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CONTENTS

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THE ACUTE TOXICITY OF SIX MONOCYCLIC AROMATIC CRUDE OIL COMPONENTS TO STRIPED BASS (*MORONE SAXATILIS*) AND BAY SHRIMP (*CRAGO FRANCISCORUM*)[1]

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The acute toxicities of benzene, toluene, ethylbenzene, p-xylene, m-xylene, and o-xylene were determined for striped bass and bay shrimp by static bioassay. The 96-hr LC_{50}'s ranged from 2.0 to 11 μl/l (ppm) for striped bass and from 0.49 to 20 μl/l (ppm) for bay shrimp. Solubilities of these aromatics were determined by gas chromatography in 16 C (61 F) seawater with a salinity of 25°/₀₀ as part of our procedure for dosing the animals. The solubilities were 1400, 330, 180, 180, 210, and 230 μl/l (ppm), respectively, which is high enough to be lethal to striped bass and bay shrimp. The toxic effect of the aromatics was more latent in shrimp than in fish as demonstrated by the difference in the 24- and 96-hr tests.

INTRODUCTION

Fish and aquatic invertebrates in San Francisco Bay are continuously being exposed to crude oil and its refined products as a consequence of the many petroleum spills occurring every year in the bay (U.S. Coast Guard Reports 1971–1975 [2]). Due to the petroleum chemicals in the bay and the programs initiated to clean it up, the acute and chronic effects of petroleum products on the marine biota in San Francisco Bay are of interest.

Aromatic hydrocarbons, being among the more toxic fractions in petroleum, are receiving much attention; this is especially true with the polycyclic aromatics some of which are carcinogenic. Aromatics are cyclic compounds containing one or more unsaturated rings, benzene being the simplest in the homologous series. Our research efforts were directed toward the monocyclic aromatics for several reasons: their mammalian toxicities (Stecher 1968; and American Petroleum Institute 1960*a*, 1960*b*, 1960*c*); relatively high composition in crude oils and its products (Goldstein and Waddams 1967); the excess production of aromatics by reforming crude oils (Horne and McAfee 1960); and water solubilities (Mackay and Wolkoff 1973; and Benville and Korn 1974). Six monocyclic aromatics were chosen for static bioassays with striped bass (*Morone saxatilis*) and bay shrimp (*Crago franciscorum*). The six aromatics—benzene, toluene, ethylbenzene, p-xylene, m-xylene and o-xylene—predominate in the aromatic fraction of many crude oils (Goldstein and Waddams 1967; and Ander-

[1] Accepted for publication September 1976.

[2] Pollution Incident Reporting System (PIRS), computer printouts available through U.S. Coast Guard, 12th District, 630 Sansome St., San Francisco, CA 94111.

son et al. 1974). The striped bass was chosen, because it is an important recreational fish in this region; the bay shrimp is a popular bait and an important food organism for striped bass and other fishes in the bay. Bioassay information was needed as a preliminary step to studies of chronic effects of aromatics.

MATERIALS AND METHODS

Mature bay shrimp (mean weight 1.8 g, 0.063 oz) were acquired from a local bait dealer and juvenile striped bass (mean weight 6.0 g, 0.21 oz) from the Bureau of Reclamation fish diversion facility at Tracy, California. The animals were acclimated in seawater (Korn 1975) for one week before transferring the animals into bioassay tanks (180-liter or 48 gal fiberglass aquaria). The salinity and temperature of the seawater was 25°/₀₀ and 16 C (61 F), respectively, which are representative of bay conditions.

Saturated aromatic solutions were prepared by shaking seawater with an excess of the aromatics in a 20-liter (5.3 gal) polyethylene carboy for three 10-second intervals and allowing the mixture to settle for 1 hour. After gas chromatographic analyses of the saturated solutions, the proper volume was mixed into the bioassay test aquaria, each containing ten animals. A 100 ml (3.38 oz) water sample was taken from the bioassay test aquaria at 0-, 24-, 48-, 72-, and 96-hour intervals for analysis. The water samples were extracted with 9.7 ml (0.33 oz) TF Freon (trichlorotrifluoroethane) in a separatory funnel and a 3–4 μl aliquot of the Freon extract injected into a Micro-Tek 220 gas chromatograph equipped with a dual flame ionization detector. Two 6-foot columns were used at 105 C (221 F)—a 5% Bentone 34 and 10% didecylphthalate on 80/100 chromosorb PAW, and a 5% SP-1200 and a 5% Bentone 34 on 100/120 supelcoport. The first column was used for quantifying benzene, and the second was used for quantifying the other five aromatics. Aromatics were considered undetectable below 0.1 μl/l (ppm) for the concentrated extract or 0.01 μl/l (ppm) for the water sample, since the water sample was concentrated by extracting with 1/10th the amount of Freon. The concentration values were corrected by the percent recovery of the first extractions of a 100 ml (3.38 oz) water sample with 9.7 ml (0.33 oz) of TF Freon.[3] All aromatics used were 99+% pure.

TABLE 1. Acute Toxicity of Six Monocyclic Aromatics to Striped Bass and Bay Shrimp at 16 C and 25°/₀₀ Salinity in Static Bioassays

Components	Solubility* (μl/l)	% Extracted w/TF Freon	*Striped bass*				*Bay shrimp*			
			24-hr		*96-hr*		*24-hr*		*96-hr*	
			LC_{50}	95% C.L.	LC_{50}	95% C.L.	LC_{50}	95% C.L.	LC_{50}	95% C.L.
Benzene	1400	90	6.9	**	5.8	—	22	20–24	20	19–22
Toluene	330	93	7.3	—	7.3	—	12	10–13	4.3	3.1–5.8
Ethylbenzene........	180	82	4.3	3.9–4.7	4.3	3.9–4.7	2.2	—	0.49	0.21–1.2
m-xylene	210	78	9.2	8.3–10	9.2	8.3–10	4.8	3.6–6.3	3.7	2.9–4.7
o-xylene	230	74	11	9.4–12	11	9.4–12	5.3	4.4–6.5	1.3	1.1–1.6
p-xylene	180	78	2.0	—	2.0	—	2.0	—	2.0	—

* Solubility in 25°/₀₀ seawater at 16 C (61 F).
** No confidence limits were calculated from tests without partial mortalities.

[3] Reference to a trade name does not imply endorsement by the National Marine Fisheries Service, NOAA.

The guidelines for the static bioassays were those outlined by Doudoroff et al. (1951), except for modifications mentioned in this section. The method used to compute the 24- and 96-hour LC_{50} and the 95% confidence limits was described by Litchfield and Wilcoxon (1949). Confidence limits were not calculated for tests without partial mortalities.

Water concentrations were analyzed with a curve-fitting program to describe the volatilization of aromatics over the elapsed time (Hewlett Packard BASIC program modified by Richard Faris at Tiburon Laboratory).

RESULTS

There were toxicity differences between the six aromatics for both the striped bass and the bay shrimp (Table 1). The range in the aromatic toxicities varied more for bay shrimp (.49–22 μl/l, ppm) than for striped bass (2.0–11 μl/l, ppm) at both time intervals (24- and 96-hr). The tolerance of these animals to the six aromatics within the 24-hr period indicated that benzene and toluene were more toxic to striped bass than to bay shrimp. Ethylbenzene, m-xylene and o-xylene were more toxic to bay shrimp than to striped bass for the 24-hr period. P-xylene exhibited the same toxicity for both animals at the 24- and the 96-hr intervals. The "toxicity order" of toluene reversed at the 96-hr interval, toluene being more toxic to bay shrimp. The toxicity of the other aromatics for the 96-hr period remained the same as for the 24-hr period.

Lethal concentrations of aromatics resulted in rapid mortalities of the striped bass. Almost all of the striped bass mortalities occurred within the first six hours of the bioassays. The latent toxic effects were more prevalent with bay shrimp than with striped bass during the testing period. Benzene was the only aromatic that showed a delay in its toxicity to both animals. P-xylene exhibited no difference in toxicity over the two time intervals to both species. Toluene, ethylbenzene, m-xylene and o-xylene were more toxic to bay shrimp at the 96-hr interval than at the 24-hr interval; however, these aromatics exhibited the same toxicity at both time intervals to striped bass.

There was a large difference in the solubility between the monocyclic aromatics in 25°/₀₀ seawater at 16 C (61 F). Benzene was the most soluble (1400 μl/l, ppm) and ethylbenzene and p-xylene the least (180 μl/l, ppm).

The extraction efficiency determined by multiple extractions of the six aromatics from seawater (25°/₀₀ salinity) was high for a 1:10 Freon to seawater ratio. One extraction resulted in recoveries of 74.1 to 93.1%.

The concentrations of the six aromatics in the aquaria decreased linearly each day, in most instances. In some cases the concentrations followed a logarithmic decrease (Table 2). Average percent losses for the four time intervals (24-, 48-, 72-, and 96-hr) were 38, 61, 85, and 96%, respectively.

DISCUSSION

The monocyclic aromatics appear to be moderately toxic to fish relative to other pollutants tested in the past. For example, bioassays with fingerling rainbow trout in fresh water at 12 C (54 F) resulted in the following $LC_{50's}$: Antimycin 30–70 pptr, DDT 8–11 ppb, and acetone 8 ppth.[4]

Striped bass succumbed rapidly to a lethal aromatic concentration with most of the fish expiring within 6 hours. The rapid mortality rate with aromatics in the

[4] Benville, P. E. Jr., June 1976. *The Acute Toxicity of Nine Hydrophilic Solvents and Their Effect on the Acute Toxicity of DDT to Rainbow Trout.* Unpublished manuscript, pp. 1–13. NMFS, Tiburon Laboratory, 3150 Paradise Dr., Tiburon, CA 94920.

TABLE 2. Percent Loss of Aromatic Concentration in Test Tanks

Compounds	*Initial conc. in µl/l*	*Percent loss*			
	0 hr	*24 hr*	*48 hr*	*72 hr*	*96 hr*
Benzene	3.5	11	34	>99	>99
	5.5	35	53	80	>99
	10	28	51	64	82
	19	37	54	64	82
	22	27	55	66	78
	31	39	—	—	—
	34	38	—	—	—
Toluene	4.5	38	56	>99	>99
	12	41	51	96	>99
	16	44	—	—	—
	21	29	—	—	—
	29	31	—	—	—
Ethylbenzene	1.0	>99	>99	>99	>99
	4.9	67	>99	>99	>99
	5.9	>99	—	—	—
	12	38	—	—	—
	20	40	—	—	—
m-xylene	1.1	21	47	66	>99
	4.7	40	62	89	>99
	8.5	45	66	84	99
	13	35	—	—	—
o-xylene	1.3	32	82	>99	>99
	4.6	33	85	>99	>99
	9.3	23	49	95	>99
	18	33	—	—	—
p-xylene	1.0	19	38	59	>99
	3.9	18	—	—	—
	7.0	21	—	—	—

first few hours of the bioassay has been observed by other researchers (Pickering and Henderson 1966; and Morrow 1974). In contrast, a greater latent effect was exhibited in bay shrimp than striped bass as evidenced by the difference in LC_{50}'s between the 24-hr and 96-hr tests. This delayed effect may be characteristic of invertebrates or of the stage the invertebrates are in (Karinen and Rice 1974). These authors noted a toxicity difference between the 24-hr and 48-hr LC_{50}'s of crab to crude oil in the postmolt stage but no toxicity difference in the premolt stage

It appears that the location of the two methyl groups on the benzene ring affects the toxicity of the xylene isomers. P-xylene with the two methyl groups located at the opposite ends of the benzene ring makes the p-isomer the most stable and the most resistent to detoxification, whereas the ortho arrangement with the two adjacent methyl groups would be the least stable and would be most easily detoxified. This hypothesis held true for striped bass and for the 24-hr bay shrimp bioassays, except for o-xylene at the 96-hr interval. The 96-hr exception in bay shrimp may be explained by the delayed toxic effect of this aromatic on invertebrates.

Aromatics appear to be more toxic to striped bass than to other fingerling fish. Pickering and Henderson (1966) reported on the following LC_{50} values in soft and in hard water for bluegill, flatheads, goldfish and guppies; 22–37 ppm for benzene; 24–59 ppm for toluene; 32–97 ppm for ethylbenzene; and 21–37 ppm for xylene. Our values for 96-hr test ranged from 2.0 to 11 ppm for striped bass. Possible causes for the differences in toxicity values (LC_{50}'s) could be attributed to bioassay technique. The bioassay technique must be adapted to the chemical and physical properties of the toxicant being tested. This is especially true with compounds that have a high volatility and a low solubility as in the case of the aromatics. In the past, toxicity values (LC_{50}'s) for aromatics were calculated from the amount of the aromatic poured into the test aquaria. This procedure assumes all of the aromatic goes into solution which we found has not been the case. Only a small portion of the aromatic will dissolve, resulting in a higher LC_{50} value. This problem was overcome by making a saturated solution of the aromatic, analytically determining the concentration of the aromatics, and diluting the saturated solution to the desired concentration. The concentration of the saturated aromatic solution can be duplicated when the salinity and temperature are constant.

It is interesting to note that an increase in salinity lowers the amount of aromatic that will dissolve. For example, the 25°/₀₀ salinity used in the bioassays reduced the concentration of benzene in a saturated solution from 1993 ppm in distilled water to 1400 ppm, and of toluene from 401 to 330 (Benville and Korn 1974). The solubility of benzene was affected the most by the increase in salinity with a 30% reduction in dissolved benzene; toluene solubility was affected less, with an 18% reduction. It appears that, as aromatics become more struturally complex, their solubility is less affected by salinity. The solubility of ethylbenzene and the xylene isomers would propably be even less affected by salinity than toluene. We do not have the solubility data to support this hypothesis, and the reported solubility data cannot be used because of the inconsistencies which are encountered with compounds below the 10,000 ppm in solubility. Gunther, Westlake, and Jaglan (1968) have suggested many reasons for the inconsistencies in solubility data.

Meyerhoff (1975) has reported slightly higher LC_{50} values for benzene and striped bass (10.9 μl/l or ppm for 96-hr). One reason for a higher value is a different technique. The benzene was introduced at a slow rate until the desired concentration was reached. This would reduce the trauma experienced by the fish when they are placed in high aromatic concentrations.

Later work by Neff et al. (1976) which includes quantitative analyses of bioassay solutions yields 96 hr LC_{50} results higher than results we found using a similar type of shrimp (*Palaemeontes*). Their LC_{50} values compared to our results were 27 to 20 μl/l (ppm) for benzene, 9.5 to 4.3 μl/l (ppm) for toluene and 7.4 to 1.3–3.7 μl/l (ppm) with xylenes. The difference in results may be explained by temperature and species differences between the two studies.

The current experiment was based on a single dose test where the concentrations were decreasing over time. The loss of these aromatics in most instances was a linear function when compared to five other functions (exponential, power function, and three hyperbolic functions). The aromatic concentration could not be accurately predicted at any time interval because of uncontrolled variables such as change in biomass from mortalities during the test and fungal and bacterial degradation. The magnitude of these and other losses (volatilization, sorption, etc.) can be determined only by measuring the amount of toxicant left in the water. Then an accurate toxicant exposure level and the persistence of the toxicant in the water are known. Our analysis showed that more than half of the aromatic usually volatilized within 48 hours, with an average biomass of 0.43 g/l (0.056 standard deviation).

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ACCLIMATION AND REARING OF STRIPED BASS LARVAE IN SEA WATER [1]

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For the first time, striped bass larvae were reared under laboratory conditions in sea water (salinity 33.73°/$_{\infty}$) for more than a year. Five-day-old larvae, hatched in fresh water, were rapidly acclimated to 20, 40, and 60% sea water and reared in these salinities for 33 days. The earliest time the larvae could survive transfer to full sea water was at 28 days of age; metamorphosis occurs between 28 and 35 days.

Separate tests were made to determine the effects of different salinities on larval growth and survival. Growth over a period of 4 weeks was measured in 20, 40, and 60% sea water with a control group in fresh water, but no adverse effect on growth was observed on larvae in diluted sea water. In tests of salinity tolerance, 1-day-old eggs and larvae after hatching in fresh water were rapidly acclimated to different salinities and reared without food for 9 and 12 days. Survival was best when the larvae were acclimated just after hatching in 10% sea water. Diluted sea water proved to be better for larval survival than fresh water alone.

INTRODUCTION

A relative lack of predator fishes in the limnetic zone of large warmwater impoundments in California is considered to be a major factor limiting potential game fish production (Anon. 1971). Attempts to correct this deficiency have centered largely on the introduction of limnetically oriented forage and game fish species. Threadfin shad (*Dorosoma petenense*) were introduced from Tennessee in 1953 (Kimsey 1954) and this forage species is now firmly established in many reservoirs throughout California (Burns 1965). Game fish species stocked in selected reservoirs in efforts to more fully utilize shad as forage include crappie (*Pomoxis* sp) (Goodson 1966), white bass (*Morone chrysops*) (von Geldern 1964), and striped bass (*Morone saxatilis*) (Wilson and Christenson 1965). In recent years, a variety of salmonids have also been successfully introduced into warmwater reservoirs containing well-oxygenated hypolimnions (Rawstron 1973, Wigglesworth and Rawstron 1974).

While crappie and white bass may be normally expected to maintain self-

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sustaining populations, the development of successful striped bass fisheries is largely dependent on maintenance stocking programs. Such programs involve the introduction of fingerlings or yearlings (Bailey 1975), and California has given high priority to an evaluation of striped bass stocking and the possible development of a firm source of fish within our hatchery system.

