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ABUNDANCE AND DISTRIBUTION OF FINGERLING LARGEMOUTH BASS, *MICROPTERUS SALMOIDES*, AS DETERMINED BY ELECTROFISHING, AT LAKE NACIMIENTO, CALIFORNIA[1]

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Electrofishing gear was used for four consecutive summers at Lake Nacimiento to obtain data on the abundance and distribution of fingerling largemouth bass. Mean catches of fingerling bass per ¼ mile of shoreline were extremely variable, ranging from a low of 3.2 in 1968 to a high of 129.9 in 1967. Ninety-five percent confidence intervals about the means ranged from ± 22.7 to ± 46.7%. Factors associated with large fingerling bass year classes were: (i) stable or rising water levels during the spawning period; (ii) high surface water elevations in April and May; and (iii) low abundance of adult threadfin shad (*Dorosoma petenense*). No relation between fingerling bass abundance and the abundance of spawners, yearling bass, or other game fish species was detected. Fingerling bass were most abundant in the westerly half of Lake Nacimiento where wind and wave action were relatively slight. The degree of shoreline slope was not a factor affecting the abundance of bass fingerlings. Shoreline sections relatively free of shelter produced larger average catches than sections containing moderate to large quantities of brush, rocks, or fallen logs.

INTRODUCTION

The maintenance of a balanced population structure between largemouth bass and the lesser centrarchids is a challenging and major fisheries management problem in many parts of the United States. Bluegill (*Lepomis machrochirus*), particularly, often overpopulate and stunt, and large populations of limited value to anglers frequently develop. Such conditions are associated with minimal recruitment of both species, and angling quality is usually poor. Management efforts and recommendations to restore population balance have been extensive and include stocking bass (Jackson 1957, Bell 1959), partial or complete treatment with fish toxicants (Beland 1960, Hooper and Crance 1960, Snow et al. 1960) trapping (Beall 1959), draining and restocking (Eschmeyer 1937, Thompson and Bennett 1939), the removal of dense aquatic weed growth (Swingle and Smith 1942, Byrd and Moss 1957), and reservoir drawdowns (Bennett 1954). These techniques have sometimes produced improved angling (Hooper and Crance 1960), or increased bass reproduction (Bennett 1954), but their successful application is largely restricted to small, easily controlled waters.

California's development in the last several decades has featured the construction of many large, fluctuating impoundments in the foothills of the Sierra and Coast Range which do not lend themselves to easy manipulation of their fish populations. Bass and bluegill usually

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dominate the sport fisheries of these waters. The majority, however, produce only mediocre angling following a period of relatively good fishing shortly after initial impoundment (Dill 1946, Abel and Fisher 1953, Kimsey 1958). Angling quality for bass usually declines to 0.5 fish or less per angler day (Abel and Fisher 1953, Strohschein 1959). Bass have traditionally been unable to control bluegill abundance, and declines in bluegill growth rates have regularly been recorded (Tharatt 1966, Miller 1971). Management measures which would economically enhance fishing quality for bass and maintain the abundance of sunfish at levels which permit rapid growth are needed for this type of impoundment in California.

A knowledge of factors which control the reproductive success of bass in reservoirs could provide a starting point for improved management. In 1965, Lake Nacimiento, a large, fluctuating impoundment, was chosen as a test water for an evaluation of experimental introductions of white bass (*Morone chrysops*) and threadfin shad. At this time, a study was undertaken to evaluate certain factors controlling fingerling bass production. This work was part of a more general research effort to measure the impact of these introductions on existing game fish populations.

Fingerling bass were sampled by nighttime electrofishing along the shoreline during midsummer from 1965 through 1968. Indices of abundance were derived from the resulting data and compared with physical and biological parameters of the lake environment.

White bass did not reproduce at Lake Nacimiento during the course of this investigation. Their impact on the fishery was, therefore, negligible.

This report summarizes the findings of these studies and considers (i) the efficiency of electrofishing as a sampling method for fingerling bass, (ii) the sampling effort required to obtain meaningful indices of abundance, and (iii) factors controlling fingerling bass abundance and distribution in the reservoir.

DESCRIPTION OF LAKE NACIMIENTO

Lake Nacimiento is located on the Nacimiento River about 18 miles northwest of Paso Robles in San Luis Obispo County. Completed in 1957, this impoundment is owned and operated by the Monterey County Flood Control and Water Conservation District. Reservoir waters are used primarily for irrigation in the Salinas Valley.

At full pool, this irregularly-shaped reservoir has a storage capacity of 350,000 acre-feet, an area of 5,300 acres, a maximum depth of 175 ft, and a surface elevation of 798 ft. Maximum storage occurs in the spring followed by a gradual drawdown during the summer and fall. Fluctuations usually range from 30 to 70 ft annually. The local geology is largely Cretaceous marine sandstone, conglomerates and shale, interspersed with Upper Pleistocene terrace deposits. Alluvium of various ages is present. The shoreline vegetation is a mixture of conifers, oaks, and deciduous plants interspersed with perennial grasses.

Surface water temperatures range from the low 50's F in winter to the low 80's F in summer. Thermal stratification with oxygen depletion in the hypolimnion occurs in summer. A thermocline occurs at depths ranging from 25 to 30 ft. The lake contained an average of

7.9 ppm $CaCO_3$ and pH values ranging from 7.5 to 8.1 in August 1962 (Rawstron 1964).

Largemouth bass, black crappie (*Pomoxis nigromaculatus*), and bluegill dominate the catch. Smallmouth bass (*M. dolomieui*), green sunfish (*L. cyanellus*), red-ear sunfish (*L. microlophus*), and white catfish (*Ictalurus catus*) also are taken regularly.

Rental fishing boats and outboard motors are available at a large marina located near the dam on the south shore. A launching ramp for private boat owners has also been developed by the Wildlife Conservation Board. The few remaining access points are largely undeveloped and most of the shoreline is accessible only by boat.

METHODS

Selection of Sample Sites

Initially it was decided that all electrofishing would be conducted at night along the shoreline of the main body of the reservoir (Loeb 1957). Largemouth bass are most often found in association with some type of shelter (Trautman 1957), and an extensive midwater trawling program conducted at Lake Nacimiento over a period of 4 years failed to produce a single specimen. Electrofishing gear successfully captured young largemouth bass along the shoreline of Bull Shoals Reservoir (Applegate et al. 1966), but they did not appear in trawl catches (Houser and Bryant 1968).

Sections of shoreline sampled were selected about eight major reference points chosen in a manner to assure broad and varied coverage of the shoreline (Figure 1). Each reference point was designated the midpoint of a 5-mile length of shoreline, which was then further divided into 20 ¼-mile sections. Sections sampled were selected randomly from

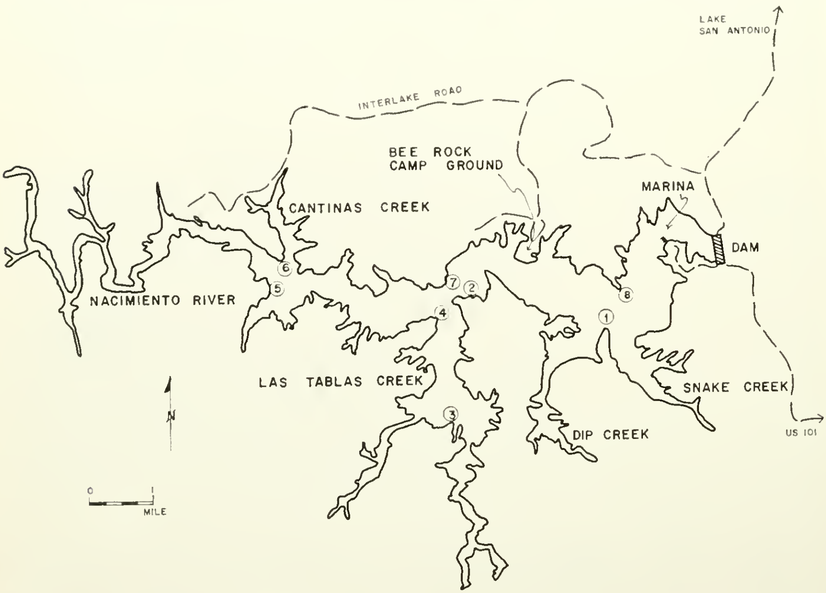

FIGURE 1. Map of Lake Nacimiento. Numbered circles indicate mid-points of electrofishing areas.

within each major 5-mile area. Those sections which included wharfs, launching ramps or other man-made artifacts were discarded and an alternative was chosen. Sections with extremely gentle slopes were not sampled because electrofishing gear does not work well in such areas. Only a very minor portion of the shoreline was represented by these types of habitat.

The Electrofishing Gear

Electrofishing was conducted from a 16- or 18-ft jon boat powered by a 6 hp outboard motor. The electrical source was a 200-V Homelite generator and a pulsing unit capable of providing a wide variety of pulsing frequencies and duty cycles. A boom with two electrodes and four 150-W flood lamps was located about 5 ft in front of the boat. One electrode, 73 inches long, was mounted in the center of the boom. A second 53-inch electrode was located about 5 ft from the center of the boom and was placed in an inshore position. During sampling, the inshore electrode extended about 6 inches below the water surface and often touched bottom, while the center electrode usually extended about 26 inches below the water surface. All sampling was done with a pulsing rate of 50/sec and a duty cycle of 60%.

The electrofishing crew consisted of a boat operator and a man positioned on the bow who collected fish with a long-handled dip net. The boat operator maneuvered the boat slowly along the shoreline while the net man retrieved stunned fish. Captured fish were placed in a tub of water, measured, and released. No attempt was made to retrieve fish other than largemouth bass. The net man also recorded the number of fingerling bass seen but not captured in each section.

Rotenone Samples

As a means of determining the validity of electrofishing as a sampling method, rotenone samples also were taken along the shoreline at night. Shoreline sections approximately 250 ft long were blocked off by a 300 x 20 ft seine (1-inch stretched mesh) tapered to 5 ft at the ends. A curtain of Pro-Noxfish was first applied around the periphery of the enclosed area by means of a boat and heavily weighted perforated hose. The remainder of the enclosed area was then treated both from the boat and by hand application. Long-handled dip nets were used to retrieve fish.

LIMITATIONS OF ELECTROFISHING GEAR

Electrofishing gear, despite its effectiveness as a tool for capturing largemouth bass (Lewis, et al. 1962), has certain limitations. The net man must act quickly when fish are sighted. Extreme concentration is always necessary. Some experience is needed to minimize the disturbance of bottom sediments when collecting fish and to distinguish bass from other species. At Lake Nacimiento, a different net man was used each year. All of them appeared to perform adequately and received comparable training, but we have no quantitative method for comparing their efficiency.

The efficiency of the electrofishing unit varies with the type of habitat sampled. Brush, logs and debris hinder boat maneuverability and fish capture. Shallow mud bottoms which cloud the water when disturbed also reduces sampling efficiency. Excessive wind action adversely affects underwater visibility and can further reduce the reliability of electrofishing operations. The probability of fish escaping capture is enhanced when large numbers are encountered in a restricted area.

In an attempt to assess the seriousness of these problems, the net man was asked to record the number of fingerling bass seen but not caught in each section sampled. These numbers ranged from zero to 30% of the catch per section and averaged about 12%. The highest percentages missed occurred in a few extremely brushy sections and in sections where fingerling bass were very abundant.

All data, hypotheses, and conclusions presented in this paper are based on fish actually caught, rather than estimated numbers which include fish missed. I compared the results using both sets of data and concluded that similar findings would have been reached with either method.

TABLE 1. Catch of Fingerling Largemouth Bass by Electrofishing at Lake Nacimiento, 1965–1968

			1965		1966		1967		1968	
Area	Section	Habitat type*	Number caught	Mean	Number caught	Mean	Number caught	Mean	Number caught	Mean
1	6	1	25	42.2	2	1.2	64	49.7	0	2.0
	8	2	21		0		NS		NS	
	11	3	17		2		21		4	
	14	3	33		1		64		2	
	17	5	27		NS†		NS		NS	
	18	3	130		NS		NS		NS	
2	12	2	101	85.0	NS	45.0	NS	188.0	NS	4.0
	18	2	69		45		188		4	
3	5	6	308	178.0	7	14.8	341	257.2	NS	3.8
	6	6	156		NS		NS		NS	
	8	5	91		7		137		6	
	10	3	185		7		312		4	
	12	3	243		24		292		4	
	20	3	85		29		204		1	
4	1	2	183	114.3	NS	30.0	NS	38.0	NS	3.0
	4	3	94		NS		NS		NS	
	17	3	66		30		38		3	
5	6	3	181	115.0	NS	27.0	NS	100.5	NS	9.0
	7	5	89		27		95		2	
	15	5	75		27		106		16	
6	9	3	103	79.2	16	18.0	64	95.7	3	1.5
	10	3	41		19		139		0	
	11	3	67		19		84		NS	
	20	2	106		NS		NS		NS	
7	5	4	65	37.0	NS	0.0	NS	62.0	NS	3.0
	7	3	21		NS		NS		NS	
	9	1	45		NS		NS		NS	
	11	2	32		0		62		3	
	13	4	22		NS		NS		NS	
8	4	3	18	11.3	NS	1.0	NS	63.5	NS	0.0
	12	3	13		2		107		0	
	13	3	3		0		20		0	
Total Catch			2,715		264		2,338		52	
Mean per section			84.8		13.9		129.9		3.2	

* 1—Gentle slope, shelter present.
2—Gentle slope, little shelter.
3—Steep slope, shelter present.
4—Steep slope, little shelter.
5—Variable slope, shelter present.
6—Variable slope, little shelter.
† NS—Not sampled.

INDICES OF FINGERLING BASS ABUNDANCE

General Data

During the period August 9 through 21, 1965, a total of 32 ¼-mile sections of shoreline was sampled. The catch totaled 2,715 fingerling bass for an average of 84.8 per ¼-mile section (Table 1). Numbers of fish caught per section ranged from 3 (area 8, section 13) to 308 (area 3, section 5). Mean numbers caught per section by area ranged from a low of 11.3 in area 8 to a high of 178.0 in area 3.

In 1966 electrofishing was conducted from August 27 to August 31. Nineteen ¼-mile sections produced a catch of 264 fingerling bass for an average of 13.9 fish per section (Table 1). Mean numbers caught per section by area ranged from a low of zero in area 7 to a high of 45.0 in area 2. The catch per section ranged from zero (area 1, section 8; area 7, section 13; area 8, section 13) to 45 (area 2, section 18).

A total of 2,338 fingerling bass was captured from 18 ¼-mile sections sampled from August 21 to August 29 in 1967. The average catch per section was 129.9, and ranged from 20 (area 8, section 13) to 341 (area 3, section 5) (Table 1). Mean catches per section by area ranged from 38.0 in area 4 to 257.2 in area 3.

In 1968, electrofishing was conducted from August 21 to August 27. A total of only 52 fingerling bass was captured from 16 ¼-mile sections. The mean catch per section was 3.2, and ranged from zero (area 1, section 6; area 6, section 10, and area 8, sections 12 and 13) to 16 (area 5, section 15) (Table 1). Sectional mean catches ranged from zero in area 8 to 9.0 in area 5.

Rotenone samples taken in September, 1965, were compared with the results of the electrofishing tests conducted in that year. Eighteen 250-ft shoreline sections not previously electrofished were sampled in area 3, 6, 7, and 8. Estimated bass densities within each of these four areas as determined by the two methods, were positively correlated but lacked close agreement. The ranges of bass abundance, however, showed considerable overlap and it appeared that chance variation could easily be responsible for these differences. Electrofishing produced an unweighted mean estimate of 76.4 bass per ¼ mile as compared to 86.9 for rotenone (Table 2). I conclude that the rotenone samples generally support the validity of electrofishing as a fish sampling device.

Statistical Analysis

Systematic sampling techniques were used to select the eight major 5-mile sections of shoreline. The primary advantage of this procedure is that it covers the population evenly, sometimes resulting in large increases in accuracy. The effects of such sampling on estimates of population means and variances, however, are poorly understood. A possible disadvantage and source of error can arise when the population being sampled has a periodic variation and the systematic sample occurs on the same wavelength. In the present case, systematic sampling would be likely to produce large errors only if fingerling bass arranged themselves along the shoreline in some rythmic pattern, i.e., large concentrations every 2 miles, 5 miles, etc. Such behavioral patterns were not evident at Lake Nacimiento nor have they been recorded in the literature. The sampling within each 5-mile length of shoreline

TABLE 2. A Comparison of the Catch of Fingerling Largemouth Bass by Rotenone and Electrofishing at Lake Nacimiento in 1965

Area Sampled	Number sections sampled		Catch per section Electrofishing		Estimated rotenone* catch per ¼ mile	
	Electrofishing	Rotenone	Range	Mean	Range	Mean
3	6	6	85–308	**178.0**	53–228	**135.2**
6	4	6	41–106	**79.2**	26–196	**127.2**
7	5	3	21–65	**37.0**	58–74	**67.3**
8	3	3	3–18	**11.3**	0–37	**17.5**
Totals	18	18	3–308	**76.4**	0–228	**86.9**

* Rotenone catch per 250-ft. section is multiplied by 5.3 (ratio of ¼ mile to 250 ft.) so that catches can be more directly compared with those obtained with electrofishing gear.

was essentially random, which partially precludes the introduction of gross errors based on the initial systematic selection of the eight reference points.

The statistical analysis involved stratifying the bass catch data in accordance with fish abundance in the upper and lower portions of Lake Nacimiento. This stratification was warranted because bass catches were much larger in the upper or westerly portion of the reservoir in all years. For purposes of comparison the reservoir was divided into two parts; reservoir waters east of the junction of Los Tablas Creek and the Nacimiento River were considered the lower half and reservoir waters west of this junction (including the Los Tablas Creek drainage) were considered the upper half. Mean numbers of fingerling bass caught per section in the upper half of the reservoir in 1965, 1966, 1967, and 1968 were, respectively, 113.2, 21.4, 166.7, and 4.3. Comparable values in the lower half were 36.8, 1.0, 56.3, and 1.5.

Basic assumptions relative to the statistical analysis are that mean estimates within strata are normally distributed and that strata variance estimates are accurate and are equivalent to those which would have been produced from simple random sampling. The formulas and notations used are from Cochran (1953) and Snedecor (1956) and are as follows:

$N = N_1 + N_2$	Total number of ¼-mile shoreline sections in reservoir.
N_h	Number of ¼-mile shoreline sections in the h^{th} stratum.
$W_h = \frac{N_h}{N}$	Proportion of ¼-mile shoreline sections in the h^{th} stratum.
n_h	Number of ¼-mile shoreline sections sampled in the h^{th} stratum.
y_{hi}	Number of fingerling largemouth bass caught in the i^{th} section of the h^{th} stratum ($i = 1,2 \ldots . n_h$).

$$\bar{Y}_h = \frac{\sum_{i=1}^{N_h} y_{hi}}{N_h}$$ True sectional mean number of fingerling largemouth bass vulnerable to capture with electrofishing gear in the h^{th} stratum.

$$\bar{y}_h = \frac{\sum_{i=1}^{n_h} y_{hi}}{n_h}$$ Estimated sectional mean number of fingerling largemouth bass vulnerable to capture with electrofishing gear in the h^{th} stratum.

$$s_h^2 = \frac{\sum_{i=1}^{n_h} (y_{hi} - \bar{y}_h)^2}{n_h - 1}$$ Sample variance in the h^{th} stratum.

The stratified estimate of the population mean is

$$\bar{y}_{st} = \frac{1}{N} \sum_{h=1}^{2} N_h \bar{y}_h = \sum_{h=1}^{2} W_h \bar{y}_h.$$

The variance, standard error and coefficient of variation of this estimate are, respectively,

$$V(\bar{y}_{st}) = \sum_{h=1}^{2} W_h^2 \frac{s_h^2}{n_h},$$

$$s(\bar{y}_{st}) = \sqrt{\sum_{h=1}^{2} W_h^2 \frac{s_h^2}{n_h}},$$

and

$$cv = \frac{s(\bar{y}_{st})}{\bar{y}_{st}}.$$

Assuming normal distribution of sample means, 95% confidence intervals about $\bar{y}_{st}$ may be expressed as

$$\bar{y}_{st} \pm z^2_{1/2}\, \alpha\, s(\bar{y}_{st})$$

where $z\frac{1}{2}\alpha$ is the standardized normal variate at the $\frac{1}{2}\alpha$ probability level.

The stratified estimates of population means in 1965, 1966, 1967, and 1968 were, respectively, 87.3, 11.4, 120.3, and 3.0 (Table 3). The variance of these estimates were positively correlated with the means and ranged from a low of 0.8 in 1968 to a high of 331.7 in 1967.

Ninety-five percent confidence intervals expressed as ± the percent of stratified sample means were inversely correlated with sample sizes and ranged from a low ±22.7% in 1965 to a high of ±46.7% in 1968 (Table 3).

TABLE 3. Indices of Abundance and Associated Statistics of Fingerling Largemouth Bass Populations in Lake Nacimiento, 1965–1968

Population parameters	Year			
	1965	1966	1967	1968
n_h (Upper half)	20	12	12	10
n_h (Lower half)	12	7	6	6
$\bar{y}_h$ (Upper half)	113.2	21.4	166.7	4.3
$\bar{y}_h$ (Lower half)	36.8	1.0	56.3	1.5
s_h^2 (Upper half)	5,374.3	129.2	10,314.8	19.8
s_h^2 (Lower half)	1,454.9	1.0	1,050.6	3.1
W_h (Upper half)	0.53	0.51	0.58	0.52
W_h (Lower half)	0.47	0.49	0.42	0.48
$\bar{y}_{st}$	87.3	11.4	120.3	3.0
$V(\bar{y}_{st})$	102.3	2.8	320.0	0.7
$s(\bar{y}_{st})$	10.1	1.7	17.9	0.8
cv	0.12	0.15	0.15	0.27
$\bar{y}_{st} \pm z^2 \tfrac{1}{2}\alpha\ s(\bar{y}_{st})$*	87.3±19.8	11.4± 3.3	120.3±35.1	3.0±1.4
95% confidence interval* expressed as ± % of $\bar{y}_{st}$	±22.7	±28.9	±29.2	±46.7

* These statistics are valid only if the assumption that sample means are distributed normally is correct.

Relationship to Sample Size of Confidence Interval

Variance estimates obtained in 1965, a year of relatively intensive sampling, provide a basis for predicting the sample sizes required to obtain confidence limits of fixed width in relation to sample means. Since the variance of $(\bar{y}_{st})$ is directly proportional to $(1/n)$ under the existing allocation of samples within strata, it follows that the standard error of $(\bar{y}_{st})$ is proportional to $(1/\sqrt{n})$. Applying this relationship, it is possible to predict confidence interval widths using a variety of sample sizes. For example, a sample size of 100 (25 miles of shoreline) would produce an expected confidence interval of ±12.8% of the sample mean. A sample of 64 (16 miles of shoreline) would produce an expected confidence interval of ±16.1% of the mean value. A sample of 16 (4 miles of shoreline) would produce an expected confidence interval of ±32.1%. This latter sampling level approximates the sampling levels in 1966, 1967, and 1968. Estimated confidence limits agree closely with results obtained in 1966 and 1967, but are somewhat less than the confidence interval obtained in 1968. In cases when small reservoirs are sampled and the sampling level exceeds 10% of the total shoreline length the formula for the standard error of $(\bar{y}_{st})$ becomes

$$s(\bar{y}_{st}) = \sqrt{\sum_{n=1}^{2} W_h^2 \frac{(N_h - n_h)}{N_h} \frac{s_h^2}{n_h}}$$

The predictions for confidence intervals at various sampling levels are generally valid regardless of mean sample values since (s_h^2) tends to be positively correlated with $(\bar{y}_h)$ in most biological populations. These predictions are further based on total shoreline lengths sampled. In cases when individual shoreline sections are reduced in length an appropriate increase in sample size is required since (s_h^2) is inversely correlated with the size of individual samples.

Variance estimates of $(\bar{y}_{st})$ are relatively small when the allocation of sampling effort between strata is proportional to the product of the stratum size and stratum standard deviation. Such allocations are generally preferred over other sampling schemes when good estimates of strata variance are available. Estimates of variance obtained in 1965 indicate that an optimal allocation of sampling effort occurs when 68% of the samples are taken in the upper half of the reservoir and 32% in the lower half. These percentages approximate the distribution of sampling effort at Nacimiento Reservoir where 56 to 67% of all yearly samples were taken from the upper stratum.

