were also concentrated near the surface. This suggests that large egg collections may indicate recent spawning at or near the surface, and that these eggs may not have had time to disperse.

DISCUSSION

The laboratory hatching and rearing experiments had some major limitations. Plankton netting provided a relatively small number of eggs and many of these were in an advanced stage of development. Thus, they were exposed to the desired physical incubating conditions for only a brief period before hatching. Also, most tests were short in duration because of a high larval mortality. This morality has been reported previously in a rearing experiment (Mansueti, 1958b) and also has been experienced at the Weldon striped bass hatchery (Raney, 1952). Despite these limitations, some definite conclusions can be drawn from this study's results.

The results indicate egg suspension by water movement is important for egg survival, and the current velocity required to insure egg suspension in fresh water is apparently about 1 foot-per-second. Since striped bass eggs normally take 2 days to hatch, about 30 miles of water flowing at 1 foot-per-second would be required to suspend eggs throughout development. However, it is possible that striped bass eggs do not need to be kept suspended continuously during incubation, and that partial or periodic intervals of suspension might suffice.

Since striped bass seek temperatures of 58° to 65° F. for spawning, and eggs and larvae can survive in constant or fluctuating water temperatures between 55 and 75° F., temperature does not appear to be a factor limiting egg and larval survival. However, Mansueti (1958b) believes starvation is the principal cause of larval mortality. Thus, at higher water temperatures the availability of natural food would become more important to larval survival.

While no one has observed striped bass spawning in brackish or salt water, their eggs have been observed in slightly saline water. This study's results indicated that eggs and larvae can survive at all salinities likely to be encountered under natural conditions. They also indicated that low salinity enhances larval survival. The importance of this needs more evaluation.

The one observation made on tolerance of eggs to sunlight indicated water clarity does not adversely affect egg survival.

Since suspension of the developing egg appears to be necessary for its survival, the factors concerned with egg buoyancy need to be considered. Egg diameter and specific gravity measurements indicated larger eggs tend to have a slightly lower specific gravity. Thus, they would be more buoyant and probably survive better. Previous studies, reviewed earlier, and our egg collections made in the Sacramento and San Joaquin rivers indicate considerable differences in egg sizes from different areas. The sizes of striped bass eggs collected from the Sacramento River at Sacramento (2.5 to 3.8 mm) correspond closely with the general sizes of bass eggs on the Atlantic Coast, while bass eggs collected from the lower San Joaquin River were considerably larger than any reported previously. However, since only two egg collections were made in the Sacramento River, it is not known if these eggs are consistently smaller than those produced in the San Joaquin River.

Mansueti (1958a) recognized egg size variation on the Atlantic Coast and listed three possible causes: (i) arrested expansion of the chorion caused by high osmotic pressure from a sharp salinity gradient; (ii) fish size; (iii) actual differences in size of eggs produced by bass from different areas. His data do not support this latter thesis.

The increase in osmotic pressure, caused by a salinity gradient, does not explain the size difference between eggs in the Sacramento and San Joaquin rivers, since there is no sharp gradient. In fact, egg size is the reverse of what would be expected from this theory since salinity is lower in the Sacramento River.

If egg size is related to fish size, and if larger eggs survive better, conservation of large bass might be desirable, providing recruitment is correlated with egg survival. However, it should be noted that there is some evidence of intermittent spawning in older female bass (Lewis, 1962).

If egg size and buoyancy are related to physical factors in the environment, certain specific areas are probably more valuable than other areas for striped bass production and special effort should be made to preserve them. However, the effects of slight salinity differences, and the importance of natural food availability need more evaluation to determine if such critical areas for larval survival exist.

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SUMMARY

Developing striped bass eggs were collected by large-mesh plankton nets from the Sacramento and San Joaquin rivers, and incubated under various water movement, salinity, and temperature conditions to study the effects of these factors on egg and larval survival. Suspension of developing eggs by water movement enhances egg survival; low salinity (920-948 ppm chlorides) enhances egg and larval survival, and moderate salinity (4,595-4,740 ppm chlorides) is not detrimental; and, eggs can survive in either constant or fluctuating water temperatures ranging from 55 to 75° F. A relatively small supply of eggs, many in an advanced stage of development when collected, and a high natural larval mortality, limited the preciseness of these results.

Egg diameter and specific gravity measurements were made also. Eggs collected in the lower San Joaquin River during May averaged 3.8-4.0 mm in diameter, while eggs collected from the upper Sacramento River in June averaged 3.2-3.3 mm. The average specific gravity of striped bass eggs was approximately 1.0005, with a range of 1.0003 to 1.00065. Egg specific gravity was related to egg size, with larger eggs having a slightly lower specific gravity. Egg diameter and specific gravity were not related to egg age.

Observations of the vertical distribution of developing eggs indicated eggs are generally concentrated nearer the bottom at velocities less than 1 foot-per-second. Egg distribution at greater velocities is probably quite random.

Of the factors investigated, egg suspension was the most important to egg survival. Since egg buoyancy is related to egg size, a knowledge of the factors affecting egg size is needed.