An extensive effort has been made across the southern United States to develop the technology for rearing striped bass in freshwater hatcheries (Bailey 1975). Freshwater culture, however, frequently results in heavy mortalities of larval fish. This problem prompted the present study which examines the salinity tolerance characteristics of striped bass larvae as part of a broad program designed to evaluate the feasibility of rearing striped bass in a sea water hatchery.

Increased survival of striped bass eggs and larvae has been reported for periods up to 3 weeks in sea water concentrations ranging from 3% (Albrecht 1964) to 30% (Doroshev 1970, Bayless 1972). Our study is an extension of earlier work and was designed to: (i) determine if striped bass eggs and larvae can be acclimated to higher salinity concentrations, and (ii) determine if larval bass could be reared through metamorphosis in 100% sea water.

METHODS AND RESULTS

Four groups of fertilized striped bass eggs, produced by hormone-induced spawning of ripe fish at the Central Valleys Hatchery of the California Department of Fish and Game, Elk Grove, were shipped by air to La Jolla, California, during May and June 1973. The eggs were hatched in a 122-cm (4-ft) diameter fiberglass trough containing tap water with chlorine reduced to 1.5 ppm. Eggs were kept from settling to the bottom by bubbling air. The incubation period varied from 40 to 48 hours at 18.5 ± 1 C (65 ± 2 F). Between 80 and 95% of the larvae hatched out from the first three groups of eggs received, but only 15 to 20% hatched in the last group due to poor fertilization. For this reason, testing of 1-day-old eggs from the last group was abandoned after hatching. Eggs or larvae for salinity tests were hand counted and transferred into experimental containers. Because of different experimental techniques in each of the three experiments to follow, we have elected to give details of each experiment separately.

Survival of Striped Bass Larvae After Exposure to Different Salinities

Survival after exposure to different salinities was measured using 1-day-old eggs and 1-day-old larvae hatched in fresh water. Larvae 8 to 14 hours after hatching were termed 1-day-old. One-day-old eggs were 16 to 20 hours old as determined from the time fish were artificially spawned at the hatchery. The various stages of development of our eggs and larvae closely resembled those illustrated by Bayless (1972). Twenty-five eggs or larvae were transferred into 4 l (1.06-gal) glass jars, each containing a different volume of tap water, so that after the gradual addition of La Jolla sea water (salinity 33.73‰), the final volume of water was 2½ l (0.66 gal). The acclimation time varied from 2 to 6 hours, depending on the volume of sea water added. In this manner, the desired salinity and stocking density of 10 eggs or larvae per liter was obtained. All the jars were placed inside a water table with running sea water at 19 ± 0.5 C (66 ± 1 F).

In this experiment, we used eggs and larvae from three different groups of eggs received from Elk Grove. Three similar experiments were done in succession. The first was terminated 9 days after acclimation, the second and third after 12 days. One-day-old eggs and 1-day-old larvae in the 9-day experiment were tested separately in 20, 40, 60, 80, and 100% sea water and, in the case of 12-day experiments in 10, 20, 30, 40, 50, 60, and 70% sea water. Eggs in the last 12-day experiment, were not tested due to poor hatch. For each experiment a control group was kept in fresh water, and replicate jars were set up for all salinities tested as well as for the controls.

No food was given to the larvae throughout the experiments. Although 6-day-old larvae commence feeding (our observation agrees with Bayless 1972), nearly all can survive without food for 10 days or longer until complete absorption of their yolk (Mansueti 1958). Dead larvae were removed and counted every day and a terminal count of all survivors was taken at the end.

We saw no abnormal development of the embryos in any salinity tested, although it took 2 to 3 hours longer for the eggs to hatch in 80 and 100% sea water. The larvae appeared shrunken in 80 and 100% sea water and died within 72 and 48 hours, respectively. Less than 50% of the larvae survived in salinities higher than 50% sea water, and survival was 75% or more in salinities ranging between 10 and 50% sea water. If more than one test was made, the combined mean for all tests is shown followed by the individual test means in parenthesis (Table 1). These results show that larvae have a high tolerance for sea water up to 50%, if they are acclimated after hatching rather than while in the egg. There was only 27% survival of acclimated larvae after 9 days in 70% sea water, but in the next lower acclimation salinities (i.e. 60% and 50% sea water), there was a remarkable increase in survival. There was a sharp decline in larval survival at the higher salinities after 12 days. We believe this was due to starvation and the stress of higher salinities.

TABLE 1. Percentage Survival of Striped Bass Larvae from 1-Day-Old Eggs and 1-Day-Old Larvae Reared Without Food at 19 C ± 0.5 C [1]

	Percent survival from 1-day-old eggs			*Percent survival from 1-day-old larvae*		
Percent sea water[1]	*After 6 days*	*After 9 days*	*After 12 days*	*After 6 days*	*After 9 days*	*After 2 days*
Fresh water	38(40,36) [2]	30(30,30)	28	64(48,68,76)	52(35,56,64)	49(44,54)
10	82	82	78	95(90,100)	94(90,98)	93(90,96)
20	78(92,64)	72(84,60)	58	93(98,92,90)	92(98,88,90)	82(82,82)
30	82	68	66	94((98,90)	91(98,84)	78(84,72)
40	77(88,66)	71(84,58)	50	87(88,84,88)	85(88,84,84)	74(80,68)
50	76	54	44	84(84,84)	73(70,76)	53(56,50)
60	34(22,46)	9(8,10)	2	63(84,78,26)	47(54,70,16)	27(50,4)
70	—	—	—	28(58,0)	27(54,0)	—
80	0	0	—	0	0	—
100	0	0	—	—	—	—

[1] Salinity of 100% seawater was 33.73 °/oo.
[2] In instances where more than one test was conducted, the combined mean of all tests is shown, followed by the individual test means in parenthesis.

Sea water with reduced salinity is beneficial for the well being of the eggs as evidenced by the enhanced survival of eggs in 10% sea water compared to those in fresh water.

TABLE 2. Increase in Dry Weight (mg) of Striped Bass Larvae Fed Brine Shrimp, Nauplii *Artemia* sp. at 18 C ± 0.5 C, N = 500 for Each Salinity

		Salinity of 100% sea water = 33.73 °/∞							
		Fresh water		20% sea water		40% sea water		60% sea water	
Age (days)	Sample Size (number of larvae)	Range (mg)	Mean (mg)	Range (mg)	Mean (mg)	Range (mg)	Mean (mg)	Range (mg)	Mean (mg)
12	5	0.107–0.185	0.148	0.112–0.277	0.198	0.117–0.227	0.169	0.146–0.223	0.174
19	10	0.093–0.229	0.159	0.123–0.466	0.346	0.114–0.406	0.293	0.155–0.537	0.327
26	10	0.207–0.792	0.480	0.315–0.956	0.738	0.228–0.997	0.645	0.535–1.291	0.892
33	10	0.367–1.384	1.064	0.647–2.598	1.202	0.549–1.363	0.853	0.608–1.931	1.464

TABLE 3. Increase in Total Length (mm) of Striped Bass Larvae Fed Brine Shrimp, Nauplii *Artemia* sp., at 18 C ± 0.5 C, N = 500 for Each Salinity

		Salinity of 100% sea water = 33.73 °/∞							
		Fresh water		20% sea water		40% sea water		60% sea water	
Age (days)	Sample size (number of larvae)	Range (mm)	Mean (mm)	Range (mm)	Mean (mm)	Range (mm)	Mean (mm)	Range (mm)	Mean (mm)
5	10	5.3–5.6	5.5	5.3–5.6	5.5	5.3–5.6	5.5	5.3–5.6	5.5
12	5	5.4–6.2	5.9	5.2–6.8	6.0	5.1–6.4	5.8	5.2–6.2	5.7
19	10	5.6–6.8	6.1	5.5–7.6	6.8	5.5–7.3	6.7	5.5–7.6	6.8
26	10	6.2–8.6	7.6	7.5–9.2	8.5	6.3–8.6	7.9	7.5–9.1	8.3
33	10	7.4–9.7	8.9	7.7–11.0	9.0	7.7–9.5	8.4	7.7–9.8	9.3

Effect of Different Salinities on Larval Growth

Five hundred 5-day-old larvae were transferred into each of four 45 l (12-gal) aquaria containing dechlorinated tap water. Sea water was added gradually into three aquaria to produce 20, 40, and 60% sea water; the fourth had fresh water only. Each aquarium was aerated gently, but there was no flow of water. Dead larvae were removed occasionally, and about a quarter of the volume of water in each aquarium was siphoned out once a week from near the bottom and replaced with an equal amount of water of the required salinity. The aquaria had no gravel or substratum on the glass bottom. Temperature was maintained at 18 ± 0.5 C (64 ± 1 F). The larvae were fed brine shrimp, nauplii *Artemia* sp., daily from day 5 until the experiment ended at 33 days.

The total length of ten 5-day-old larvae was measured at the start of the experiment. Thereafter, both total length and dry weight were recorded from a random sample of 10 larvae taken from each aquarium at 7-day intervals, when the larvae were 12, 19, 26, and 33 days old. Total larval length was measured and the larvae were dried in an oven at 60 C (140 F) for a week. The weight of each larva was recorded to within ± 0.2 μg (.00007 oz) on a Cahn balance (Tables 2 and 3).

From age 12 days, i.e., after 1 week of feeding, until age 33 days, growth, as measured by increase in total length, was not different in diluted sea water and in fresh water (Table 3). On the other hand, rate of growth by weight in 60% sea water averaged 0.06 mg/day (.0002 oz), which is more than 25% faster than that in the lower salinities (Table 4). We observed maximal survival in 40% sea water (Table 4). The lowest growth rate in that salinity may have been due to competition for food among the many survivors. On the other hand, the brine shrimp, *Artemia* sp, did not survive well in fresh water and this may have accounted for the slower growth and poor survival.

TABLE 4. Percentage Survival After 33 Days, and Growth Rate for the Last 21 Days of Larvae Reared in Different Salinities Fed Brine Shrimp, Nauplii *Artemia* sp. at 18 C ± 0.5 C.

Percent sea water[1]	*Percent survival*[2] *(N = 500)*	*Growth rate (N = 10)*	
		Dry weight (mg/day)	*Total length (mm/day)*
Fresh water	9	0.044	0.145
20	25	0.048	0.144
40	47	0.034	0.124
60	22	0.060	0.168

[1] Salinity of 100% sea water was 33.73‰.
[2] Does not include 7% larvae killed for length-weight measurements.

Rapid Acclimation of Striped Bass Larvae and Fry to Sea Water

Our goal was to acclimate striped bass larvae to full sea water at the earliest possible age, but, as found earlier, 1-day-old larvae had died within the first 6 days in 80 and 100% sea water. We therefore sought to reduce the mortality of larvae by rearing them initially in 60% sea water and eventually transferring them to higher salinities, until larvae could withstand full sea water. Our criterion for successful acclimation was at least 50% survival of larvae after the increase in salinity.

Larvae reared in a 45 l (12-gal) aquarium containing fresh water were acclimated to 60% sea water within 24 hours at age 5 days. At age 44 days, fry were acclimated again to 95% sea water within 24 hours. At 114 days, these fry were transferred to a 1,900-liter (500-gal) aquarium provided with 100% sea water at 19 ± 2 C (66 ± 3 F).

Larvae up to the age of 37 days were fed a mixed diet of live brine shrimp, nauplii *Artemia* sp and live marine copepods, *Tisbe* sp After that period, fry were fed at least three times a day on trout chow, Oregon Moist Pellets (OMP), chopped anchovies, and squid.

A second batch of larvae reared in a 135 l (35-gal) aquarium containing fresh water was also acclimated to 60% sea water at age 7 days. At age 19 days, five larvae were acclimated to 95% sea water in a 2 l (0.53-gallon) beaker, but none survived beyond 2 days. At age 28 days, another five larvae were acclimated to 95% sea water in 24 hours with 100% survival after 5 days. The remaining untested 34-day-old fry were also acclimated to 95% sea water in 24 hours. We then combined these 31 surviving 96-day-old fry with 16, 115-day-old fry from the previous batch in a 1,900-l (500-gal) aquarium.

The above 47 fry were reared in sea water for 11 months without mortality. Of these, 23 were killed and measured at this time. Only 4 fingerlings were reared for an additional 4 months, when they were measured (Table 5).

TABLE 5. Growth of Striped Bass Fingerlings in Sea Water After Rapid Acclimation as Fry from 60 to 100% Sea Water[1] at 19 ± 2 C.

Age (months)	*Number of fingerlings*	*Range*	*Mean*	*Median*
Total length (cm)				
11	23	10.0–15.0	13.0	13.0
15	4	16.4–23.8	19.3	18.5
Wet weight (g)				
11	23	15.0–47.1	30.7	31.0
15	4	44.0–135.3	77.7	65.7

[1] Salinity of 100% sea water was 33.73$^{\circ}/_{oo}$.

DISCUSSION

Albrecht (1964) pointed out that striped bass eggs can withstand a moderate increase in salinity and that survival of resulting larvae is best in 3% sea water (chlorides 948 ppm). In his experiments, larvae did not survive beyond 3 days in 40% sea water (chlorides 14,100 ppm), whereas in ours, survival was excellent up to 9 days. Turner and Farley (1971) found that survival of striped bass eggs hardened in fresh water at 14.5, 18.5, and 22 C (58, 65, and 72 F) was higher in 3% sea water (TDS 1,000 ppm) than in fresh water (TDS 163 ppm). They also found that at salinities of 6, 15, and 30% sea water (TDS 2,000; 5,000; and 10,000 ppm) at 14.5 C (58 F) survival was about *twice* as high as at 18 and 22 C (65 and 72 F), and that survival of eggs incubated at salinities from 3 to 30% sea water was about the same. Our results showed a similar trend. Survival of 1-day-old eggs hatched in salinities ranging between 10 and 50% sea water was higher than in fresh water control. On the other hand, larval survival progressively declined for eggs hatched in salinities greater than 10% sea water. Therefore, we do not suggest incubating striped bass eggs at salinities exceeding 10% sea water and at a temperature greater than 19 C (66 F). In our experiments, survival of larvae at 19 C (66 F) after 6 days was 50% greater than survival of newly-hatched larvae at 18.5 C (65 F) from 2-hour-old fertilized eggs (Turner and Farley 1971). Evidently, 2-hour-old fertilized eggs are more vulnerable to increased salinities at higher temperatures than 1-day-old eggs. Furthermore, at salinities between 10 and 70% sea water, we obtained 25 to 32% better survival of 1-day-old larvae than with 1-day-old eggs (Table 1).

Different survival rates under identical salinities, as found between our experiments and those of other workers, could be due to differences in the ionic composition of the water. Turner and Farley (1971) showed that survival of striped bass eggs incubated in San Joaquin River water with a TDS of 623 ppm after getting mixed with natural estuarine water was 50% higher than in Tuolumne River water with a lower TDS of 525 ppm, but containing saline irrigation runoff water. Consequently, we regard the ionic composition of diluted sea water to be far more beneficial for the eggs and larvae than comparable fresh water with a high load of total dissolved solids.

We did not find any remarkable growth differences based on length of larvae reared up to 33 days in fresh water and those reared in different salinities (20, 40, and 60% sea water). Length measurements alone are an insufficient index for growth since they do not always reveal the weak and emanciated condition of larvae. Also, we observed that after the first week there was slight shrinkage of larvae in the higher salinities but not in fresh water, and this may have minimized the length differences. This is reflected in growth differences based on dry weight of larvae, because growth rate by weight in 60% sea water was 25% better than in lower salinities or even fresh water, although our best survival was in 40% sea water. Our results do not entirely agree with Bayless (1972) who found maximum growth in 40% sea water and best survival in 30% sea water over a period of 21 days, but he did not test growth in higher salinities. It appears that larvae survive better in low salinities but grow faster in higher salinities. Tolerance to higher salinities increases with age. Even though we recognize that food has a direct effect on growth, it was impossible for us to study this variable because the type of food and the concentration of food organisms available to the larvae in different salinities need to be standardized before exact differences in growth can be accounted for.

Our results show that striped bass fry can be reared in full sea water immediately after metamorphosis without obvious signs of stress behavior, for at least a period of 15 months. Even though our study indicated that the larvae can adjust to full sea water while undergoing metamorphosis, it was safer to transfer them after complete metamorphosis, when they were 33 to 35 days old. The average growth of 13 cm (5.2 inches) in 11 months and the maximum growth of 23.8 cm (9.5 inches) in 15 months in our experiments was approximately the same as Steven (1966) found in a natural population in California, but was 30% above the average first-year growth of 10 cm (4 inches) reported by Clark (1938).

The results of our study indicate that rearing of striped bass larvae in diluted sea water and the fry in sea water should ensure a better survival than found in freshwater hatcheries. The high rate of mortality of larvae reared in fresh water which continues even after metamorphosis has not occurred in our experiments with sea water. To overcome the difficulties encountered in rearing of striped bass larvae, we suggest a program of progressive increase in salinity to enhance survival and growth of striped bass larvae. To hatch eggs, only slightly brackish water, salinity not exceeding that of 10% sea water should be used. For larval rearing through metamorphosis the following regimes are best for growth and survival.

Optimal growth		*Optimal survival*	
Age	*Percent sea water*	*Age*	*Percent sea water*
Day 1 thru 9	20	Day 1 thru 6	10
Day 10 thru 19	40	Day 7 thru 13	20
Day 20 thru 29	60	Day 14 thru 20	40
Day 30 thru 35	80	Day 21 thru 29	60
Day 36	100	Day 30 thru 35	100

SUMMARY

Our study shows that diluted sea water is beneficial for rearing striped bass larvae and for hatching of eggs. Our results on salinity tolerance of striped bass eggs showed higher survival of larvae in salinities between 10 to 50% sea water than in fresh water. However, survival in these salinities was enhanced further by acclimating 1-day-old larvae instead of eggs.