FACTORS AFFECTING FINGERLING BASS ABUNDANCE

Largemouth bass year class strength in lakes and reservoirs is determined by many factors. Excessive reservoir drawdowns during the spawning season can result in year class failures. Large year classes have been associated with rising spring water levels (Bross 1969), high water temperature and a relative lack of wind during the spawning season (Kramer and Smith 1962) and a lack of competing or predatory fishes (Bennett 1954, Kramer and Smith 1960). Supplementary studies conducted at Lake Nacimiento over the period 1965–1968, coupled with data provided by the Monterey County Flood Control and Water Conservation District provide a basis for qualitatively assessing the effects of a variety of physical and biological factors on the production of fingerling bass at Lake Nacimiento.

A reasonable definition of the bass spawning period is required before an analysis of factors affecting fingerling bass production can be made. Limited limnological data collected during the study period indicate that reservoir waters warm sufficiently for bass spawning about mid-April. Suitable bass spawning temperatures have been reported ranging from 60–63 F (Eddy and Surber 1947) to 68–75 F (Swingle 1956). Based on these observations it appears that the bulk of largemouth bass reproduction occurs from mid-April to late May at Lake Nacimiento.

Reservoir Fluctuation Patterns

The relatively strong 1965 and 1967 largemouth bass year classes were associated with either increasing or stable reservoir surface elevations over the period April 15–June 1. Surface elevations on April 15, May 1, May 15, and June 1, were, respectively, 769, 770, 771, and 770 ft. Comparable values for 1967 were 792, 799, 800, and 799 ft. Conversely, the relatively weak year classes in 1966 and 1968 were associated with decreasing reservoir surface elevations over the same period. In 1966 the reservoir declined steadily from a surface elevation of 770 ft on April 15 to 760 ft on June 1. A decline from 766 to 757 ft occurred between April 15 and June 1, 1968.

There was no direct evidence that the drawdowns in 1966 and 1968 exposed bass nests before egg hatching and sac fry development had occurred. The depth at which bass nests were constructed at Nacimiento is not known, but a median value of 30 inches was recorded at Lake George, Minnesota, by Kramer and Smith (1962). In addition, these workers found that the period between egg deposition and free-swimming fry ranged up to 12 days and that broods of young bass often remained in close association with the nesting site for an additional 4 or 5 days.

In 1966 and 1968, reservoir surface elevations decreased at the rate of about 2.6 inches per day in the spring, a total of about 30 inches over a 12-day period. By inference, this rate of decline could have had serious effects on nesting success by reducing water depths over bass nests during the developmental period and increasing their exposure to the detrimental effects of wind and wave action. Decreasing reservoir elevations may also produce physiological stresses among very young bass, which could cause increased mortalities.

Reservoir Surface Elevation During Spring Spawning Periods

Large year classes of fingerling bass were associated with relatively high reservoir surface elevations during the spring. Mean reservoir surface elevations over the period April 15 through June 1, 1965 and 1967, years of relatively high fingerling bass production, were 770 and 798 ft, respectively. In 1966 and 1968, mean reservoir surface elevations over the same period were, respectively, 765 and 762 ft.

The distribution of brush and other forms of shelter in the reservoir basin is such that a much higher percentage of the shoreline is protected by various forms of vegetation when the reservoir is high. It seems reasonable to assume that the large year classes produced in 1965 and 1967 may, in part, be due to greater shoreline stability during the spawning period. Shoreline areas protected by brush and other vegetation receive much less direct wave action and provide more stable substrates for nesting purposes. Kramer and Smith (1962) have noted that bass nests constructed on needlerush were more successful than those constructed on sand. While little sand is present in the Lake Nacimiento basin, a high percentage of the shoreline in the fluctuation zone is composed of shifting silt interspersed with gravel. Presumably, bass nesting success is less in such areas.

Abundance of Yearling and Adult Game Fish

Extensive creel checks conducted at Lake Nacimiento from 1965 through 1968 provide a basis for relating fingerling bass abundance to indirect measures of game fish abundance as determined by recorded angler catch rates. Largemouth bass anglers had success rates of 0.20, 0.25, 0.19, and 0.22 fish per angler hour, respectively, in 1965, 1966, 1967, and 1968. Assuming that catch rates reflect adult bass abundance, the differences in recorded success were not of a magnitude which could account for the differences in fingerling bass production. I conclude that largemouth bass fingerling production at Lake Nacimiento is not related to the abundance of adult bass.

Black crappie angler success was relatively high in 1965 and 1966, and significantly lower in 1967 and 1968. Respective catches per hour were 1.52, 1.57, 0.78, and 0.72. No relation between fingerling bass and black crappie abundance was apparent from these data.

Anglers fishing for bluegill had modest success in 1965 and 1966 when recorded catch rates were 1.06 and 0.90 bluegill per angler hour, respectively. Angling quality increased in 1967 and 1968 to 1.48 and 1.50 bluegill per angler hour. Fluctuations in bluegill densities within the limits reflected by these data had no apparent effects on fingerling bass production.

The production of large bass year classes in alternate years raised the possibility that an abundance of yearling bass had a depressing effect on fingerling bass survival. Yearling bass were routinely collected during electrofishing in all years. Mean numbers of yearlings caught per $\frac{1}{4}$ mile section in 1965, 1966, 1967, and 1968 were, respectively, 5.0, 4.5, 1.4, and 5.6. The roughly comparable densities of yearlings in 1965, 1966, and 1968 were accompanied by wide variations in fingerling bass production. The small number of yearlings caught in 1967, however, was associated with a relatively large year class of fingerlings. Based on the low densities of yearling bass in relation to other fishes in the littoral zone and the broad variations in fingerling bass abundance in years when the density of yearlings was similar, I conclude that the abundance of yearling bass had only minor effects on the abundance of fingerlings.

Abundance of Adult Threadfin Shad

Trawling studies designed to monitor the abundance of threadfin shad were conducted routinely during the summers of 1966, 1967, and 1968. This forage species was first introduced in August 1964. No reproduction occurred that year, and a subsequent plant of 1,000 adults was made in April 1965. This plant was successful and large numbers of young-of-the-year threadfin shad were produced a few months later. Because adult threadfin shad were extremely abundant in littoral areas in some years and because of the probability that they compete with fingerling bass for food, I compared the density of adult threadfin shad, as determined by trawling, with the abundance of fingerling bass.

The relatively large 1965 and 1967 bass year classes were associated with low densities of adult threadfin shad. In 1965, the numbers of adult threadfin shad present were limited to the 1,000 adults stocked in April 1965, and the survivors of a plant of 2,000 young-of-the-year made in August 1964. Trawling during the summer of 1967 produced a mean catch of only 0.3 adult threadfin shad per standard haul. Conversely, the weak largemouth bass year classes of 1966 and 1968 were associated with much greater densities of adult threadfin shad. Mean numbers of adult threadfin shad caught per standard haul in the summers of 1966 and 1968 were, respectively, 9.0 and 25.0. While the trawling program was conducted in limnetic areas, the observations of the electrofishing crews were that adult threadfin shad dominated the fish fauna of the littoral zone in 1966 and 1968. I concur in the hypothesis that an abundance of adult threadfin shad is detrimental to largemouth bass spawning success or fingerling bass survival.

Miller (1971) has noted that the presence of threadfin shad is associated with relatively slow growth of largemouth bass to Age I in two major California impoundments on the east side of the Central Valley. At Lake Havasu, largemouth bass of all ages grew more rapidly in 1955 following the initial introduction of threadfin shad in 1954 (Kimsey, et al. 1957). Fingerling bass growth at Lake Havasu in 1956, however, appeared much slower. These findings may relate to the obviously low abundance of adult threadfin shad in 1955.

Mean lengths of fingerling bass captured by electrofishing at Lake Nacimiento in 1965, 1966, 1967, and 1968 were, respectively, 2.9, 2.5, 2.8, and 4.4 inches (FL). These data indicate an inverse relationship between adult shad abundance and the mean length of fingerlings from 1965 through 1967. The relatively large size of fingerling bass in 1968, however, was associated with the greatest density of adult shad recorded over the study period. A nearly total absence of smaller individuals rather than an upward extension of the size range was responsible for the large mean size of fingerling bass in 1968. This suggests the possibility that rigorous environmental conditions in 1968 permitted only the largest and most aggressive fingerling bass to survive.

Other Factors

Unfortunately, direct measures of other factors known to affect largemouth bass production such as differences in wind action and variations in water temperature during the bass nesting period are not available from the present study. By inference, it is reasonable to assume that the spring drawdowns in 1966 and 1968 decreased mean water depths over bass nests and that they were more susceptible to wave damage and water temperature fluctuations.

FACTORS AFFECTING FINGERLING BASS DISTRIBUTION

The electrofishing program at Lake Nacimiento provided an opportunity to compare qualitatively fingerling bass abundance in various types of shoreline habitat. All sections sampled were photographed and classified by degree of slope and amount of shelter present. Eight sections had uniformly gentle slopes (less than 30°) and 19 sections had uniformly steep slopes (more than 30°) (Figure 2). The remaining sections had both steep and gentle slopes within their boundaries. Ten sections were classified as being relatively free of shelter, while the remaining 22 sections contained moderate to abundant quantities of rock, rubble, brush, or fallen trees (Figure 3). Other factors considered include wind and wave action, reservoir drawdowns, and the distribution of spawners during the spring.

FIGURE 2. Shoreline section with a gentle slope (left) and steep slope (right).

FIGURE 3. Shoreline section containing shelter (left) and relatively free of shelter (right).

Shoreline Slope and Shelter

Fingerling bass catches in shoreline sections with steep slopes were roughly comparable to catches in sections with gentle slopes in all years (Table 4). These data indicate that the degree of shoreline slope is not a factor which grossly affects the capacity of littoral environments to support fingerling bass.

Shoreline sections judged relatively free of shelter produced considerably larger fingerling bass catches than sections with moderate to abundant shelter in 1965 and 1967, and a slightly lesser catch in 1966 and 1968 (Table 4). I conclude that the presence of dense shelter of the types described is not an essential requirement for the maintenance of fingerling bass populations during mid-summer. Kimsey et al. (1957) have noted that fingerling bass leave areas adjacent to weed beds and forage for threadfin shad when they reach a length of about 3 inches.

TABLE 4. Catch of Fingerling Largemouth Bass in Relation to Habitat Type in Lake Nacimienta, 1965–1968

Habitat type	Mean number of bass caught per section*			
	1965	1966	1967	1968
Steep slopes	77.5 (19)	14.7 (12)	116.4 (12)	3.4 (11)
Gentle slopes	72.8 (8)	11.8 (4)	104.3 (3)	2.3 (3)
Relatively free of shelter	106.3 (10)	13.0 (4)	197.0 (3)	3.5 (2)
Moderate to dense shelter	75.1 (22)	14.1 (22)	116.5 (15)	3.2 (14)

* Number in parentheses indicates number of sections sampled.

Wind and Wave Action

As previously noted, the upper or westerly half of Lake Nacimiento produced far greater catches of fingerling bass than the lower half (Table 3). The prevailing westerly winds, the location of the marina and resultant boat traffic, and the sheltering mountain range west of Lake Nacimiento were factors which combined to produce far more turbulence and wave action in the lower or eastern half of the reservoir as compared to the upper or western half. This finding strongly suggests that wave action was detrimental to largemouth bass spawning success.

Reservoir Drawdowns

At Lake Nacimiento maximum water levels are achieved in April and May, at the approximate time that largemouth bass are expected to spawn. Water levels steadily receded during the summer months and averaged about 30 ft lower during the electrofishing periods than they did in the spring. Since reservoirs characteristically lose a greater percentage of their shoreline length in their upper portions as they are drawn down, it was considered necessary to examine the possibility that fingerling bass were being artificially crowded in the upper half of the reservoir.

Shoreline length in the upper half of Lake Nacimiento were reduced by an average of 29% during the period of summer drawndown. A 19% reduction was recorded in 1965, 30% in 1966, 35% in 1967, and 31% in 1968. By contrast, shoreline lengths in the lower half of the reservoir was reduced by an average of only 11% during the same period. Reductions ranged from a low of 4% in 1965 to a high of 17% in 1967.

The differential loss of shoreline in the upper and lower halves of Lake Nacimiento would tend to increase relative bass densities in the upper half by 30%. Since fingerling bass catches averaged more than

300% higher in the upper half, I conclude that factors other than summer drawdowns were responsible for most of the increased fingerling bass production in the upper portion of the reservoir.

Distribution of Spawners

The selection of spawning sites by adult bass could influence the distribution of fingerlings. Despite the lack of evidence that crops of fingerling bass are positively correlated with the abundance of spawners, I considered the possibility that the low fingerling bass production in the lower half of the reservoir was related to an extremely low abundance of spawners. In the absence of direct measures of adult bass abundance, I compared creel census data obtained from bass anglers fishing in the two halves of the reservoir in April and May of 1965, 1966, 1967, and 1968.

Bass anglers had higher April and May success rates in the upper half of Lake Nacimiento in 1965 and 1966, and lower success rates in 1967 and 1968. The catch per angler hour in the upper half of the reservoir in the years 1965 through 1968 was, respectively, 0.31, 0.22, 0.13 and 0.18. Comparable values for the lower half were 0.14, 0.10, 0.21, and 0.28. The mean catch per angler hour over the 4-year period was 0.21 in the upper half and 0.18 in the lower half. From these data, I conclude that differences in fingerling bass abundance in the two halves of the reservoir are not related to the number of spawners present. The conclusion follows that variations in bass abundance in different parts of the reservoir result primarily from differences in survival of eggs and fry or from the migration of young bass.

MANAGEMENT IMPLICATIONS

Observations made during the course of this investigation coupled with known bluegill life history data suggest that shelter may be manipulated in ways to enhance bass production in fluctuating impoundments. As previously noted, bass nesting success was greatest in years when Lake Nacimiento was high and a relatively large percentage of the shoreline was sheltered. This immediately suggests that shelter should be left in reservoir basins at surface elevations normally associated with bass spawning. Conversely, the removal of shelter capable of providing refuge for small fish from the summer fluctuation zone may discourage excessive bluegill reproduction and facilitate bass predation. Based on the distribution of fingerling bass in the summer, it does not appear that the removal of dense shelter from the summer fluctuation zone would be detrimental to them.

While fishery managers usually have limited control over water withdrawal patterns from reservoirs, it is desirable to keep water levels from receding during the bass nesting period. Theoretically, stable or rising water levels in the spring followed by a rapid summer drawdown is preferable to a more gradual drawdown over spring and summer. The former water withdrawal pattern would enhance largemouth bass production and should divert some of the production of the lesser sunfishes from bluegill to the deeper-nesting red-ear sunfish. This is probably desirable because red-ear sunfish are faster growing than bluegill, have less tendency to stunt, and reach a larger size in most California impoundments. While red-ear sunfish are generally considered more difficult to harvest than bluegill (Bennett 1962), differential exploitation rates may not be excessive. For example, the mean annual angler harvest rate from three Indiana lakes where bluegill and red-ear sunfish were present was 37% for bluegill and 31% for red-ear sunfish (Ricker 1945, 1955; Gerking 1953).

The inverse relationship between the abundance of adult threadfin shad and the abundance of bass fingerlings suggests that improved reservoir management can be achieved by finding ways to increase predation on threadfin shad during their first growing season. The enormous variations in the survival of threadfin shad to Age I in the face of fairly stable game fish populations further suggests that factors other than predation are responsible for differences in their survival. The conclusion follows that existing crops of threadfin shad are underutilized by the present game fish species complex at Lake Nacimiento.

Threadfin shad make extensive use of both limnetic and littoral areas while the game fish species at Lake Nacimiento are oriented largely to the littoral zone. Only black crappie were taken regularly with a midwater trawl. The introduction of additional limnetic predators such as striped bass (*Morone saxatilis*), white bass, and salmonids should increase game fish production in reservoirs and reduce the detrimental effects of adult threadfin shad on largemouth bass fingerlings.

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NONREPORTING OF TAGGED WHITE CATFISH, LARGEMOUTH BASS, AND BLUEGILLS BY ANGLERS AT FOLSOM LAKE, CALIFORNIA [1]

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Nonreporting of tagged white catfish, largemouth bass, and bluegills by anglers at Folsom Lake, California, was 39%, 46%, and 69%, respectively. Nonreporting of white catfish less than 10.0 inches and largemouth bass less than 11.0 inches was approximately 2.5 times that for larger fish, although all size classes were equally vulnerable to the fishery. The $5-reward tag encouraged anglers to keep fish that otherwise would not have been retained. Anglers in California have shown a nonresponse ranging from 30 to 50% for a wide variety of freshwater fishes and approximately 40% as a general rule.

INTRODUCTION

In every tagging study in which estimation of exploitation rate is the prime goal, the hypothesis that all tagged fish have been reported should be tested (Paulik 1963). Commonly, exploitation rates have been obtained through tagging experiments in which nonresponse is either disregarded or presumed negligible, but exploitation rates may vary from 0.84 to 0.16 for a given population when the nonreported proportion varies from 0.00 to 0.75 (Horsted 1963).

Therefore, a tagging study to determine the variation and general level of nonreporting of the capture of tagged fish by anglers fishing for largemouth bass *(Micropterus salmoides)*, white catfish *(Ictalurus catus)*, and bluegills *(Lepomis macrochirus)* was conducted from April 1962 to 1968 at Folsom Lake, California, a 10,000-acre, fluctuating reservoir. The lake and certain aspects of its fishery and limnology have been described by Rawstron (1964, 1967), von Geldern (1964), and Tharratt (1966). Information about nonresponse was necessary for more precise estimation of the exploitation rates of stocks of similar species that were the subject of a concurrent tagging study in which no reward was offered for return of tags. It would serve also as a basis for evaluation, and correction if necessary, of the exploitation rates obtained for fish of the same species in similar waters in California.

METHODS

Tagging operations were discontinuous; there were periods of 2 weeks when no tagging was done. Bass and bluegills were tagged from April 26 through June 20, 1962 and catfish from April 26 through August 24, 1962. Fish were captured with seines, electrofishing appara-

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tus, Oneida traps, and fyke nets, but most centrarchids were taken by electrofishing at night and the catfish by trapping. Generally, fish caught by electrofishing were held overnight in live-cars and tagged the following day in the vicinity of capture. Fish caught by seining and trapping were tagged immediately at the site of capture.

A modified Atkins tag was used. Tags of this type had proved satisfactory for largemouth bass (Kimsey 1957; LaFaunce, Kimsey, and Chadwick 1964; Rawstron 1967); striped bass *(Morone saxatilis)* (Calhoun 1953; Chadwick 1963); channel catfish *(Ictalurus punctatus)* (McCammon 1956; and white catfish (Pelgen and McCammon 1955). Mine were cellulose nitrate disks 0.040-inch thick and either 1 cm or ½-inch in diameter. The smaller ones were used on the centrarchids and the larger ones on catfish. They were attached with tantalum wire 0.020-inch in diameter, midway between the first dorsal fin and the lateral line under the longest spine, using the technique described by Chadwick (1963), except for the catfish, which were tagged similarly under the dorsal spine.

A numbered tag inscribed "$5 REWARD, California Fish and Game, Sacramento, Calif." was placed also on approximately 50% of each species of fish tagged. On the remaining 50% a numbered tag inscribed only with the name and address of the Department was attached. To provide approximately equal numbers of reward and nonreward tags in each length class, fish were tagged alternately with reward and nonreward tags.

Only largemouth bass greater than 9.0 inches fork length, white catfish greater than 8.0 inches and bluegill greater than 6.0 inches were tagged. These sizes were considered the minimum completely acceptable to the angler.

Posters advertising the program were displayed conspicuously around the Lake. Posters and franked envelopes were placed at all state park entrances, at the only marina, and at other local businesses. In addition, creel census clerks advised many anglers of the program. A commendation card was mailed to every angler returning a tag, along with $5 when the tag bore an offer of reward.

The proportion of tags not returned from tagged fish caught by anglers was estimated from the formula:

$$n = 1 - \frac{M' \quad R''}{R' \quad M''}$$

$$= 1 - r$$

where:
n = proportion of recaptured tags not returned (nonresponse)
r = proportion of recaptured tags returned (response)
M' = number of reward tags applied
R' = number of reward tags returned
M'' = number of nonreward tags applied
R'' = number of nonreward tags returned

Variance of nonresponse is equal to variance of response (Chadwick 1968) and was calculated using his formula. Confidence limits were estimated assuming a normal distribution.

Implicit in this definition of nonresponse is the assumption that all $5-reward tags were returned. Undoubtedly, a few anglers did not return reward tags and, therefore, a consistent underestimate of nonresponse resulted. No attempt was made to measure the magnitude of this error, but its effect was considered minimal. Because the $5 reward itself might have created a higher response, nonresponse was analyzed by length class.

RESULTS

White Catfish

Of 440 white catfish tagged, 211 were tagged with nonreward tags and 219 with reward tags (Table 1). Both groups averaged 10.8 inches FL when tagged.

TABLE 1. Length-Frequency Distribution of White Catfish at Tagging, and Yearly Returns of Reward and Nonreward Tags by Length Class at Tagging, 1962 Through 1966

Fork length (inches)	Number tagged	Number tags returned						
		1962–1963	1963–1964	1964–1965	1965–1966	1966–1967	1967–1968	Total
8.0–8.9								
Reward	37	7	5	5	4	2	1	24
Nonreward	40	1	0	3	2	1	1	8
9.0–9.9								
Reward	65	10	7	5	4	2	1	29
Nonreward	55	4	2	3	8	1	1	19
10.0–10.9								
Reward	41	7	1	2	3	2	1	16
Nonreward	40	2	4	1	3	0	1	11
11.0–11.9								
Reward	22	7	0	2	3	0	2	14
Nonreward	28	4	1	2	2	1	0	10
12.0–12.9								
Reward	28	7	3	1	5	0	2	18
Nonreward	25	6	3	2	2	0	0	13
13.0–16.0+								
Reward	28	3	7	1	5	1	0	17
Nonreward	31	7	0	2	2	0	0	11
Totals								
Reward	221	41	23	16	24	7	7	118
Nonreward	219	24	10	13	19	3	3	72

Over 6 years, nonresponse by white catfish anglers was highly variable, ranging from 0.22–0.66 with a mean of 0.39 ± 0.14 (Table 2). During the first 2 years there were few returns of fish less than 10.0 inches, when tagged. Mean nonresponse for these fish was 0.74 ± 0.20, whereas it was only 0.28 ± 0.24 for fish of larger size when tagged. Size at the time of tagging, however, did not significantly influence the number of reward tags returned (Rawstron 1967); therefore, all fish were equally vulnerable to the fishery. A significant difference, however, did occur in numbers of nonreward tags returned by size of fish when tagged (ibid.) These two facts indicated anglers did not return nonreward tags from small fish as readily and/or that the $5 tag induced anglers to keep fish less than 10 inches that they would otherwise have released.

The former is borne out by the sharp reduction in nonresponse in the third and fourth year, presumably as the catfish 8.0 and 9.9 inches long, when tagged, had reached a size at which anglers returned the nonreward tags at a higher rate (Tables 1 and 2). However, anglers returned approximately three times as many reward tags during the first 2 years from smaller fish. Unpublished data from a creel census conducted at Folsom Lake during 1962 showed that only 26.9% of the annual angler catch of white catfish was less than 10.0 inches, while the mean length in the catch was 11.4 inches (von Geldern 1964). Anglers apparently did not consider white catfish less than 10.0 inches completely acceptable, but would return a reward tag from fish of this size.

TABLE 2. Nonreporting by Anglers of Tagged White Catfish from Folsom Lake, California

Year	Number of reward tags returned	Number of nonreward tags returned	Nonresponse (n)
1962–63	41	24	0.42 ±0.28
1963–64	23	10	0.57 ±0.22
1964–65	16	13	0.20 ±0.19
1965–66	24	19	0.22 ±0.20
1966–67	7	3	0.66*
1967–68	7	3	0.66*
Totals	118	72	
Mean nonresponse			0.39 ±0.14

* No confidence limits computed; sample size too small.

Although both factors operated concurrently to lower response, from the latter two observations of the creel census I conclude that the greatest effect came from anglers returning the $5-reward tag from small fish, resulting in overestimates of exploitation rates for small fish based on reward tags.