Salinity and temperature fluctuations, within the range likely to be encountered, were not detrimental to egg survival, but larval survival was enhanced by low salinities, and larval mortality was greater at higher temperatures. Further work on the role of slight salinity differences and natural food availability is needed to evaluate the significance of these results.

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PARTYBOAT LOGS SHOW HOW SKINDIVERS FARED DURING 1960, 1961, AND 1962[1]

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Skindivers, particularly in southern California, are chartering an increasing number of fishing boats each year in an effort to find first-rate diving. California law (California Department of Fish and Game, 1961a) requires the operators of fishing (diving) charters to keep daily records of the fish caught from their boats. This paper summarizes all diving catch records received from 1960 through 1962 except a few unreadable, incomplete, or improbable logs.

Greater charter-diving effort in southern California, as compared to central and northern California, is apparently fostered by physical factors. The ocean is warmer, ranging to 70° F. or more, and usually is quieter. To reach many of the better diving areas, a boat is required, whereas good diving from shore is abundantly available along central California coast. Water clarity may also be a plus factor in the south.

Unlike hook-and-line fishermen, skindivers are not limited to whatever action is provided when the fish takes the hook. Many divers spend all or part of their underwater time taking photographs, shell collecting, exploring, searching for treasure, and in pure "fish watching." These activities should be considered when catch and effort are discussed; however, at present we have no way to measure them.

During 1960-1962, the Department of Fish and Game received 527 useful catch records for diving charters, 14 from central and 513 from southern California.

TABLE 1

Marine Species, Catch and Effort, in the San Francisco Bay and Monterey Areas, 1960-1962

	Number reported			
Common name	*1960*	*1961*	*1962*	*Total*
Abalone *	128	20	12	160
Rockfish *	15	37	71	123
Lingcod	22	17	40	79
Cabezon	19	12	--	31
Perch *	--	--	11	11
Kelp bass	-	-	2	2
Total	184	86	136	406
Number of trips	5	2	7	14
Number of divers	32	29	96	157
Number of diver-hours	138	127	348	613
Catch/diver	5.8	3.0	1.4	2.6
Catch/diver-hour	1.3	0.68	0.39	0.66

* Probably more than one kind.

[1] Submitted for publication November 1963.

Central California charter boat operators reported 157 divers caught 406 fish of six kinds (Table 1). There were probably more than one species each of rockfish, perch, and abalone. The most frequented area was the Farallon Islands, but divers working Monterey Peninsula had greater success (Table 2).

Southern California boat operators reported 8,893 divers caught 21,137 fish, mollusks, and crustaceans of 24 kinds (Table 3). Few

TABLE 2

Marine Species, Catch and Effort by Diving Area, Central California, 1960-1962

	Catch by area			
Common name	*Farallon Is.*	*Monterey Peninsula*	*Monterey Bay*	*Total*
Abalone *	105	55		160
Rockfish *	108	15		123
Lingcod	44	35		79
Cabezon	17	14	No Catch	31
Perch *		11		11
Kelp bass		2		2
Total	274	132		406
Number of trips	8	5	1	14
Number of divers	114	23	20	157
Number of diver-hours	426	87	100	613
Catch/diver	2.4	5.7		
Catch/diver-hour	0.64	1.5		

* Probably more than one kind.

TABLE 3

Marine Species Taken by Charter-divers off Southern California, 1960-1962

	Number reported			
Common name	*1960*	*1961*	*1962*	*Total*
Abalone *	2,044	3,374	7,026	12,444
Kelp bass	715	852	1,169	2,736
Spiny lobster	150	628	1,446	2,224
California sheephead	453	660	1,004	2,117
Rockfish *	238	92	48	378
Perch *	144	164	66	374
Opaleye	95	88	89	272
Pacific bonito	47	35	23	105
Sculpin	38	21	28	87
California halibut	11	4	31	46
White seabass	20	19	4	43
Flatfish *	17	11	14	42
California yellowtail	17	18	2	37
Cabezon	1	3	31	35
California barracuda	13	9	10	32
Rock scallop	--	21	10	31
Lingcod	9	4	18	31
Halfmoon	--	11	7	18
Giant sea bass	5	--	4	9
Miscellaneous *	5	7	64	76
Total	4,022	6,021	11,094	21,137
Number of trips	71	160	282	513
Number of divers	1,239	2,604	5,050	8,893
Number of diver-hours	5,722	11,597	23,841.25	41,160.25
Catch/diver	3.25	2.3	2.2	2.4
Catch/diver-hour	0.70	0.52	0.47	0.51

white seabass, yellowtail, barracuda, bonito, and giant sea bass were taken; however, individual fish were often large. The average reported weight of 43 white seabass was 32 pounds, with one individual weighing 66 pounds. Giant sea bass averaged 200 pounds, while one leviathan weighing 400 pounds was reported. The miscellaneous group (Table 3) includes three Pacific angel sharks, three California morays, two horn sharks, two California swell sharks, two white croakers, and 64 unnamed fish.