Five-day-old larvae acclimated to salinities of 20, 40, and 60% sea water and reared up to 33 days of age, continued normal development through metamorphosis. Subsequent growth in higher salinities was faster than in fresh water, over a period of 4 weeks. The larvae in salt water looked healthier and better than those in fresh water.

Striped bass larvae were rapidly acclimated to full sea water within 1 month and reared successfully under laboratory conditions for a period of 15 months. Over this extended period of time, the average and maximum growth compared favorably with that found in natural waters. The larvae, if acclimated to full sea water before metamorphosis, did not survive. We found that the best time for the introduction of larvae to full sea water is just after metamorphosis.

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EFFECT OF A REDUCED BAG LIMIT AND LATER PLANTING DATE ON THE MORTALITY, SURVIVAL, AND COST AND YIELD OF THREE DOMESTIC STRAINS OF RAINBOW TROUT AT LAKE BERRYESSA AND MERLE COLLINS RESERVOIR 1971–1974 [1]

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Rainbow trout of three domestic strains were tagged and planted in Lake Berryessa and Merle Collins Reservoir after imposition of a reduced bag limit and a later planting date. Coleman showed a clear superiority over the Shasta and Whitney strains. Anglers landed a higher percentage of the originally planted weight of Coleman at both lakes than of the other two strains. Coleman also produced the lowest cost to the angler's creel at both lakes. I concluded that the reduced bag limit was primarily responsible for the substantial increase in mean weight landed and cheaper cost to the angler's creel for all strains, compared to that of two of my previous experiments.

INTRODUCTION

Prior experiments in planting "catchable" rainbow trout (*Salmo gairdneri*) to create trophy fisheries in California impoundments with abundant threadfin shad (*Dorosoma petenense*) showed anglers efficiently harvested trout shortly after planting and reduced the numbers of trout subsequently taken at greater than 454 g (1 lb) (Rawstron 1972; 1973*a*). Moreover, the degree of early vulnerability varied with strain. This early harvest effectively reduced survival to larger sizes, reduced the ratio of weight landed to weight planted, and increased the cost to the angler's creel. Daily bag and possession limits in 1969 and 1970 for four lakes under study were 10 trout during regular trout season (May 1–November 15) and 5 trout during the remainder of the year. These lakes, all close to large population centers, were thus open to all-year angling while the majority of trout waters were closed for a 5½-month period. Therefore, much effort was expended by anglers during the spring before other waters were open. In addition, fish in previous experiments were planted in March and April before the opening of the general trout season. To reduce this early catch and put more fish into a trophy fishery after substantial growth had occurred, an all-year daily possession and bag limit of three trout was imposed experimentally on March 1, 1971 and fish were planted in May. This study examines the exploitation, survival and growth rates, and cost to the creel of three strains of tagged domestic rainbow trout stocked in 1971 at Lake Berryessa (Napa County) and Merle Collins Reservoir (Yuba County), and compares the results with those from previous experiments. Rawstron (1972, 1973*a*), Wigglesworth and Rawstron (1974), and Rawstron and Reavis (1974) have described the former 8,094 ha (20,000 acre) reservoir and other elements in its fishery. Merle Collins Reservoir, a 405 ha (1,000 acre) reservoir, and some features of its fishery, have been previously

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described (Rawstron 1971, Rawstron and Hashagen 1972, Hashagen 1973, Rawstron 1973*a*). Chamberlain (1972) presented details of its limnology.

Methods and Materials

I used three strains of rainbow trout: the Shasta, Whitney, and Coleman Kamloops[1]. These were the same domestic strains used in my earlier experiments. Cordone and Nicola (1970) gave the history of development of the first two strains and Rawstron (1972) described the Coleman strain.

In Lake Berryessa, 106,000 trout were planted, equally divided among the three strains. Fish of each strain had distinctive fin clips to further identify them so growth information could be obtained from creel surveys conducted each October. In addition, approximately 500 of each strain bore trailer tags (modified Carlin tags), the same tags I used successfuly in previous experiments (Rawstron 1972, Rawstron 1973*a, b*). Nicola and Cordone (1969) described this tag and its application for salmonids. Tags were serially numbered and had a legend offering a $5 reward for their return.

At Merle Collins Reservoir, 5,250 rainbow trout were planted, equally divided among the same three strains. Only 250 trailer tags were applied to fish of each strain and no reward was offered for their return. These tags were recovered in an intensive creel survey and by voluntary mail returns. The survey was conducted on two rotating weekdays each week and all weekends and national holidays. Complete censuses, conducted for 7 consecutive days each spring, summer, and fall, showed that at normal survey levels nearly 70% of the actual landings were observed. Therefore, mortality estimates were corrected by a factor of 1.43. In addition to tags, all fish of each strain were distinctively marked with a fin clip to compare harvest and survival estimates from the creel survey with those derived from tag returns and to monitor growth to determine total weight recovered. Tag recoveries yielded estimates of total harvest rates 3.8% lower than that of fin clipped fish, while no difference in survival was noted. Therefore, only mortality estimates generated by tag returns are reported here. Growth rates, however, were determined from marked fish seen in the catch.

A previous study showed that growth rates of rainbow trout in these two lakes were similar (Rawstron 1973*a*). Therefore, estimates of total weight of tagged trout landed from both lakes were usually developed by summing the products of the mean monthly weights of rainbow trout observed in the survey at Merle Collins Reservoir and the number of tags returned in the same month. There were three exceptions to this: (1) Mean weights developed from rainbow trout weighed during the annual October creel surveys at Lake Berryessa were used for Lake Berryessa for those months; (2) For months when no marked rainbow were seen in the survey at Merle Collins, values from a line fitted by eye from the Lake Berryessa data were used for both lakes; (3) Since too few fish were actually observed after October 1973, the mean weight observed in that month was arbitrarily assigned to the remaining months for Lake Berryessa, thus yielding a conservative estimate.

Fish were planted daily in approximately equal lots of each strain from May 11 to May 19 at Lake Berryessa. The median date, May 15, was used as the

[1] California's original stock of Kamloops was imported from the Kamloops Lakes in British Columbia and raised at Coleman National Fish Hatchery (Shasta County). It has been hybridized with a variety of rainbow strains and lost its original identity. These fish are now designated as the Coleman strain.

planting date for computation of survival rates. At Merle Collins Reservoir, all fish were planted on May 10.

Survival and weighted mean exploitation rates (Ricker 1958) were determined by assigning those tags returned from 0 to 365 days after planting to first year returns, etc. This program had achieved wide publicity from previous experiments and was enthusiastically supported by most anglers. All reward tags were assumed to be returned. Posters describing the program and the new experimental limit were placed at all resorts, boat landings, and camping and picnic areas at both lakes.

Trout for both lakes were reared at American River Hatchery (Sacramento County). All strains had similar mean lengths and length frequencies at planting (Figure 1). Tagged Shasta rainbow averaged 154 g (0.34 lb), while Whitney and Coleman averaged 141 g (0.31 lb), and 145 g (0.32 lb), respectively.

RESULTS

Lake Berryessa

Mortality and Survival

Anglers ultimately captured 190 (38.2%) Shasta, 198 (39.9%) Whitney, and 234 (47.0%) of the Coleman rainbow (Table 1) through December 1974. All strains had at least a 0.21 mean weighted survival, with Coleman strain the highest at 0.29. Anglers exploited an average of 0.32 of the available stock of Shasta and Whitney trout annually, while they caught 0.36 of the Coleman rainbow. Anglers returned the majority of tags after October 1 of the year of planting (Table 2), when most fish had achieved nearly 454 g (1.0 lb). From returns of all strains combined, nearly 75% of the total returns came after October 1, 1971.

TABLE 1. Tag and Weight Returns, Mortality and Survival Rates, and Cost of Three Strains of Domestic Rainbow Trout Planted in Lake Berryessa.

Rainbow trout strain	*Number tagged*	*Total returns*	*Total harvest (percent)*	*Mean weighted exploitation*	*Mean weighted survival*	*Percent weight returned / weight planted*	*Cost/kg*[1] *to creel*	*Mean weight (grams) at return (weighted)*
Shasta	497	190	38.2	0.32	0.21	139.5	$1.30	562
Whitney	496	198	39.9	0.32	0.24	180.8	$0.93	635
Coleman	498	234	47.0	0.36	0.29	218.7	$0.77	662
Totals	1,491	622						
Means			41.7	0.33	0.25	179.7	$1.00	620

[1] Based on production cost of $1.67/kg (Bruley 1972).

Growth, Weight Returns, and Cost

Growth rates of all strains showed no significant differences at the 0.05 level. All strains combined achieved a mean weight of 0.44 kg (0.97 lb) by mid-October 1971 and 1.10 kg (2.42 lb) by the following October (Figure 2). One Whitney rainbow in the October 1973 census weighed 1.86 kg (4.10 lb) and a Coleman in November 1974 weighed 2.49 kg (5.50 lb). Total weight of tagged trout at planting was 76.7 kg (169.0 lb) for Shasta, 69.4 kg (152.9 lb), and 70.8 kg (156.1 lb) for Whitney and Coleman, respectively. Anglers ultimately landed

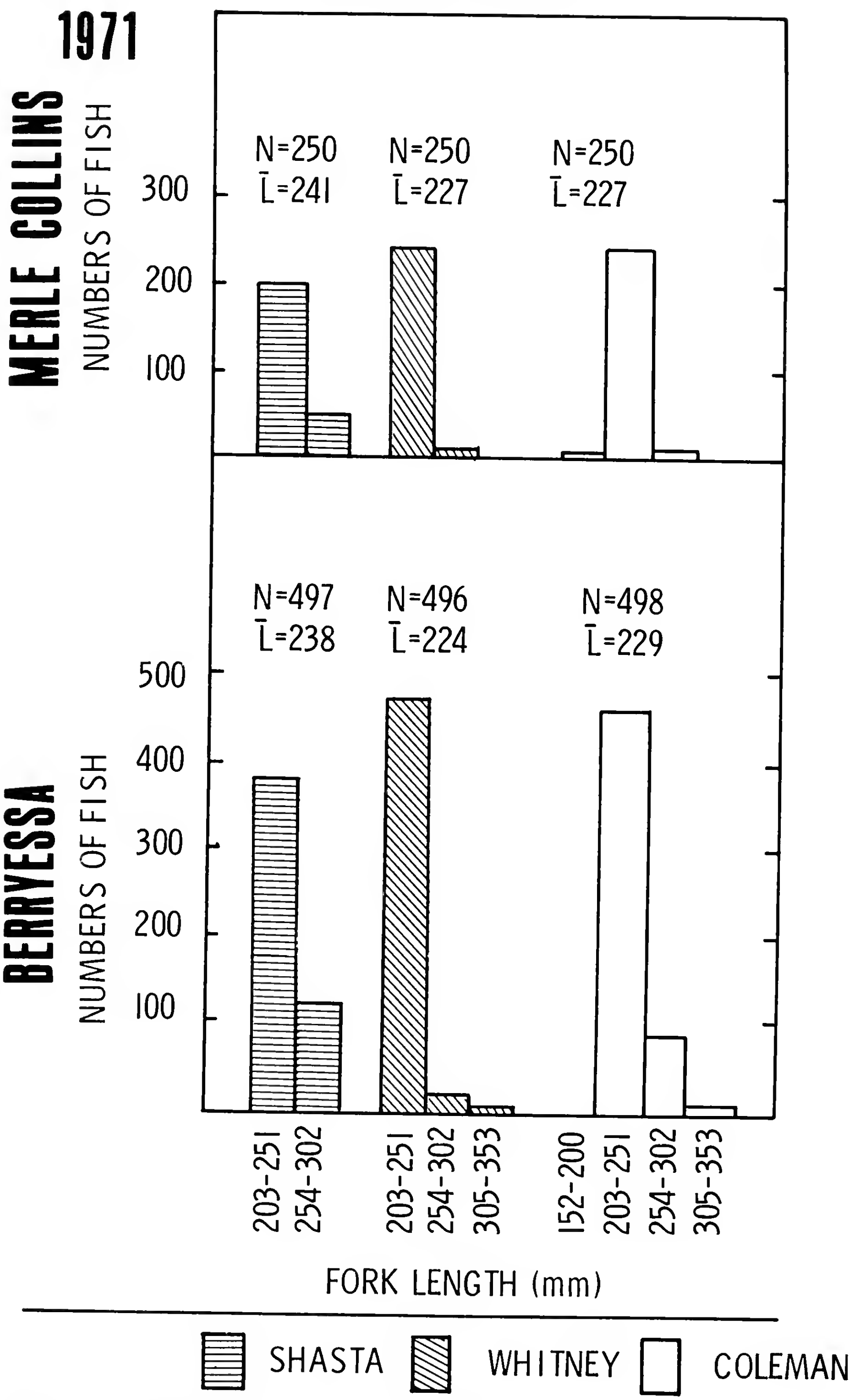

FIGURE 1. Length frequency and mean length of three strains of tagged rainbow trout at Lake Berryessa and Merle Collins Reservoir, 1971. RTS = Shasta; RTW = Whitney; RTC = Coleman.

TABLE 2. Tag Returns by Strain, Month, and Year for Three Strains of Rainbow Trout Planted in Lake Berryessa in 1971.

	Number returned											
	Shasta				Whitney				Colman			
Period	Year 1 1971–72	Year 2 1972–73	Year 3 1973–74	Year 4 1974–75	Year 1 1971–72	Year 2 1972–73	Year 3 1973–74	Year 4 1974–75	Year 1 1971–72	Year 2 1972–73	Year 3 1973–74	Year 4 1974–75
May	28	3	0	0	6	3	1	0	19	4	0	0
June	8	1	0	0	7	2	0	1	10	2	1	0
July	3	3	0	0	7	3	0	0	13	2	0	0
August	7	0	0	0	10	3	0	0	8	4	1	0
September	5	0	0	0	9	0	0	0	14	8	0	0
October	18	15	0	0	17	2	1	0	25	5	1	1
November	32	12	0	0	36	14	2	2	25	20	1	2
December	17	2	0	0	21	4	1	0	20	5	0	0
January	19	1	0	—	25	5	0	—	13	9	1	—
February	8	2	0	—	6	2	0	—	3	2	0	—
March	3	0	0	—	6	1	0	—	6	0	0	—
April	3	0	0	—	1	0	0	—	9	0	0	—
Total	151	39	0	0	151	39	5	3	165	61	5	3

TABLE 3. Calculated and (Observed) Tag and Weight Returns, Mortality and Survival Rates, and Cost of Three Strains of Domestic Rainbow Trout Planted in Merle Collins Reservoir.

Rainbow trout strain	Number tagged	Total[1] returns	Total[1] harvest (percent)	Mean[1] weighted exploitation	Mean[2] weighted survival	Percent[1] weight returned/ weight planted	Cost/kg to[3] creel	Mean weight[2] (grams) at return (weighted)
Shasta	250	111	44.4	0.43	0.03	90.1	$1.85	311
		(78)	(31.2)	(0.30)				
Whitney	250	88	35.2	0.32	0.11	108.9	$1.54	435
		(62)	(24.8)	(0.22)				
Coleman	250	102	40.8	0.35	0.17	129.2	$1.30	458
		(72)	(28.8)	(0.25)				
Totals	750	301						
		(212)						
Means			40.1	0.36	0.10	109.4	$1.56	401
			(28.3)	(0.32)				

[1] Observed returns and/or weight adjusted by 1.43 and rounded to nearest whole number.
[2] Based on observed returns.
[3] Based on production cost of $1.67/kg (Bruley 1972).

106.9 kg (235.7 lb), 125.4 kg (276.5 lb), and 154.9 kg (341.4 lb) of tagged Shasta, Whitney, and Coleman, respectively. These weights amounted to a return of 139.5%, 180.8%, and 218.7% of the originally planted weight for the three strains listed in the same order (Table 1). Similarly, their mean weight at return (weighted) amounted to 562 g (1.24 lb), 635 g (1.40 lb), and 662 g (1.46 lb). This constituted an increase over mean planting weight ranging from 364.9% for Shasta trout to 456.6% for Coleman fish.

Based on costs of $1.67/kg ($0.76/lb) to rear rainbow trout to catchable size in the hatchery (Bruley 1972), Shasta rainbow cost $1.30/kg ($0.59/lb), Whitney strain $0.93/kg ($0.42/lb), and Coleman $0.77 kg ($0.35/lb) to the angler's creel.

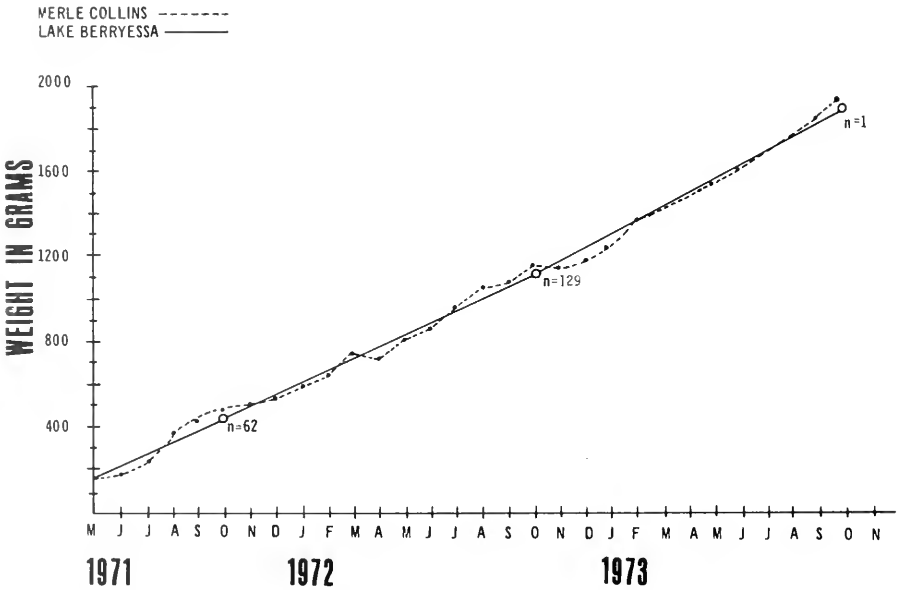

FIGURE 2. Mean monthly growth of all strains combined rainbow trout Lake Berryessa (———) and Merle Collins Reservoir (———), 1971–1973.