Largemouth Bass

Mean fork length of largemouth bass tagged with reward tags was 11.7 inches, while fish with nonreward tags averaged 11.8 inches. Anglers returned 122 reward tags and 76 nonreward tags over 4 years (Table 3). The mean nonresponse for this period was 0.38 ± 0.13, but first-year nonresponse of 0.46 ± 0.13 appears to be more meaningful because of low returns in succeeding years. This value is about twice the angler nonresponse (0.25) for strap and cheek tags on adult bass in Massachusetts (Stroud and Bitzer 1955).

Although all tagged fish were equally vulnerable to the fishery (Rawstron 1967), anglers again showed a lower nonresponse for larger fish. First-year nonresponse for fish 11.0 inches or longer at tagging was only 0.24 ± 0.20, whereas it was 0.59 ± 0.16 for fish less than 11.0 inches. For all 4 years combined, angler nonresponse amounted to only 0.05 for fish longer than 11.0 inches, when tagged, while it was 0.52 for fish less than 11.0 inches, when tagged. Unlike the data for white catfish these suggest strongly that any bias in response arose primarily from anglers failing to return nonreward tags from small fish and not from the inducement of the $5 reward to return tags.

Further evidence to support this hypothesis comes from the same creel census, which showed that 63% of the largemouth bass catch annually was less than 11.0 inches (unpublished data), while their mean length in the catch was 11.7 inches (von Geldern 1964). Thus, bass between 9.0 and 11.0 inches were completely acceptable to the angler. Reported estimates of exploitation rates (Rawstron 1967), therefore, were close to the true rate.

TABLE 3. Length-Frequency Distribution of Largemouth Bass at Tagging, and Yearly Returns of Reward and Nonreward Tags by Length Class at Tagging, 1962 Through 1966

Fork length (inches)	Total tagged	Number of tags returned 1962–1963	1963–1964	1964–1965	1965–1966	Total
9.0–9.9						
Reward	40	23	0	0	0	23
Nonreward	41	10	0	0	0	10
10.0–10.9						
Reward	75	48	3	0	0	51
Nonreward	67	17	4	2	0	23
11.0–11.9						
Reward	39	9	4	0	0	13
Nonreward	38	16	1	1	1	19
12.0–12.9						
Reward	15	8	0	1	0	9
Nonreward	19	4	0	1	0	5
13.0–13.9						
Reward	18	7	0	0	0	7
Nonreward	18	6	1	0	0	7
14.0–14.9						
Reward	18	8	0	0	1	9
Nonreward	22	3	0	1	2	9
15.0–15.9						
Reward	14	4	0	0	1	5
Nonreward	12	3	1	0	0	4
16.0+						
Reward	11	4	1	0	0	5
Nonreward	13	1	0	0	1	2
Totals						
Reward	230	111	8	1	2	**122**
Nonreward	230	60	7	5	4	**76**

Bluegill

Only 89 reward and 89 nonreward tags were placed on bluegill over 6.0 inches. Both tagged groups averaged 7.4 inches FL. Anglers returned 35 reward tags and 11 nonreward tags over the first 3 years of the study (Table 4). No tags have been returned in later years.

Calculated nonresponse for the first 3 years amounted to 0.69 ± 0.19, but first-year nonresponse (0.84 ± 0.14) was more reliable because of the few returns in the next 2 years.

Insufficient returns precluded any analysis of differential nonresponse by size (Table 4), but since the mean length in the angler's catch

TABLE 4. Length-Frequency Distribution of Bluegills at Tagging and Yearly Returns of Reward and Nonreward Tags by Length Class at Tagging, 1962 Through 1965.

Fork length (inches)	Number tagged	Number of tags returned 1962–1963	1963–1964	1964–1965	Total
6.0–6.9					
Reward	36	16	0	1	17
Nonreward	37	3	1	1	5
7.0–7.9					
Reward	23	6	1	0	7
Nonreward	25	0	1	0	1
8.0–8.9					
Reward	27	9	1	1	11
Nonreward	25	2	1	1	4
9.0–9.9					
Reward	3	0	0	0	0
Nonreward	2	0	1	0	1
Totals					
Reward	89	31	2	2	**35**
Nonreward	89	5	4	2	**11**

was 5.6 inches (von Geldern 1964) and 50.9% were less than 6.0 inches (unpublished data), I believe that anglers released most bluegill with nonreward tags, but returned the reward tags. Thus, the calculated apparent exploitation rate (0.37) (ibid.) based on reward tags, is probably higher than the true rate.

DISCUSSION

It was obvious that not all reward tags were returned, since interviews with anglers showed that some considered a $5 reward insufficient inducement and preferred to keep the tag as a memento. However, the great majority of anglers were eager to cooperate with the Department and receive the reward and it seems safe to assume that nearly all reward tags were returned. In 6 years of study at Merle Collins Reservoir, a smaller lake with a single access point, all reward tags from largemouth bass seen and recorded at a census station were later returned for the $5 reward. Mean nonresponse, calculated similarly as in this study, again amounted to approximately 40% (Rawstron 1964).

The original assumption that the $5 reward for the return of a tag did not bias exploitation rates proved invalid. Anglers returned tags from significantly more small fish with a $5 reward tag than with a nonreward tag, although all fish tagged were equally vulnerable to the fishery. In tagging studies in which a reward is offered for the return of a tag, to minimize errors in estimated exploitation rate, account must be taken of the smallest size of fish completely acceptable to the fishermen, so that the effects of overreporting will be reduced. This judgment must be based on the quality of the fishery and established size and bag limits.

For example, in the California striped bass fishery, which has a three-fish bag limit and 16-inch size limit, errors in estimated exploitation rates based on reward tags should be less, since the limit is rarely attained by the average angler and the size limit is sufficiently large to maintain angler interest. Similarly, where "put-and-take" trout programs exist as a result of stocking catchable-sized fish of relatively uniform size, errors again would be less since all fish are probably "acceptable" to the angler.

Other California researchers have measured nonresponse for striped bass and trout, using similar tags. Values ranging from 30 to 44% have been reported for striped bass anglers in the Sacramento-San Joaquin Delta over a 10-year period (Chadwick 1968). Unpublished data from a study with tagged rainbow trout in Lake Tahoe, where a $5 reward for tag return was offered, showed nonresponse of 39% in the first year after tagging and 36% in the second year. A $1 reward for tag return in this same study resulted in a nonresponse of 51% in the first year and 53% in the second year. The results showed that nonresponse varies widely and that a $1 reward for tag return was not sufficient inducement to the angler to return the tag.

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HARVEST AND SURVIVAL OF RAINBOW TROUT INFECTED WITH *SANGUINICOLA DAVISI* WALES[1]

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Rainbow trout, heavily infested with the blood fluke, *Sanguinicola davisi*, showed good annual harvest and survival rates, good growth, and a low cost to the angler's creel in an intermediate type of reservoir with few limnetic predators or competitors.

INTRODUCTION

Annual harvest and survival rates were estimated for a group of stocked rainbow trout, *Salmo gairdneri*, 100% heavily infested with the parasitic fluke, *Sanguinicola davisi* Wales.

This fluke in the past has caused heavy losses at Darrah Springs Hatchery, California (Wales 1958). However, this situation has been largely corrected through environmental control of the snail which serves as an intermediate host. Trout in otherwise satisfactory condition which harbor some of these parasites can be stocked safely in drainages lacking the snail host, where there is no danger of spreading the range of the disease. Moreover, moderate infestations do not seriously lower the quality of the fish. At times in the past, a large proportion of the trout produced at Darrah Springs Hatchery carried this fluke in their gills. Their ability to survive in natural waters was, therefore, a matter of considerable interest. This paper presents the first known information on harvest, survival, growth rates, yield and cost per pound to the angler's creel of parasite-infested trout stocked in a reservoir.

Life Cycle of *Sanguinicola davisi*

The distribution of this digenetic trematode (family Sanguinicolidae) coincides with that of the snail, *Oxytrema circumlineata*, its intermediate host (ibid.) Adults live in the gill arteries of fish. Their eggs develop into miricidia in the gill capillaries; subsequently they emerge and swim about until they find and penetrate their snail host. Within the snail, miricidia develop further into cercariae. At this stage the parasite leaves the snail, enters its fish host and develops into the adult form which then lays eggs. Thus, all stages from the egg to miricidia occur in the gills. If the miricidia become sufficiently abundant they may kill the host. The most critical periods in the hatchery occur when the miricidia leave the gill capillaries and/or the fish are stressed. Wales (ibid.) gives a more complete life history of the species.

Description of Study Water

Merle Collins Reservoir, the study reservoir, is a 1,000-acre lake impounded behind Virginia Ranch Dam, Yuba County, California. It lies

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at an elevation of 1,180 ft and fluctuates approximately 40 ft a year. At the time of this study it contained a large littoral population of largemouth bass (*Micropterus salmoides*) 5 to 10 inches in length, numerous black bullheads (*Ictalurus melas*), and small numbers of sunfish (Centrarchidae) of several species. Virtually no limnetic predators, competitors, or other salmonids were present. *O. circumlineata* was unknown in the watershed. Consequently, infestation of wild fish could not take place.

METHODS

Rainbow trout of the Mt. Shasta strain, raised at Darrah Springs Hatchery, Shasta County, California, were planted on December 16, 1966. This strain has been previously described by Cordone and Nicola (1970). They numbered 6,795 with a mean fork length of 7.2 inches and a mean weight of 0.19 lb.

A sample of this group of trout remaining at the hatchery was examined on January 23, 1967 and harbored the following parasites:

Gills:

Sanguinicola davisi:

100% incidence; moderate to heavy infestation; two and three stages of egg development; many eggs with pigment spots and active miricidia, also early and intermediate stages of development.

Trichodina sp.:

35% incidence; 1 to 3 organisms in a scraping, when present.

Ichthyopthirius sp.:

10% incidence; 1 to 2 organisms in a scraping, when present.

Plistophora sp.:

100% incidence; few to numerous cysts in each fish.

Integument:

Gyrodactylus sp.:

very light incidence (less than 10%); an occasional organism present in skin scraping.

A creel census modified from Best and Boles (1956) provided the basis for estimating yield, exploitation rates and survival. All fish observed were weighed and measured. Creel census was conducted on two weekdays per week and all weekends and national holidays. Monthly observed catch data were expanded by multiplying the number of fish observed on the weekdays by the ratio of the number of week days during the month to the number of week days censused. These values were then added to the observed catch on weekends and national holidays to estimate the total monthly catch. From November through February, only one weekday per week was censused. Estimates of monthly weight landed were obtained by multiplying the observed monthly mean weight by the estimated total monthly catch.

The left ventral fin was excised on all fish. Annual exploitation and survival rates (Ricker 1958) were calculated by considering those marked fish at liberty 0 through 365 days after planting as first-year returns, while second-year returns included those recaptured from 366 through 730 days after planting.

RESULTS AND DISCUSSION

A total of 1,561 trout was caught over the 2 years of the study beginning on March 4, 1967, when the lake officially opened to the public. Anglers caught 1,290 the first year and 271 the second year (Table 1). None were observed after October 1968. Fishermen caught most of the fish during the first four months, although fishing improved again during the fall and continued into the following spring. Fishing effort during late fall and early winter declined because of poor weather conditions and turbid water.

TABLE 1. Observed and Estimated Catch, and Mean Weight of Rainbow Trout Infested with *S. davisi* at Merle Collins Reservoir, 1967–68.

	Observed catch			Estimated catch	
	Number	Weight* (lb.)	Mean weight (lb.)	Number	Weight* (lb.)
March 4, 1967	41	13	0.32	91	29
April	311	131	0.42	379	159
May	158	82	0.52	186	97
June	270	162	0.60	462	277
July	54	34	0.63	97	61
August	73	48	0.66	159	105
September	88	58	0.66	220	145
October	191	134	0.70	303	212
November	83	61	0.74	210	155
December 15, 1967	21	15	0.71	77	55
Total 1st year	1,290	738		2,184	1,295
December 16, 1967	15	11	0.71	55	39
January 1968	66	49	0.74	125	93
February	139	101	0.73	271	198
March	37	27	0.73	71	52
April	12	11	0.91	19	17
May	0	0		0	0
June	1	2	1.54	1	2
July	0	0		0	0
August	0	0		0	0
September	0	0		0	0
October 1968	1	3	3.26	1	3
Total 2nd year	271	204		543	404
Grand total	1,561	942		2,727	1,699

* Weight to nearest pound.

Mean annual exploitation and survival rates, computed from the expanded data, were 0.32 and 0.25, respectively. The calculated exploitation rate underestimated the true rate because trespassers caught many fish between December 1966 and March 4, 1967, and a few anglers, who gained access to the lake from areas other than the access road, were not censused.

During May 1967 anglers also caught 660 infested trout from the stream below the dam. These trout emigrated during a prolonged period of spillway discharge. These data are not included here.

Trout grew rapidly during the early part of the study, feeding primarily on zooplankton. Their mean weight leveled off during the summer and remained fairly constant at approximately 0.7 lb. until the following spring (Table 1). During the spring of 1968, a large population of small threadfin shad (*Dorosoma petenense*) developed.

Trout fed heavily upon them, accounting for the surge in weight noted for the few fish sampled from April to October (Table 1).

Based on an annual mean area of 860 acres and the estimated weight landed, these trout yielded 1.97 lb. per acre. This value compares favorably to yields of 0.62 to 8.78 lb. acre for the other lakes in California of poor to medium fertility and managed only for trout (Nicola and Borgeson 1970).

Infested trout returned an estimated 1,697 lb. This amounted to 131% of the original weight of trout planted. Dividing the cost of producing these fish (@ \$.86 lb. Ward 1968) by the number of pounds harvested, gives a cost of \$.65 lb. to the angler's creel, which is significantly lower than for "put and take" programs. However, it is slightly higher than \$.48 lb. calculated for rainbow trout of similar size planted at Lake Berryessa, California (Robert R. Rawstron, MS). There, however, fish grew more rapidly, feeding on abundant threadfin shad, and achieved a mean weight of 1.75 lb. 6 months after planting.

CONCLUSIONS

Under the conditions noted in this study, rainbow trout infested with *S. davisi* did create an economical fishery of satisfactory quality and quantity in a reservoir without competing or predatory fish. How such fish would respond when planted in other environments remains unanswered.

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THE 1965–1967 MIGRATIONS OF THE SACRAMENTO-SAN JOAQUIN ESTUARY STRIPED BASS POPULATION[1]

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Striped bass *(Morone saxatilis)* migrations are described based on tag returns from the third in a series of tagging programs dating back to 1950.

In 1965–66 the general migration pattern was essentially the same as it was in 1958–61. No return to the pattern of the early 1950's in which few bass entered San Francisco Bay or the Pacific Ocean occurred.

In general, larger fish moved farther downstream. Only medium-sized and large fish went to sea, and then only in the summer and fall. Small fish were the only ones common in fresh water during the summer.

Major differences between 1958–61 and 1965–66 were a population shift from San Francisco Bay to San Pablo Bay during the winter, a downstream movement of small and medium-sized fish into San Francisco Bay during the fall, a shorter residence time in the ocean during the summer and a reduced oceanic range. All are difficult to explain.

Fish length seemed to influence migration pattern more than sex did.

INTRODUCTION

Only the general seasonal nature of California striped bass migrations was known prior to a tagging study during 1950–52 (Calhoun, 1952). Tag returns from that study showed that striped bass in the Sacramento-San Joaquin estuary had an anadromous migration pattern. They moved upstream to fresh water in the fall, remained there to spawn in the spring, and returned to the brackish bays in the late spring. Very few tagged fish were taken in San Francisco Bay and none in the Pacific Ocean.

In 1958, changes in the fishery led Chadwick (1967) to conduct another tagging program to determine if the bass had altered their migration pattern. They had. More bass were entering San Francisco Bay and the Pacific Ocean than had done so in the early 1950's.

In 1965 and 1966, a third tagging program was conducted. Its primary purpose was to measure mortality rates, but the results provide a continuing description of migrations. This paper compares the results of this third study with those of Calhoun and Chadwick. Angler returns were analyzed to clarify the general migration pattern and to determine how size and sex affect migration.

METHODS

Tagging methods were essentially the same as Chadwick (1967) described for the 1958–1961 study. The main difference was that bass were tagged at fewer locations. Most of the bass were tagged near Schad Landing on Sherman Island in the lower San Joaquin River (Figure 1, location C). In 1966 substantial numbers were also tagged at Pri-

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soner's Point in the eastern Delta (Figure 1, location F and Table 1). All bass were caught in gill nets, and only disc dangler tags were used.

All fish were tagged in April and May. First year returns are tagged fish caught within 365 days after tagging; consequently, first year returns do not cover a definite calendar period but run generally from spring to spring.

The location and time of tagging resulted in the capture mainly of mature fish over 15 inches, because most immature, legal-sized fish are downstream at that time (Chadwick, 1967).

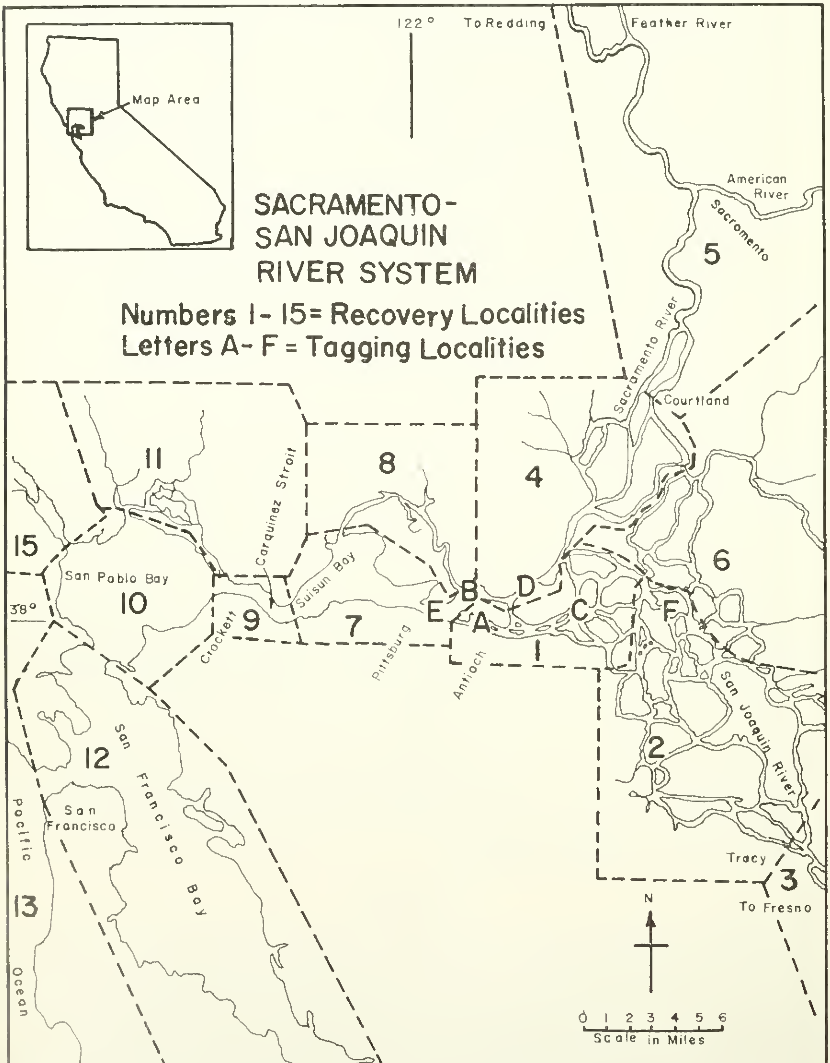

FIGURE 1. Map of the study area. The network of channels in the area bounded by Pittsburg, Tracy and Sacramento is known as the Delta. Tagging sites are located by letters. The numbers refer to recovery areas, the limits of which are the dashed lines.

Since the tags were returned by anglers, the results reflect the location of the fishermen as well as the fish. For instance, relatively few tags were ever returned from Suisun Bay although most adult bass pass through the area twice a year. The lack of launching and berthing facilities in this area discourages anglers from using it. Hence, the number of returns from it does not reflect bass abundance. Chadwick (1967) discusses at length the problems of differential fishing pressure on tag returns.

TABLE 1. Summary of Striped Bass Tagged During Springs of 1965 and 1966.

Location	1965					1966			
	Males	Females	Unknown	Total	Mean length	Males	Females	Total	Mean length
A Broad Slough	9	17	1	27	27.5	1	1	2	22.0
B Chain Island	12	32	0	44	27.3	0	0	0	--
C Sehad Landing	2,814	1,118	54	3,986	25.1	1,790	1,114	2,904	26.5
D Sacramento River	26	51	5	82	28.5	1	2	3	31.7
E Chipps Island	14	11	0	25	26.7	0	0	0	--
F Prisoner's Point	4	3	0	7	24.8	328	83	411	24.2
Total	2,879	1,232	60	4,171	25.0	2,119	1,201	3,320	26.2
Mean length	23.7	28.7	--			24.3	29.5		

RESULTS

General Migration Pattern

Bass tagged in the western Delta (Figure 1, A,B,C,D,E) in the spring moved downstream to saline water in the late spring (Table 2). During the summer they were most abundant in north San Francisco Bay. Large numbers were also present in the Pacific Ocean from Tomales Bay, 40 miles north of the Golden Gate, to Half Moon Bay, 25 miles south of the Golden Gate. Adult bass began returning to the Delta in the fall, although many overwintered in San Pablo Bay. In the spring they moved into the Delta and the upper Sacramento River to spawn.

TABLE 2. Summary of Striped Bass Migration From June 1965 to May 1967.

Locality†	Tag returns by months*				
	June–Aug.	Sept.–Nov.	Dec.–Feb.	Mar.–May	Annual total
Upper Sacramento River (5)	0.21	0.04	0.02	0.25	0.52
Delta (1, 2, 4 & 6)	0.21	0.35	0.24	0.31	1.11
Suisun Bay (7 & 8)	0.01	0.39	0.04	0.03	0.47
Carquinez Strait, Napa River (9 & 11)	0.59	0.25	0.06	0.04	0.94
San Pablo Bay (10)	0.60	0.99	1.01	0.24	2.84
San Francisco Bay (12)	1.44	1.89	0.10	0.26	3.69
Pacific Ocean (13)	0.72	0.21	0	0	0.93
Total	3.78	4.12	1.47	1.13	10.50

* Numbers are the mean percentages of numbers tagged in the western Delta. Only first year returns from each year's tags were used. No returns were received from the upper San Joaquin River (3) or Petaluma Creek (15).

† Numbers in parentheses refer to recovery areas in Figure 1.

Migration of Eastern Delta Fish

Returns from fish tagged in the eastern Delta were analyzed to determine if eastern Delta fish migrated differently from those tagged in the western Delta.

In 1966, 411 bass were tagged at Prisoner's Point on the San Joaquin River in the eastern Delta (Figure 1, location F). They averaged about 2 inches smaller than fish tagged in the western Delta that year (Table 1). The 52 first year tag returns from these fish showed a migration pattern similar to that of fish tagged in the western Delta. However, none of the tagged fish were caught in the tagging area. Only 4 of the returns originated upstream of Suisun Bay and 3 of these were from the lower Sacramento River. On the other hand, 9.7% of the 15- to 20-inch bass tagged in the western Delta in 1965 and 1966 were caught in the eastern Delta. Few larger western Delta bass turned up in the eastern Delta, however.

Effects of Size on Migration

Tagged fish were divided into three length groups: 15 to 20 inches FL, 21 to 24 inches, and 25 inches or larger (Table 3). Length significantly influenced the time and place of recovery of male bass (Table 4). The relationship between size and migration could not be defined for females because most of them were 25 inches or larger when tagged.

Analysis of the movement of the two smaller size groups is hampered by the low number of tag returns from these groups, especially during the winter and spring (Table 3). The following description of migration is based on the combined 1965 and 1966 first year returns.

Fifteen to 20-Inch Fish. These small fish showed a strong tendency to remain in fresh water during the summer. The largest number of returns came from the Delta and lower Sacramento River, with Carquinez Strait close behind. Returns during the fall months indicated a downstream shift in the population to San Francisco Bay (Tables 3 and 5), although substantial numbers apparently remained in the Delta. The winter distribution duplicated that of the fall. Returns from the upper Sacramento River during the spring revealed an upstream migration to the spawning grounds. Returns from the Delta, another spawning area, peaked in this season, while recoveries from the Bay areas declined.