Most of the divers favored Santa Catalina Island, but the catch-per-diver-day there was the lowest of all the known areas (Table 4). Novice divers frequently pick this area as a training ground.

TABLE 4

Marine Species, Catch and Effort by Diving Area, Southern California, 1960-1962

	Catch by area					
Common name	*Santa Catalina Is.*	*Santa Cruz. Is.*	*Anacapa Is.*	*Santa Barbara Is.*	*San Clemente Is.*	*Palos Verdes*
Abalone *	7,027	2,896	2,141	185	190	5
Kelp bass	343	1,451	866	36	40	
Spiny lobster	735	784	324	291	64	26
California sheephead	617	701	568	151	80	--
Rockfish *	4	242	130			2
Perch *	7	188	179			
Opaleye		153	119			
Pacific bonito	7	63	35			
Sculpin	25	39	20		3	
California halibut	28	16	2			
White seabass	3	22	18			
Flatfish *	1	17	24			
California yellowtail	3	21	13			
Cabezon	32		1		1	1
California barracuda	5	18	9			
Rock scallop	6		--	5		20
Lingcod	7	15	9			
Halfmoon	18					
Giant sea bass		7	2			
Miscellaneous *	24	50	2			--
Total	8,892	6,683	4,462	668	378	54
Number of trips	300	104	84	8	14	3
Number of divers	5,069	1,878	1,465	278	176	27
Number of diver-hours	23,971.25	8,644	6,531.5	1,219.5	669	125
Catch/diver	1.75	3.6	3.0	2.4	2.1	2.0
Catch/diver-hour	0.37	0.77	0.68	0.55	0.57	0.43

* Probably more than one kind.

Santa Cruz, Anacapa, Santa Barbara, and San Clemente Islands and the Palos Verdes Peninsula were also popular diving locations. The best all-around diving area in southern California was Santa Cruz Island, where only 21 percent of the divers bagged 23 percent of the abalones, 53 percent of the kelp bass, 35 percent of the spiny lobsters, and 33 percent of the sheephead.

Logs submitted by the skippers of southern California diving-charter boats in 1958 and 1959 showed that 1,725 divers bagged 3.3 fish, mollusks, and crustaceans per-diving-day (Young, 1961). During 1960-1962, divers averaged 2.4 animals per-diving-day (Table 3). The seven

TABLE 5

Common and Scientific Names of Marine Species Taken by Charter-divers in California, 1960-1962

Common name	*Scientific name*
	Fishes
Bass, giant sea	*Stereolepis gigas*
Bass, kelp	*Paralabrax clathratus*
Barracuda, California	*Sphyraena argentea*
Bonito, Pacific	*Sarda chiliensis*
Cabezon	*Scorpaenichthys marmoratus*
Croaker, white	*Genyonemus lineatus*
Flatfish*	species of bothids and pleuronectids
Halfmoon	*Medialuna californiensis*
Halibut, California	*Paralichthys californicus*
Lingcod	*Ophiodon elongatus*
Moray, California	*Gymnothorax mordax*
Sculpin	*Scorpaena guttata*
Seabass, white	*Cynoscion nobilis*
Shark, California swell	*Cephaloscyllium uter*
Shark, horn	*Heterodontus francisci*
Shark, Pacific angel	*Squatina californica*
Sheephead, California	*Pimelometopon pulchrum*
Rockfish*	*Sebastodes* spp.
Perch*	species of embiotocids
Opaleye	*Girella nigricans*
Yellowtail, California	*Seriola dorsalis*
	Mollusks
Abalone *	*Haliotis* spp.
Scallop, rock	*Hinnites multirugosus*
	Crustaceans
Lobster, spiny	*Panulirus interruptus*

* Probably more than one kind

most frequently taken species were the same in both periods. Hook-and-line fishermen averaged approximately six fish-per-day, 1960-1962, according to the logs from skippers in the California partyboat fleet (California Department of Fish and Game, 1961b, 1962, and 1963).

ACKNOWLEDGMENTS

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RECENT OCCURRENCES OF INTERGENERIC HYBRID FLOUNDERS, *INOPSETTA ISCHYRA* (JORDAN AND GILBERT), FROM CALIFORNIA AND OREGON[1]

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Intergeneric hybridization occurs between several species of pleuronectids. Norman (1934) mentioned six examples within the family and Hubbs and Kuronuma (1942) reported another. *Inopsetta ischyra* (Jordan and Gilbert), the only hybrid flounder known to occur off the coast of western North America, has been rarely taken in California waters, although reported as common off Washington. Recently, two of these hybrid flounders were brought to my attention. I received a female specimen, 390 mm SL, from Dick Young, master of the trawler *City of Eureka*, on February 2, 1962 (Figure 1). It was caught about 14 miles north of the California-Oregon border at Mack Arch, Oregon in 150 to 360 fathoms of water and was placed in the California Academy of Sciences collection (CAS 23174). The second specimen, placed in the same collection (CAS 12651) by the University of California, was a male, 149 mm SL, collected at Drakes Bay by a Mr. Arnheim prior to 1945. It represents the second authenticated California occurrence, although Eureka and San Francisco fishermen have occasionally reported catching hybrid flounders.