Yield

Assuming that untagged fish were harvested and grew at similar rates to tagged fish and were caught at similar times, all rainbow strains combined yielded a total of 3.40 kg/ha (3.04 lb/acre). Coleman trout made the strongest contribution, yielding 1.36 kg/ha (1.21 lb/acre), followed by Whitney strain with 1.11 kg/ha (0.99 lb/acre), and Shasta 0.94 kg/ha (0.84 lb/acre).

Merle Collins Reservoir

Mortality and Survival

After adjusting for the fish caught on nonsurvey dates and fish not seen during the surveys, anglers caught an average of 40.1% of the total number of tagged fish (Table 3) through December 1973. No tagged or marked fish were observed in 1974. Shasta rainbows showed the highest total harvest (44.4%), followed by Coleman and Whitney trout. Shasta strain survived at (0.03), approximately one-sixth that of Coleman (0.17), and one-fourth that of Whitney rainbow (0.11). Over 60% of the total return of tagged Shasta rainbow were observed before October 1 following planting, while only 50.9% and 56.7% of the Whitney and Coleman were recorded (Table 4).

TABLE 4. Observed Tag Returns by Strain, Month, and Year for Three Strains of Rainbow Trout Planted in Merle Collins Reservoir in 1971.

	Number returned								
	Shasta			*Whitney*			*Coleman*		
Period	*Year 1 1971–72*	*Year 2 1972–73*	*Year 3 1973–74*	*Year 1 1971–72*	*Year 2 1972–73*	*Year 3 1973–74*	*Year 1 1971–72*	*Year 2 1972–73*	*Year 3 1973–74*
May	41	0	0	18	0	1	28	0	0
June	2	0	0	8	2	0	5	2	0
July	0	0	0	1	0	0	1	0	0
August	2	0	0	1	0	0	0	1	0
September	2	0	0	0	1	0	0	2	1
October	20	0	0	12	1	0	12	4	0
November	3	2	0	4	1	0	4	1	0
December	2	0	0	2	0	0	0	0	0
January	2	0	—	3	0	—	2	0	—
February	0	0	—	4	1	—	3	0	—
March	0	0	—	0	0	—	2	1	—
April	2	0	—	2	0	—	3	0	—
Total	76	2	0	55	6	1	60	11	1

Growth, Weight Returns, and Cost

Mean monthly weights of fin clipped trout examined in the intensive survey at Merle Collins Reservoir closely paralleled those estimated from the October surveys at Lake Berryessa (Figure 2). They were slightly heavier in the late summer and early fall months, but the growth rate diminished slightly each winter and early spring.

Tagged Shasta, Whitney, and Coleman trout weighed a total of 38.3 kg (84.5 lb), 35.3 kg (77.8 lb), and 36.3 kg (80.0 lb) at planting, respectively. Similarly, anglers ultimately landed adjusted total weights of 34.5 kg (76.0 lb), 38.4 kg (84.7 lb), and 46.9 kg (103.4 lb). These amounted to a return for tagged fish of 90.1%, 108.9%, and 129.2% of the planted weight of the three strains as listed above. Cost to the angler's creel, therefore, amounted to $1.85/kg ($0.84/lb), $1.54/kg ($0.70/lb), and $1.30/kg ($0.59/lb) for Shasta, Whitney, and Coleman strain rainbows, respectively. Coleman strain had the highest weighted mean weight at return 458 g (1.01 lb) compared to Shasta strain at 311 g (0.69 lb) and 435 g (0.96) for Whitney rainbow.

Yield

Coleman trout yielded 0.81 kg/ha (0.72 lb/acre), approximately one-third more than Shasta strain (0.61 kg/ha; 0.54 lb/acre) and Whitney rainbow 0.74 kg/ha (0.66 lb/acre). All strains combined yielded 2.16 kg/ha (1.93 lb/acre).

DISCUSSION

This experiment confirms the importance of strain in the performance of rainbow trout in "put and grow" programs and reaffirms the superiority of Coleman rainbows over the Whitney and Shasta strains for most efficient utilization of limnetic zones of typical large impoundments with threadfin shad populations. Coleman rainbow have consistently shown highest annual survival rate, lowest early harvest, highest rate of weight returned to weight planted, and the lowest cost to the angler's creel (Rawstron 1972, 1973*a*).

Previous plantings in March and April under higher daily bag limits resulted in higher costs to the angler's creel for all strains (Table 5). By planting later in May (after the opening of the general trout season) and reducing the daily possession limit to three trout, angler harvest in early months reversed findings from previous experiments. Then, anglers typically took 80% of the ultimate harvest shortly after planting and before substantial growth had occurred. Now, by harvesting fish after they have reached "trophy" size, the mean size of individuals in the catch has increased dramatically and produced a more economical fishery.

TABLE 5. Cost per Kilogram (Dollars) to the Creel of Shasta, Whitney, and Coleman Rainbow Trout Planted in Three California Reservoirs, 1968–1971.

	1968	*1969*		*1970*			*1971*		
	Berryessa [1]	*Berryessa* [2]	*Pine Flat* [2]	*Berryessa* [2]	*Merle* [2] *Collins*	*Pine Flat* [2]	*Berryessa* [3]	*Merle* [3] *Collins*	*Mean* [4]
Shasta	None Planted	2.18	3.28	2.82	2.78	2.01	1.30	1.85	2.32 (1.05)
Whitney	2.31	2.27	2.60	1.27	1.55	None Planted	0.93	1.54	1.78 (0.81)
Coleman	0.99	1.90	2.62	1.17	1.46	None Planted	0.77	1.30	1.46 (0.66)

[1] Rawstron, 1972
[2] Rawstron, 1973*a*
[3] Present Study
[4] Cost/lb in parenthesis

Which cause, the later planting or the reduced bag limit, was responsible for the increased yields of all strains was not specifically answered. However, with a five fish limit, 189 (63%) of 300 reward tagged Whitney rainbow trout, averaging 159 g (0.35 lb), stocked at Shasta Lake (Shasta County) on April 27, 1972, were harvested in the first year (W. D. Weidlein, Calif. Dept. Fish and Game, pers. commun.). Of those, 183 (97%) were caught within 6 months. Estimated percentage of weight returned to weight planted amounted to only 84%, substantially below the 181% for the same strain at Lake Berryessa in this study. Additionally, anglers landed only 1,277 trout from May through September in 1971 at Merle Collins Reservoir, compared to the previous year's landings of 1,866 (author's unpublished data). Planting density was the same in both years. Fish were planted May 27, 1970 and May 20, 1971. Fishing pressure, however, increased 146%, from 4,839 anglers in 1970 to 7,064 in 1971. Many anglers, interviewed in the spring, indicated that they would not fish for only three trout and concentrated on a large year class of black crappie (*Pomoxis nigromaculatus*).

Based on these two observations, I believe that the reduced bag limit is primarily responsible for the reduced early harvest. One caution should be observed, however. Threadfin shad typically produce their young in May (Kimsey, Hagy, and McCammon 1957; Kjelson 1971; von Geldern and Mitchell 1975). If trout are planted too early, they may face additional physiological stress until these shad become abundant. Stomach samples taken from rainbow trout in 1970 and 1971 at Merle Collins Reservoir showed that trout planted in late May immediately began consuming larval shad. In previous years, March and April plantings showed that rainbow trout fed principally on the sparse plankton and terrestrial insects until the first larval shad appeared in mid-May. For this reason I believe that planting should not occur before May 1.

In 1973, I listed the overall objectives of this long-term experiment conducted since 1969. Among these was the development of a strain of rainbow trout that initially matured later (3 or 4 years, rather than 2 years as do most of our present domestic strains) (Rawstron 1973*a*). While I still view this as highly desirable, its immediate importance has diminished. Obviously, the reduced bag limit and later planting increased survival sufficiently to create a more economically sound program for managing these waters. However, as soon as the details and costs of developing a broodstock of later maturing Coleman for "put and grow" programs specifically for large intermediate reservoirs can be determined, a program for the evaluation of their progeny should be conducted. Their potential for producing truly "trophy trout" of 2.3 kg (5.0 lb) and further decreasing management costs needs to be examined.

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TEMPERATURE REQUIREMENTS OF *TILAPIA ZILLII*[1]

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Laboratory experiments and field observations were combined to define the temperature requirements of *Tilapia zillii,* an African cichlid used for biological control of aquatic weeds in irrigation systems in southern California. The optimal temperature range for feeding, growth, and spawning is between about 20 and 32 C (68 and 89.6 F). Deaths occur at water temperatures above 39.5 C (103.1 F) and below 11.2 C (52.2 F), but the extreme upper and lower lethal temperature tolerance limits are 42.5 C and 6.5 C (108.5 and 43.7 F), respectively. In nature, however, few, if any, *T. zillii* would be expected to survive a 2-week exposure to 13.0 C (55.4 F) water temperature. Because of its thermal requirements, the value of *T. zillii* as a biological control agent for aquatic weeds in southern California irrigation canals is lessened.

Tilapia zillii has been introduced into southern California irrigation canals in an attempt to biologically control aquatic weeds (Hauser 1975 *a,b*), thereby offsetting the high cost of mechanical control of weeds and enhancing delivery of water. Initially, *T. zillii* were expected to survive water temperatures as low as 7 C (44.6 F) (Legner and Medved 1973) and maintain populations throughout the year in these canals. Chimits (1957), however, reported that the minimum temperature tolerated by *T. zillii* is 9 C (48.2 F) while Sterba (1963) reported *T. zillii* can tolerate 14 to 16 C (57.2 to 60.8 F). Welcomme (1964) reported that the maximum temperature tolerated by *T. zillii* juveniles is 41 C (105.8 F). The purpose of my study, therefore, was to evaluate the effects of changes in water temperature on *T. zillii* commonly experienced in the irrigation systems and to determine its lower lethal temperature tolerance level. This information will permit biologists to predict whether water temperatures may be a limiting factor in the possible survival of *T. zillii* in southern California canals and other waters.

METHODS

Laboratory Experiments

One laboratory experiment was performed to evaluate the effects of increasing water temperatures and four experiments were performed to evaluate the effects of lowering water temperatures. In these, I attempted to simulate conditions observed in southern California irrigation canals. Fish were held in aerated aquaria in a temperature-controlled refrigerator box. Photoperiod was constant at 12 hour light and 12 hour dark. Most test specimens were collected from a drainage ditch filled with seepage water, but some were collected from an Imperial Irrigation District rearing pond. Large numbers of specimens could not be tested because facilities and space were limited and since sufficient numbers of uniform-sized fish were not always available, the size of fish used for the different experiments could not be precisely controlled. The numbers and size of fish, therefore, varied slightly among the experiments.

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After the fish were acclimated for 4 to 6 days at 20–29 C (68 to 84.2 F), the temperature inside the test chamber was varied depending on the test. Water temperatures were constantly monitored using maximum-minimum recording thermometers and checked periodically with bulb thermometers.

In the first experiment, the temperature was increased at a rate of 1 C (1.8 F) per 24 hours, and the diel fluctuation was about 2 C (3.6 F). For the second and third experiments, the temperature was decreased 1 C (1.8 F) per 24 hours with a diel range of about 2 C (3.6 F). The fourth experiment was the same as the second and third except the diel range was 6 C (10.8 F). This diel range of temperature approximates diel temperature fluctuations observed in southern California canals. In the fifth experiment, the water temperature was decreased at a rate of 1 C (1.8 F) per 24 hours until the temperature was 15 C (59 F), then, the rate of change was reduced to 0.3 C (.54 F) per 24 hours to approximate the seasonal rate of change in water temperatures observed in southern California canals.

Periodically during the experiments, fish were observed for changes in behavior. These were classified as "reduced feeding," "lethargic," "loss of equilibrium," and "dead." When food residues were apparent, feeding was considered reduced. Fish were considered lethargic when their movements became sluggish and they were easily caught by hand. Fish with equilibrium loss had slow, ineffective fin and opercle movements and abnormal orientation. Test specimens died over a range of temperatures, and the average temperature at the time the first fish died; more than half the fish died (TLm/50); and all the fish died are reported. The extreme lethal limit is the extreme temperature recorded at the time of the last death.

Field Observations

In the field, water temperatures were monitored throughout the year using maximum-minimum recording thermometers or recording thermographs. Usually, these were read weekly, but they were read more frequently during periods of rapid temperature change and during periods of fish mortality. The average values are used for this report. Observations of fish behavior and mortality were made using a variety of techniques. In drainage ditches and an irrigation canal, some fish were held in removable cages and some were stocked in enclosures built into the channel. In one case, fish were free-swimming in a 10 m by 13 m (33 by 43 ft) by 35 cm (13.8 inches) deep pond. Observations to correlate spawning activity with water temperature were made twice weekly of free-swimming fish in a drainage ditch where the water temperature was monitored using maximum-minimum recording thermometers.

All thermometers used in these studies were calibrated with a reference thermometer from the Chemistry Department, University of California, Riverside.

RESULTS

T. zillii exposed to increasing water temperatures under controlled conditions became lethargic and feeding was reduced when the average temperature reached 32 C (89.6 F) (Table 1). They lost their equilibrium at 39 C (102.2 F) and died between 39.5 and 42 C (103.1 and 107.6 F). The TLm/50 was 40.2 C (104.4 F), and the maximum temperature recorded when the last fish died was 42.5 C (108.5 F).

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Table 1. Effects of Controlled Water Temperature Changes on *Tilapia zillii*.

Test	Number of fish	Mean TL (mm)	Initial temp. (C)	Diel range (C)	Rate of change (C/24 hr)	Response (Average temperature (C))						Extreme lethal limit (C)
						Reduced feeding	Lethargic	Loss of equilibrium	First death	TLm/50	Last death	
1	16	73.3	25.0	2.0	+1.0	32.0	32.0	39.0	39.5	40.2	42.0	42.5
2	18	62.9	21.0	2.0	−1.0	14.5	12.7	11.7	11.4	9.7	8.1	6.7
3	14	83.4	29.0	2.0	−1.0	17.7	13.3	11.2	10.4	9.5	7.0	6.5
2,3 (combined)	32	63.9	25.0	2.0	−1.0	16.1	13.0	11.4	10.9	9.6	7.6	6.6
4	10	75.9	22.0	6.0	−1.0		14.5	13.0	13.1	10.5	10.0	6.7
5	5	109.0	22.0	2.0 6.0	−1.0, then −0.3 below 15.0 C		15.0	13.5	13.7	13.4	11.6	9.0

Table 2. Effects of Naturally Changing Water Temperatures on *Tilapia zillii* in the Imperial Irrigation District, Imperial, CA.

Date	Type of habitat	Number of fish	Total length (mm, approx.)	Average rate of temperature change (C/24 hr)	Diel temperature range (C)	Restrictions on test specimens	Response (Average temperature (C))			Minimum temp. recorded (C)
							First death	TLm/50	Last death	
Dec. 1973 to Jan. 1974	Canal	8	80	0.15	1.0–4.0	Cage and enclosure	13.3	11.8	11.0	9.0
Dec. 1974	Canal	10	80	0.17	1.0–4.0	Cage and enclosure	—	14.0	12.0	11.0
Dec. 1974	Drainage ditch	8	80	0.14	2.5–4.0	Cage and enclosure	—	—	12.5	9.0
Dec. 1974	Pond	Approx. 175	50	0.25	2.5–8.5	Loose	—	14.1	11.4	7.2

When *T. zillii* were exposed to water temperatures declining at a rate of 1 C (1.8 F) per 24 hours and with a 2 C (3.6 F) diel variation, their feeding rate declined when the water temperature was approximately 16 C (60.8 F). They became lethargic at approximately 13 C (55.4 F) and lost equilibrium at about 11.4 C (52.5 F). The TLm/50 was 9.6 C (49.3 F), but the first fish died when the temperature was 11.4 C (52.5 F); the last died when the temperature was 7.6 C (45.7 F). The minimum temperature recorded when the last dead fish was found was 6.5 C (43.7 F).

When the diel variation in water temperature was 6 C (10.8 F) instead of 2 C (3.6 F), deaths were observed at higher average water temperatures, but the extreme lower lethal tolerance level was the same (Table 1, test 4).

When the duration of exposure was increased by reducing the rate of temperature change (Table 1, test 5), behavior changes and deaths were observed at even higher average water temperatures and the extreme lower lethal tolerance level was higher.

Under field conditions, no mortality of *T. zillii* was attributed to high summer water temperature conditions (maximum observed was 39 C (102.2 F). The low TLm/50, however, was between 11.8 and 14.1 C (53.2 and 57.4 F) (Table 2). None survived average water temperatures lower than 11.0 C (51.8 F), and the minimum water temperature when all the fish were dead was 7.2 C (45.0 F).

Spawning behavior of *T. zillii* was first observed in a drainage ditch after the average water temperatures increased to 20 C (68 F) in late spring. Successful spawning was observed after the average water temperature reached 22.5 C (72.5 F). Nesting activity continued throughout the summer until the average water temperature declined to 21 C (69.8 F), but most spawning occurred during spring as the water temperature increased from 22.5 to 25 C (72.5 to 77 F).