Twenty-one to 24-Inch Fish. Almost all medium-sized fish were in brackish or salt water during the summer. Returns from upstream areas date from June and are probably seaward moving fish. Some bass had entered the ocean but most were in San Pablo Bay and Carquinez Strait. During the fall, the bulk of the population shifted downstream to San Francisco Bay (Tables 3 and 5), but rising Delta recoveries signaled an upstream movement of some fish. Winter recoveries were too few to provide a good picture of distribution, but San Pablo Bay appears to have been an important overwintering area. During the spring, many bass moved into the upper Sacramento River to spawn. There were few returns from below Suisun Bay in this season.

The summer location of the medium-sized bass differed considerably between 1965 and 1966. In the latter year there were very few bass in

TABLE 3. Comparison of Percentage Returns by Size Group, 1965 and 1966 Returns Combined.

Recovery areas†	Tag returns by month and size group*														
	June–August			September–November			December–February			March–May			Totals		
	15–20	21–24	≥25″	15–20	21–24	≥25″	15–20	21–24	≥25″	15–20	21–24	≥25″	15–20	21–24	≥25″
Upper Sacramento River (5)	7.2	3.8	0.5	0	0	0.5	0	0	0	2.7	7.6	1.3	9.9	11.4	2.3
Delta and lower Sacramento River (1, 2, 4, 6)	9.9	0.9	0.5	9.9	4.8	1.7	6.3	1.9	1.5	8.1	1.9	2.1	34.2	9.5	5.8
Suisun Bay (7, 8)	0	0.9	0	0.9	0.9	4.9	0.9	0	0.4	0	0	0.4	1.8	1.8	5.7
Carquinez Strait, Napa River (9, 11)	7.2	9.5	4.5	5.4	3.8	1.5	0	0.9	0.5	1.8	0.9	0	14.4	15.1	6.5
San Pablo Bay (10)	2.7	12.3	5.1	3.6	3.8	11.7	1.8	2.9	12.6	1.8	2.9	2.3	9.9	21.9	31.7
San Francisco Bay (12)	4.5	7.6	16.7	17.1	26.6	16.4	4.5	0	0.4	3.6	2.9	2.3	29.7	37.1	35.8
Pacific Ocean (13)	0	0.9	9.4	0	1.9	2.4	0	0	0	0	0	0	0	2.8	11.8
Total percentage	31.5	35.9	36.7	36.9	41.8	39.1	13.5	5.7	15.4	18.0	16.2	8.4	99.9	99.6	99.6
Total number	35	38	196	41	44	208	15	6	82	20	17	44	111	105	530

* Numbers in table are percentage of total returns for respective size groups.
† Numbers in parentheses refer to the recovery areas in Figure 1.

TABLE 4. Results of Chi-square Tests to Determine Whether Fish Length or Sex Affected Area or Time of Recovery Significantly.

Tag group	Tests for differences in recovery area*		Tests for differences in recovery time	
	Length group (Males only)	Sex	Length group (Males only)	Sex
1965	<.001	<.005	<.30	<.54
1966	<.001	.025	<.10>.05	<.09

* Values in the table are the approximate probabilities of obtaining a larger χ^2 value by chance. Only first year returns are included.

TABLE 5. Comparison of 1958–61 and 1965–66 Summer and Fall Tag Returns for Small (15–20 inch) and Medium-sized (21–24 inch) Striped Bass.

Recovery area*	Summer (June, July, August)		Fall (September, October, November)	
	1958–61	1965–66	1958–61	1965–66
Upper Sacramento River (5)	†1.1	16.7	1.3	0
Delta and Lower Sacramento River (1, 2, 4, 6)	3.4	16.7	15.1	18.8
Suisun Bay (7, 8)	3.0	1.4	9.6	2.3
Carquinez Strait, Napa River (9, 11)	13.5	25.0	11.3	11.7
San Pablo Bay (10)	11.5	22.2	22.8	9.8
San Francisco Bay (12)	56.2	16.7	36.5	55.3
Pacific Ocean (13)	11.3	1.4	3.4	2.3
Total number	468	72	762	85

* Number in parentheses refer to the recovery areas in Figure 1.
† Numbers in table are percentage of the seasonal returns.

San Francisco Bay. Most were in San Pablo Bay and Carquinez Strait. In 1965 most bass were in San Francisco Bay, with good numbers also present in San Pablo Bay and Carquinez Strait.

Fish 25 Inches or Larger. Large bass, like medium-sized ones, were located in brackish or salt water during the summer. Most were in San Francisco Bay and the ocean. Ocean recoveries were much higher for large bass than for any other size group. The upstream migration began in the fall as witnessed by the decreasing ocean returns and the increasing Suisun Bay and Delta recoveries. During the winter, ocean returns were zero and San Francisco Bay returns fell to low levels. The large bass were localized in San Pablo Bay in this season. Small numbers were present in the Delta, but none were caught in the upper Sacramento. Movement into the upper Sacramento occurred during the spring. The Delta returns also increased during this season. Many large bass were captured in San Francisco and San Pablo Bays during the spring, presumably indicating that many bass remain in the bays until immediately before spawning and return immediately afterwards. Observations of angler catches there in 1961 support this hypothesis (Chadwick, 1967).

Summary. In general, larger fish moved farther downstream. Only medium-sized and large fish went to sea, and then only in the summer and fall. Returns from the Pacific Ocean were greatest for the 25-inch size group. San Francisco Bay returns were highest for the 21- to

24-inch fish. The 15- to 20-inch group ranked highest in returns from the Delta and lower Sacramento River. The small fish were the only ones common in fresh water during the summer.

Effects of Sex on Migration

Recovery areas for males and females differed significantly in both 1965 and 1966 (Table 4). Approximately 77% of female bass returns in 1965 originated in San Pablo Bay, San Francisco Bay and the Pacific Ocean as compared to 55% of the male returns (Table 6). Comparable percentages in 1966 were 84 and 69.

TABLE 6. Percent of Total Yearly Returns From Each Recovery Area by Sex.

Recovery area*	1965		1966	
	Males	Females	Males	Females
Western San Joaquin Delta (1)	5.7	2.8	4.8	0.7
Eastern San Joaquin Delta (2)	3.4	0.7	2.4	0.7
Lower Sacramento River (4)	4.5	3.6	3.3	4.0
Upper Sacramento River (5)	17.0	3.6	2.9	0.7
Mokelumne River and Delta (6)	0.4	0.0	0.0	0.7
Suisun Bay Area (7)	3.8	6.4	3.8	4.0
Montezuma Slough Area (8)	0.4	0.0	0.0	0.7
Carquinez Strait (9)	7.6	4.9	11.5	4.0
San Pablo Bay (10)	23.0	33.6	23.9	30.9
Napa River (11)	1.9	0.7	2.4	0.7
San Francisco Bay (12)	28.3	36.4	34.9	36.9
Pacific Ocean (13)	4.1	7.1	10.0	16.1
Total number of returns	265	140	209	149

* Numbers in parentheses refer to the recovery areas in Figure 1.

Upstream recoveries showed a marked difference in the recovery of males and females from the spawning areas during the spring. From March to May 1966, 25 tagged females were caught, only eight of them upstream of Suisun Bay. During the same period 41 males were taken, 27 of them in upstream areas.

Recovery months did not differ significantly in either year. Chi-square tests were also run on second year returns, by which time the small males would have grown several inches. Recovery areas did not differ significantly for these second year returns. In addition, there were no significant differences in recovery areas or months for males and females 25 inches and larger in the first year. These results suggest that migration differences are caused principally by size rather than sex.

Seaward Migration

A great change in the downstream migration had occurred by 1958. Since at least 1958, large percentages of the adult bass population have moved into San Francisco Bay and the Pacific Ocean each summer (Figure 2). However, the geographical range and duration of the bass catches in the ocean have been reduced since 1963. No tagged bass have been caught south of San Mateo County since 1963 (Table 7). Nor have any tagged bass been taken in the ocean during the winter or spring (November to May) since 1962 (Table 8). The percentage taken in October has also declined sharply.

TABLE 7. Annual Geographical Distribution of Tag Returns from Striped Bass Caught in the Pacific Ocean. 1958–1964 Data from Chadwick (1967).

Location	Percentage of total annual ocean recoveries										
	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
Marin County beaches	5	6	5	6	8	13	16	5	5	0	21
San Francisco beaches	47	69	53	32	43	30	14	0	15	11	17
San Mateo County beaches	27	16	25	58	29	47	59	86	65	24	54
Santa Cruz and Monterey Bay beaches	19	6	5	3	15	2	0	0	0	0	0
Boats out of San Francisco	2	4	13	1	5	9	11	10	15	64	8
Number returned	129	51	106	69	65	47	37	21	80	45	24

DISCUSSION

The general migration pattern has remained essentially as it was in 1958–1961 (Table 9 and Figure 2). A return to the pattern of the early 1950's, during which very few bass seemed to enter San Francisco Bay and the Pacific Ocean, has not occurred.

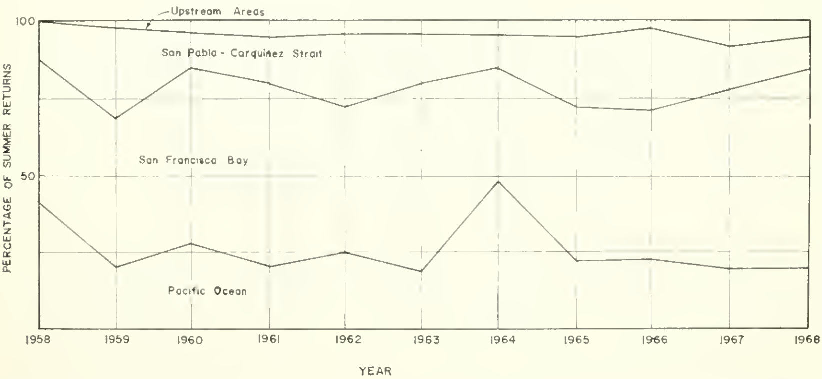

FIGURE 2. Annual variation in summer striped bass migration based on fish estimated to be 25 inches or larger when caught. Data from 1958–1964 are from Chadwick (1967).

The major differences in distribution between the period of this study and that of the immediately preceding one are a shift from San Francisco Bay to San Pablo Bay during the winter, a downstream movement of small and medium-sized fish into San Francisco Bay during the fall, a shorter residence time in the ocean, and a reduced oceanic range. All are difficult to explain because of our limited knowledge of the environment and its effects on striped bass.

The winter displacement of bass from San Francisco to San Pablo bays may be correlated with a decline in herring abundance in San Francisco Bay since bass feed on spawning herring during the winter (Thomas, 1967). Winter commercial herring landings in San Francisco were high in 1959–1960 as was the winter party boat catch per angler day in San Francisco Bay. After 1961 the landings plummeted

TABLE 8. Variations in Timing of Migrations to the Pacific Ocean as Indicated by Tag Returns. Data from June 1958–May 1965 from Chadwick (1967). Figures are Percentages of Annual Totals.

Month recaptured	Percentages of total annual ocean recoveries										
	June 58 May 59	June 59 May 60	June 60 May 61	June 61 May 62	June 62 May 63	June 63 May 64	June 64 May 65	June 65 May 66	June 66 May 67	June 67 May 68	June 68 May 69
June	12	27	18	14	2	17	5	5	3	2	17
July	28	29	44	26	38	30	19	9	53	20	39
August	17	14	27	30	29	21	59	68	28	38	22
September	19	22	8	25	29	21	16	18	15	36	22
October	16	4	3	0	2	11	0	0	1.3	4	0
November to May	9	4	0	4	0	0	0	0	0	0	0
Number returned	129	51	106	69	65	47	37	22	80	45	24

TABLE 9. Comparsion of Tag Returns from Striped Bass Tagged in 1950–52, 1958–61 and 1965–66.

Recovery area*	Percentages of total annual returns																	
	June–August			September–October			November			December–February			March–May			Total percentage		
	1950–52	1958–61	1965–66	1950–52	1958–61	1965–66	1950–52	1958–61	1965–66	1950–52	1958–61	1965–66	1950–52	1958–61	1965–66	1950–52	1958–61	1965–66
Upper Sacramento River (5)	1	†	2	0	†	†	0	†	†	0	†	0	3	7	3	4	7	5
Eastern Delta (2, 3, 6)	2	†	1	3	†	1	1	1	†	0	1	1	10	1	†	16	3	3
Lower Sacramento River (4)	3	1	1	5	2	1	3	1	†	1	1	†	5	2	1	17	7	3
Western San Joaquin Delta (1)	3	†	†	10	1	1	4	2	†	4	1	1	12	3	2	33	7	4
Suisun Bay (7, 8)	2	1	†	†	2	1	0	2	2	1	1	†	1	†	†	4	6	3
San Pablo Area (9, 10, 11, 15)	15	6	13	5	9	3	†	3	6	†	2	12	5	1	2	25	21	36
San Francisco Bay (12)	1	17	16	1	11	10	0	3	4	0	8	1	0	2	3	2	41	34
Pacific Ocean (13)	0	5	9	0	2	1	0	†	0	0	†	0	0	†	0	0	7	10
Total percentage	26	30	43	24	26	17	9	12	13	6	14	16	35	17	11			
Total number	80	720	268	74	699	108	27	332	79	19	342	97	109	421	70	309	2,514	622

* Numbers in parentheses refer to the recovery areas in Figure 1.
† Denotes percentages between 0 and 0.5.

and remained low in succeeding years. (Figure 3). The catch per day also fell after 1961, but less sharply (McKechnie and Miller, 1971). The San Francisco commercial landings may not accurately reflect the abundance of herring in the Bay, because they include some catches made elsewhere and may be affected by economic as well as biological factors. However, the fact that the angler catch rate declined more slowly than did the herring catch suggests that the angler catch was partially but not wholly dependent on herring abundance.

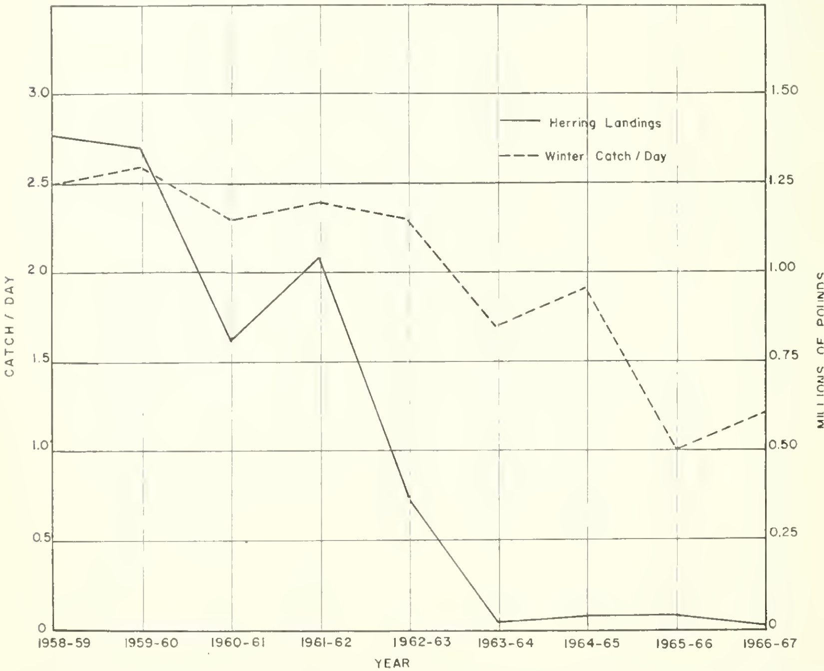

FIGURE 3. Relationship between striped bass catch per angler day on north San Francisco Bay party boats from December to February and commercial herring landings at San Francisco.

The eastern Delta returns are quite the opposite of what Chadwick (1967) found in his study. He discovered that tag returns from the eastern Delta were three times as great for fish tagged at Prisoner's Point as for fish tagged in the western Delta. He took this for confirmation of the hypothesis that bass return to the same spawning grounds each year. During this study no bass tagged in the eastern Delta were caught there, although 9.7% of the returns from small bass tagged elsewhere came from this area. These facts contradict the homing hypothesis but it may well have happened by chance, since few bass were tagged in the eastern Delta and only four of them were recaptured upstream from Suisun Bay.

The results for sex and length support the hypothesis that length influences migration patterns of mature bass more than sex does. An exception is that males probably spend a longer time on the spawning ground than females (Chadwick, 1967). Other apparent migration differences between sexes are actually functions of size, associated with the fact that the average size of females is greater.

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EFFECTS OF TEMPERATURE, SALINITY, AND DISSOLVED OXYGEN ON THE SURVIVAL OF STRIPED BASS EGGS AND LARVAE[1]

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Laboratory experiments were conducted on the effects of salinity, temperature, and dissolved oxygen on the survival of artificially spawned striped bass eggs and larvae. Egg survival in salinities greater than about 1,000 ppm TDS, especially at higher temperatures, are greatly reduced if eggs are not water hardened in fresh water. Moderate reductions in dissolved oxygen (to 4 to 5 mg/liter) adversely affect the percent hatch of eggs and have a detrimental effect on larval survival.

INTRODUCTION

Knowledge of the effects of various environmental factors on the survival of eggs and larvae of striped bass, *Morone saxatilis* (Walbaum), is essential for making decisions which will protect the striped bass population. Water quality in the present spawning and nursery areas will be degraded increasingly by decreases in freshwater flows and increases in waste discharges.

The water quality parameters which will change in the future include salinity, temperature and dissolved oxygen. This paper describes laboratory experiments conducted to define the effects of these parameters on the survival of artificially spawned striped bass eggs and larvae.

METHODS

In the spring of 1968, adult striped bass were captured during their spawning migration with large wire fyke traps as described by Hallock, Fry and LaFaunce (1957). Following capture, female bass were anesthetized in a large tank with 5.0 ppm Quinaldine. Egg samples were taken from each fish with a small glass catheter to determine suitability for induced ovulation as described by Stevens (1964). Suitable fish were injected with 2,500 International Units of human chorionic gonadotropin and then returned to a holding trap in the river for approximately 18 hr. The fish were then anesthetized again and transported a distance of 25 miles to our laboratory, where they were held under sedation in an 80-gallon tank until ovulation took place. The time of ovulation was determined by periodically removing eggs with a catheter tube and comparing them with the developing stages described by Stevens (1964).

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The fish were spawned by hand stripping and the eggs were dry fertilized with sperm from at least two males. Samples of fertilized eggs were then dispensed volumetrically with a syringe into test containers. There were three replicates for each test condition. The number of eggs per test was estimated by counting eggs in at least six samples for each batch of eggs.

The test containers for rearing eggs were constructed of 3-inch sections of 2½-inch polyvinylchloride pipe covered at one end with stainless steel bolting cloth of 38 meshes per lineal inch (mesh opening 0.0198 inch). As many as nine containers were suspended in water in a 5-gallon aquarium.

The aquariums were placed in large wooden tanks in which the temperature was controlled by a Braun constant temperature circulator. Salinities in the aquariums were prepared by adding natural seawater to fresh water from the Delta until the required salinity was reached. Specific conductance was measured with a Wheatstone Bridge. These conductivity values were multiplied by 0.64 to derive a rough estimate of total dissolved solids in parts per million (Richards, 1954).

In tests in which dissolved oxygen was a variable, oxygen concentrations were reduced by passing water through a partial vacuum in an apparatus similar to that described by Mount (1961, 1964). All parts of the system conveying water were plastic or coated with epoxy resin except for several galvanized valves. Water of the desired oxygen level was supplied through ¼-inch Tygon plastic tubing to each test container in the 5-gallon aquarium. A siphon in the center of the aquarium maintained the water at the desired level. Dissolved oxygen levels were measured in the water entering the container and at the center of the aquarium by the azide modification of the standard Winkler procedure.

In the oxygen experiments the deoxygenating apparatus and aquariums were a closed system. In the salinity experiments each aquarium was a closed system.

One million units of penicillin G and 1 g of streptomycin were added to each 5 gallons of water for bacteria control. The water was filtered daily through a fiberglass filter.

Only three of the 42 female striped bass handled were successfully ovulated. The percent hatch of eggs in the controls was 29.4, 16.3 and 9.7 for the three fish. Control conditions were a water temperature of 65 F, fresh water (130 ppm TDS), and saturated dissolved oxygen. Hatches in all experiments are expressed as a percentage of the hatch of controls.

SALINITY AND TEMPERATURE

Two series of tests were conducted on the effects of salinity and temperature on striped bass egg survival. In one, the eggs were placed directly into the test salinity and temperature; in the other, the eggs were water hardened in fresh water (130 ppm TDS) at 65 F for 2 hr and then placed into the desired test condition. Striped bass eggs water hardened in approximately 1.5 hr (Mansueti, 1958).

In each series of tests, eggs were incubated at 18 salinity-temperature combinations (Tables 1 and 2). The results for concentrations of total dissolved solids (TDS) from 130 to 1,000 are from one spawning and the results from 2,000 to 10,000 are from another.

For the striped bass eggs placed directly into the test conditions (Table 1), the survival is generally good (88% or more of control) in total dissolved solids of 1,000 and less throughout the temperature range tested. The highest survival occurred at 1,000 ppm and 65 F. Survival decreases rapidly above 1,000 ppm, especially at the higher temperatures. None of the eggs survived at 72 F in any salinities above 1,000 ppm.

The survival of eggs water hardened in fresh water (Table 2) was similar to the survival of eggs water hardened at the test salinities up to 1,000 ppm TDS. However, the survival of eggs water hardened in

TABLE 1. Incubation of Striped Bass Eggs at 18 Salinity-Temperature Combinations. The Fertilized Eggs Were Placed Directly into Various Factor Combinations.

Factor level				Total eggs in sample	Egg survival as percent control hatch	
Salinity		Temperature (F)				
Assumed mg/liter TDS	Actual EC	Assumed	Actual	$\bar{X} \pm t_{.05}S_{\bar{x}}$	Range	Mean
130	189	58	57.2–58.9	159.3±9.3	96.9–106.4	102.3
130	196	65	64.8–65.6		97.6–104.0	100.0
130	189	72	71.8–72.6		93.5–114.9	106.4
500	768	58	57.2–58.9		102.0–110.5	106.4
500	837	65	64.8–65.6		106.4–144.5	121.0
500	787	72	71.8–72.6		65.9–106.8	88.7
1000	1617	58	57.2–58.9		89.4–106.4	95.2
1000	1515	65	64.8–65.6		131.2–144.5	136.0
1000	1531	72	71.8–72.6		95.5–114.9	105.4
2000	3046	58	56.4–59.0	259.6±5.2	52.2–141.6	93.8
2000	3007	65	64.0–65.2		52.2–66.2	57.3
2000	3148	72	71.4–72.2		0.0	0.0
5000	7828	58	56.4–59.0		35.4–59.0	44.7
5000	7601	65	64.0–65.2		7.4–40.1	20.4
5000	7640	72	71.4–72.2		0.0	0.0
10000	15671	58	56.4–59.0		11.5–16.3	13.9
10000	15890	65	64.0–65.2		0.0	0.0
10000	15593	72	71.4–72.2		0.0	0.0

TABLE 2. Incubation of Striped Bass Eggs at 18 Salinity-Temperature Combinations. The Fertilized Eggs Were Water-Hardened in Fresh Water (130 mg/liter TDS) for 2 hr and Then Placed Into Various Factor Combinations.

Factor level				Total eggs in sample	Egg survival as percent control hatch	
Salinity		Temperature (F)				
Assumed mg/liter TDS	Actual EC	Assumed	Actual	$\bar{X} \pm t_{.05}S_{\bar{x}}$	Range	Mean
130	189	58	57.2–58.9	159.3±9.3	96.9–106.4	102.3
130	196	65	64.8–65.6		97.6–104.0	100.0
130	189	72	71.8–72.6		93.5–110.5	102.3
500	768	58	57.2–58.9		76.5–89.4	84.3
500	837	65	64.8–65.5		80.9–97.9	89.4
500	787	72	71.8–72.6		68.0–100.0	84.3
1000	1617	58	57.2–58.9		112.5–114.9	113.2
1000	1515	65	64.8–65.6		95.5–129.5	109.1
1000	1531	72	71.8–72.6		87.0–129.5	111.9
2000	3046	58	56.4–59.0	259.6±5.2	84.6–132.0	108.5
2000	3007	65	64.0–65.2		17.4–108.1	66.6
2000	3148	72	71.4–72.2		53.9–61.4	56.1
5000	7828	58	56.4–59.0		99.6–134.0	114.3
5000	7601	65	64.0–65.2		33.1–84.6	60.4
5000	7640	72	71.4–72.2		40.0–70.6	59.7
10000	15671	58	56.4–59.0		108.8–118.0	111.5
10000	15890	65	64.0–65.2		42.3–63.8	54.0
10000	15593	72	71.4–72.2		58.7–75.4	64.1

fresh water was much greater in the higher salinities and temperatures. At the higher salinities and temperatures, survival was consistently on the order of 50 to 60% of control survival, which contrasts with survivals of 0 to 20% under the same conditions for eggs water hardened at test salinities.