Jordan and Gilbert (1880) originally described *Inopsetta ischyra* as a distinct species (*Parophrys ischyrus*) from four specimens collected at Seattle, Washington. Jordan and Gilbert (1882) suggested the name *Pleuronectes ischyrus*, and Jordan (1887) proposed the name *Inopsetta ischyra* which persists today. Villadolid (1927) maintained specific status in his description of three additional specimens from the Puget Sound area. Norman (1934) was first to suspect that *Inopsetta* was a hybrid and recorded *Lepidopsetta bilineata* and *Platichthys stellatus* as probable parents. Schultz and Delacy (1936) accepted the same species as possible parents, but later Schultz and Smith (1936) compared 11 hybrids from Puget Sound with all possible parent species and convincingly presented *Parophrys vetulus* and *Platichthys stellatus* as probable parents. Aron (1958) substantiated the hybrid nature of *Inopsetta* by establishing abnormalities in gonads and gonadal products.

Herald (1941) documented the first California occurrence of *Inopsetta*. It was caught off San Fancisco and established the southern range limit. Clemens and Wilby (1961), apparently unaware of this occurrence, reported the range from Washington to the Bering Sea.

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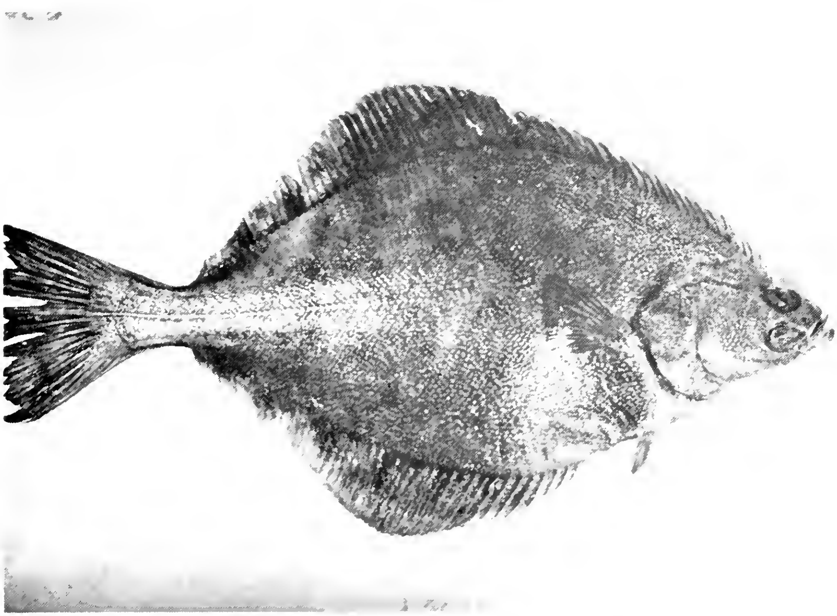

FIGURE 1. Hybrid flaunder *Inapsetta ischyra* (Jordan and Gilbert), CAS 23174, taken off southern Oregon in February 1962. *Photograph by the author, May 1963.*

To establish the hybrid nature of the Drakes Bay and Mack Arch specimens, I compared them with 10 individuals of each parent species caught off Humboldt County, California (Table 1). Values intermediate between the parent averages were calculated to facilitate comparisons. Counts and measurements were made in accordance with Hubbs and Lagler (1958) unless otherwise indicated.

Comparison of the hybrids with the parent species reveals the typical intermediacy of meristic and morphometric data characteristic of hybrid flatfish. Most of these data for both hybrids closely approach or equal the intermediate condition. The principal caudal ray count and the snout length of the Drakes Bay hybrid fall outside the extremes of the parent ranges. As the ranges are narrow and overlap, these normal variations should be expected. Hybrid data presented in Table 1 agree closely with those reported by Schultz and Smith (1936) for 11 *Inopsetta ischyra* from Puget Sound.

Scales on both hybrids bore marginal ctenii. The scale surfaces of the Mack Arch specimen were partially covered with spinous projections resembling the tubercles of *Platichthys stellatus*. Scale spination was pronounced on the eyed side. Spines were most abundant anteriorly on both sides. No spinous projections were found on scale surfaces of the Drakes Bay specimen.

The body on the eyed side of the Mack Arch hybrid was olive-brown mottled with black. Dorsal and anal fins were yellow-brown with dusky blotches at regular intervals near their bases. The blind side was a typical creamy-white. Faint dusky blotches were present on the blind side of the dorsal and anal fins. Coloration of the Drakes Bay hybrid had been obliterated by extended storage in formalin.