DISCUSSION

The upper lethal temperature tolerance limit I observed is similar to that reported by Welcomme (1964), and deaths due to exposure to high water temperatures occur over a relatively narrow range. Normal life activities, however, require water temperatures between about 16 and 32 C (60.8 and 89.6 F). Optimum conditions for active movements and good growth apparently are in the upper portions of this range. Fukusho (1968) reported that *T. zillii* exhibited good "cruising performance" at 28 C (82.4 F) water temperature and Cridland (1962) reported that *T. zillii* grew faster and matured sooner when reared at 31 C (87.8 F). The growing season for *T. zillii* in the Lake Quarun, Egypt, is when water temperatures exceed 18.9 C (66 F) (El-Zarka 1961). Other unpublished data (Hauser and Platt) also suggests that the optimal range of temperatures for *T. zillii* is between 20 and 30 C (68 and 86 F).

In Egypt, *T. zillii* spawns at water temperatures between 23.1 and 31.5 C (73.6 and 88.7 F) (El-Zarka 1956; El Bolock and Koura 1960; El-Zarka 1962). *T. zillii* usually spawns, therefore, at average water temperatures between 23 and 27 C (73.4 and 80.6 F), but successful spawning may occur at water temperatures from 22.5 to 31.5 C (72.5 to 88.7 F).

When *T. zillii* are exposed to average water temperatures colder than 16 C (60.8 F), they become lethargic or respond to stimuli in an irregular manner. Before death occurs, they lose equilibrium, then become moribund and unresponsive to stimuli. Under these conditions, *T. zillii* would be extremely vulnerable to predators and disease, and under lotic conditions, would be carried away by the current.

Under field conditions, where the rate of temperature change typically is slow (e.g., 0.2 C (0.4 F) per 24 hours), and the diel fluctuation is great (e.g., 4 C (7.2 F)), mortality due to seasonally cooling water temperatures occurs at a relatively higher temperature than under laboratory conditions. The fish die at temperatures which in the laboratory would be sublethal. This probably results in part because they are in poor physical condition since they have not fed during the long period of exposure to the sublethal temperatures. Mortality results, therefore, from the combined effects of the actual water temperature and the duration of exposure to that temperature.

Most likely, under normal environmental conditions, few *T. zillii* would survive exposure to 13.0 C (55.4 F) water temperature longer than about 2 weeks and, when the average canal water temperature declines to 10 C (50.0 F), one must expect complete mortality of *T. zillii* populations.

The extreme lower lethal limit I observed is similar to that reported by Legner and Medved (1973), and the average temperatures I observed at the time of last deaths is similar to that reported by Chimits (1957). These authors, however, do not describe their methods. The TLm/50 I observed under laboratory conditions, however, is identical to that found by Rickel (1975).

The wide variation of lower lethal temperature tolerance of *T. zillii* previously reported probably results from differences in acclimation and experimental techniques since the effects of low temperatures depend on the exposure temperature and the duration of exposure. I observed considerable variation in temperature tolerance among experiments and individuals within an experiment, but I found no definite correlation between fish size and temperature-related mortality. Rickel (1975) also found no correlation between size of *T. zillii* and cold tolerance.

Because of the strong thermophillic nature of *T. zillii,* its value as a biological control agent for aquatic weeds in irrigation canals is diminished. Its widespread use in California is further limited by the current California Fish and Game Department policy restricting the introduction of *T. zillii* to certain areas in southern California. This is a conservative attitude, but until the potential impact of *T. zillii* on assocated fishes and the aquatic environment is better understood, it is the best approach.

Based on water temperature data collected in the Central Main Canal, Imperial Irrigation District, near Imperial, California, from 1973 to 1976, conditions for survival of *T. zillii* typically would be lethal or marginal (i.e., less than 14.0 C (57.2 F) average water temperature) from December through late March (author's unpublished data). No *T. zillii* are known to have survived over winter in irrigation canals in souther California though some populations are self-sustaining in drainage ditches fed by seepage water. Population mortality occurred by 3 January, 24 December, 16 December, and 5 January, respectively, during four successive winters. Active feeding and growth could be expected only from April through mid-November and reproduction from May through October. By April, however, aquatic weeds have already begun their annual growth. Control of aquatic weeds in irrigation canals by *T. zillii* in southern California, therefore, would require annual restocking of the fish. This would require intensive rearing operations so the fish could be stocked at sufficient densities as early in the season as water temperatures allow. With proper management based on annual large scale releases, however, satisfactory weed control in canals may be possible at lower cost than with current chemical or mechanical control techniques.

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FECUNDITY AND REPRODUCTION OF THE VIVIPAROUS PERCHES *HYPSURUS CARYI* (AGASSIZ) AND *EMBIOTOCA JACKSONI* AGASSIZ [1]

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Aspects of the reproductive biology of the rainbow seapearch, *Hypsurus caryi*, and the black perch, *Embiotoca jacksoni*, from Half Moon Bay, California were studied. Ovaries in both species were found to be spindle-shaped, bifurcating anteriorly into tapering horns. Each ovary was compartimentalized and divided by six partitions. Fecundity increased with the size of females. Females of *Hypsurus caryi* averaged 11.6 embryos and *Embiotoca jacksoni* 14.4. *H. caryi* embryos shift head for tail within the ovarian compartments. Prenatal mortality of *H. Caryi* in the late stages of development was found to be 11%. In both species hypertrophied fins were observed folded upon themselves and, or, adjacent to the fins of other embryos rather than in close juxtaposition with the ovigerous tissue. Gestation was estimated at 5 to 6 months for both species. Newborn *Hypsurus caryi* were approximately 55 mm (2.2 inches) SL, while newborn *Embiotoca jacksoni* were 54 to 61 mm (2.1 to 2.4 inches) SL. In *H. caryi* embryos hypertrophied median fins were observed to reach their peaks in height simultaneously with the completion of scale development but assume their normal height soon after birth.

INTRODUCTION

Viviparity has developed in only eight of more than 500 families of teleost fishes known today. The viviparous nature of the embiotocids was described in 1853 by Louis Agassiz. Since then the life history and embryology of the family have been the focus of a great deal of attention from the scientific community. However, the two members of the subfamily Embiotocinae (Tarp 1952) which were available to me have not been the subject of much study: *Hypsurus caryi* (Agassiz), the rainbow surfperch, and *Embiotoca jacksoni* Agassiz, the black surfperch. *Hypsurus caryi* ranges from Rio Santo Tomas, Baja California, to Cape Mendocino, California, and *Embiotoca jacksoni* from Pt. Abreojos, Baja California, to Fort Bragg, California, including Guadalupe Island (Miller and Lea 1972). Both characteristically inhabit rocky shores and occasionally embayments.

The objectives of this study were to measure fecundity, prenatal mortality, and size of young at birth, and to describe changes in orientation of the embryos in the ovary during development and the relationship between spawning time and size of parent. Information concerning prenatal respiration was also accumulated.

METHODS AND MATERIALS

Gravid females of the species *Hypsurus caryi* and *Embiotoca jacksoni* were taken in 11 collections from April 6 to November 15, 1971. All collections were made at the west end of Princeton Harbor, San Mateo County, California (Figure 1). This man-made harbor, built by the U. S. Army Corps of Engineers in 1961, is protected from surf action and is shallow in the collection area, averaging about 3 m (10 ft) deep at mean tide. The area is characterized by sandy bottom

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bordered with rocky intertidal on the west side and sandy beach and *Phyllospadix* on the north side.

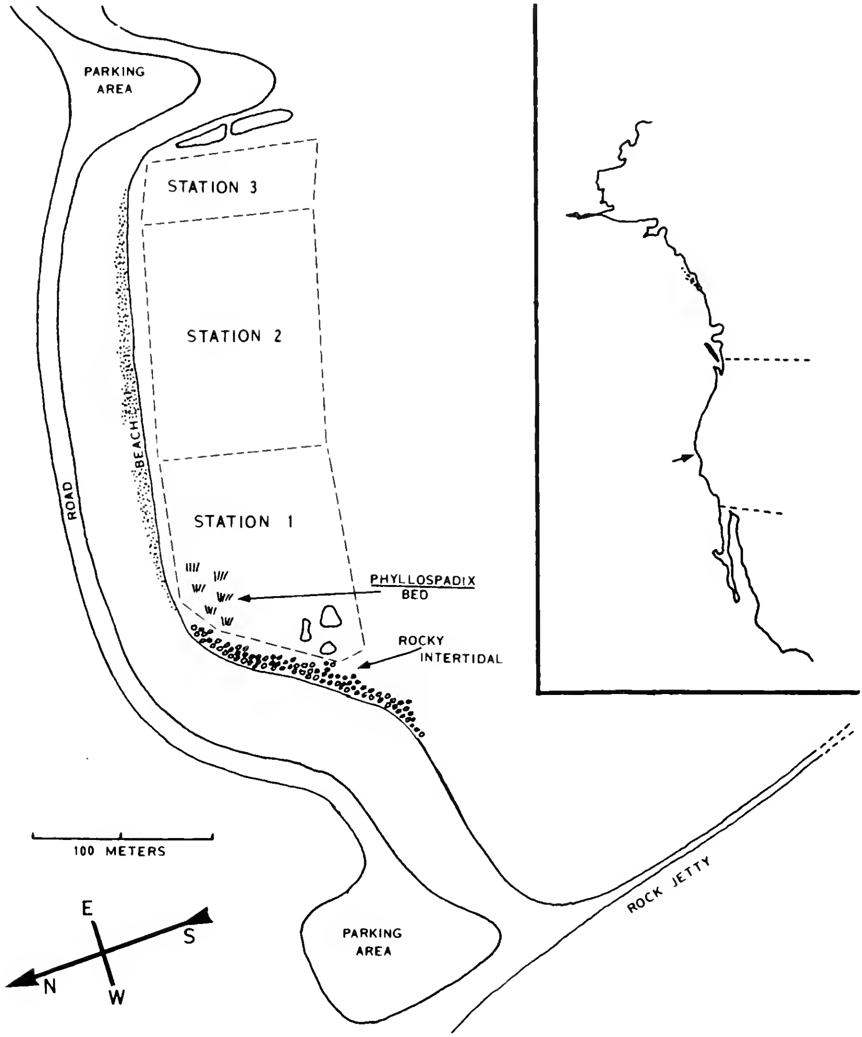

FIGURE 1. West end of Princeton Harbor, Half Moon Bay, California.

Fishes were collected with various sized beach seines and a 45-m (150-ft) gill net and preserved in 10% formalin solution. Each female was measured for standard length (SL) to the nearest mm and her ovary removed. Preserved ovaries then were opened carefully and, as each embryo was removed, the direction in which the head was facing was noted. The standard length and height of dorsal fin of each embryo was measured to the nearest 0.1 mm with a Helios dial caliper.

To determine development of scales and their radiation over the skin surface, a series of embryos from 14.5 to 46.5 mm (0.6 to 1.8 inches) SL were cleared and stained in a solution of 5% KOH and 0.5 g (0.02 oz) of alizarin red S dye. The embryos were then examined for presence of scales, size of scales (number of circuli), and extent of the body covered by scales.

In order to ascertain the morphological juxtaposition of the fins to the ovarian folds, paraffin sections were prepared.

RESULTS

Nature of the Ovary

The gravid ovaries of *Hypsurus caryi* and *Embiotoca jacksoni* were somewhat spindle-shaped, with the anterior end bifurcated into two tapering horns. Internally, right and left ovaries are largely but not completely fused into a single organ. The paired condition is much more obvious early in gestation (Figure 2).

FIGURE 2. Ovary of a specimen of *Embiotoca jacksoni* taken early in the season, showing bifurcating lobes. Anterior end to left. Photograph by D. W. Behrens.

It was found that the ovaries of both species are divided into seven compartments by six thin, vascular ovigerous sheets (Figure 3). These multi-folded sheets are attached dorsally and are connected anteriorly producing two open-ended subdivided sacs. Presumably this condition of compartmentalization of the ovary is a vestige of the original paired lobes. The surface of the ovarian cavity is covered with tall cuboidal epithelium cells under which is a layer of connective tissue (Figure 4).

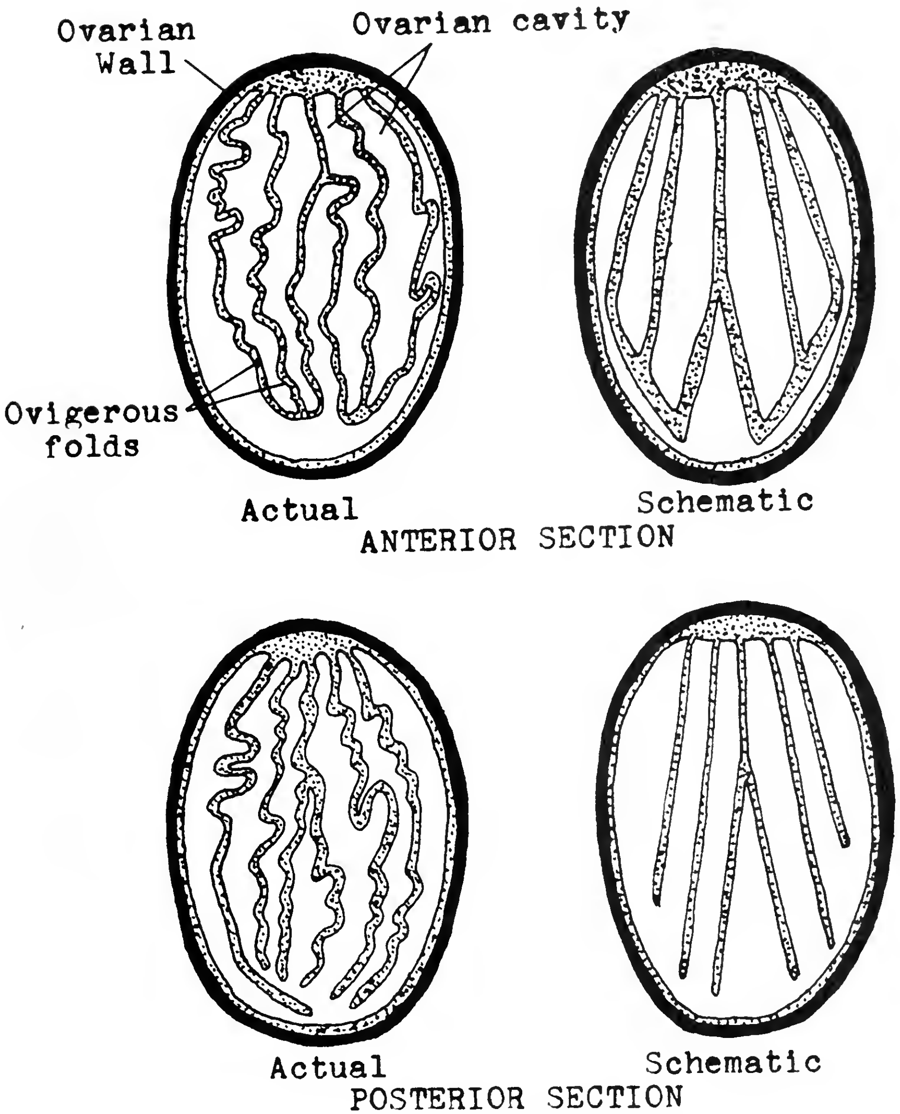

FIGURE 3. Cross-section of a perch ovary showing compartments produced by ovigerous sheets.

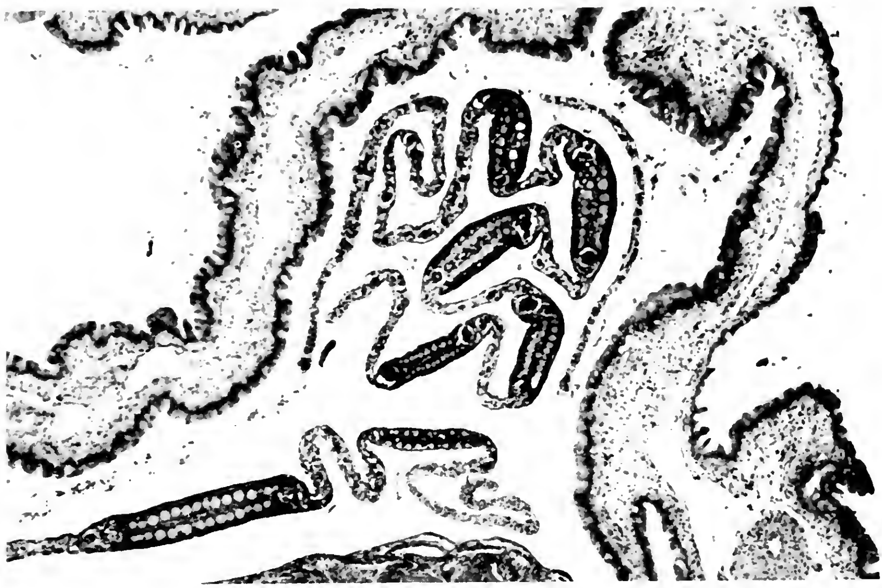

FIGURE 4. Cross-section through the ovary of *Embiotoca jacksoni* showing folding of median fins (A) and juxtaposition with ovigerous folds (B). The ovigerous folds are seen to be covered by tall cuboidal epithelium cells (C) under which lies a layer of connective tissue (D). Photograph by D. W. Behrens.

Fecundity

The size of the mother relative to the number of embryos present shows a positive correlation (Figures 5 and 6), larger females containing on the average more embryos.