Another series of experiments were run to determine whether the mixture of ions making up salinity from inland drainage affects egg survival similarly to the mixture of ions in sea water. This is pertinent because in dry years the flow in the San Joaquin River above Stockton consists of largely saline irrigation return water. Salinity of this type blocks adult striped bass migrations when concentrations exceed about 350 ppm TDS (Radtke and Turner, 1967). In the laboratory experiments, striped bass eggs survived equally well in high and low salinity San Joaquin River water, but fewer eggs survived when incubated in Tuolumne River water (Table 3).

OXYGEN AND TEMPERATURE

Striped bass eggs were exposed to two levels of dissolved oxygen at two temperatures for varying lengths of time. All eggs were placed directly into the various temperature and dissolved oxygen levels to be tested. Samples were removed from the low dissolved oxygen at the end of the different exposure times and placed into water with high oxygen concentrations until the eggs hatched.

TABLE 3. Incubation of Striped Bass Eggs in Different Sources of River Water.

Source of water	Salinity: Approximate mg/liter TDS	Salinity: Actual EC	Temperature (F)	Total eggs in sample: $\bar{X} \pm t_{.05}S_{\bar{x}}$	Egg survival as percent control hatch: Range	Egg survival as percent control hatch: Mean
San Joaquin River at Oulton Point (20 miles below Stockton)	147	230	65	238.2±5.7	85.7–124.1	100.0
San Joaquin River at Patterson (65 miles above Stockton)	623	973	65	238.2±5.7	74.8–115.6	98.6
Tuolumne River at Tuolumne City (58 miles above Stockton)	525	820	65	238.2±5.7	56.1–68.7	64.6

The results for dissolved oxygen values of 5.0 mg/liter are from one spawning and the results from 4.0 mg/liter are from another. The percent hatch in the controls was 16.4 and 9.9 respectively.

Generally, egg survival decreased with an increase in temperature or exposure time or a decrease in dissolved oxygen level (Table 4). The mean survival value of the eggs at 72 F was below 50% of the control hatch for all exposure times at 4.0 mg/liter of dissolved oxygen and for five of six exposure times at 5.0 mg/liter dissolved oxygen. There was a consistent reduction in survival for all exposure times even under the least rigorous conditions (65 F and 5.0 mg/liter dissolved oxygen). The length of time for hatching was slightly longer at the lower concentration of dissolved oxygen.

A number of the larvae hatched with various abnormalities at the 4.0 dissolved oxygen level. To determine their survival, newly hatched larvae were separated by their duration of exposure to low dissolved oxygen levels and held for a period of 6 days (Table 5). The longer that eggs were exposed to low oxygen conditions, the lower the percent survival of larvae after 6 days.

DISCUSSION

We encountered numerous difficulties with our experimental procedures both in successfully ovulating the female bass and in hatching the eggs. As a result we had few fish to work with and low survival of eggs in the controls (9.7 to 29.4%). Hence, all results presented here need to be checked under more suitable environmental conditions. Meanwhile though, the experimental results described here have consistent trends which strongly suggest oxygen and salinity requirements for which there is no other experimental evidence.

TABLE 4. Incubation of Striped Bass Eggs at Several Dissolved Oxygen-Temperature Combinations Exposed for Various Lengths of Time.

Dissolved oxygen (mg/liter)		Temperature (F)		Exposure time in hours	Total eggs in sample	Egg survival as percent control hatch	
Assumed	Actual	Assumed	Actual		$\bar{X} \pm t_{.05}S_{\bar{x}}$	Range	Mean
Saturation	7.6–8.4	65	64.3–67.8	Control	238.2±5.7	94.0–103.6	100.0
Saturation	7.3–8.8	72	71.7–72.6	Control		94.6–101.6	98.3
4.0	3.5–4.8	65	66.8–68.7	6		25.2–62.4	43.5
	3.5–4.6	72	71.8–72.6	6		24.9–58.4	41.8
	3.5–4.8	65	66.8–68.7	12		54.4–71.0	64.1
	3.5–4.6	72	71.8–72.6	12		8.3–20.9	16.6
	3.5–4.8	65	66.8–68.7	18		29.2–71.0	47.5
	3.5–4.6	72	71.8–72.6	18		12.6–24.9	20.9
	3.5–4.8	65	66.8–68.7	24		50.1–58.4	54.4
	3.5–4.6	72	71.8–72.6	24		11.9–29.2	20.5
	3.5–4.8	65	66.8–68.7	30		29.2–54.1	41.8
	3.5–4.6	72	71.8–72.6	30		0.0–16.6	10.9
	3.5–4.8	65	66.8–68.7	56 (Hatch)		3.9–71.0	40.1
	3.5–4.6	72	71.8–72.6	40 (Hatch)		0.0–3.9	1.3
Saturation	7.5–8.4	65	64.5–65.8	Control	259.6±5.2	93.1–107.4	100.0
Saturation	7.1–8.7	72	71.6–72.8	Control		97.6–116.6	106.8
5.0	4.6–5.6	65	65.0–66.7	6		46.9–77.5	65.6
	4.6–5.6	72	70.6–72.2	6		38.0–56.1	46.2
	4.6–5.6	65	65.0–66.7	12		58.5–91.8	73.4
	4.6–5.6	72	70.6–72.2	12		27.8–58.5	44.5
	4.6–5.6	65	65.0–66.7	18		79.9–101.0	89.1
	4.6–5.6	72	70.6–72.2	18		21.4–39.7	33.6
	4.6–5.6	65	65.0–66.7	24		77.5–95.9	85.7
	4.6–5.6	72	70.6–72.2	24		42.1–63.6	55.7
	4.6–5.6	65	65.0–66.7	30		68.3–98.9	79.9
	4.6–5.6	72	70.6–72.2	30		25.8–52.0	37.7
	4.6–5.6	65	65.0–66.7	54 (Hatch)		52.0–65.9	57.1
	4.6–5.6	72	70.6–72.2	38 (Hatch)		27.8–37.7	31.9

TABLE 5. Survival of Striped Bass Larvae from Hatching to 6 Days of Age. These Larvae Were Hatched from Striped Bass Eggs Exposed to 4 mg/liter Dissolved Oxygen for Varying Lengths of Time.

Exposure time in hours	Sample size	Number surviving	Percent survival
0	70	38	54.3
6	54	28	51.9
12	58	26	44.8
18	49	23	46.9
24	54	21	38.9
30	38	10	26.3
Hatched	30	7	23.3

Numerous authors and our field studies over the past 6 years have found that striped bass spawn principally in fresh water (1,000 mg/liter TDS or less). Albrecht (1964) and this study indicate that eggs can survive in higher salinities than where the adult bass spawn. However, the results of the current experiments indicate that egg survival in salinities greater than about 1,000 ppm TDS are greatly reduced if the eggs are not water hardened in fresh water.

Few studies have been done on the dissolved oxygen requirements of striped bass eggs. Our observations suggest that even moderate reductions in dissolved oxygen adversely affect the percent hatch of eggs and have a detrimental effect on larval survival.

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AN ANNUAL REPRODUCTIVE CYCLE OF THE GAPER CLAM, *TRESUS CAPAX* (GOULD), IN SOUTH HUMBOLDT BAY, CALIFORNIA

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A gaper clam bed in south Humboldt Bay was sampled from April, 1966, through April, 1967, to determine an annual reproductive cycle of the clams. Phases of gonad development are described. Ripe gonads were found from November through January. Spawning occurred from January through March and began at the time of the seasonal minimums in water temperature and salinity. Spent specimens first appeared at the end of February and were present through April. Leucocytes were common in spent gonads and were associated with cytolysis of residual gametes. An inactive phase followed beginning in May and ending in July. Sex was not discernible during this latter phase. An active phase started in August and continued into November. Gonia apparently are derived from follicular cells of the gonad. Sex is discernible from the active phase into the spent phase. The sex ratio was 1:1. The relationship of gonadal glycogen content, as determined by Reid (1969), and phases of gonad development are discussed.

INTRODUCTION

The gaper clam, *Tresus capax*, ranges from northern California to Alaska (Morris, 1966). It is an important sport species in south Humboldt Bay (lat 40° 45′ N, long 124° 10′ W) occurring mainly below datum in intertidal flats of high sand content.

The objective of our study is to determine the reproductive cycle of the gaper clam in south Humboldt Bay. For proper management of the gaper clam detailed knowledge of its reproductive cycle is essential. Swan and Finucane (1952) considered gaper clams winter spawners along the San Juan Archipelago. Reid (1969) believes that it is a winter spawner in British Columbia, Canada and winter spawning was suspected in Humboldt Bay (Fred Telonicher, Professor emeritus, Department of Biology, Humboldt State College, pers. comm.).

The gaper clam belongs to the family Mactridae. Mactrid reproductive cycles are poorly known. Ropes (1968) described the reproductive cycle of the surf clam (*Spisula solidissima*) and Calabrese (1970) described the cycle of the coot clam (*Mulinia lateralis*).

MATERIALS AND METHODS

The study began in April, 1966, and ended in April, 1967. Samples were taken monthly except during the spawning period, February and March, 1967, during which two semi-monthly samples were collected and during May, 1966, when no sample was taken. All animals were removed by shovel from a limited area, the northernmost end of an intertidal island located between Southport and Fields Landing Channels, in south Humboldt Bay.

At least 10 animals ranging from 5.5 cm to 14 cm long were collected and transported to the laboratory. Here the superficial appearance of each gonad was noted and a sample of the gonadal tissue was taken from the visceral mass at the level of the visceral skirt. The samples were preserved in Rossman's fixative, dehydrated with ethyl alcohol, embedded, sectioned at 10μ, and stained with hematoxylin and eosin.

Based on examinations of gonadal slide preparations, the reproductive cycle was arbitrarily divided into the five phases used by Ropes and Stickney (1965) for the eastern soft shell clam *Mya arenaria:* (i) inactive, (ii) active, (iii) ripe, (iv) partially spawned, and (v) spent.

Water temperatures were taken during low tide with an ordinary laboratory thermometer on most sampling dates. Salinities were taken from September, 1966, through February, 1967, at the surface during low tide and analyzed in the laboratory with a Portable Induction Salinometer (Model R. S.—FB Beckman Instruments, Inc.) (Figure 5).

RESULTS AND DISCUSSION

A histological basis for classifying the gonadal condition was used because the superficial appearance of the gonad did not reflect accurately the phase of gonad development. The superficial appearance of the gonad of both sexes is the same for each phase and is given with the description of ovarian phases. A strong correlation exists between gonadal phase and season (Figure 1). The sex ratio was 1:1 for phases in which sex was detectable. We did not study the anatomy of the reproductive system.

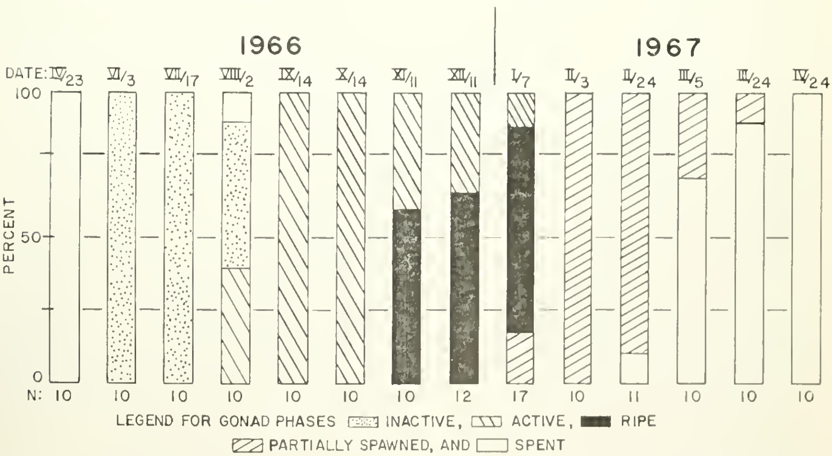

FIGURE 1. Gonadal phases of gaper clam from south Humboldt Bay. The percentage of clams in each gonadal condition is represented by the length of each shaded area. N = sample size.

The Indifferent Gonad

The Inactive Phase

During the inactive phase sex was indiscernible histologically, thus the gonad was termed indifferent. Under low magnification the inactive gonad appeared as a system of anastomosing cylinders similar to those described for the surf clam by Ropes (1968) (Figure 2A). The cylinders consisted of solidly packed follicular tissue (Figures 2A and 2B). Each follicular cell usually contained a large inclusion. The nucleus was small and elongate; the cytoplasm was basophilic. Gonia were lacking. Neither Ropes (1968) nor Calabrese (1970) noted the presence of follicular cells in the mactrids, the surf clam and the coot clam, respectively.

All gonads sectioned in June and July were inactive. During subsequent phases inactive regions persisted. The inactive phase probably began in May, during which time no sample was taken, and continued into August (Figure 1). In general appearance the viscera was yellowish-white internally and externally and appeared turgid.

The Ovary

Active Phase

In this phase the follicular cells contained numerous eosinophilic inclusions 3 to 8 μ in diameter. Foci of follicular cells were highly basophilic and apparently were transforming into oogonia. We could not determine whether all cells of the transforming regions became oogonia. As the transformation proceeded follicular alveoli formed and enlarged (Figures 2C and 2D).

In the literature we found no statement that in bivalves oogonia may be derived from follicle cells. Only nutritive functions have been given (Coe and Turner, 1938; Quayle, 1943; Ropes and Stickney, 1965). Porter (1964) states that due to the fact that follicle cells were so numerous in the hard clam (*Mercenaria mercenaria)* from North Carolina that they probably were not precursors of oogonia. In *Macoma balthica* oogonia and follicular cells are derived from a common cell (Caddy, 1967).

As the active phase continued more foci of transformation appeared and the follicular alveoli continued to form and to enlarge. Definitive oogonia were attached to the follicular walls. Upon initiation of elongation, oogonia were termed primary oocytes. During elongation the distal end of the oocyte projected centripetally. The nucleus moved into the distal end of the cell, whereupon the distal portions enlarged and the proximal region served as a stalk (Figure 2E). The nuclei of young oocytes averaged about 15 μ in diameter. A chorion was produced around the oocyte as development progressed (Figure 2F). Eventually the swollen distal portion detached from the stalk and lay freely within the lumen (Figure 2G). The detached oocytes averaged 37 μ in diameter and their nuclei averaged 20 μ in diameter.

Several ovaries sectioned in August were in the active phase, and all ovaries were in this phase in September, October, and November. Several ovaries were still in this phase as late as January (Figure 1). The visceral mass maintained the superficial appearance of the inactive phase.

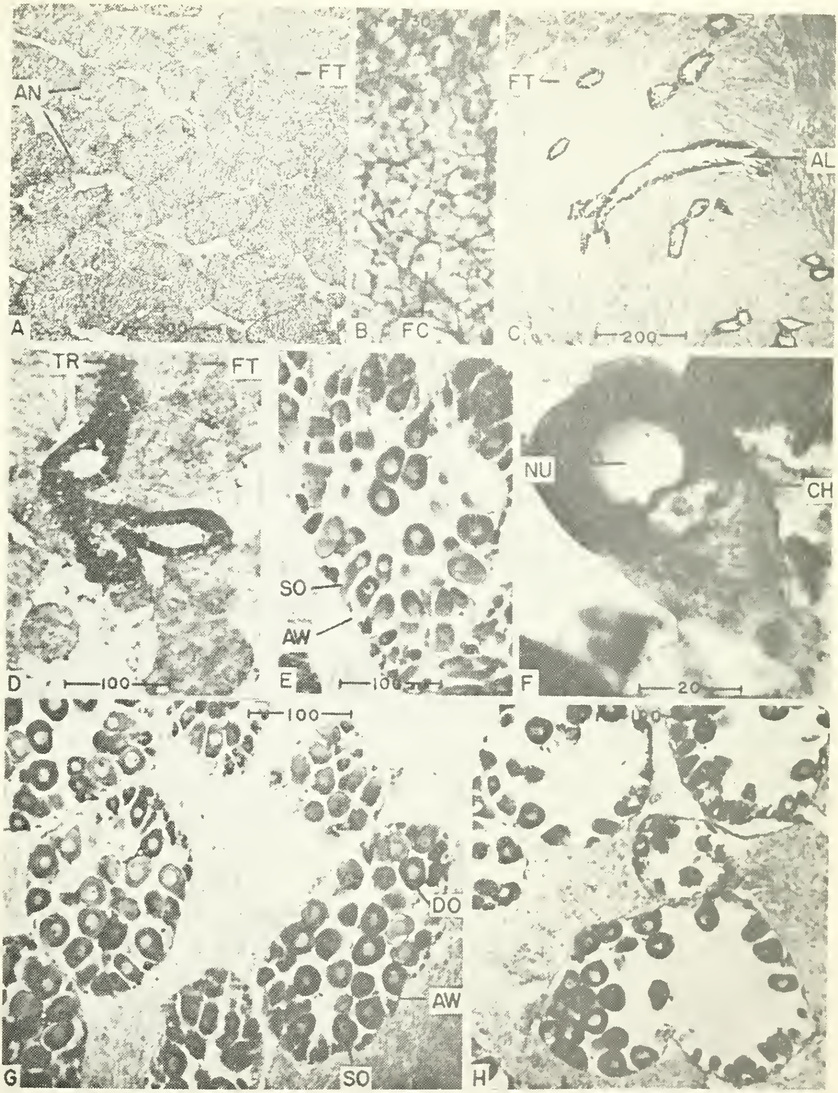

FIGURE 2A. Follicular system of inactive gonad. AN = anastomosis, FT = follicular tissue; **2B,** Follicular tissue. FC = follicular cell; **2C,** Early active ovary. AL = alveolus, FT = follicular tissue; **2D,** Portion of early active ovary showing transformatians of follicle cells into oogonia. FT = follicular tissue, TR = transforming region; **2E,** Alveolus in late active phase. AW = alveolar wall, SO = stalked oocyte; **2F,** Stalked oocyte. CH = chorion, NU = nucleus; **2G,** Ripe alveoli. Detached oocytes outnumber stalked oocytes. AW = alveolar wall, DO = detached oocytes, SO = stalked oocytes; **2H,** Partially spawned alveoli. Measurements are in microns.

Ripe Phase

The ovary was termed ripe when the number of detached oocytes was greater than the number of attached oocytes (Figure 2G). Mature oocytes averaged 43 μ in diameter; their nuclei averaged 20 μ in diameter. The nuclei often displayed amphinucleoli (Figure 3A). Eosinophilic follicular tissue was still very abundant but occupied less volume than in earlier phases. In the sections ripe regions generally were separated by cylinders of follicular tissue. The ovary spawns primary oocytes.

The ripe phase was observed initially in November and continued into January (Figure 1). The gonad was very extensive and white. During the latter portion of this phase oogonia exuded as white rivulets upon excision of the ovary.

Partially Spawned Phase

In this phase most alveoli were partially empty, and the follicular wall had slightly thickened (Figure 2H). The follicular tissue appeared disorganized and separated from the spawned alveoli. As spawning continued, the follicular tissue appeared to become more disorganized and the presence of leucocytes (phagocytes) was observed, similar to the condition noted in the eastern oyster (*Crassostrea virginica*) by Galtsoff (1964).

A few partially spawned ovaries were noted in January. The majority of animals in our samples spawned in February, but spawning continued into March (Figure 1).

In the early portion of this phase the general appearance of the visceral mass resembled the appearance of the previous phase. Subsequently, the visceral mass became grayish externally and brownish to orange-brown internally. This color change was first noted in the sample taken in February.

Spent Phase

Early in this phase the remaining follicular tissue became basophilic and appeared to be very disorganized (Figure 3B). The interstitial spaces between masses of follicular tissue contained debris. Leucocytes were numerous in the follicles (Figure 3C). The follicles had shrunk and contained unspawned oocytes in stages of cytolysis apparently caused by leucocytes (phagocytes) similar to the "migrating cells" found in the eastern soft shell clam by Ropes and Stickney (1965). Cytolysis appeared to be the primary method of oocyte destruction. No evidence of expulsion, as seen in the hard clam (Loosanoff, 1937) and in the eastern oyster (Loosanoff, 1965), was noted. This portion of the spent phase was first observed at the end of February and seen through March.

The mid-portion of this phase was histologically distinct. The leucocytes had vacated and left the follicles partially filled with debris and an occasional cytolyzed oocyte. Thus sex was difficult to determine in most cases. The follicles remained shrunken with thickened walls which commonly were no longer intact. The follicular tissue was reduced to numerous clusters of condensed, basophilic cells located around the periphery of the follicles. Most of the sections contained some digestive gland. This part of the spent phase was observed in all sections made in April, 1967.

Later in this phase only the remnants of an occasional follicle could be discerned, and in most cases the sex could not be determined. The gonad was reduced to a thin layer between the wall of the visceral mass and the digestive gland. The few remaining follicles were filled with vacuolated cells and were embedded in the disorganized follicular tissue. The appearance of vacuolated cells in the follicles following spawning has also been observed in *Cyprina islandica* (Loosanoff, 1953). All sections made during the later portion of the spent phase consisted mainly of digestive gland. The late spent phase was observed in April. The visceral mass appeared flaccid, was grayish externally, and orange-brown internally throughout the spent phase.

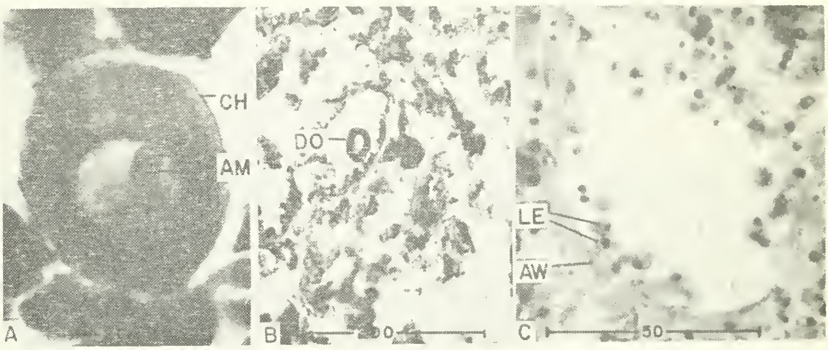

FIGURE 3A. Primary oocyte. AM = amphinucleolus, CH = chorion; **3B,** Spent ovarian alveoli. DO = degenerating residual oocyte; **3C,** Spent alveolus. AW = alveolar wall, LE = leucocytes.

The Testis

Active Phase

As in the ovary this phase was initiated by the apparent tranformation of follicular tissue into gonia, in this case spermatogonia (Figure 4A and 4B). The follicular cells were eosinophilic; transforming cells and spermatogonia were basophilic. No definite germinal epithelium was observed. As the phase continued the spermatozoa became numerous in the center of the follicle and their antecedents became restricted to the periphery (Figure 4C). The active phase first appeared in August and prevailed into October.

Ripe Phase

The testis was termed ripe when the alveoli contained mainly spermatozoa (Figure 4D). The heads of the spermatozoa were oriented radially toward the follicular walls. Their antecedents formed a thin layer peripherally. Ripening alveoli increased in number and in size and thus the volume of the testis also increased. This phase was observed first in November; thus in our samples males were histologically ripe before females. It predominated until the first week in January.

Partially Spawned Phase

This phase was not as well defined in the testis as it was in the ovary. The number of spermatozoa was reduced, and the follicular tissue became partially disorganized. Most of the follicles remained intact throughout. This phase was dominant throughout February.

Spent Phase

As in the preceding phase, the early portion of this phase was less definite in the testis than in the ovary. The follicular tissue had shrunk. The alveolar walls apparently had broken down and the spermatozoa dispersed. Leucocytes became numerous during the early portion (Figure 4E and 4F).