TABLE 1

A Comparison of *Parophrys vetulus*, *Platichthys stellatus* and *Inopsetta ischyra*

Counts	10 Humboldt County *Parophrys vetulus*		10 Humboldt County *Platichthys stellatus*		Calculated intermediate condition	Mack Arch *Inopsetta ischyra*	Drakes Bay *Inopsetta ischyra*
	Range	Average	Range	Average		CAS 23174	CAS 12651
Dorsal rays (last single)	80-89	**83.3**	56-62	**59.2**	71.3	72	77
Anal rays (last single)	58-69	**62.7**	39-45	**42.5**	52.6	54	55
Pectoral rays (eyed side)	12-14	**12.3**	10-12	**11.3**	11.8	13	11
Ventral rays (eyed side)	5-6	**5.9**	6	**6.0**	6.0	6	6
Principal caudal rays	14-15	**14.1**	13-15	**13.9**	14.0	14	16
Gill rakers above angle (eyed side)	5-6	**5.7**	3-5	**4.0**	4.9	5	5
Gill rakers below angle (eyed side)	12-13	**12.5**	8-10	**8.7**	10.6	9	9
Pored lateral line scales (eyed side)	95-109	**102.2**	68-81	**74.3**	88.3	82	79
Vertebrae	43-45	**43.9**	36	**36.0**	40.0	41	40
Measurements (Thousandths of standard length)							
Total length	1174-1205	1187.9	1195-1228	1210.3	1199.1	1189.7	1208.1
Head length	266-295	283.5	291-321	305.8	294.7	287.2	302.0
Snout length	48-66	59.1	52-68	59.8	59.5	64.1	47.0
Snout to ventral fin insertion	268-296	283.8	301-328	316.8	300.3	289.7	308.7
Maximum body depth (fin base)	364-433	401.3	503-580	539.9	470.6	464.5	436.2
Least depth of caudal peduncle	82-96	88.2	90-113	100.5	94.4	92.3	100.7
Ventral peduncle length	101-118	108.0	133-155	143.0	125.5	112.8	114.1
Accessory lateral line length	181-314	241.7	none	none	120.9	79.5	60.4
Height of lateral line arch	11-19	15.4	21-27	23.8	19.5	25.6	20.1

Herald (1941) reported a ventral lateral line branch on the blind side of the first California *Inopsetta* but believed it was an anomalous condition. Neither hybrid treated in this study possessed such a branch.

All specimens of *Parophrys vetulus* and *Inopsetta ischyra* were dextral. Dextrality was 30 percent for the 10 Humboldt County *Platichthys stellatus* (normally, over 40 percent are dextral).

ACKNOWLEDGMENTS

I wish to extend thanks to W. I. Follett of the California Academy of Sciences for his assistance in this study. To Dick Young, master of the *City of Eureka*, and his crew, I also express thanks for contributing the Mack Arch *Inopsetta*.

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NORTHWARD MOVEMENT OF THE CALIFORNIA SEA OTTER[1]

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Since California sea otters (*Enhydra lutris nereis*) were rediscovered in 1938 off Bixby Creek, Monterey County, these animals have extended their range southward at least to Point Conception and probably to the Channel Islands. Northward movement, however, has been slight, with the species now regularly occurring in Carmel Bay and around parts of the Monterey Peninsula. Boolootian (1961) has carefully summarized the recently authenticated California occurrences and quite justifiably questioned several sight records reported north of the Monterey region.

Since May 1961, we have been visiting Año Nuevo Island, San Mateo County, 40 miles north of the Monterey Peninsula, in connection with studies on the pinnipeds of that area (Orr and Poulter, 1962). These visits have been weekly, if not more often, during the summer and generally bi-weekly, weather permitting, during the remainder of the year. On nearly each occasion the area around Año Nuevo Point, as well as the surrounding kelp beds, have been scanned for sea otters.

Until the summer of 1963 this species was not observed in the area. On July 11, Alex Ermacoff, Stanford Research Institute, was on the island and saw two sea otters in a cove on the seaward side. Unaware of this discovery we observed two otters in the same cove on the following day. One animal swam around a point and out of view shortly after the two were sighted at 11:30 A.M., but the other remained until we left in mid-afternoon. On a number of subsequent visits during July and the first half of August, a sea otter was seen in the same cove. It could be observed from a blind as close as 75 feet, and was thought to be the same individual.

On August 23, there was no otter in this cove, but one was seen off the northwest end of the island in a small bay formed by a series of exposed reefs. None was seen on August 30 although the area around the island, as well as Año Nuevo Point and part of Año Nuevo Bay, was examined carefully. However, these animals could easily be overlooked among the numerous sea lions, harbor seals, and kelp floats.

Because the pinniped population in this region reaches its peak at the end of August, as a result of an influx of California sea lions (*Zalophus californianus*), we thought this might have caused the otters

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FIGURE. 1. The usual position of a resting sea otter, floating on its back with front and hind legs raised. Note the flipper-like appearance of the hind limbs. Año Nuevo Island, San Mateo County, California. *Photo by Thomas C. Poulter, August 8, 1963.*

to move to less densely populated kelp beds nearby, possibly between Año Nuevo Point and Pigeon Point. On September 6, however, an otter was seen again off the northwest end of the island.