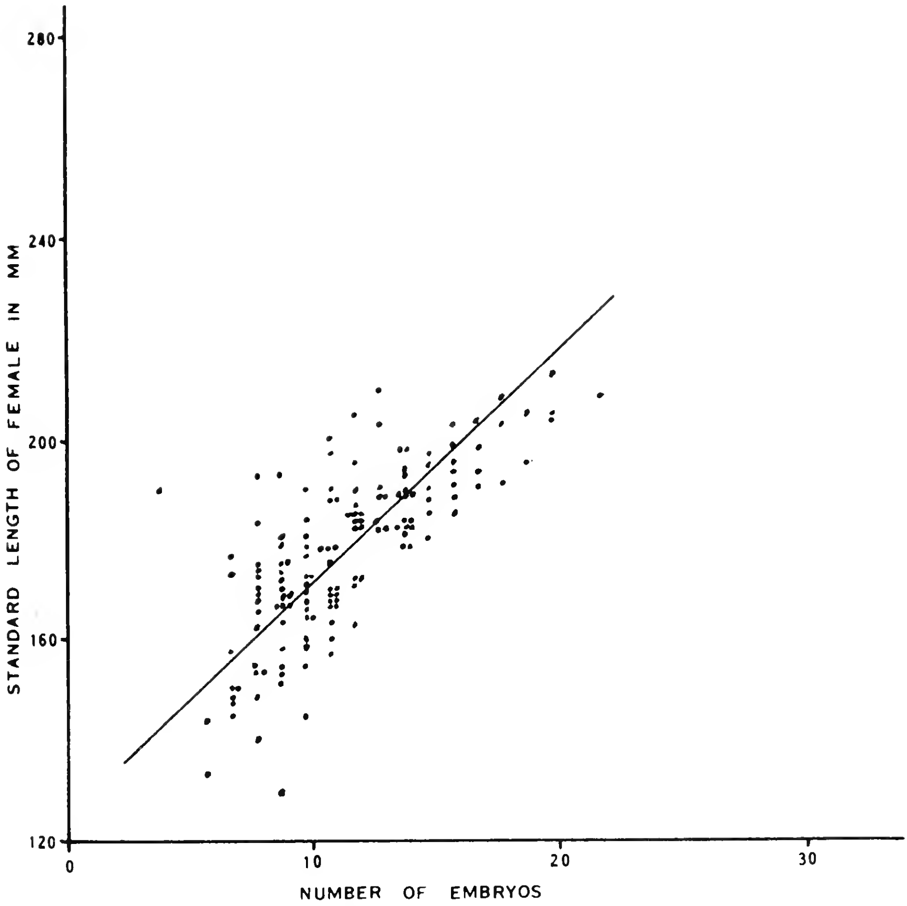

FIGURE 5. Number of embryos per gravid female related to standard length of females of *Hypsurus caryi.* (Regression line fitted by eye.) N=149.

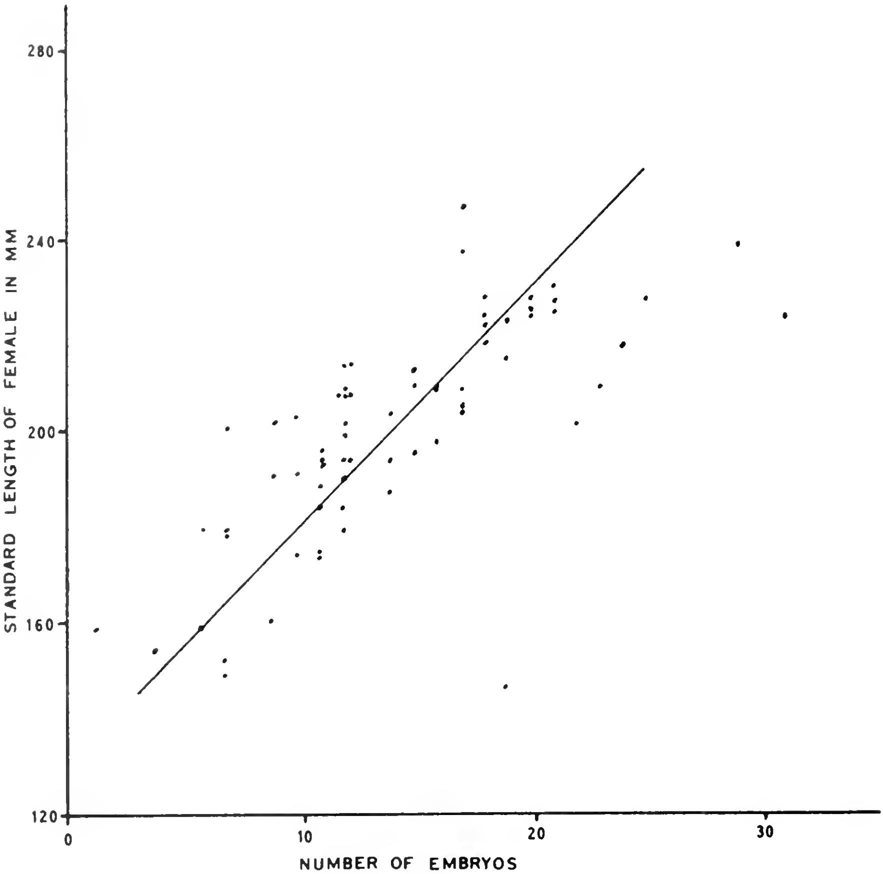

FIGURE 6. Number of embryos per gravid female related to standard length of females of *Embiotoca jacksoni.* (Regression line fitted by eye.) N=65.

From April through mid-September, 155 female *Hypsurus caryi* were taken (Table 1), of which 149 (96.1%) were gravid. These gravid females ranged from 131 to 214 mm (5.2 to 8.4 inches) SL and were found to carry an average of 11.6 embryos. The smallest gravid female was 131 mm (5.2 inches) SL and carried nine embryos. The greatest number of embryos found was 22, in a female measuring 210 mm (8.3 inches) SL.

TABLE 1. Numbers of Males, Females and Newborns of *Hypsurus caryi* and *Embiotoca jacksoni* Taken in Each Collection from April Through November 1971. Newborns Were Arbitrarily Scored as Those Free-swimming Fish Measuring Less Than 70 mm in Standard Length.

	Hypsurus caryi			*Embiotoca jacksoni*		
	Female	*male*	*newborn*	*Female*	*male*	*newborn*
April 6	44			37		
April 29	18			38	12	
May 18	22			9		
May 27	10			3		
June 12	30			10		
July 10	13			7	2	
August 8	3	1	2			
August 14	14		5	4		
September 11	1		1	10	4	12
October 31			1	3	2	12
November 15				23	35	20
Totals	155	1	9	144	55	44

From April through mid-November, 144 female *Embiotoca jacksoni* were taken (Table 1), of which 65 (45.2%) were gravid. The total number of females collected includes many taken after spawning. The 65 gravid females ranged from 146 to 249 mm (5.7 to 9.8 inches) SL and were found to carry an average of 14.4 embryos. The smallest gravid female was 146 mm (5.7 inches) SL and carried 19 young, an unusually high number for small females (Figure 6). The next smallest gravid female was 153 mm (6.0 inches) SL and carried 7 embryos. Both of these female *E. jacksoni* were 2 years old according to the aging studies of Isaacson and Isaacson (1966). The greatest number of embryos was 31, found in a 4-year-old female measuring 227 mm (8.9 inches) SL.

Orientation of the Embryos in the Ovary

Only *Hypsurus caryi* was studied for alignment of embryos in the ovary. Embryos were determined as facing anteriorly or posteriorly in the ovary by the direction in which the head was facing, because approximately half of the embryos were found doubled over. Ovaries were selected from 112 specimens of *H. caryi.* A wide range of embryo size was included to determine whether any difference exists in alignment of embryos with increasing size of embryos. Embryos were removed from ovaries and their lengths taken. Standard lengths of embryos from any one ovary are always similar and so the values for standard length of embryos from a single ovary were averaged to give a mean value for the brood. The brood mean values were arranged in magnitude array, and the array was subdivided into seven groups ranging from the first group with brood mean values 12 to 17.9 mm (0.5 to 0.7 inches) SL to the seventh group with brood mean values 48 to 53.9 mm (1.9 to 2.1 inches) SL (Figure 7). For each group of broods, the number of individual embryos facing anteriorly was counted and given as a percentage of the total number of embryos for all the broods in the group. The percentages show that during development the majority of embryos face anteriorly and that ovaries containing older embryos tend to have more embryos facing anteriorly.

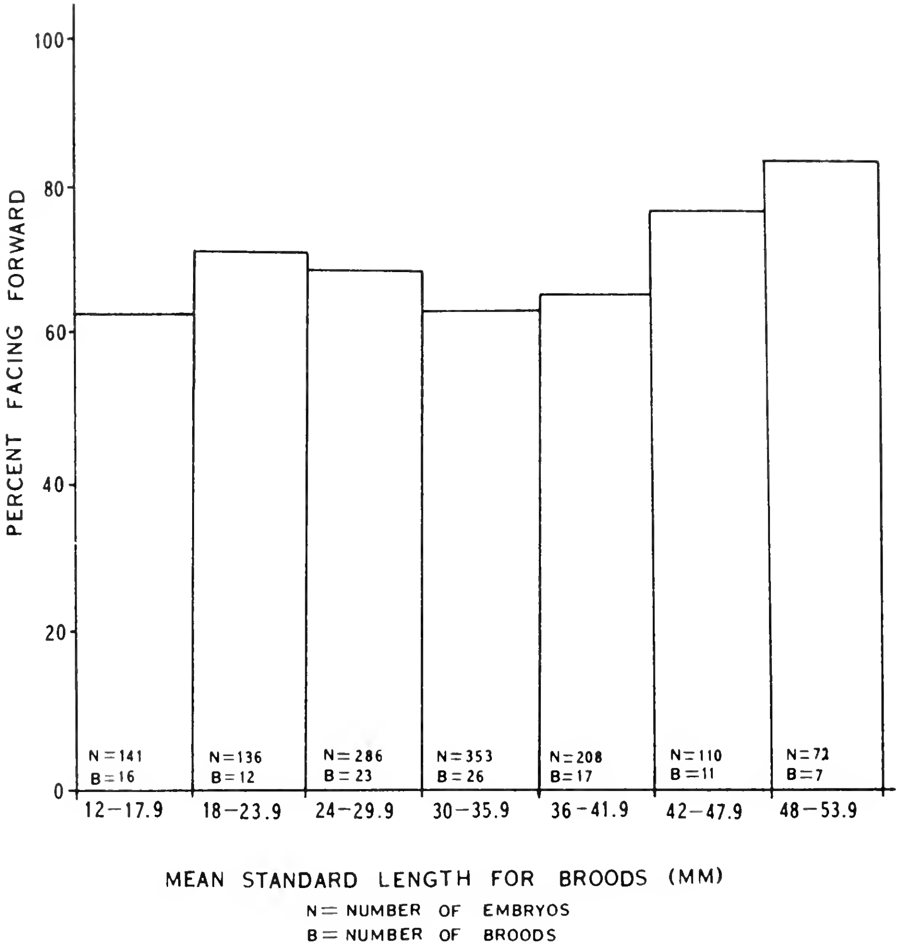

FIGURE 7. The orientation of embryos in ovaries in 112 *Hypsurus caryi* with reference to their standard length.

Although I have no data to indicate frequency, I noted that it was not uncommon for an embryo to be found lying upside down within the ovary. This position did not appear to have any detrimental effect upon the embryo, development appeared quite normal.

While counting embryos of *Hypsurus caryi* in late developmental stages greater than or equal to 48 mm (1.9 inches) SL, I observed that the embryos' bodies gradually became more rigid as their bones developed and fewer embryos were preserved doubled over.

Prenatal Mortality

The number of embryos per female was plotted monthly from April to August in 27 female *Hypsurus caryi* 165 to 175 mm (6.5 to 6.9 inches) SL (Figure 8). Because large females were shown to have larger broods than small females, only females in the 165 to 175 mm SL range were used so that brood figures could be compared. A decrease of approximately 11% in the average number of embryos per female occurred.

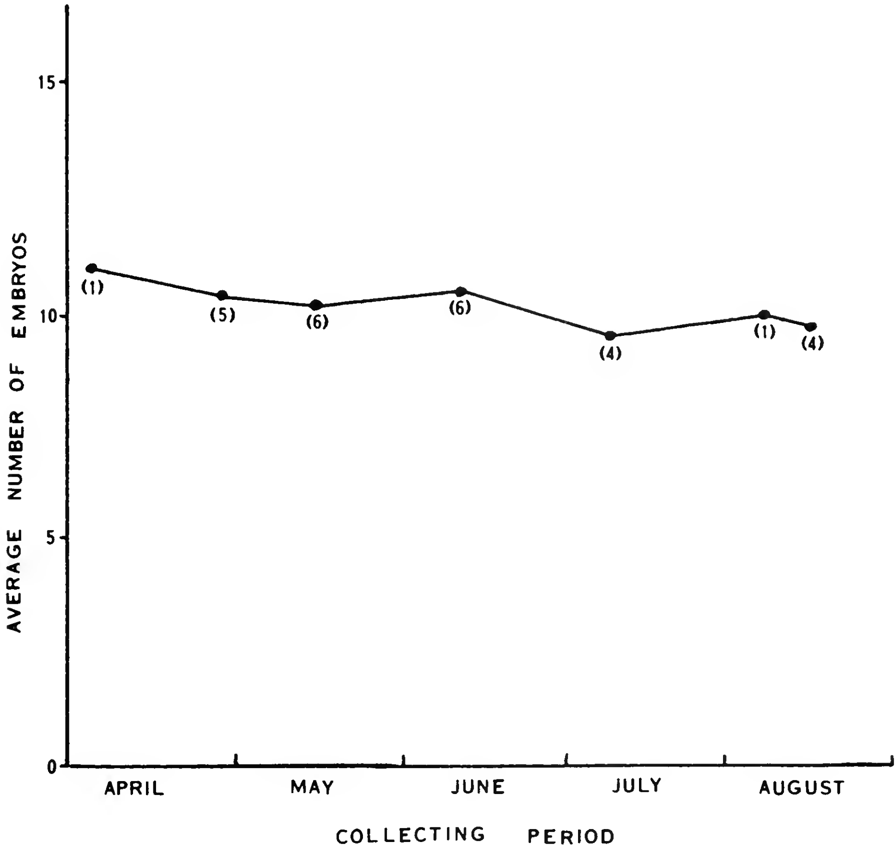

FIGURE 8. Intra-Ovarian mortality in 27 *Hypsurus caryi,* 165–175 mm in SL. Numbers in parentheses = numbers of broods.

During my collecting I observed that near-term embryos could be aborted if the parent was handled harshly. However, I observed this tendency only late in the season, which suggests that individuals carrying younger embryos are not so likely to abort.

Carlisle *et al.* (1960) and Banerjee (1971) occasionally found an "out-sized" or very small, abnormal embryo. Wares (1971) reported that 1.2% of the embryos of *Rhacochilus vacca* examined were malformed. In 149 gravid *Hypsurus caryi,* I found five abnormally small embryos. All five were slightly over one-half the length of their companion embryos. These under-sized embryos seemed in every other respect to be perfectly normal. None were found in this condition in the ovaries of the 65 *E. jacksoni.*

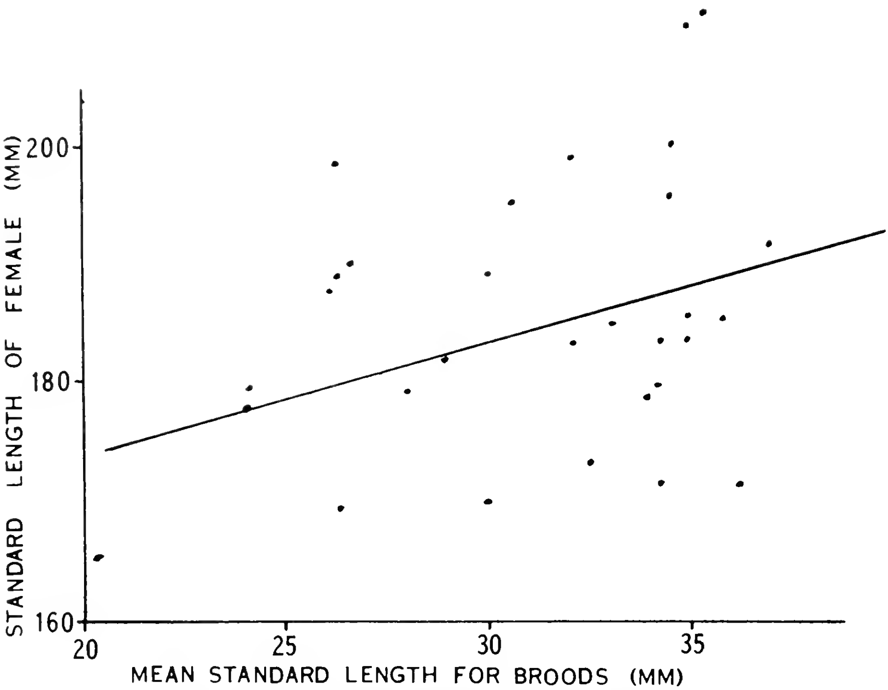

FIGURE 9. Scatter diagram showing size of embryos (given as mean SL for a brood) plotted against size of females (given as SL) for 30 gravid females of *Hypsurus caryi.*

Time of Spawning

All females of the species *Embiotoca jacksoni* collected between April and September were found to be gravid, while females with spent ovaries began to appear in mid-September; the collection in which all females were found to be spent was that of November 15. This span of time suggests a gestation period of between 5 and 6 months. It was also on November 15 that the greatest number of male *E. jacksoni* was taken. Specimens of newborn *E. jacksoni* did not appear in the collection until September 11 (Table 1) but occurred in all collections after that. These findings indicate that *E. jacksoni* in Half Moon Bay bear young from mid-September to mid-November.