The mid-portion of the spent phase in the male was similar to its counterpart in the female. The leucocyte invasion had ceased, leaving only debris and a few spermatocytes near the follicular wall. The follicular tissue was reduced to groups of condensed cells as it was in the female. The later portion of the spent phase was similar in both sexes and sex was rarely discernible.

FIGURE 4A. Early active testes. FT = follicular tissue, TR = transforming region; **4B,** Early active male alveolus. SG = spermatogonia; **4C,** Late active alveolus. FT = follicular tiosue, SC = spermatocytes, SP = spermatozoa, ST = spermatids; **4D,** Ripe alveolus. FT = follicular tissue, SP = spermatozoa; **4E,** Spent testis. AW = alveolar wall (note thickening), LE = leucocytes; **4F,** Spent alveolus. AW = alveolar wall, LE = leucocytes.

This phase was observed in the first week of March and was prevalent in samples of April, 1966 and 1967 and probably continued into the following May.

THE RELATIONSHIPS OF TEMPERATURE, SALINITY AND GLYCOGEN CONTENT TO THE REPRODUCTIVE CYCLE

The active phase was associated with the periods in which we obtained highest temperature and salinity measurements. Subsequent phase changes were associated with a decrease in both parameters. Spawning occurred during seasonal low values (Figure 1 and 5). The role of temperature in controlling annual reproductive cycles is well documented (Giese, 1959).

Reid (1969) studied the levels of glycogen and lipid in the horse (gaper) clam in Esquimalt Lagoon, British Columbia. Close correlations exist between seasonal gonadal glycogen levels that he observed and our observed phases of gonadal development. In December a sharp decrease in gonadal glycogen and lipid occurred which he associated with spawning. Winter spawning occurred in our samples. Glycogen levels remained low until May, corresponding to the time in which we observed the spent phase. From May into July gonadal glycogen content increased rapidly corresponding to the period in which we observed the inactive phase. After July through December, gonadal glycogens level dropped uniformly while we observed the active and ripe phases.

Recent studies supervised by the junior author indicate that winter spawning is the rule in south Humboldt Bay. During January, 1970, superficial examination of a number of gaper clams indicated that they had spawned. During 1968 and 1970 spat were recovered only during the spring. No spat was found in 1969.

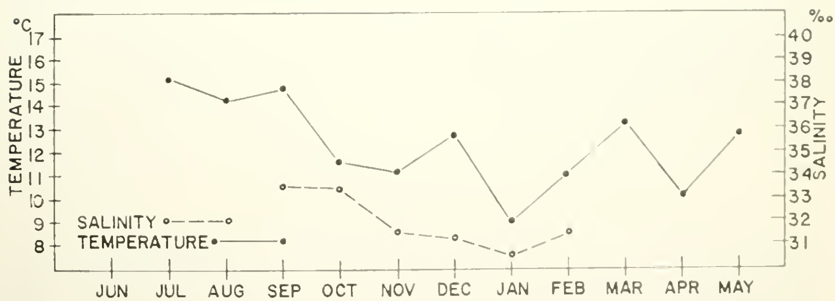

FIGURE 5. Salinity and temperature measurements taken during the period of study, May, 1966, through May, 1967.

SUMMARY

1) Specimens of gaper clams were removed periodically from a clam bed in south Humboldt Bay to follow an annual reproductive cycle.

2) Phases of gonadal development and corresponding superficial appearance of the gonad are described.

3) Gonia are apparently derived from transformed follicle cells.

4) The sex ratio is 1 : 1.

5) Spawning during the winter 1966–67 is associated with corresponding minimum seasonal temperature and salinity measurements.

6) Phases of gonad development in our samples correspond well with changes in gonadal glycogen content of gaper clams studied by Reid (1969) in British Columbia.

7) Gross examination of gaper clams during January, 1970, and the observation of spat settlement only during the spring of 1968 and 1970, indicate that spawning is limited to the winter in south Humboldt Bay.

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SIZE AND AGE COMPOSITION OF NORTHERN ANCHOVIES *(ENGRAULIS MORDAX)* IN THE CALIFORNIA REDUCTION AND CANNING FISHERIES, 1968–69 SEASON [1]

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Over 1.3 billion northern anchovies weighing 57,173,594 lb. were landed for reduction and canning during the 1968–69 anchovy season. Sampling in southern and central California revealed that the catch landed in southern California was composed primarily of 1 and 2 year old anchovies, while 2 and 3 year old fish dominated the central California catch.

INTRODUCTION

This is the second in a series of reports on size and age composition of California catches of northern anchovies taken for reduction and canning. It covers landings made during the 1968–69 anchovy season (June 1, 1968, through May 31, 1969). Landings for pet food, bait, and fresh fish were not sampled.

Landings in California for reduction and canning are principally at four ports: Moss Landing, Monterey, Port Hueneme, and San Pedro. Moss Landing and Monterey are separated from the latter two ports for record keeping and sampling purposes, dividing the fishery into two major areas, central California and southern California. Each of these major areas has its own fishing fleet, fishery regulations, and characteristic development of the fishery (Messersmith, 1969). During the 1968–69 season, 56,038,844 lb. were landed for reduction; 50,619,844 lb. at southern California plants and 5,419,000 lb. at central California plants. An additional 1,134,750 lb. were canned; 219,750 lb. in southern California, and 915,000 lb. in central California.

The fishery catch and effort and its development for this season are to be discussed in a separate article.

SAMPLING

Two separate stratified sampling plans are in use for the two catch areas (Collins, 1969). Both plans utilize a subsample of a given weight of fish (cluster) drawn from a sample boat load chosen from a population of those boats landing fish in a given period. Sampling in the two areas differs in method used to choose the particular boat load for sampling, and in the method of stratifying the population.

The southern California procedure is a stratified two-stage plan. Primary units (boat loads) are of *unequal* size chosen with probability proportional to estimated size, *with* replacement. Second stage units (clusters) are of equal size chosen with equal probability, and without

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replacement. A stratum consists of 5,000 tons of landed fish regardless of the number of boats making deliveries or the time period covered.

Sampling at central California ports is less ideal since the time and order of arrival of boat loads is unknown before sampling. We assume that the order in which boats arrive at the unloading dock is random, and a boat or boats are chosen arbitrarily to be sampled on each day of landing. A subsample is chosen from the sample boat load in the same manner as at southern California ports. A stratum is the period of a calendar month, irrespective of number or weight of boat loads landed. The sampling is described as stratified two-stage subsampling with primary units (boat loads) of unequal size chosen with *equal* probability and *without* replacement. Equal second-stage units (clusters) are chosen with equal probability and without replacement.

Estimates of pounds and numbers of fish landed are made for each area by stratum, and these estimates combined to produce the season totals given here.

The sampling theory and derivation of estimates from samples have been discussed by Tomlinson (in press).

Mechanics in use previously for choosing the sample boat load and processing the sample were described by Collins (1969). At the beginning of the 1968–69 season these procedures were modified in order to make best use of the sampling time and manpower available. The number of samples per stratum for southern California was increased from 20 to 30 and the number of clusters drawn from each sampled boat load was reduced from two to one. The estimate of within boat load variance previously derived by comparing the two clusters per sample is now obtained by comparing those boat loads that have two or more samples drawn from them. Central California sampling was changed only by increasing the weight of the second stage unit (cluster) from 200 g (0.44 lb.) to 250 g (0.55 lb.) in order to make it comparable to the southern California procedure.

In both areas the practice of taking lengths only was discontinued and all fish in the samples were measured for length and weight, sexed, and the state of maturity assessed. Otoliths were taken from each fish for age determination. Other than these changes the sampling procedure remained as in previous seasons (Collins, 1969).

AGE DETERMINATION

Beginning with the 1967–68 season, the method for determining age was changed from using scales to using otoliths (Collins, 1969). Otoliths obtained from each sampling strata were distributed between two readers. Each reader assigned ages to his share and compiled an age composition from them. The two age compositions for each stratum were tested by chi-square (χ^2) to determine if they were significantly different. When no such difference was found, the combined age composition was accepted. In the event that the χ^2 test showed a significant difference between readers, all otoliths in the disputed stratum were reviewed jointly by the readers and an age composition agreed upon by both. No such differences were found in any 1968–69 season stratum so the combined age compositions derived by the two readers for all strata were accepted.

SIZE AND AGE COMPOSITION

The southern California fishery relied heavily on fish less than 125 mm in length which comprised 70% of the almost 1.2 billion anchovies caught (Table 1). In previous seasons this size group has contributed slightly over 50% of the catch (Collins, 1969). The same distribution was apparent in the age composition. Fish of the year and 1 year olds contributed 763 million or 64% of the total number taken and 57% of the weight (Tables 3, 4). This shift in the size and age composition of the catch apparently was due to an unusually large incoming 1967 year class. These 1 year old fish alone contributed 46% of the catch by numbers and 42% by weight. The dominance of this year class (1967) also was reflected in live bait catches for 1967 and 1968 (Crooke, 1969). There was a notable lack of 3 and 4 year old fish (12% by numbers) when compared to the 1965–66 and 1966–67 seasons (31 and 30%). Central California catches also shifted to smaller, younger fish (Tables 2, 5). Two year old fish were dominant accounting for 30% of the almost 96 million caught (Tables 5 & 6). In previous years, 2 and 3 year olds prevailed with 3 year old fish being the most abundant.

SEX RATIOS

Sampling data were used to estimate numbers and pounds landed by sex, and numerical and biomass ratios were calculated. The ratio of females to males for 1968–69 season catches in southern California were 1.4 : 1 by numbers and 1.5 : 1 by weight (Table 7). By contrast 1966–67 season data produced estimates of a numerical ratio of 1.6 : 1 and a weight or biomass ratio of 1.8 : 1.

Estimates of the numerical and weight ratios of the central California fishery gave a similar variance from prior data. The female to male ratios for the 1968–69 season were 1.2 : 1 by number and 1.4 : 1 by weight (Table 7). The combined data for 1966–67 and 1967–68 season yielded mean ratios of 1.4 : 1 by numbers and 1.5 : 1 by weight. In view of these differences, I have included the standard deviation of the estimates and the extreme ratios for mean values ±2 SD. For example, the lower extreme for the female to male ratio for the San Pedro sampling was calculated as follows: mean number of females minus two times its standard deviation divided by the mean number of males plus two times its standard deviation.

$$\frac{657{,}418{,}506 - 2(79{,}251{,}728)}{463{,}462{,}683 + 2(16{,}484\,445)} = 1.00$$

The range of values for the San Pedro sampling were: 1.00 to 1.89 : 1 by numbers and 1.36 to 1.74 : 1 by weight. For central California they were: 0.65 to 2.17 : 1 by numbers and 0.78 to 2.54 : 1 by weight. These ranges are included only as an indication of the variation in ratios that can be expected from sampling data.

ACKNOWLEDGMENTS

I wish to thank those people who participated in the data collection and analysis. Will Reed did most of the sampling at San Pedro, while Dick Parrish sampled at Monterey. Many commercial fishermen as-

sisted by allowing Department personnel aboard their vessels to sample and observe fishing operations. Catherine Berude oversaw the computer production of the strata estimates.

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TABLE 1. Estimated Number of Anchovies by Length Class Landed at San Pedro During the 1968–69 Anchovy Season

Length class mm	Estimated number	Standard deviation	Estimated percent of landings
75–84	1,093,000	785,000	0.10
85–94	2,068,000	1,646,000	0.17
95–104	37,819,000	6,821,000	3.19
105–114	373,639,000	18,936,000	31.54
115–124	398,387,000	16,806,000	33.63
125–134	242,790,000	13,905,000	20.49
135–144	113,280,000	9,541,000	9.56
145–154	13,740,000	5,219,000	1.16
155–164	1,872,000	1,071,000	0.16
Total	1,184,688,000	----	100.00

TABLE 2. Estimated Number of Anchovies by Length Class Landed in Central California During the 1968–69 Anchovy Season

Length class mm	Estimated number	Standard deviation	Estimated percent of landings
85–94	177,000	168,003	0.18
95–104	939,000	706,133	0.96
105–114	1,316,500	667,020	1.35
115–124	10,216,000	2,439,936	10.44
125–134	27,754,000	4,092,784	28.34
135–144	37,125,500	2,758,789	37.92
145–154	9,692,500	2,368,170	9.89
155–164	9,359,500	3,667,558	9.56
165–174	1,333,500	827,246	1.36
Total	97,913,500	----	100.00

TABLE 3. Estimated Numbers of Anchovies Landed for Reduction by Age and Year Class, San Pedro, 1968–69 Season

Age	0	I	II	III	IV	V	VI	Total
Year class	1968	1967	1966	1965	1964	1963	1962	
Number	219,627,000	543,613,000	265,307,000	96,835,000	51,111,000	6,938,000	1,256,000	1,184,687,000
Standard deviation	24,376,107	20,386,546	12,298,532	8,654,537	6,270,579	1,864,553	888,059	
Percent of landings	18.54	45.89	22.39	8.17	4.31	0.59	0.11	100.00

TABLE 4. Estimated Weight of Year Classes Landed for Reduction, San Pedro, 1968–69 Season

Age	0	I	II	III	IV	V	VI	Total
Year class	1968	1967	1966	1965	1964	1963	1962	
Estimated weight	6,757,000	19,232,000	11,386,000	4,861,000	2,880,000	387,000	87,000	45,590,000
Standard deviation	683,514	651,287	576,445	444,461	369,238	111,285	63,107	
Percent of landings	14.82	42.19	24.97	10.66	6.32	0.85	0.19	100.00

TABLE 5. Estimated Numbers of Anchovies Landed for Reduction by Age and Year Class, Central California, 1968–69 Season

Age	0	I	II	III	IV	V	VI	Total
Year class	1968	1967	1966	1965	1964	1963	1962	
Estimated number	8,775,500	20,140,500	29,079,500	20,380,000	11,833,500	4,247,000	3,457,500	97,913,500
Standard deviation	1,763,805	2,970,120	3,351,526	2,668,215	2,861,720	1,563,121	1,443,903	
Percent of landings	8.96	20.57	29.70	20.81	12.09	4.35	3.53	100.00

TABLE 6. Estimated Weight of Year Classes Landed far Reduction, Central Califarnia, 1968–69 Season

Age	0	I	II	III	IV	V	VI	Total
Year class	1968	1967	1966	1965	1964	1963	1962	
Weight in pounds	175,000	1,006,000	1,850,000	1,547,000	987,000	395,000	374,000	6,334,000
Standard deviation	57,981	149,059	264,537	331,109	422,563	184,452	207,659	
Percent of landings	2.76	15.88	29.22	21.42	15.59	6.23	5.90	100.00

TABLE 7. Estimated Sex and Biomass Ratio in Numbers and Pounds for the 1968–69 Anchovy Season

Sex Ratio (numbers)	San Pedro	Central California
Males		
Number	463,462,683	43,805,029
Standard deviation	16,484,445	7,193,938
Percent	39.1	46.1
Females		
Number	657,418,506	50,694,921
Standard deviation	79,251,728	6,547,391
Percent	55.5	53.6
Unknown		
Number	63,807,231	0
Standard deviation	17,129,911	0
Percent	5.4	0
Mean female to male ratio	1.42:1	1.15:1
Range of ratios ± 2 SD	1.00:1 to 1.89:1	0.65:1 to 2.17:1

Sex Ratio (pounds)	San Pedro	Central California
Males		
Pounds	17,205,477	2,660,138
Standard deviation	591,595	424,359
Percent	37.7	42.0
Females		
Pounds	26,425,143	3,671,369
Standard deviation	702,424	461,242
Percent	58.0	58.0
Unknown		
Pounds	1,960,680	0
Standard deviation	494,749	0
Percent	4.3	0
Mean female to male ratio	1.54:1	1.38:1
Range of ratios ± 2 SD	1.36:1 to 1.74:1	0.78:1 to 2.54:1

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CHLORINATED HYDROCARBON PESTICIDES IN CALIFORNIA SEA OTTERS AND HARBOR SEALS[1]

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Levels of DDT, DDD, DDE, and total DDT residues were determined in selected tissues of 10 sea otters and 2 harbor seals from central Californian waters, using gas-liquid chromatography. In both species the highest levels were generally found in fat. In sea otters total residues in fat ranged from 0.41 to 36 ppm wet weight. In harbor seals total residues in the blubbers of the two animals were 18 and 158 ppm wet weight.

INTRODUCTION

Marine mammals of the west coast of North America have been studied little from the standpoint of their content of chlorinated hydrocarbon pesticides, and there are no published accounts to date of pesticide residues in the California sea otter, *Enhydra lutris,* and the harbor seal, *Phoca vitulina.*

The sea otter now occurs on the California coast from Soquel Point, Santa Cruz County, to Cayucos Point, San Luis Obispo County (Odemar and Wilson, 1969; Wilson and Odemar, 1970). Its food varies widely with availability, season, and locality; but consists mainly of sea urchins, abalones, mussels, crabs, and turban snails. Some squids, octopods, starfishes, tubeworms, limpets, clams, scallops, fish, and kelp are taken less frequently (Ebert, 1967; Peterson and Odemar, 1969). With such a varied diet (plants, herbivores, filter feeders, primary and secondary carnivores) pesticide content is difficult to predict and might be expected to vary from individual to individual.

Harbor seals occur from Herschel Island in the Arctic to San Geronimo Island, Baja California (Scheffer and Slipp, 1944). They feed on a wide variety of fish and shellfish, chiefly those easily captured in shallow water, but a limited number of more active forms like salmon are taken. Scheffer and Sperry (1931), in summarizing food habits, reported that fishes made up 93.58%, mollusks (largely squid and octopus) 5.82%, and crustaceans 0.6% of the total volume of stomach contents. Since organo chlorine pesticides are concentrated along food chains and the seal diet is richer in carnivores than the sea otter diet, one might expect a higher concentration of DDT residues in harbor seals than in sea otters. Furthermore, harbor seals have a relatively high proportion of body weight in the form of subcutaneous fat which should provide a major repository for chlorinated hydrocarbon residues (Holden and Marsden, 1967). Sea otters in contrast have a lower proportion of body weight in the form of subcutaneous fat; however, adipose tissue is present and the liver has a high lipid content, and both of these can be expected to be repositories for accumulated pesticides.

[1] Accepted for publication April 1971.

Shortage of suitable study materials has hitherto prevented residue analyses in sea otters, but in recent months the California Department of Fish and Game has made samples of autopsied animals available to me. Harbor seals were found dead on the beach. The objective of this study was to measure abundance of chlorinated hydrocarbons, specifically DDT and its metabolites DDE and DDD, in the fat, liver, and other organs of these marine mammals.

METHODS

All studies were carried out at the Hopkins Marine Station of Stanford University. Wet weights were taken on all tissue samples. Samples analyzed ranged from 0.70 to 57.70 g and included fat, liver, testis, brain, muscle, ovary, adrenal, kidney, and heart. DDT residues were extracted and cleaned up by the method of Stanley and LeFavoure (1965). Final extracts were concentrated in a flash evaporator, and were analyzed with a Beckman GC 4 gas chromatograph equipped with an electron capture detector. The glass column was 6 ft long, I.D. 4 mm and operated at 200 C. The carrier gas was helium and the column used was 3% SE 52 on acid washed Chromosorb W mesh size 80/100. All chemicals and other materials were checked for purity before use to ensure the absence of DDT and its metabolites.

RESULTS AND DISCUSSION

Pesticide residues found in all sea otter samples indicated DDE almost always was present in greater quantities than DDD and DDT (Table 1). The highest level was found in sea otter number 180, shot in Cambria, California, on May 25, 1970, which contained total residue in the fat of 36 ppm. Sea otter 134 found in Monterey Bay on February 8, 1970, contained the highest level of total residues in the liver (15 ppm), in the testis (14 ppm), and in the brain (10 ppm); while the highest total residue in the kidney (12 ppm) was found in sea otter number 191 which drowned off Hopkins Marine Station on July 10, 1970. Greatest quantities of DDE found in the fat (34 ppm) occurred in sea otter number 180; greatest amounts in the liver (14 ppm), in the testis (13 ppm), and in the brain (9 ppm) were found in sea otter number 134; and largest amounts in the kidney (12 ppm) were found in sea otter number 191. In all samples analyzed, DDD ranged from an unmeasurable trace to a high of 1.5 ppm, and DDT ranged from a trace to 1.3 ppm.

Subcutaneous fat (blubber) of harbor seals is obviously the main repository of chlorinated hydrocarbons, having the highest concentrations of DDE, DDD, and DDT (Table 2). Values for total residues and ratios of DDE to DDD and DDT in liver and subcutaneous fat are generally comparable to those reported by Koeman and van Genderen (1966) for *Phoca vitulina* taken off the Netherlands.

TABLE 1. Residues of Chlorinated Hydrocarbon Pesticides in California Sea Otters

Specimen no. (California Fish and Game)	Sex	Region found and cause of death	Tissue	DDE-ppm	DDD-ppm	DDT-ppm	Total residue
KW 69-1	F	Morro Bay, August 13, 1969 (drowned)	liver	0.49	0.03	trace	0.52
			brain	0.17	0.008	trace	0.18
134	M	Monterey Bay, February 8, 1970 (hit by boat)	liver	14	0.59	0.74	15
			testis	13	0.55	0.46	14
			brain	9.2	0.39	0.42	10
138	M	Montery Wharf 2, April 12, 1970 (natural causes)	fat	7.7	0.20	0.19	8.1
			liver	0.87	0.044	0.029	0.94
			testis	2.1	0.072	0.056	2.2
			brain	0.53	0.13	0.14	0.80
177	F	Point Lobos, May 2, 1970 (natural causes)	fat	1.1	0.024	0.059	1.2
			liver	0.55	0.04	0.059	0.65
178	F	Lover's Point, May 8, 1970 (natural causes)	liver	7.8	0.044	0.049	7.9
			ovary	0.84	trace	trace	0.84
			adrenal	7.1	0.10	1.3	8.5
179	M	Morro Bay, May 25, 1970 (shot)	fat	0.39	0.0068	0.015	0.41
			liver	3.4	0.032	0.051	3.48
			testis	0.093	0.0036	0.019	0.11
			brain	0.025	trace	0.079	0.10
			kidney	0.0069	trace	trace	0.0069
			heart	0.012	trace	trace	0.012
180	M	Cambria, May 25, 1970 (shot)	fat	34	1.5	0.64	36
			liver	0.11	0.012	0.0052	0.13
			kidney	0.64	0.032	0.020	0.69
			testis	0.69	0.056	0.022	0.77
182	M	Cambria, May 25, 1970 (shot)	fat	7.0	0.33	0.18	7.5
			liver	0.03	0.0003	0.0013	0.032
			kidney	1.5	0.067	0.023	1.6
			testis	0.20	0.021	0.013	0.23
191	F	Hopkins Marine Station, July 10, 1970 (drowned)	fat	18	1.3	0.87	20
			liver	0.059	0.0054	0.0065	0.071
			kidney	12	0.19	0.14	12
			ovary	1.26	0.15	0.201	1.61
192	M	Monterey Bay, August 3, 1970 (hit by boat)	fat	3.7	0.40	0.26	4.4
			liver	0.32	0.022	0.016	0.36
			kidney	0.47	0.031	0.021	0.52
			testis	5.7	0.24	0.24	6.2

TABLE 2. Residues of Chlorinated Hydracarbon Pesticides in Harbor Seals

Species	Region	Tissue	DDE-ppm	DDD-ppm	DDT-ppm	Total residue
Harbor seal	Cypress Point, May 14, 1970	blubber	15	0.76	2.6	18
		liver	2.0	0.18	0.21	2.4
		testis	0.47	0.054	0.069	0.59
		brain	0.053	0.0031	0.011	0.67
		muscle	0.49	0.023	0.064	0.58
Harbor seal	Point Joe, August 7, 1970	blubber	142	7.1	0.11	158
		liver	2.7	0.15	0.14	3.0
		ovary	0.89	0.11	0.093	1.1
		brain	1.4	0.095	0.084	1.6
Harbor seal*	Wadden Sea	subcutaneous fat	14	3.6	9.8	27
Harbor seal*	Wadden Sea	subcutaneous fat	5.4	0.70	3.5	9.6
		liver	0.40	--	--	0.40
Harbor seal*	Texel	subcutaneous fat	3.7	7.4	1.0	12
		liver	0.10	--	--	0.10

* Residues of chlorinated hydrocarbon pesticides in seals found dead or dying in a coastal habitat (Koeman and van Genderen, 1966).