The relationship between sea otters and sea lions was of considerable interest to us. The otter seen in the cove on July 12 usually dove when a Steller sea lion (*Eumetopias jubata*) came within 4 or 5 feet of it. When not diving for food, eating, scratching, or otherwise engaged, it floated on its back, anchored by a piece of kelp (*Macrocystis*), often within a few feet of a reef with an active breeding Steller sea lion rookery. No animosity was exhibited by any of the female or non-established male Steller sea lions that often swam close to the otter. They did, however, evince curiosity.

Subsequently, the sea otter permitted both Steller and California sea lions to come close and even contact it with their muzzles. On August 23, individuals of both species were observed at the northwest end of the island touching their noses to the sea otter while it floated on its back seemingly unperturbed.

On September 6, however, the presence of numerous Steller pups, as well as a number of cows, seemed to disturb a sea otter seen between 1 PM and 1:30 PM. The pups at this season of year spend a considerable part of their time playing in the coves and surge channels. They even attempt to play with the adult females as well as California sea lions that may venture within their range of activity. Their reaction to the otter was essentially the same as to another pup. The otter, however, dove frequently to escape their attention and surfaced at a different locality each time. Gradually it moved seaward toward one of the outlying rocks about 200 yards west of the north end of the island where there were no young sea lions to annoy it.

FIGURE 2. A sea otter and a Steller sea lion viewing each other at very close range. Año Nuevo Island, San Mateo County, California. *Photo by Thomas C. Poulter, August 8, 1963.*

It seems pertinent here to mention another older record north of Monterey. On December 28, 1940, a dead sea otter was brought to the California Academy of Sciences, San Francisco, by a representative of the California Department of Fish and Game. This animal had been found the previous day on the beach at Twin Lakes, Santa Cruz County, by Mrs. William R. Pera and Mrs. Clyde Smith of Santa Cruz. It was a female, 1136 mm TL, weighing 41¾ pounds. Several external and internal injuries were noted, but their cause was not known. In view of later information about great white sharks *(Carcharodon carcharias)* attacking sea otters (Orr, 1959), it may have been a victim of one of these fish. The condition of the reproductive tract indicated it had recently given birth to a young.

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NOTE

GRASS ROCKFISH, *SEBASTODES RASTRELLIGER* (JORDAN AND GILBERT), FROM THE YAQUINA BAY AREA, OREGON

Grass rockfish have been reported as ranging from Playa Maria Bay, Baja California, to Eureka, California (Phillips, 1957). Four specimens captured in the Yaquina Bay vicinity extend their known range northward some 270 miles.

On May 27, 1962, during a spearfishing "species contest" (Van Arsdel, 1963) the senior author found a 43 cm SL grass rockfish weighing 6 pounds 11 ounces perched on the gravel rim of a current-scoured depression at the end of a spur of the Yaquina Bay south jetty. The fish faced a strong tidal current and presented a sculpin-like appearance in a striking pose with the spines erect and pectoral fins fanned out perpendicular to the body. Recognized as unusual for this area, it was presented to the junior author for identification and is now preserved in the collection of the Department of Fish and Game Management, Oregon State University as OS 1300.

On June 9, 1963, a second specimen, 27 cm SL (OS 1301), was obtained from Mr. Steve Ryan during a spearfishing meet in the same area. The waters off Yaquina Head yielded a third individual, 30 cm SL (OS 1302), from a depth of 25 feet, below the vegetation zone, August 4, 1963. Mr. Bill Herder speared the fourth on August 27, 1963. This specimen (OS 1304) is 45 cm SL; its 53-cm total length (21 inches) makes it one of the longest recorded. Steve Ryan and other divers in the area claim to have taken grass rockfish several times from the kelp beds in the Yaquina vicinity where they apparently are not rare.

Measurements and meristic data from the first three specimens compared with Phillips's (1957) values show only minor deviations which probably represent geographical variation.

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BOOK REVIEWS

Freshwater Fishes of the World

By Gunther Sterba (translated and revised by Denys W. Tucker) The Viking Press, New York, 1963; 878 pp., numerous black and white plus color illustrations; $17.50.

Freshwater Fishes of the World is the second major German work on aquarium fishes to be translated into English. The book was "Printed in East Germany, U.S.S.R. occupied." As indicated by the title, this is not a book of tropical aquarium fishes. Fishes from almost every habitat, geographical area and temperature range are discussed, and many have never been described in an aquarium handbook.

Professor Gunther Sterba, Director of the Zoological Institute, Leipzig University, has made a major contribution to Aquatic Biology with this volume. It deals with the identification, care, and biology of over 1,300 species, and contains 1,193 illustrations consisting of 102 color photographs, 423 black and white photos, and 668 line drawings. The quality of the photos ranges from good to excellent. Unfortunately, the caliber of the line drawings is not up to the quality expected in a volume of this type.

My main criticism of this book lies with the relation of the figures to the text. The photos and drawings do not follow the order in which the species are presented in the text. In order to find a figure referred to in the text, one must constantly turn pages. Conversely, it is extremely difficult to locate the text that applies to a particular figure without reference to the index. It is hoped that the next edition will have a more logical placement of the figures. The common names of many species, particularly those of North America, are omitted.