In *Hypsurus caryi,* spent females appeared in the collections in August and September, as did newborn fish. No specimens of *H. caryi* were taken in October or November (Table 1), indicating that both the females and newborns leave the embayment after spawning, which occurs from mid-August to mid-September. Relatively large numbers of females of *E. jacksoni* were taken in October and November, after the disappearance of *H. caryi,* suggesting that either *E. jacksoni* remains in the embayment for most of the year or, if it leaves the embayment after spawning as *H. caryi* appears to do, its spawning period lasts later into the year. The gestation period for *H. caryi* also seems to be 5 to 6 months.

I found the largest embryo of *E. jacksoni* to be 61 mm (2.4 inches) SL and the smallest free-swimming newborn collected to be 54 mm (2.1 inches) SL. The largest embryo of *H. caryi* measured 53 mm (2.1 inches) SL and the smallest free-swimming newborn collected was 55 mm (2.2 inches) SL.

In some embiotocids, older females spawn earlier in the season than younger females (Eigenmann 1894; Hubbs 1921; Carlisle *et al.* 1960; Triplett 1960; Wiebe 1968). A distribution comparing parent length to embryo development (embryos' standard length) was prepared to see whether this is also true for *Hypsurus Caryi* (Figure 9). The sample of 30 *Hypsurus caryi* collected on June 6, 1971, was used in this comparison because of the large size of the collection. Since the range in length of females taken in this collection was 165 to 210 mm (6.5 to 8.3 inches) SL or close to the limits of the 130 to 215 mm (5.1 to 8.5 inch) range of gravid females taken during the entire study, I assumed the sample included all age groups with the possible exception of the youngest. If older females spawn earlier in the season as proposed by Eigenmann (1894), I would have expected to find larger females with broods further along in development. Utilizing the Pearson correlation coefficient, a correlation was found to exist between size of female and mean size of her embryos, with $r = 0.12$. However, this correlation was found to be insignificant at the 95% level.

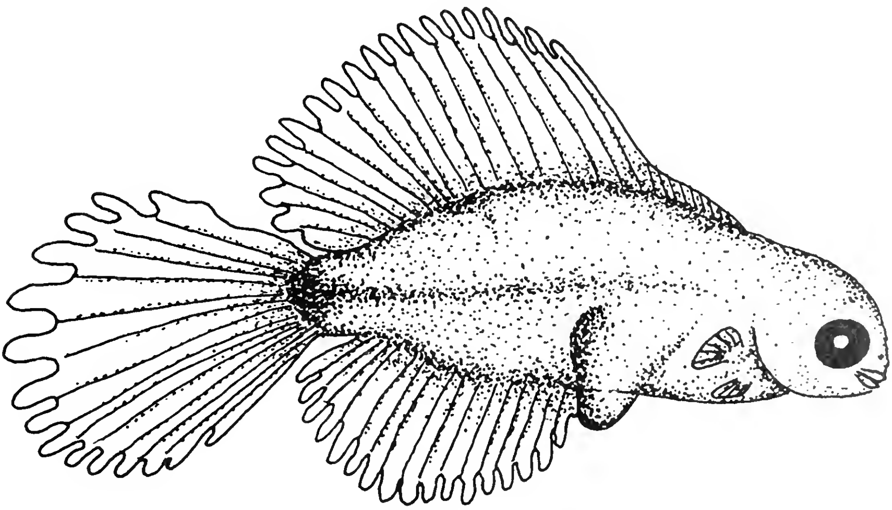

FIGURE 10. Drawing of a *Hypsurus caryi* embryo, 40 mm SL, showing spatulate-shaped dermal flaps interdigitating with soft fin ray elements.

Prenatal Gas Exchange

It was found that median fin membranes, including the spatulate-shaped dermal flaps (Figure 10) which interdigitate with the soft fin ray elements, were made up of dense beds of capillaries (Figure 11). The dense capillary beds suggest sites of exchange between the embryonic circulatory system and the internal ovarian milieu. A capillary network was seen in the subepithelial connective tissue of both the extremely hypertrophied ovarian folds and in the wall of the ovarian cavity, but was not nearly as extensive as the network seen in the fins of the embryo. The tall columnar epithelial cells which completely line all the internal surfaces in the ovarian cavity appear secretory in nature because many are vacuolated. Extensive folding of the ovarian sheets greatly increases the area of the secretory epithelium. Also it was noted that the hypertrophied median fins of the embryos are folded up upon themselves and, or adjacent to, the fins of other embryos, rather than to the ovarian tissue (Figure 4), which one would expect if there were exchange between maternal and embryonic tissue.

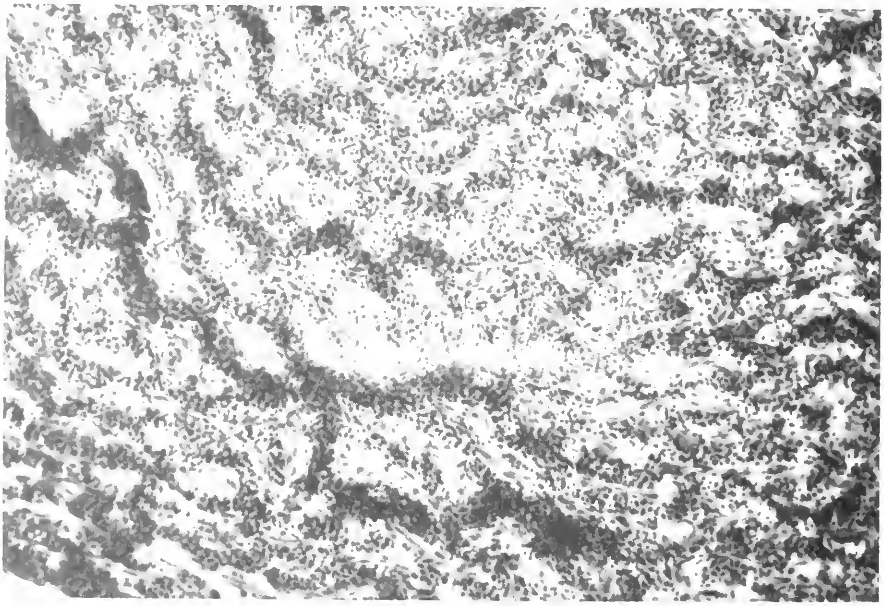

FIGURE 11. View of dense capillary bed found in dermal flap flanking dorsal fin *H. caryi.* Dark spots are red blood corpusceles, lighter areas connective tissue of dermal flap. Photograph by D. W. Behrens.

The presence of an accessory respiratory device consisting of a tissue extension protruding from the ovarian wall into the opercular opening of the embryo, as reported by Turner (1952) and Wiebe (1968) in *Cymatogaster aggregata,* and by Webb and Brett (1972) in *Rhacochilus vacca,* was sought in *Hypsurus caryi* and *Embiotoca jacksoni* but was never found.

Measurements of *Hypsurus caryi* embryos showed a rapid yet temporary increase in the respiratory surface of their bodies. The fin elongates faster than the body until it reaches a peak of about 13 mm (0.5 inch) when the embryo is about 48 mm (1.9 inches) SL (Figure 12). At this stage, the dorsal fin appears greatly exaggerated in height. Measurements of the dorsal fins of 60 embryos showed that embryos 25 to 45 mm (1.0 to 1.8 inches) SL have a dorsal fin height nearly 25% their standard length, compared to 8.1% in newborn fish. By the time the newborn reaches 62 mm (2.4 inches) SL, the height of the dorsal fin in *H. caryi* has been reduced to about 5 mm (0.2 inch) and its proportional height is normal for free-living individuals. In the embryos of *Embiotoca jacksoni,* the final margin of the median fins is foretold as the embryo becomes pigmented. In these embryos, the dark pigment of the fin extends from the base of the fin only to a line which will become the distal margin of the completely developed fin (Figure 13).

Further correlated with the temporary respiratory tissue of the fins is the development of scales over the body surface. The presence of scales was easily determined by alizarin red S dye. Scales first appear along the lateral line when the embryo is about 25 to 30 mm (1.0 to 1.2 inches) SL. The embryo is entirely covered with scales by the time the dorsal fin reaches its greatest height (Figure 12). I am not sure when the first circulus forms on a scale, but at 30 mm (1.2 inches) SL, there are two circuli on the scales. By the time the embryo reaches 47 mm (1.9 inches) SL, each scale has six circuli. It was not determined how many circuli each scale will accrue before it lays down a metamorphic annulus immediately after birth. The metamorphic annulus is particularly obvious in the Embiotocidae, and is formed after birth while the embryo is making the transition from receiving maternal nutrition and respiration to supplying its own (Hubbs 1921).

DISCUSSION

Nature of the Ovary

The structure of the ovaries of *Hypsurus caryi* and *Embiotoca jacksoni* was found to be similar to that of the ovaries of other embiotocids except for number of partitions and general shape. I found *H. caryi* and *E. jacksoni* each to have ovaries with six partitions. Turner (1938) reported the same number in *Cymatogaster aggregata* as did Ishii (1957) in *Ditrema temmincki,* while Carlisle *et al.* (1960) and Triplett (1960) found 10 partitions in *Amphistichus argenteus,* and Banerjee (1971) reports 11 to 12 in *Phanerodon furcatus.* Blanco (1938) reports *Embiotoca lateralis* to have an ovary composed of two sacs divided into five compartments. Hopkirk (1962) suggested that differences in ovarian compartmentalization make up another subfamily separation, the Embiotocinae having six partitiions as described here for *Hypsurus caryi* and *Embiotoca jacksoni,* and the Amphistichinae having more than six partitions, which have lost the septal connection and hang free.

I found that early in the season the ovaries of both *Hypsurus caryi* and *Embiotoca jacksoni* are bilobed in appearance. This is also in agreement with Blanco (1938), Turner (1938), and Ishii (1957). Triplett (1960) and Banerjee (1971) report, however, that all embiotocids have single-lobed ovaries, but they presumably had reference only to late-term ovaries.

Fecundity

The fecundities of *Hypsurus caryi* and *Embiotoca jacksoni* were found to be within range of other species of embiotocids: *Amphistichus argenteus* (Carlisle *et al.* 1960; Triplett 1960), *Cymatogaster aggregata* (Eigenmann 1894; Wiebe 1968; Wilson and Millemann 1969; Bane 1970), *Ditrema temmincki* and *Ditrema viridis* (Abe 1969), *Embiotoca jacksoni* (Isaacson and Isaacson 1966), *Embiotoca lateralis* (Swedberg 1965; Webb and Brett 1972), *Hyperprosopon ellipticum* (Wydoski and Bennett 1973), *Hysterocarpus traskii* (Bundy 1970), *Micrometrus aurora* and *Micrometrus minimus* (Hubbs 1921), *Phanerodon furcatus* (Banerjee 1971) *Rhacochilus vacca* (Wares 1971; Webb and Brett 1972). Isaacson and Isaacson (1966) measured the fecundity of *Embiotoca jacksoni* and their results are in close agreement with mine. They also reported the

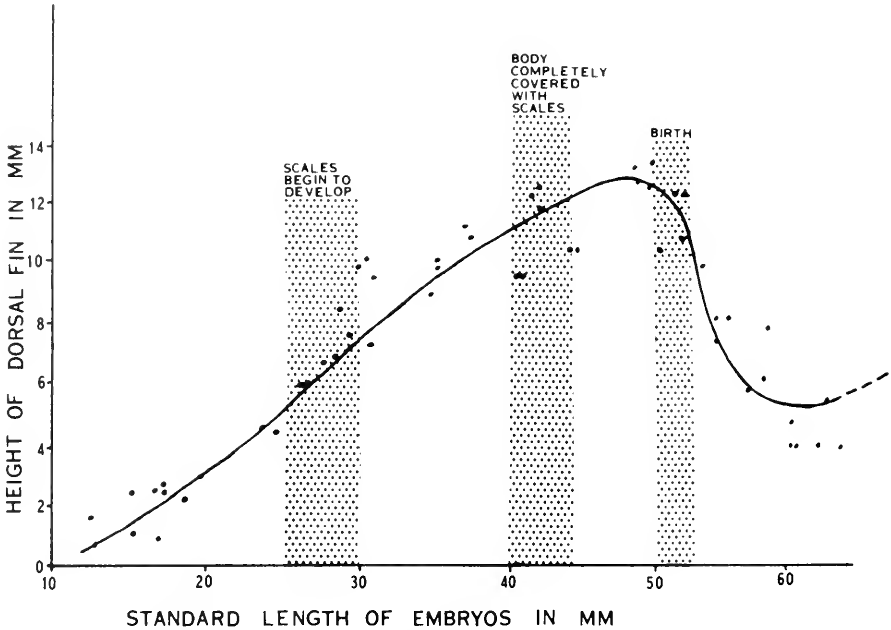

FIGURE 12. Growth of the dorsal fin relative to development of the scales in *Hypsurus caryi.* Dorsal fin growth was measured as dorsal fin height versus standard length. N=55.

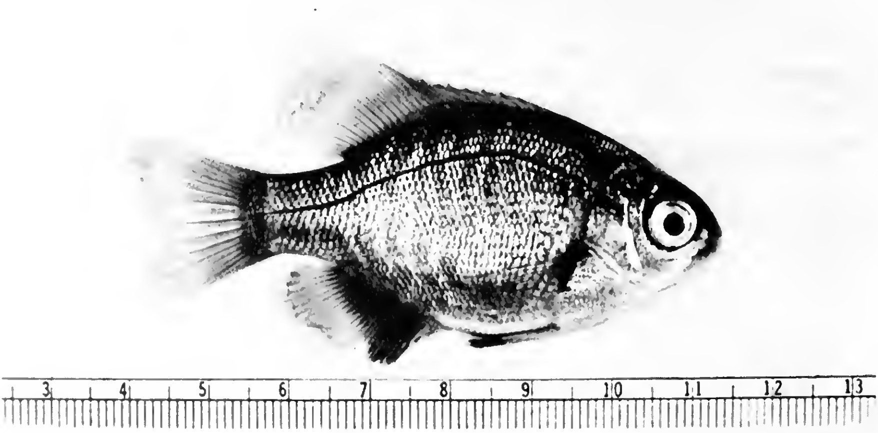

FIGURE 13. A near term embryo of *Embiotoca jacksoni* still exhibiting its exaggerated median fins and dermal flaps. Note the pigmentation on the anal fin denoting the future margin of the fin which will be established soon after birth. (Reprinted from *Pacific Discovery,* November 1973).

youngest female to be carrying embryos was 121 mm (4.8 inches) SL; this individual was 25 mm (1.10 inches) shorter than the smallest gravid female in my study.

Time of Spawning

Isaacson and Isaacson (1966) reported that black perch in Long Beach Harbor and San Francisco Bay drop their young throughout the year. Their collections of gravid females from San Francisco Bay, however, were taken between April and September, and not throughout the entire year. According to my data (Table 1), this is not late enough in the year to observe spawning, which I observed to take place from mid-September to mid-November. Baxter (1963) reported that spawning occurs in the spring and summer and less commonly at other times of the year throughout the range.

The gestation periods suggested in this study for *Hypsurus caryi* and *Embiotoca jacksoni* are similar to those reported for *Cymatogaster aggregata* (Eigenmann 1894 and Wiebe 1968), *Amphistichus argenteus* (Carlisle *et al.* 1960), *Hyperprosopon argenteum* (Engen 1968), and *Ditrema temmincki* (Ishii 1957; Abe 1969).

My findings suggest that early spawning by older females does not occur in *Hypsurus caryi.* An aspect overlooked in this study, however, was that considered by Wilson and Millemann (1969) who found that the size of the embryo at birth is directly related to the size of the parent, larger females bearing larger young. This being the case, spawning time cannot be estimated on the basis of embryo size alone, as has been done by earlier researchers. Wares (1971) reports that in *Rhacochilus vacca* the apparent differences in spawning time are negligible when the ratio of embryo size to parent size is considered. This brings up the question of whether larger females have longer gestation periods to produce larger and more numerous embryos, or whether embryo growth in large females is simply faster.

Orientation of Embryos at Birth

The occurrence of embryos preserved doubled over in approximately half of the ovaries of *Hypsurus caryi* indicates that the embryos do move within the ovary during development and are capable of changing head for tail. The doubled-over position supports the conclusions of Eigenmann (1894) and the observations of Evelyn Shaw (pers. commun.) for *Cymatogaster aggregata* and Blanco (1938) for *Embiotoca lateralis* that embryos do change position in the ovary. The final attitude of the embryos is determined by their attitude when bone development makes the body too rigid for the embryo to turn about in the confining space of the ovary. Girard (1859) reported that in *Hysterocarpus traskii* all embryos align themselves with heads facing anteriorly and are all born tail first, as did Eigenmann (1894) and Wiebe (1968) for *Cymatogaster aggregata.* Although there was a strong tendency for embryos to face forward in *Hypsurus caryi* (Figure 7) results indicate that some *Hypsurus caryi* are born head first instead.

Agassiz was first to contend that arrangement of the embryos, some facing anteriorly, some posteriorly, was for the purpose of conservation of space. This view has been endorsed by Hubbs (1921), Carlisle *et al.* (1960), and Banerjee (1971). Any movement of the embryos in the ovary is limited to sliding between highly flexible tissue sheets which totally envelop them. An individual is never really moving into or out of an empty space, but merely exchanging space with another embryo. Alignment of the embryos in the ovary based on conservation of space alone may be true but would be extremely difficult to test, as observations would have to be made with a live, gravid ovary without changing the organ in any way.