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OCCURRENCES OF THE BEARDED EELPOUT *LYCONEMA BARBATUM* OFF NORTHERN CALIFORNIA AND SOUTHERN OREGON[1]

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Bearded eelpouts collected off northern California and southern Oregon from 1965 through 1970 during shrimp surveys represent new northern range, minimum depth, and maximum size records. The collection consisting of 37 specimens exceeds the total number of this species that had previously been deposited in museum collections. Notes on fecundity and meristics are included.

INTRODUCTION

Published records of the bearded eelpout (Figure 1) are limited to two accounts by Gilbert (1895, 1915). His records consist of 12 specimens trawled off Monterey Bay (lat 36° 39′ 40″N, long 122° 01′W) in 204 fathoms (Albatross Station 3129); and one specimen taken off San Diego in 167 to 191 fathoms (Albatross Station 4358). I am aware of only three unpublished records; one female, 152 mm TL taken off Pt. San Luis (lat 35° 06′N, long 120° 53′W) in 80 fathoms (UCLA-

FIGURE 1. The bearded eelpout, *Lyconema barbatum*.

W53-388); a male and female, 113 and 116 mm TL respectively, trawled off Bahia San Quintin, Baja California, Mexico, lat 30° 12.3′N, long 116° 3.7′W to lat 30° 14.3′N, long 116° 3.7′W (SIO 62-308); and three fish trawled off Pt. La Jolla in 100 fathoms, a male 89 mm TL and two females 85 and 132 mm TL respectively (SIO 65-13); (John Fitch pers. comm.). Jordan and Evermann (1898) give the range as Coast of Alaska, however, this is an error, as it is based on Gilbert's (1895) Monterey collections.

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RECENT SPECIMENS

On June 12, 1965 while conducting trawl surveys of ocean shrimp, *Pandalus jordani* off northern California (Gotshall, in press), I collected an eelpout later identified by John Fitch as *Lyconema barbatum*. On subsequent surveys in October 1965, April and August 1966, March, April and September 1967, and April 1970, I collected an additional 36 of these unusual eelpouts (Table 1). The bearded eelpout captured on August 26, 1967 off Mack Arch, Oregon, in 85 fathoms represents the northernmost record from our shrimp surveys and extends the known range approximately 400 miles northward. The depth range extends from 45 fathoms, represented by the fish trawled off Crescent City on September 1966, out to 204 fathoms (Gilbert 1895).

The bearded eelpout can be easily identified as it is the only California eelpout (family Zoarcidae) with dark brown spots on the body, dorsal and anal fins, and a dense fringe of small barbels on the underside of the lower jaw.

Gilbert (1895) recorded the maximum size as 150 mm TL, thus the 176 mm TL female collected on September 1, 1967, represents a new size record. Several of the females I collected appeared to be ripe, the number of eggs per female ranged from 10 to 15, with a size range of 3 to 4 mm in diameter.

TABLE 1. Location and Depth of Capture, Size and Sex of *Lyconema barbatum* Collected Off Northern California and Southern Oregon

Date	Location	Latitude	Longitude	Depth (fathoms)	Length (mm) TL	Sex
June 12, 1965	8.2 miles WNW of Redding Rock	41° 22′ N	124° 20′ W	85	157	♂
Oct. 11, 1965	17.5 miles WSW of Klamath River	41° 27′ N	124° 27′ W	65	127	♀ spent
Oct. 11, 1965	10.2 miles NW of Redding Rock	41° 26′ N	124° 22′ W	79–80	128	♂
Oct. 11, 1965	10.2 miles NW of Redding Rock	41° 26′ N	124° 22′ W	79–80	129	--
Oct. 13, 1965	8.8 miles WSW of Redding Rock	41° 15′ N	124° 20′ W	62	157	♀ gravid
April 9, 1966	11.0 miles WNW of Redding Rock	41° 22′ N	124° 25′ W	84	126	♂
April 24, 1966	17.4 miles WNW of Klamath River	41° 36′ N	124° 27′ W	96	165	♀
Aug. 22, 1966	17.4 miles NNW of Trinidad Head	41° 19′ N	124° 17′ W	49	147*	♀
Aug. 23, 1966	11.4 miles WNW of Redding Rock	41° 24′ N	124° 24′ W	64	120*	--
Aug. 23, 1966	11.4 miles WNW of Redding Rock	41° 24′ N	124° 24′ W	64	135*	--
Aug. 23, 1966	11.9 miles WNW of Redding Rock	41° 21′ N	124° 22′ W	62	72*	--
Aug. 23, 1966	11.9 miles WNW of Redding Rock	41° 21′ N	124° 22′ W	62	---	--
Aug. 23, 1966	11.9 miles WNW of Redding Rock	41° 21′ N	124° 22′ W	62	---	--
Aug. 23, 1966	11.9 miles WNW of Redding Rock	41° 21′ N	124° 22′ W	62	148*	♂
Aug. 26, 1966	8.6 miles WNW of Crescent City	41° 46′ N	124° 23′ W	59	154*	--
Sept. 3, 1966	12.2 miles SW of Crescent City	41° 39′ N	124° 26′ W	80	121*	--
Sept. 3, 1966	14.6 miles SW of Crescent City	41° 34′ N	124° 25′ W	59	---	--
Sept. 4, 1966	10.6 miles SW of Crescent City	41° 37′ N	124° 21′ W	45	131*	--
Sept. 4, 1966	12.7 miles W of Klamath River	41° 33′ N	124° 22′ W	50	---	--
Sept. 4, 1966	12.8 miles WSW of Klamath River	41° 30′ N	124° 21′ W	49	---	--
Sept. 4, 1966	12.8 miles WSW of Klamath River	41° 30′ N	124° 21′ W	49	---	--
Sept. 4, 1966	14.6 miles WSW of Klamath River	41° 29′ W	124° 23′ W	55	---	--
Sept. 10, 1966	13.5 miles WSW of Trinidad Head	40° 58′ N	124° 26′ W	150–155	83*	--
March 18, 1967	24.5 miles SSW of Crescent City	41° 23′ N	124° 27′ W	94	136*	--
April 6, 1967	9.0 miles WSW of Redding Rock	41° 19′ N	124° 22′ W	73	142*	--
Aug. 26, 1967	8.7 miles SW of Mack Arch, Oregon	42° 09′ N	124° 34′ W	85	110	--
Sept. 1, 1967	12.6 miles W of Redding Rock	41° 26′ N	124° 26′ W	70	158	♀ gravid
Sept. 1, 1967	11.3 miles WSW of Redding Rock	41° 24′ N	124° 26′ W	74	155	♀ gravid
Sept. 1, 1967	11.4 miles WSW of Redding Rock	41° 22′ N	124° 26′ W	90	176	♀ gravid
April 4, 1970	11.8 miles WNW of Mad River	40° 57′ N	124° 23′ W	110–112	151	--
April 4, 1970	11.8 miles WNW of Mad River	40° 57′ N	124° 23′ W	110–112	170	--
April 4, 1970	11.8 miles WNW of Mad River	40° 57′ N	124° 23′ W	110–112	---	--
April 4, 1970	12.3 miles WNW of Mad River	40° 57′ N	124° 24′ W	115–120	153	--
April 5, 1970	13.0 miles WSW of Mad River	40° 56′ N	124° 25′ W	126–130	161	--
April 5, 1970	13.0 miles WSW of Mad River	40° 56′ N	124° 25′ W	126–130	165	--
April 5, 1970	13.4 miles WSW of Mad River	40° 56′ N	124° 26′ W	139–142	153	--
April 5, 1970	13.4 miles WSW of Mad River	40° 56′ N	124° 26′ W	139–142	165	--

* Standard length.

Vertebral, and dorsal and anal ray counts from x-rays of five fish were: 20 to 21 abdominal vertebrae and 88 to 91 caudal vertebrae. Total vertebral counts ranged from 109 to 112. Dorsal and anal ray counts ranged from 101 to 105 and 92 to 94 respectively (Shelly Johnson, U.S.C., pers. comm.). Gilbert (1895) gives dorsal 103, and anal 91 in the type description.

As this went to press, I was informed that Occidental College has a collection of bearded eelpouts collected since 1969 from the San Pedro Channel in depths of 50 to 125 fathoms (John Stephens, pers. comm.).

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LANDOWNER UTILIZATION OF A WILD PHEASANT RESOURCE[1]

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Data were collected during 1968 on the utilization and economic importance of the wild ringneck pheasant *(Phasianus colchicus)* resource in the Oakdale area, Stanislaus County, California. The primary vegetative cover in the study area was ladino clover. Of 340 property owners in the study area, 221 were interviewed for the information. Only 15 landowners (7% of the landowners sampled) leased their lands for pheasant hunting. Over 1,600 hunters were given permission to hunt on unleased lands without fee, while 219 hunters paid for their hunting on leased lands. Compensation received by landowners for hunting rights was $9,905.

The estimated pheasant population was 86 per 100 acres. The estimated pheasant kill was 5,983 birds. The average hunter success ranged from 6.6 birds per hunter per year on leased lands to 2.8 birds per hunter on unleased lands. Hunting occurred mainly on weekends. The majority of hunters in the study area lived within Stanislaus County and the second largest point of hunter origin was the San Francisco Bay area. The occupation of most hunters utilizing the study area was in non-professional fields, the majority being skilled laborers. The landowners with smaller areas utilized the pheasant resource to a greater degree than did those with larger areas.

INTRODUCTION

The use of wildlife by a growing population necessitates better information on the utilization and economics of wildlife resources to provide proper management of these resources. The ringnecked pheasant resource was studied in the Oakdale area of Stanislaus County, California in the summer of 1968. According to several long-time residents of the Oakdale area the ringnecked pheasant was introduced there during the early 1900's. The pheasant population has been well established for over 25 years. Leach, et al. (1953) estimated the pheasant population in this area to be 50 birds or more per 100 acres. This figure is comparable to the pheasant population in the Sacramento Valley, which is considered to be the best pheasant area in California.

There has been much concern among unattached pheasant hunters regarding the availability of land for hunting. Their premise is that nearly all the land in the Oakdale area is leased for pheasant hunting and that there is insufficient land open to the unattached hunter. This contention and the hypothesis that owners of the larger land areas would be more likely to lease hunting rights rather than those of small areas are answered.

DESCRIPTION OF STUDY AREA

The study area was 32,011 acres located in northeastern Stanislaus County just south of Oakdale (Figure 1). It comprised 549 parcels of land owned by 340 landowners.

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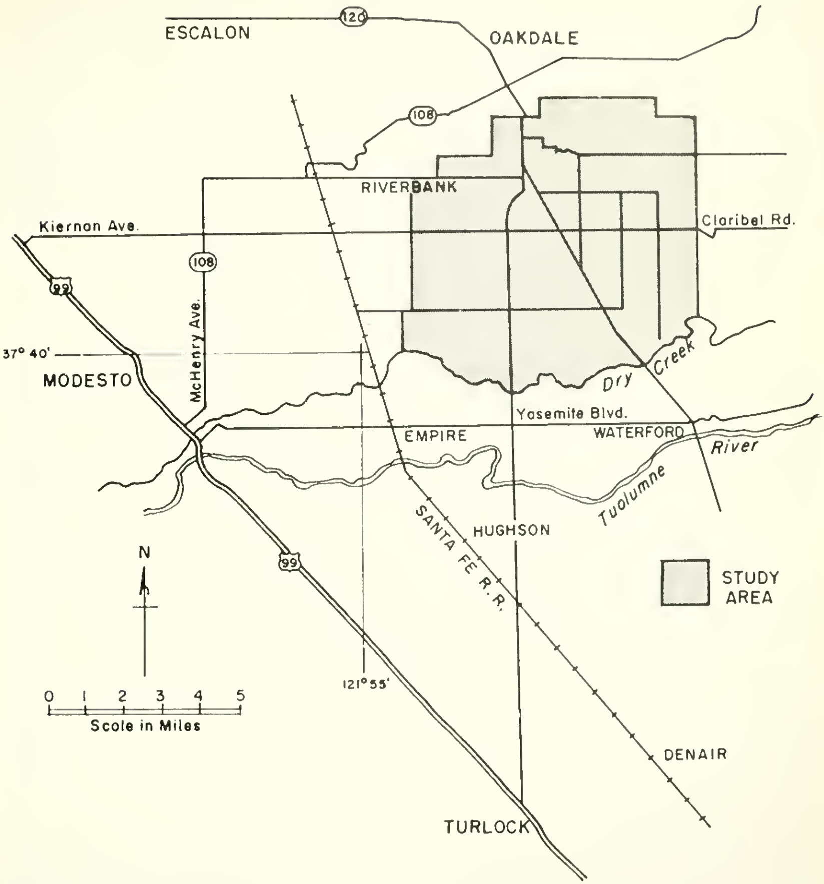

FIGURE 1. Map of study area. Drawn by Cliffa Carson.

The land use pattern in the study site was (i) irrigated pasture, 87%; (ii) native grassland, 6%; (iii) silage corn and cereal grains including rice, rye and oats, 3%; (iv) and miscellaneous crops which included orchards, vineyards and wastelands, 4%.

The irrigated pastureland included ladino clover, dallas grass-ladino clover combinations, or a mixed pasture with ladino clover, rye grass, fescue and other pasture grasses (Table 1).

The Oakdale site was selected because of high pheasant density, heavy hunting pressure, familiarity with the land and food habits (Leach et al., 1953), and routes used for pheasant brood counts were known.

METHODS

A questionnaire was prepared to obtain data on the utilization of the pheasant resource and hunting cost on private land. The questionnaire was divided into two sections. The first section dealt primarily with field data, including vegetative cover, habitat condition and an estimate of the pheasant population. Bird densities were estimated by Fish and

TABLE 1. The Vegetative Analysis of the Pheasant Habitat in the Study Area in Acres

Vegetative cover	Category I (50 acres or less)	Category II (51–150 acres)	Category III (151 acres plus)	Total acreage
Irrigated pasture	2,570	4,027	16,210	22,807
Native grassland	220	91	1,176	1,487
Orchard	290	179	60	529
Corn (silage)	25	81	395	501
Alfalfa	--	--	380	380
Oats	--	--	164	164
Vineyard	56	--	33	89
Wasteland	41	30	5	76
Rye	40	20	--	60
Rice	--	25	--	25
Totals	3,242	4,453	18,423	26,118

Game personnel with landowner assistance through field observations. The second section covered the landowner's use of the resouree and some economic implications which were gathered through three interview methods (i) personal contract was primary, (ii) telephone calls, and (iii) letters. Information was also collected on the hunter's occupation and residence, other types of hunting allowed, and data on posting and patrolling of the land.

The landowners' names, addresses, land parcel locations and total acreages were taken from the assessor's records of Stanislaus County. An attempt was made to contact all the landowners, however, it was understood 100% coverage was highly improbable.

All data on the landowners were placed into one of three categories according to the total acreage. Category I included all landowners with 50 acres or less, category II included all landowners with 51 to 150 acres, and category III included all the landowners with 151 acres or more. This classification was made in order to define the land parcels and to assist in gathering data.

The field data were collected in the fall of 1968. The habitat condition was evaluated according to the availability of water, feed and cover. When all three conditions were found in good supply the habitat was rated good. If one or more conditions were depleted, but still provided a minimum condition, the habitat was rated average. If one or more conditions were lacking the habitat was rated poor. The pheasant population was estimated prior to the 1968 hunting season.

RESULTS

The gathering of data ended in the fall of 1968. Of the 340 landowners 221 provided information about pheasant hunting on their lands. This was a 65% landowner sample, but it accounted for 82% of the area, or 26,118 of 32,011 acres, Table 2. The land parcels varied from less than 1 acre to over 2,800 acres per landowner, and averaged 94 acres.

Eighty-seven percent of the land was classified as irrigated pasture, with ladino clover the primary cover plant. The 1953 Oakdale food habits study (Leach et al., 1953) described about 60% irrigated pasture.

Hunting was permitted on 24,345 acres in the study area during 1967. This was 93% of the land surveyed and was owned by 188 of the interviewed landowners. Only 33 landowners (1,773 acres) did not

TABLE 2. Study Area Statistics

	Category I (50 acres or less)	Category II (51–150 acres)	Category III (151 acres plus)	Total
Total landowners	222	67	51	340
Total area in acres	3,980	5,873	22,158	32,011
Percentage of total area	12	18	69	*100
Total landowners sampled	135	46	40	221
Total area sampled in acres	3,242	4,453	18,423	26,118
Percent of area sampled	81	76	83	82

* Percentage does not equal 100 as 1% was split between the three classes.

allow hunting during this period for varied reasons, but primarily due to conflict with livestock use.

A total of 2,061 hunters were given permission to hunt on private lands. Ninety percent of these hunters actually hunted. A total of 7,258 man-days hunting were spent by 1,853 hunters in the study area during the 1967 pheasant season. This was an average of 3.9 man-days use for each hunter. The leased land averaged 5.2 man-days use, while hunting on unleased lands averaged 3.7 man-days use. The larger land areas (category III) had a higher man-day use but had the lowest average man-day use per acre so were not utilized to capacity (Table 3). The unleased land area had heavier hunting use on the larger areas than on the smaller areas. The hunter effort per man on the leased lands was greater than on the unleased lands. The hunting pressure on smaller unleased land parcels was more intense.

The landowner in the small land category utilized the pheasant resource to a greater degree than the landowner in the larger land categories (Table 3 and 4). The hypothesis that the larger landowners would be more likely to lease their lands can be substantiated. Although only 15 landowners leased their lands for pheasant hunting, 10 were in category III.

The fees paid by the individual hunters increased as the hunting area increased. A total of $6,655 was paid in cash while an additional $3,250 worth of merchandise or labor was given to the landowners for pheasant hunting rights. This $9,905 was paid by 219 hunters for the privilege to hunt on private property. Four landowners received compensations other than monetary. These included repair of a farm truck

TABLE 3. Data on Hunter Use

	Number of hunters		Man-days use					
							General public	
	Allowed to hunt	Actually hunted	Family	Friends	Employees	Paying hunter	Paying	Non-paying
Category I (50 acres or less)	949	842	1,737	883	4	67	0	309
Category II (51–150 acres)	578	505	1,117	416	18	86	0	180
Category III (151 acres plus)	534	506	937	360	105	992	0	47
Totals	2,061	1,853	3,791	1,659	127	1,145	0	536

TABLE 4. Hunter Use on Leased and Unleased Lands

	Number of landowners sampled		Total acreage		Total hunters		Total man-day use		Average man-day use	
	Leased	Unleased	Leased	Unleased	Leased	Unleased	Leased	Unleased	Leased	Unleased
Category I (50 acres or less)	3	100	104	2,747	13	829	67	2,933	5.2	3.5
Category II (51–151 acres)	2	44	238	4,215	12	493	86	1,731	7.2	3.5
Category III (151 acres plus)	10	29	4,023	13,018	194	312	992	1,449	5.1	4.6
Totals	15	173	4,365	19,980	219	1,634	1,145	6,113	5.2	3.7

($200); construction work on a ranch ($500), which included land leveling and levee building; a new car $2,500; and a clock radio ($50). Each hunter on leased lands paid $45.23, on the average, for the right to hunt on private land. The average cost was $2.27 per acre. The pheasant hunters on leased lands paid an average of $6.90 for leasing privileges for every bird in the bag. The average cost per hunter for hunting privileges about doubled in each category (Table 5).

TABLE 5. Fees Paid by Hunters on Leased Lands

	Total hunters	Total fees paid	Average cost per acre	Average cost per hunter	Average cost per bird bagged
Category I (50 acres or less)	13	$130	$1.25	$10.00	$1.97
Category II (51-150 acres)	12	350	1.47	29.19	3.89
Category III (151 acres plus)	194	9,425	2.34	48.58	7.37
Totals	219	$9,905	$2.27	$45.23	$6.90

The estimated pheasant population in the study area in 1968 was 27,645 birds with an average of 0.86 pheasant per acre. The larger areas had 70% of the population. A total of 5,983 male pheasants were killed during the 1967 season which was 22% of the estimated pheasant population. Hens were not legal game in 1967.

The hunter success was greater on the leased lands, with an average of 6.6 birds per hunter. Hunters on the unleased lands averaged only 2.8 birds (Table 6). A slightly higher success ratio occurred on leased lands with respect to the number of birds killed per acre of land.

TABLE 6. Data on the Pheasant Kill on Leased and Unleased Lands

	Category I (50 acres or less)	Category II (51-150 acres)	Category III (151 acres plus)	Totals or averages
Hunter success on unleased lands (birds/hunter)	2.1	2.6	4.9	2.8
Hunter success on leased lands (birds/hunter)	5.1	7.5	6.5	6.6
Number pheasants killed/acre on unleased lands	0.6	0.3	0.1	0.2
Number pheasants killed/acre on leased lands	0.6	0.4	0.3	0.3

It required less time to kill a bird on leased lands than on unleased lands. It took 1.3 man-days' effort to bag a pheasant on unleased lands, whereas it required only 0.8 man-day on leased property. Each hunter had available an average of 19.9 acres on leased land while on unleased lands the average was 12.2 acres. The larger land parcels provided substantially more land for each hunter as compared to the smaller land parcels (Table 7).

TABLE 7. Data on Hunter Use on Leased and Unleased Lands

	Category I (50 acres or less)	Category II (51–150 acres)	Category III (151 acres plus)	Averages or totals
Man-days used per pheasant killed on unleased lands	1.7	1.3	0.9	1.3
Man-days used per pheasant killed on leased lands	1.0	1.0	0.8	0.8
Average number of acres per hunter on unleased lands	3.3	8.5	41.7	12.2
Average number of acres per hunter on leased lands	8.0	19.8	20.7	19.9

The largest percentage (55%) of hunters that hunted pheasants in the study area in 1967 came from within Stanislaus County. The San Francisco Bay Area, San Joaquin, Tuolumne and Los Angeles counties provided 75% of the hunters who lived outside of the area. Distance extremes were from 6 miles (Escalon) to 1,030 miles (Vancouver, B.C.). The average distance from the hunter's home to the study area for those hunters from outside of Stanislaus County was 96 miles. About 48% of the hunters that used leased property came from within Stanislaus County (Table 8).

TABLE 8. Resident County of Hunters Using the Study Area Both Leased and Unleased Lands

County and average distance from study area (in miles)	Category I (50 acres or less)		Category II (51–150 acres)		Category III (151 acres plus)		Total	
	Leased	Unleased	Leased	Unleased	Leased	Unleased	Leased	Unleased
Stanislaus	2	71	2	33	6	30	10	134
*San Francisco Bay Area—80	1	34	--	16	5	8	6	58
San Joaquin—30	--	14	--	3	--	1	--	18
Tuolumne—33	--	5	1	2	--	1	1	8
Los Angeles—300	--	2	1	1	1	4	2	7
Fresno—91	--	3	--	--	--	--	--	3
Sacramento—65	1	--	--	2	1	--	2	2
Calaveras—28	--	--	--	--	--	1	--	1
El Dorado—60	--	--	--	1	--	--	--	1
Kern—197	--	1	--	--	--	--	--	1
Mariposa—34	--	--	--	--	--	1	--	1
Merced—40	--	--	--	1	--	--	--	1
Orange—355	--	1	--	--	--	--	--	1
San Luis Obispo—172	--	1	--	--	--	--	--	1
Tehama—180	--	1	--	--	--	--	--	1
†British Columbia—1,030	--	1	--	--	--	--	--	1
Totals	4	134	4	59	13	46	21	239

* Bay Area includes: Santa Clara, Alameda, Contra Costa, San Mateo, San Francisco, Solano, Sonoma, Marin and Napa counties.
† Canadian Province.

The occupations of the hunters that used the leased and unleased lands were quite similar. It was evident that hunters from most occupational categories could afford the fees charged by the landowners. The hunters using the larger land parcels paid more for their hunting than those using smaller land parcels. Higher salaried, or self-employed, higher income hunters took advantage of the larger land areas. The majority listed would be considered from middle income occupations (Table 9).