Professor Sterba writes in a concise style which enables him to transmit a wealth of information in a minimum of space. He starts with general information on the biology of a family, including breeding habits and suitability for the aquarium. Then, the specific biology of individual species is discussed.

The beginning aquarist may find the descriptions of the biology of individual species somewhat on the sketchy side. The amateur will have to look elsewhere for help regarding aquarium plants, fish diseases, water quality, filtration, and the other myriad problems which plague the home aquarium.

Much credit for this volume must be given to Denys W. Tucker, of Great Britain, who was able to translate and update this massive volume in only 5 months. The efforts of Professor Sterba and Mr. Tucker have resulted in a book which will prove to be of great value to the professional fisheries worker as well as the serious aquarist.—*Michael L. Johnson, California Department of Fish and Game.*

The Complete Illustrated Guide to Casting

By Joe Brooks, Doubleday and Company, Inc., New York, 1963; 192 pp., illustrated; $4.95.

For the fisherman who wants to learn how, reading "The complete illustrated guide to casting" is a must.

The author has enlisted the aid of foremost experts in fresh and saltwater fishing to come up with over 200 photographs profusely illustrating the casting techniques he describes. The photographs were taken under actual fishing conditions especially for the book. Almost without exception the text and numbered picture appear on the same page. They are so skillfully coordinated that the reader is never lost searching for the picture that illustrates the text.

The book is easily readable and the author, a recognized authority on fishing, has drawn on a lifetime of experience to describe and illustrate how experts handle different kinds of fishing gear. The categories covered include fly casting, plug casting, spinning, and surf casting. Experienced fishermen as well as beginners should welcome this comprehensive volume for its coverage of both the basic and advanced information on casting.—*George D. Seymour, California Department of Fish and Game.*

The Valley: Meadow, Grove, and Stream

By Lorus J. and Margery Milne. Harper & Row, Publ., New York, 1963; xiii + 178 pp., illustrated; $4.50.

Very few people, other than naturalists, seem to sense fully the pulse and throb of life as it exists in any natural area in which they live. Authors Lorus and Margery Milne have, through keen observations and descriptive writing, interpreted the daily natural life of both plants and animals in a small river valley in rural New England.

The valley's cycle of life, its inter-relationships and adjustments of organisms to their environment, is dramatically portrayed. Similar descriptions should be recorded of other common regional environments throughout the world. (I would like to see a similar treatment given to some western valley with its plant and animal associations.) It is an interesting book for those who enjoy an informative and philosophic account of nature. Perhaps its greatest contribution may be to encourage others to make similar detailed observations of local flora and fauna. *Willis A. Evans, California Department of Fish and Game.*

Fur and Fury

By C. B. Colby. Duell, Sloan and Pearce, New York, 1963; 127 pp., 16 halftones; $3.50.

Without the dust cover, one might wonder just what kind of a book he has chosen to browse. The title indicates anything from science-fiction to a pulp western. However, the dust cover and the title page divulge the secret that the pages will introduce the reader to, "Natures most talented family" the weasels or Mustelidae. From the well-known skunks and the playful otters to the comical-looking badger and the treacherous wolverine the life history and habits of each member of the family are discussed. After a short introduction explains the title and describes more tangible family characteristics, 15 species are treated in 14 chapters. Why the hooded and hognose skunks were combined in a single chapter while the striped and spotted skunks each rated a separate chapter is not explained. There are 16 excellent photographic illustrations of the mustelids, only one by the author, and the footprint of each animal is sketched near the photo for the benefit of amateur trackers.

The author's background is widely varied. His education was in art but his career began as an editor of aviation magazines. For slightly over a decade he has been writing stories on a variety of subjects, many devoted to the outdoors and slanted toward the youthful audience.

Mr. Colby has collected a great deal of factual information about the "weasels" and has presented a most interesting story upon the 127 pages between the covers of *Fur and Fury*.—*William L. Craig, California Department of Fish and Game.*

100 Desert Wildflowers

By Natt N. Dodge. Southwestern Monuments Association, Globe, Ariz., 1963; 32 p., 100 color photos; $1.50 (paperbound).

This small book presents 100 color photographs of some of the more common desert flowers (including cacti) of Arizona, New Mexico, California, Texas, Nevada, and northern Mexico. Good color photographs are seldom found in the available identification manuals, making this book particularly valuable when used with definitive keys.

Common and botanical names accompany each photograph along with a brief description of the usual habitat and notes on field lore. Hints for flower photographers appear on the inside of the front cover. Suggestions for additional reading follow the text.—*Parke H. Young, California Department of Fish and Game.*

Advances in Marine Biology—Volume 1

Edited by F. S. Russell. Academic Press, Inc., London, 1963; xiii + 410 p., illustrated; $13.50.

This is the first volume of a new series which will condense into concise articles recent developments in marine biological research. These reports bring together articles, many known only to professional researchers in the given field, widely scattered throughout the growing number of scientific publications. The editor has covered a variety of subjects in Volume 1, each prepared by one or more experts.