TABLE 9. Data on Hunter Occupations, Both Leased and Unleased Lands

General Occupation	Category I (50 acres or less)		Category II (51–150 acres)		Category III (151–acres plus)		Total Total	
	Leased	Unleased	Leased	Unleased	Leased	Unleased	Leased	Unleased
Skilled Labor	2	50	--	17	7	13	9	80
Rancher or Farmer	--	23	--	16	2	11	2	53
Professional	--	23	1	14	11	9	12	46
Businessmen	2	21	--	13	4	11	6	45
Unskilled Labor	--	14	--	5	3	4	3	23
Retired	1	12	1	6	2	2	4	20
Sales	--	9	1	6	8	2	9	17
City, State or Federal	--	4	--	4	1	4	1	12
Student	--	5	1	5	--	1	1	11
Public Utilities	--	6	--	3	--	1	--	10
Law Enforcement	--	2	--	1	--	1	--	4
Totals	5	169	4	90	38	62	47	321

Thirty percent of the property owners permitted dove, duck and goose, rabbit and California quail hunting. Dove hunting was the most prevalent use other than pheasant hunting. No estimate was made of the numbers of these wildlife species harvested. Generally, the population of other wildlife species was low. Some ducks, mainly mallards (*Anas platyrhynchos*) and cinnamon teal (*Anas cyanoptera*) used the various canals, sumps and marshes within the study area. There were no fees charged for hunting these game species.

Over 80% of the landowners had no restriction on which days could be hunted, but generally most hunting occurred on the weekends and holidays. Nineteen percent of the landowners restricted hunting to some degree during the pheasant season for reasons of interference with livestock or use by the owners' immediate families. One landowner did not allow hunting on the first weekend.

Ninety percent of the land in the study area was posted against hunting or trespassing. The lands that were not posted were either small in size, or located in remote areas with limited access.

Sixty-one percent of the landowners provided some patrol during the 1967 pheasant season. The patrolling was by landowners, lessees, friends or ranch employees. The intensity of patrol varied from just casual observation to a scheduled inspection routine. Four ranches hired a full-time deputy sheriff to patrol during the 16-day pheasant season. Few landowners prosecuted hunters on a trespass violation unless damage was done to equipment or livestock. The amount of trespass declined as the size of the land decreased. Category III averaged 14 man-days of trespass per ownership during the 1967 season. Category II and category I averaged 4 man-days and less than 1 man-day respectively of trespass per land ownership.

Pheasants have been hunted in the Oakdale area for some time. The landowners in category I have allowed pheasant hunting for an average of 14 years; the landowners in category II for 16 years; and the owners in category III for 18 years. These averages include the relatively new landowners as well as the old-time residents.

DISCUSSION

The primary objectives of this study were to obtain data on the use of the natural pheasant resource in the Oakdale area, and what economic benefits the landowners derive from its use. It is apparent from the data collected that the owners of larger land areas are not utilizing their lands to their full potential for pheasant hunting. The owners of smaller land areas are providing the greatest utilization.

The hypothesis that the majority of the landowners in the Oakdale area lease their land for pheasant hunting is false. Only 15 landowners of 221 that were questioned leased their lands for pheasant hunting. These 15 landowners received an average of $2.27 for each acre of land leased. The total compensation received for pheasant hunting amounted to $9,905. A total of 1,435 pheasants was killed on leased lands, while 4,548 birds were bagged on unleased lands. It cost the pheasant hunters $6.90 for each bird killed on leased lands.

The majority of landowners did not lease their lands due to commitments made to members of the family, friends and business acquaintances.

With continued increase in property taxes, landowners whom now do not lease their hunting rights possibly will look to leasing as another avenue of economic income. The current demand for good pheasant hunting will probably increase in the future, therefore landowners may wish to obtain additional economic benefits from this wildlife resource. If all landowners in the study area leased their lands at the present rate, they could realize an economic reward of close to $100,000 instead of the current receipt of less than $10,000.

ACKNOWLEDGMENTS

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NOTES

PROGRESS REPORT ON REESTABLISHMENT OF THE MOJAVE CHUB, *GILA MOHAVENSIS* (SNYDER), AN ENDANGERED SPECIES

The Mohave chub, *Gila mohavensis,* once found extensively in the Mohave River and its tributaries, is the only native fish known to the Mohave River drainage (Hubbs and Miller 1943). Pure strains of these chubs have steadily declined since about 1938, with the introduction of the arroyo chub, *Gila orcutti,* which resulted in competition and hybridization between the two species. They had been completely eliminated in the main river by 1967 (Miller 1967). Until recently the Mohave chub was found only in Lake Tuendae at Zzyzx Resort south of Baker, California.

The population in Lake Tuendae is flourishing, but is in a precarious condition due to the present undetermined ownership of the property on which the lake is located. In 1969, following the recommendations of Miller (1967), the California Department of Fish and Game began transplanting the chubs to additional refugiums from Lake Tuendae. Three locations, Piute Springs, South Coast Botantic Garden Pond, and Two Hole Springs, have been planted to date. A brief summary of the introductions follows.

Piute Springs

Piute Springs, San Bernardino County, is located on Bureau of Land Management land northwest of the town of Needles, California. The spring lies at the bottom of a canyon and is sometimes subjected to flash floods. On December 18 and 19, 1969, Messrs. L. Fisk, E. Lesh, D. Frye, and R. Winn all with this Department, introduced 150 Mohave chubs into Piute Springs. The chubs averaged about 3.5 inches in length.

An inspection of Piute Springs this winter did not reveal any chubs in the streams. A flood that occurred after the introduction may have eliminated them.

South Coast Botanic Garden Pond

This 2-acre pond constructed at the South Coast Botanic Garden in Palo Verdes, California is managed by the Los Angeles County Department of Arboretum and Botanic Gardens. The authors introduced 147 Mohave chubs into the pond on January 27, 1970. The chubs measured approximately 1.5 to 2 inches in length, with the exception of 5 fish that were 4 to 7 inches.

On July 2, 1970 we observed that 3 different spawnings had apparently occurred.

Two Hole Springs

This spring is located in San Bernardino County on Bureau of Land Management land, 1 to 2 miles south of Old Woman Springs Road east of Lucerne Valley, California. Maximum depth of the pool formed by the spring is 2 ft. On August 20, 1970, Messrs. J. St. Amant, E. Lesh, and Bureau of Land Management personnel, W. Templeton and R. Manus, planted 41 chubs into the pool. Average length of the chubs was approximately 2 inches; several measured approximately 4 inches. Mr. Templeton, prior to the introduction, constructed a fence around the 30- by 40-ft pool to keep cattle out.

Future plans for management of *G. mohavensis* include the periodic inspection of Piute Springs and Two Hole Springs. If additional introductions are necessary, chubs from the South Coast Botantic Garden will be transplanted to these sites. The South Coast Botantic Garden will be used as a source for additional introductions when suitable refugiums are located. An introduction will be made into Lark Seep located on the United States Naval Weapons Station, China Lake, California.

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THE EFFECT OF TEMPERATURE ON THE NUMBER OF CIRCULATING HEMOCYTES IN THE CALIFORNIA SEA HARE, *APLYSIA CALIFORNICA*[1,2]

The number of circulating hemocytes in the California sea hare, *Aplysia californica,* decreases immediately following injections of various bacteria (Pauley, et al. in press). In order to understand changes resulting from experimental or pathological conditions, it is essential that we know the normal number of circulating hemocytes. Total hemocyte values are known for some mollusks (Yeager and Tauber, 1935) and there is information concerning the relationship between temperature and hemocyte numbers in the American oyster, *Crassostrea virginica,* (Feng, 1965). However, we know nothing about these values in the California sea hare. This research note summarizes our observations on the total number of circulating blood cells in the California sea hare at two different temperatures.

Hemocytes were obtained by withdrawing fresh hemolymph from the engorged pedal sinus. The external surface of the foot was sterilized with 70% ethanol and the fluid extracted with a sterile syringe and 25 gauge needle. No apparent trauma was found if hemolymph with-

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[2] Part of a dissertation by the senior author submitted to the Faculty of the University of California in partial fulfillment of the requirements for the degree Doctor of Philosophy.

drawal was done while the animal was held in a damp paper towel. Hemolymph was kept in sterile test tubes in an ice bath until the cells were counted (usually less than 60 min after bleeding). A vortex stirrer was used just prior to counting to insure an even distribution of blood cells. Equal volumes of hemolymph and 0.2% Eosin Y were gently mixed and immediately counted with a Neubauer hemocytometer. Four counts were made on individual samples taken from 16 different animals held at each of two different temperatures (12 C and 18 C). These animals were approximately equal in size and were assigned at random to either a 12 C tank or 18 C tank 1 week prior to bleeding.

Although the range of total hemocyte counts overlapped somewhat, the mean number of hemocytes present at 18 C (146.47 ± 40.70) was nearly twice the number observed at 12 C (76.03 ± 20.86) (Table 1). The t-test for comparing the means of two randomized groups of equal size was used for statistical analysis of the data according to the procedure outlined by Snedecor (1956). There was a significant difference in the number of hemocytes between organisms held at 12 C and at 18 C ($p = 0.01$).

TABLE 1. Hemocyte Numbers in *Aplysia californica* at 18 C and at 12 C

Temperature	Number of test animals	Mean number of total hemocytes/animal/ml blood $\times 10^4$	Range of total hemocytes/animal/ml blood $\times 10^4$
18C	16	146.47 ± 40.70	48–187
12C	16	76.03 ± 20.86	30–117

The total hemocyte values found in the California sea hare differ from those obtained for other mollusks (Yeager and Tauber, 1935; Feng, 1965). However, more circulating hemocytes were observed at the higher temperature (18 C) than at the lower temperature (12 C) in the California sea hare corroborating Feng's (1965) results on the American oyster. It is significant that more potential phagocytic cells are circulating in the hemolymph at 18 C than at 12 C, because marine bacteria are cleared *in vivo* in the California sea hare more rapidly at higher temperature than at the lower temperature (Pauley et al., in press).

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BOOK REVIEWS

Parasitic Diseases of Wild Mammals

Edited by John W. Davis and Roy C. Anderson; Iowa State University Press, Ames, Iowa 50010, 1971; x + 364 p., illustrated. $15.00.

This is the third and final volume of the series on diseases and parasites of wild birds and mammals published by the Iowa State University Press. The subject matter covered by these volumes has been sorely needed for many years, but the delay has been occasioned by gaps in our knowledge which only lately have been bridged.

There are some outstanding chapters among the best of which are those devoted to Mites and Pentastomes by Gordon K. Sweatman, the Bighorn Sheep Lungworm-Pneumonia Complex by Donald J. Forrester, and Elaeophorosis by Charles P. Hibler and Jerry L. Adcock.

One of the faults of books produced by the efforts of contributing authors is the lack of quality control. This is the responsibility of the editors, but in most cases such work is a monumental task. Despite the excuse inadvertently made in the preface, "Although (each chapter is) not intended to be a complete survey of the subject", the omissions within the book are detrimental to what this volume is purported to be.

An important ectoparasite completely excluded is the tick. Although various genera are included in the previous volume as vectors of infectious diseases on wild mammals, this arthropod does cause disease in its own right, e.g. tick paralysis.

The cause of the highest mortality among California deer is parasitism by stomach and intestinal worms, and they are an important cause of deer losses in Oregon, British Columbia, and other areas. Nevertheless, this book does not have any space devoted to these nematodes.

Roy Anderson is an authority on lungworms and gives an excellent account of some of the important genera. However, there are two species which are serious in the cervidae and bighorn sheep, namely *Dictyocaulus viviparus* and *D. filaria* which he omits. They are mentioned by Forrester in the lungworm-pneumonia complex chapter.

Two of the more common tapeworms encountered in deer, *Moniezia* sp. and *Thysanosoma actinioides* are not mentioned among the 30 cyclophyllideans adequately discussed in the chapter by Leiby and Dyer.

There are several other serious omissions, and some of the parasites are mentioned as part of the host-parasite lists. Obviously the full treatment of each parasite is impossible in a book with this scope; however, the important parasites should not be completely excluded.

One noteworthy error is the statement by Davis and Libke, "It (*Fasciola hepatica*) is rarely found in North American deer." This parasite is common in deer of the western United States and is replaced by the liver fluke *Fascioloides magna* in deer of the eastern United States.

This volume is a step in the right direction, but at the present time it should bear the title "*Some* Parasitic Diseases of Wild Mammals". Most of the material which is covered incorporates newer knowledge of the parasites which afflict the wildlife resource and provides not only the basic knowledge of life histories and effects, but discusses methods of treatment and control. From this point of view, and realizing the omissions, there is useful reference material in the book.—*Merton N. Rosen.*

Everyman's Guide to Ecological Living

By Greg Cailliet, Paulette Setzer and Milton Love; the MacMillan Company, 866 Third Avenue, New York, N.Y., 1971: 119 p., illustrated. $0.95 paper.

In this age, when the market is being flooded with books on ecology and what to do to lead a more ecologically sound life style, one finds at last a book like this that "tells it like it is". Packed into this 119 page pocket or purse size paperback are the best ways you as an individual can help recycle and conserve resources including such things as air, water, minerals, land and endangered species. It gives details on the use of consumer power and political action to constructively change our overconsumption-overpopulation syndrome.

I have only one criticism and that is the subject of population as usual has been relegated to the second to the last "chapter".

It is the combination of overconsumption and population increase that has gotten us to the point where many fish and wildlife biologists wonder whether man is the most endangered species of all and this book reinforces this hypothesis.

I recommend this manual as the best one out yet "for people who want to adopt their own lifestyle so as to be less a part of the environmental deterioration problem and more a part of the solution". Next time you have to give a talk on what one can do to save our fish and wildlife resources, tell them to invest 95¢ on the answers. —*Ted Wooster*

Pictorial Guide to the Birds of North America

By Leonard Lee Rue III; Thomas Y. Crowell Co., New York, 1970; 363 p., illustrated. $12.50

Those who are aware of the ecological problems we face would agree with Lee Rue's comments "Often man's technological advances outrun his knowledge, and the full extent of the destruction loosed by pesticides and insecticides on the wildlife populations as well as on the human population is not yet known. The mounting evidence of such destruction has aroused a growing human awareness, although it may already be too little and too late."

Lee goes on to discuss briefly how some of the problems created by man's attempts to alter the environment have consequently threatened the existence of many species.

In his continuous mentioning of natural predators of various birds, the author may have led the uninformed reader to believe that predation is undesirable.

Sixteen of the 27 orders of birds are described with observations, made mainly by the author on selected species. The excellent black and white photographs and drawings of representative species illustrate the interesting, well organized text providing easy reading for acquiring basic knowledge of birds.

An appendix lists National Wildlife Refuges and areas where specific birds may be observed.

Aldo Leopold in his book, *A Sand County Almanac*, refers to naturalists such as Lee, whose observations, studies and photography of wildlife are a contribution of the highest cultural value. I agree with Leopold.—*James A. St. Amant*

Wildlife for America

By William R. Van Dersal; Henry Z. Walck, Inc., New York City, 1970. 160 p., illustrated.

"Wildlife for America" is both an absorbing book for adults and an excellent wildlife conservation primer. Dr. Van Dersal of the U.S. Soil Conservation Service has accomplished this difficult literary feat by careful matching of opposing pages of simple text and well selected photographs.

This enlarged and revised version of the 1949 edition is more than a picture story. It is a story of many pictures, the great auk of the Atlantic coast and the California condor, exploitation, a national awakening, and hope for the future.

The now-classic photos of the black-footed ferret and the red-tailed hawk with captured mouse help tell the story of endangered species and predator and prey, but it is the author's skillful treatment of man's impact upon habitat that makes the book so outstanding. It can do much to stimulate landowners, sportsmen and students in selection and adoption of wildlife conservation projects. "Wildlife for America" merits acquisition by school libraries; agricultural extension workers; 4-H, Boy Scout, and other youth organizations; and all others interested in improving the nation's wildlife habitat.

Dr. Van Dersal's brevity, graphic eloquence, and provocative messages are best summarized in his concluding photo and the caption: "As the new pattern of conservation spreads, America will become a better place for wildlife."—*Paul E. Giguere*

American Hawking—A General Account of Falconry in the New World

By Hans J. Peeters and E. W. Jameson, Jr., available only through authors, 1970 Oakside, Davis, California 95616; 1970, 145 p. illustrated with colored plates and sketches by senior author. $25.00.

American Hawking is an appropriate and timely book devoted to falconry in the new world. Through the news media and television the general public has recently been captivated by birds of prey. The need for protection and the enjoyment one experiences from possession of these birds for purposes of falconry has become a focal point of interest to many.

The authors introduce the reader to the history and essence of hawking as well as acquaintance with the American hawks used in the sport of falconry. The capture of a hawk, its care, and training are well covered. Most importantly, throughout the text is stressed the devotion and sacrifice of time and expense one must make to adequately care for a bird and train it for falconry. After thoroughly reading American Hawking one should seriously question does he really want to become a falconer. If so, he will find the book a convenient reference source; if not, an excellent addition to his library and knowledge of birds of prey.

The only shortcoming of the book is need for a section on regulations governing state licensing of falconers. Birds of prey are with few exceptions, protected in all states by laws and one cannot legally engage in falconry without compliance to such laws.—*Howard R. Leach*

Climate, Man and History

By Robert Claiborne; W. W. Norton and Co., Inc., New York, 1970; 444 p.

The author, a free-lance writer and not a scientist, has written an entertaining and informative book. His humorous barbs at both scientists and politicians help give the book a levity much needed for our times.

The first part of the book deals with climatic principles and delves into paleoclimatic conditions and changes which shaped the evolution of life and particularly man. Various theories explaining the ice ages are given exposure and no one theory appears to be completely satisfactory.

Nearly half the book describes the effect of climate on civilization and human history. This portion is extremely interesting for the ecologist. Claiborne points out that favorable climatic conditions often cause population explosions which in turn result in ecological damage, warfare, and the decline of civilization. The decline of cultures in Egypt, Mesopotamia, Rome, Greece, India and China are all documented. Fishery biologists might note that the decline of the Hanseatic League resulted from the collapse of the Baltic herring fishery around 1420 A.D. This eco-catastrophe was most likely caused by changes in temperature and salinity in the Baltic Sea.

Current environmental problems related to climate such as the green house effect, atmospheric pollution, irrigation of deserts by hydraulic tampering and efforts at climate control are summarized in the final chapters. The book brings together a great deal of information and takes a generalized overview of climate and man which is very much needed.—*Lee W. Miller*

Before Nature Dies

By Jean Dorst; Houghton Mifflin Company, Boston; 1970. 352 p. illus. $8.95.

Mankind is currently being deluged with books concerning our relationship with the natural world. This book is one of the best overall histories of man's ecological crisis that I have read. The book is well written, well documented and beautifully illustrated.

The first chapters record man's assault upon nature. The extinction of many species of birds, mammals and even insects due to ruthless exploitation are recorded. The author then recounts what conservationists have been able to accomplish by way of restoration and preservation of habitat.

In Chapter 4 the population explosion and its impact are given exposure. Chapter 5 is devoted to man's destruction of the land by agriculture, overgrazing, deforestation and fire. He does not mention mining, road building and the other geological activities of man. The following two chapters are devoted to pesticide damage and pollution by waste products. The problem of the introduction and spread of exotic plants and animals is treated in Chapter 8. It is in this area that man has probably done the greatest damage to ecosystems. Unfortunately man continues such folly often in the name of conservation.

One of the best documented bits of stupidity was the spread of the water hyacinth over much of the tropical and sub-tropical areas of the world.

Chapter 9 deals with the exploitation of maritime resources. The author points out several classic examples of overexploitation such as whaling, sealing, the Pacific sardine fishery, and destruction of sea turtle populations. The author tries to make a case for circumventing the second law of thermodynamics by harvesting at lower trophic levels such as plankton in order to feed more people. However, such schemes would require tremendous inputs of energy which makes it impractical. Fossil fuels will be needed to harvest, process and distribute such catches and these reserves are dwindling daily. He also ignores the ecological disasters which could result from disrupting food webs in the ocean.

In the final chapter, Dorst points out the need for population control and rational use of land and resources. Population control can be achieved by increasing mortality through the slaughter of old people and excess children or by birth control. The author favors the latter. Dorst foresees that technological civilization may well collapse but if enough remnants of nature can be preserved, some of humanity may also survive.

Some omissions are evident such as the introduction of striped bass, centrarchids and other teleosts into western North America.

He also failed to mention the unabated destruction of estuaries by 20th century man and he does not appear to grasp that mineral and energy resources are probably now the most critical limiting factors to the continuance of civilization aside from the possibility of nuclear annihilation or economic collapse—*Lee W. Miller*

Atlantic Salmon Flies and Fishing

By Joseph D. Bates, Jr.; Stackpole Books, Cameron and Kelker Streets, Harrisburg, Pa., 1970; 362 p., illustrated. $14.95.

The author, one of today's leading experts on fishing, discusses factually and interestingly all you need to know to become a successful Atlantic salmon fisherman.

The life history of the salmon is given in detail, as well as today's problems with predators, pollution, and poaching. An entire chapter is devoted to tackle-lines, leaders, knots, rods, reels, hooks, and flies; why, when, and where particular equipment is used. Next, a detailed section on salmon flies, including their history, types, sizes, and some beautiful colored plates of wet flies. Instructions on how to fish both the wet and dry flies, with drawings of typical pools and salmon lies, are given clearly and concisely. The last two chapters of the first part of the book tell the angler where Atlantic salmon fishing is available, what it costs, and the best times and equipment for the major waters.

The second half of the book—really an entire book by itself—is about Atlantic salmon flies. The several chapters are broken down into fly tying techniques and hints. North American and British feather-wing and hair-wing patterns, and dry-fly and nymph patterns. Detailed dressing formulas are given for over 200 favorite patterns and the interesting historical notes and color plates save this section from being just another "recipe" book.

Even if you never manage to fish for Atlantic salmon, the book is guaranteed to get your adrenalin flowing.—*K. A. Hashagen, Jr.*

Selective Trout

By Doug Swisher and Carl Richards; Crown Publishers, Inc., New York, 1971; 184 p., illustrated in color and black and white. $6.95.

This book should be an instant classic! The authors have combined their mutual interests in aquatic entomology, photography, and fly-tying with a desire to take large, wary, "selective" trout and have developed an entirely new concept in dry-fly fishing. Breaking with tradition, they feel the hackle on a fly is less important to the fish than the wing, and that color and size are of prime importance. Using these concepts, they have developed a series of flies called the No-Hackles, Paraduns, Emergers, Wiggle Nymphs, and Hen Spinners to imitate the natural nymphs, emergers, duns, and spinners.

The book is a beautiful piece of work on stream entomology. Information is given clearly and handsomely illustrated with color photographs and line drawings. Major emphasis is placed on the mayflies, with detailed information on collection, identification, and life cycles. Emergence data are given for major species in the East, mid-West, and West, and are broken down into early, mid, and late season hatches.

The concept of the no-hackle fly is clearly stated and excellent line drawings explain how "tried-and-true" patterns are tied in the new style.

There are two drawbacks—if they can be called that—for California fishermen: (1) the fishing described is the matching-the-hatch type and there are relatively few areas in California which have the heavy hatches described by the authors, (2) the "western" mayflies identified are Montana and Idaho species, although many of the genera listed are found in California.

There is a tremendous amount of information for both the beginner and the expert. For the expert there is an exciting new concept to be tried; for the beginner, a logical and simplified introduction to fly-fishing.—*K. A. Hashagen, Jr.*

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AUTHOR

SCIENTIFIC NAMES

SUBJECT

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Notice is hereby given that the Fish and Game Commission shall meet on October 1, 1971 at 9:00 a.m. Room 115 Old State Building, 217 W. First Street, Los Angeles, 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 groups as to what, if any, regulations should be made relating to fish, amphibia, and reptiles, or any species or subspecies thereof.

Notice is hereby given that the Fish and Game Commission shall meet at 9:00 a.m. on November 5, 1971, in Room B-109, 1350 Front Street, San Diego, California, for public discussion of and presentation of objections to, the proposals presented to the Commission on October 1, 1971, and after considering such discussion and objections, the commission, at this meeting, shall announce the regulations which it proposes to make relating to fish, amphibia and reptiles.

Notice is hereby given that the Fish and Game Commission shall meet on December 10, 1971 at 9:00 a.m. in the Main Auditorium, Resources Building, 1416 Ninth Street, Sacramento, California to hear and consider any objections to its determinations or proposed orders in relation to fish, amphibia and reptiles or any species or subspecies thereof for the 1972 sport fishing season, such determinations and orders resulting from the hearings held on October 1, 1971 and November 5, 1971.

FISH AND GAME COMMISSION
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