"Rearing of Bivalve Mollusks" describes the special equipment and techniques developed for spawning and rearing bivalves through early stages to metamorphosis. It discusses foods, growth, diseases, and breeding of several species under laboratory conditions. Primary emphasis is on *Crassostrea virginica* and *Mercenaria* (= *Venus*) *mercenaria* but 15 other species of clams, mussels, scallops, and shipworms are covered, including photographs of larvae grown in the laboratory. Anyone involved with rearing larval forms will certainly be interested in the techniques discussed.

"The Breeding of the North Atlantic Freshwater-eels" analyzes the differing opinions on the breeding of *Anguilla anguilla*.

"Some Aspects of Photoreception and Vision in Fishes" compiles recent work on extra-ocular light reception, and ecological and behavioral studies. The section on ecology and behavior summarizes light in relation to migration, vertical movements, schooling, and responses to lights and light intensity.

"The Biology of Coral Reefs" summarizes work on coral reef and atoll biology. The paper has been divided into appropriate sub-headings, describing corals, and their reef-building activities, and the productivity associated with the resultant structure.

"The Behavior and Physiology of Herring and Other Clupeids" is a rather complete treatise on the physiology and behavior of *Clupea harengus*, in particular, and other clupeids in general. Papers on fishing mortality and its estimation, and fecundity as a means of distinguishing races and for estimating stock size have not been included.

Each paper has been conveniently broken up into sub-sections for easy location of specific topics. An extensive bibliography follows every article. This series will become a valuable reference source and should be available in marine laboratories and libraries. The price may seem rather high to the individual, but considering the amount of research and effort condensed into this book, it is a bargain.

An annual volume is planned and in the preface Dr. Russell requests suggestions for future volumes.—*E. A. Best, California Department of Fish and Game.*

The Origins of Angling and a new printing of "The Treatise of Fishing with an Angle"

By John McDonald assisted by Sherman Kuhn and Dwight Webster and the editors of Sports Illustrated. Doubleday & Co., Inc., New York, 1963; xiii + 273 p., black and white plus color illustrations. $10.

The Treatise of Fishing with an Angle was written in manuscript form about 1425, several centuries before Walton's more notorious work. It started the long sequence of "how to do it" fishing books.

In his introduction, John McDonald says, "The principal justification for this book is that *The Treatise of Fishing with an Angle*, the first writing on modern sport fishing, has long been out of print." It is hard to disagree with his statement that no better essay on fishing has been written, and that it should always be in print.

I found the extensive background material about the *Treatise*, and the supplementary historical discussions in the first part of the book unusually interesting. It gave many insights into the nature of angling and of people's attitudes toward it at its inception as the sport we know. The author has a knack for making scholarly material readable. In this respect, he did a particularly good job in explaining how the cult of chivalry influenced angling traditions in many significant ways.

It was disappointing to learn that the engaging nun, Dame Juliana Berners, almost certainly did not write the *Treatise*, particularly after enjoying so much Beatrice Cook's anecdote about her in *Truth is Stranger Than Fishin*. The persistence of this myth down the centuries is an interesting story in itself.

The *Treatise* introduced the first modern trout flies, discussing twelve established patterns. McDonald discusses them in detail, and the whole history of trout flies at some length. He gives his concept of the twelve patterns, which are described but not illustrated in the *Treatise*. There are four color plates of these flies tied from the written descriptions in the *Treatise*.

The second part of the book includes facsimilies of an incomplete manuscript copy of the *Treatise* written by a scribe about 1450, and of the first edition in the second *Book of St. Albans*, printed in 1946. Transcripts of the two documents in modern script parallel them on facing pages.

This handsome volume will please the angler with a historical or philosophical bent.—*Alex Calhoun, California Department of Fish and Game.*

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Notice is hereby given that the Fish and Game Commission shall meet on April 3, 1964, at 10 A.M., in the State Employment Building, 722 Capitol Mall, Sacramento, California, to receive recommendations from its own officers and employees, from the department and other public agencies, from organizations of private citizens, and from any interested person as to what, if any, orders should be made relating to birds or mammals, or any species or variety thereof, in accordance with Section 206 of the Fish and Game Code.

Notice is hereby given, pursuant to Section 206 of the Fish and Game Code, that the Fish and Game Commission shall meet at 10 A.M. on April 24, 1964, in room 358, City Council Chamber, 1600 Pacific Center, San Diego, California, to announce publicly the regulations it proposes to make relating to birds or mammals, or any species or variety thereof for the 1964 hunting season.

Notice is hereby given that the Fish and Game Commission shall meet on May 29, 1964, at 10 A.M. in room 1138, New State Building, 107 South Broadway, Los Angeles, California, to hear and consider any objections to its determinations or proposed orders in relation to birds and mammals for the 1964 hunting season, such determinations resulting from hearing held on April 24, 1964. This notice is published in accordance with the provisions of Section 206 of the Fish and Game Code.

FISH AND GAME COMMISSION
Monica O'Brien
Secretary to the Commission

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