Observations on *Cymatogaster aggregata* indicating that the young are all born tail first suggest that the forward-facing attitude in the ovary lends either a mechanical or some other advantage to the embryo at birth. Because embryos are born facing both directions in *Hypsurus caryi* (the majority faces anteriorly) it appears that there is little or no advantage to either orientation in this species.

Prenatal Mortality

In this study only the late larval stages, approximately 11 mm (0.4 inch) SL through parturition, were studied. Due to this limitation, only mortality associated with the final two-thirds of gestation was observed. Turner (1938) found in *Cymatogaster aggregata* that, of the number of eggs hatched into the intra-ovarian cavity, 75% failed to reach maturity. In this study, a much lower mortality of 11% was noted, indicating either that prenatal mortality is higher in *Cymatogaster* than *Hypsurus* or that prenatal mortality is highest early in development for members of the family.

Turner (1933) has made the only explanation for high intra-ovarian mortality in Embiotocidae. He reported that in *C. aggregata* competition among the embryos for an inadequate supply of nutrients would eliminate the weaker ones by starvation. This in turn would benefit the stronger ones by making available to them an increased proportion of the supply of nutrients plus the tissues of the decaying embryos.

Intra-ovarian mortality, however, is probably determined by a number of factors, yet to be discovered, whose combined effects establish the low fecundity and allow for the long-term retention of embryos during development. This long period of protection presumably provides for high survival of relatively few young born in a very mature state and soon to reproduce for themelves, thereby preventing wide fluctuations in population numbers.

The tendency for premature birth of embryos late in the season by *Amphistichus argenteus* (Carlisle *et al.* 1960) and *Phanerodon furcatus* (Banerjee 1971) was also observed in this study. This phenomenon, however is not natural because, to my knowledge, it occurs only during collecting when specimens are stressed by harsh handling.

Fecundity measurements will differ with the development at time of collection and care taken during handling. Researchers who begin collecting embryos in early stages will find higher fecundity figures than those collecting later. Considering Turner's mortality figure of 75%, one sees that collection time means substantial differences in the number of young per individual. Future fecundity studies will have to be standardized for comparison.

Prenatal Gas Exchange

In the embiotocid embryo the dermal flaps on the margins of the highly elevated median fins are certainly a specialized tissue because of their profuse vascularization and temporary existence. The fins reach their most exaggerated height at a time when the body becomes covered with scales, thus augmenting the absorptive surface of the body of the embryo as reported by Eigenmann (1894). This too, is evidence that the dermal flaps are extremely important in prenatal respiration. The re-establishment of the normal height of the median fins at birth was first reported by Girard (1855) and then Eigenmann (1894). The mechanism for the reduction of the fin height, however, has not been described.

Embryonic respiration by direct dialysis as reported by Eigenmann (1894) and since accepted by most embiotocid researchers is not supported by my findings. Nowhere in the ovary is there tissue morphologically comparable to that of the dermal flaps. It would appear, therefore, that the internal surface does not provide for direct exchange as a pseudoplacenta, but that the primary activity of the ovary directed toward the development of the embryo is secretory.

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ABUNDANCE OF THE "RARE" ZOARCID, *MAYNEA CALIFORNICA* GILBERT, 1915, IN THE MONTEREY CANYON, MONTEREY BAY, CALIFORNIA[1]

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ABSTRACT

The capture of over 1,200 specimens of *Maynea californica* (family Zoarcidae) from the Monterey Submarine Canyon indicates that this species is not rare, but lives in a unique environment that is seldom adequately sampled due to its inaccessibility. Our original capture of seven specimens was from a clump of drift kelp snagged by a gill net at the head of the canyon. In two subsequent samples using a seaweed habitat trap, 85 additional specimens were obtained. Locations and depths of capture of 18 previously known specimens are presented. Meristic characters and morphometrics are given for seven specimens and are compared with the holotype. Diagnostic characters are given to distinguish this species from the other California zoarcids. Notes on behavior, feeding habits, and parasites are presented. The ecological significance of the unique bottom drifting seaweed habitat is discussed.

INTRODUCTION

The persimmon eelpout*, *Maynea californica* Gilbert, 1915, was thought to be a "rare" fish since it has been captured fewer than 20 times and was not included by Miller and Lea (1972) in their guide to California marine fishes. Gilbert (1915) had only one specimen available (USNM 75819) from southern California for the original description of the species. Hubbs (1916) followed with measurements of five additional specimens, also from southern California. A subsequent survey of museum collections revealed that exclusive of our material only 12 other specimens of this species have been taken and recorded: one was found in the Stanford University collection (now in the California Academy of Sciences collection), nine are in the Santa Barbara Museum of Natural History, and two were collected recently by researchers at the Southern California Coastal Water Research Project (Table 1). All of these specimens were taken south of Point Conception, in deep water near submarine canyons or basins, and generally were associated with broken pieces of kelp or seaweed. On December 1, 1972, a group of students accompanying G. V. Morejohn was retrieving a large gill net set in the axis of the Monterey Submarine Canyon, and noticed that a large clump of drift eelgrass, *Phyllospadix scouleri,* was entangled in the net. Among the fronds of this eelgrass were some persimmon-colored eelpouts that were later identified as *Maynea californica.*

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* We propose persimmon eelpout as the common name for *Maynea californica,* due to its color.

TABLE 1. Capture Information for All Known Specimens of *Maynea californica* Gilbert, 1915.

Location of specimen (Catalog number)	*Collection locality (collector)*	*Latitude*	*Longitude*	*Depth captured (m)*	*Date*	*Number of individuals*	*Total lengths (mm)*
USNM[a] 75819 Holotype	San Nicolas Island (R/V Albatross)	33°18′N	119°12′W	409–545	Apr. 12, 1904	1	140
SIO[b] 64-295	LaJolla (Barnhart Material #190)	"Off La Jolla" (Hubbs, 1916)		?	?	5	69, 112, 113, 121, 128
SU[c] 22399	San Diego (San Diego Biological Association, Identified by Starks)	"San Diego, Ca." (Label notation)		?	?	1	86
SBMNH[d] 00204	Off Rincon Point	34°10′N	119°30′W	201	Aug. 17, 1967	3	41, 69, 92
00225	Off Rincon Point	34°15′N	119°30′W	73	Aug. 13, 1967	1	142
00485	Off Gaviota Point	34°24′N	120°14′W	192	June 27, 1968	1	90
00199	Off Rincon Point	34°10′N	119°30′W	201	Aug. 17, 1967	1	127
00419	Off Arroyo Burro Beach (all by P. Brophy and R. Lee)	34°19′N	119°48′W	159	Jan. 29, 1968	3	99, 122, 141
LACM[e]	7.6 mi. West of El Segundo, Ca. (S.C.C.W.R.P.)[h]	33°56′N	118°34′W	183	May 31, 1972	2	112, 148
CAS[f] 17623	Monterey Bay (MLML)	36°48′N	121°48′W	119	Dec. 1, 1972	7	36—188
MLML[g]	Monterey Bay (MLML)	36°48′N	121°48′W	119	Apr. 7 & 12, 1973	85	34—225

[a] United States National Museum
[b] Scripps Institution of Oceanography
[c] Stanford University
[d] Santa Barbara Museum of Natural History
[e] Los Angeles County Museum of Natural History
[f] California Academy of Sciences
[g] Moss Landing Marine Laboratories
[h] Southern California Coastal Water Research Project

This unexpected capture stimulated efforts to obtain additional specimens for studies of morphology and natural history. This report contains new catch records, which extend the northern limit of the range; a description of the first seven specimens caught in Monterey Bay; a summary of additional catches of *Maynea californica* during the spring of 1973; and notes on the natural history of this fish.

METHODS

Our first collection of seven specimens of *Maynea californica* was made by accidentally snagging a clump of drift eelgrass, in a 100-m (330-ft) gill net (with panels of 4- and 6-inch square mesh) set overnight in 119 m (390 ft) of water at the head of the Monterey Submarine Canyon (lat 36°48'N, long 121°48'W). The gill net was retrieved aboard the R/V *Orca* at 0600 hrs on December 1, 1972, and the specimens were transported alive to the laboratory for identification. Prior to preservation, otoliths were removed from two specimens, and the largest individual was photographed (Figure 1). Standard measurements were made on all seven specimens and counts from radiographs of four were made for comparison with published descriptions of the holotype and five other specimens collected off southern California. For dorsal and anal fin ray counts, only those rays with an interneural or interhemal were included. Similar counts were

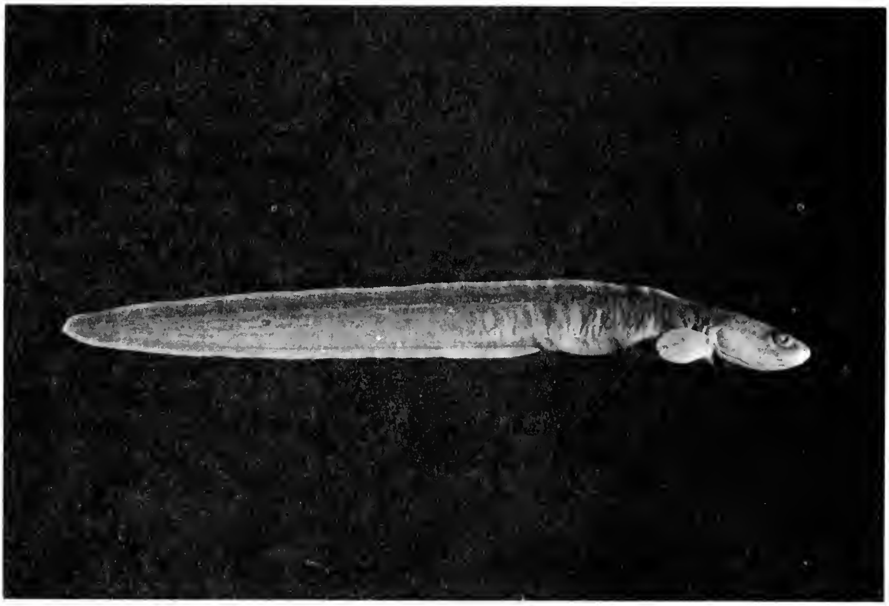

FIGURE 1. *Maynea californica* (CAS 17623, No. 7, 182 mm SL). Specimen taken December 1, 1972, in Monterey Bay, California. Photograph by Gary McDonald, October 1975.

made from a radiograph of the holotype. These seven specimens, and the otoliths removed from two of them, are deposited in the ichthyology collection of the California Academy of Sciences (CAS 17623).

Two additional collections were made using a "habitat trap" consisting of a 1.1-m (44-inch) square frame made with reinforcing rod, and hung from four bridles to a common shackle which was attached to a buoy line. A 1.8-kg (4-lb) weight was attached to each corner and ½-inch stretch mesh cotton netting was hung on all four sides to hold the kelp or seaweed "habitat" used to attract the fish. A panel of 6-inch stretch mesh nylon gill netting was attached to three sides of the frame, above the finer-meshed netting, and the fourth side of this panel was sewn to a piece of surgical tubing so that the seaweed could be placed inside the two panels of netting. This "habitat trap" was then filled with approximately 2.3 kg (5 lb) (wet weight) of *Phyllospadix scouleri* and was lowered into the canyon to the same depth and location as the original capture. The first set was at 1600 hrs on April 5, 1973, and lasted until 1800 hrs, April 7, 1973, when it was pulled aboard by hand. The second set went from 1800 hrs, April 10, to 1000 hrs, April 12, 1973, when it was retrieved using a small power winch on the R/V *Orca*.

Organisms caught in these two trap sets were sorted, identified, measured, and either preserved in 10% formalin or held in aquaria for behavioral observations. Those *Maynea* preserved were dissected later and examined for stomach contents and parasites.

RESULTS AND DISCUSSION

The seven specimens of *Maynea californica* captured in a clump of eelgrass on December 1, 1972, ranged between 36.3 and 187.6 mm (1.4 and 7.4 inches) total length (TL) (Table 2). Other species of fish collected in the gill net were *Hydrolagus colliei* (1), *Hexanchus griseus* (6), *Echinorhinus cookei* (4), and *Eptatretus stoutii* (5). All *Maynea* were captured alive and were persimmon or "light rose-red" in color (Gilbert 1915). After preservation, they became more brownish-yellow, especially in the region of the venter. The meristic and morphometric data (Table 2) are similar to those given by Gilbert (1915) for the holotype, and by Hubbs (1916) for five additional southern California specimens. Our seven specimens included several that were smaller than previously studied and there appears to be a tendency for the orbit diameter (as percent of standard length) to be larger in smaller specimens. Otherwise, variation in body proportions did not differ much with size. The ratio of head length (HL) to TL ranged from 6.4 to 7.3, which is considerably more than the value of 4.0 reported by McAllister and Rees (1964) in their key to the species of *Maynea*. However, it does appear that the number of pectoral rays (12) is consistent with their findings, and should serve to distinguish *Maynea californica* from *M. bulbiceps*. Our dorsal and anal fin ray counts were consistently less than those of Gilbert's holotype, but this is because Gilbert counted to the middle of the caudal fin, while we counted only those rays associated with pterygiophores. Counting the caudal fin rays proved extremely difficult, but they probably number 11 total. It is also possible that Gilbert missed several caudal fin rays without the aid of radiography. The otolith of *Maynea californica* is quite small, oval, with a rounded rostrum, no antirostrum, a fan-shaped depression above the sulcus which is typical of the zoarcid sagittae (J. Fitch, pers. commun.), the entire rim or margin smooth, the height approximately 70% of length, and the greatest height anterior to the midpoint (Figure 2).

TABLE 2. Morphometric and Meristic Data from the Holotype of *Maynea californica* and from Seven Additional Specimens from Monterey Bay.

	USNM 75819*								CAS 17623							
			1		*2*		*3*		*4*		*5*		*6*		*7*	
MORPHOMETRICS	*mm*	*%S.L.*	*mm*	*%S.L.*	*mm*	*%S.L.*	*mm*	*%S.L.*	*mm*	*%S.L.*	*mm*	*%S.L.*	*mm*	*%S.L.*	*mm*	*%S.L.*
Standard length	134.8		35.9		37.8		66.2		131.4		137.0		177.2		182.2	
Total length	140.0		36.3		38.3		67.6		136.0		141.1		181.0		187.6	
Head length	21.0	15.6	5.7	15.9	6.0	15.9	9.8	14.8	18.6	14.2	19.4	14.2	25.5	14.4	26.7	14.7
(SL/HL)	6.4		6.3		6.3		6.8		7.1		7.1		7.0		6.8	
(TL/HL)	6.7		6.4		6.4		6.9		7.3		7.3		7.1		7.0	
Orbit diameter	3.2	2.4	1.4	3.9	1.2	3.2	1.8	2.7	2.9	2.2	3.2	2.3	5.1	2.9	4.5	2.5
Snout length	4.9	3.6	1.4	3.9	1.3	3.4	2.2	3.3	4.3	3.3	4.2	3.1	6.5	3.7	7.2	4.0
Maxillary length	7.0	5.2	1.9	5.3	1.6	4.2	2.7	4.1	6.0	4.6	6.0	4.4	8.1	4.6	10.2	5.6
Body depth	12.6	9.3	2.6	7.2	2.4	6.4	4.5	6.8	11.0	8.4	9.4	6.9	16.0	9.0	17.1	9.4
Pectoral length	11.2	8.3	3.0	8.4	3.0	7.9	5.0	7.6	8.6	6.3	8.9	6.5	11.9	6.7	12.0	6.6
Pectoral base, width	4.2	3.1	0.9	2.5	0.8	2.1	1.2	1.8	3.6	2.7	3.5	2.6	4.3	2.4	5.9	3.2
Pre-dorsal length	25.2	18.7	6.2	17.3	5.7	15.1	11.8	17.8	22.1	16.8	23.0	16.8	35.1	19.8	36.2	19.9
Pre-anal length	50.4	37.4	13.5	37.6	13.7	36.2	23.5	35.5	47.4	36.1	51.0	37.2	65.3	36.9	66.2	36.3
MERISTICS																
Number dorsal rays	110	(108)							104		102		104		106	
Number anal rays	93	(90)			not	counted			85		84		85		88	
Number vertebrae	108								109		108		111		113	

* All values, except total length and meristic counts, have been calculated from Gilbert's (1915) published data, which are presented as percent of total length. The vertebral count was from the radiograph of the holotype. The dorsal and anal fin ray counts in parentheses were also from this radiograph and include only those rays with a pterygiophore.

Since *Maynea californica* was not included in Miller and Lea's (1972) California fish guide and now appears to be relatively abundant, it is important to note how it can be distinguished from other California zoarcids. First, *Maynea* has no pelvic fins, which distinguishes it from all but five species listed in Miller and Lea (1972). It can be distinguished from the midwater eelpout, *Melanostigma pammelas,* by its large opercular opening, since *Melanostigma* has only a small round opercular opening above the pectoral fin base. *Maynea* is different than all species of *Lycodapus* in that it has gill membranes attached broadly at the isthmus, whereas *Lycodapus* has gill membranes free from the isthmus. Finally, *Maynea* can be distinguished from both species of *Bothrocara* with which it often has been confused in the systematic literature (Bayliff 1959), since *Maynea*'s gill openings are narrower. In *Bothrocara,* the gill openings are large and therefore the gill membranes are narrowly joined at the isthmus (Hart 1973), while in *Maynea,* the distance between the lower ends of each gill slit (i.e., isthmus width) is approximately the length of the snout and less than two-thirds the length of the gill slit (Gilbert 1915). Also, *Maynea californica* has tubular nostrils and is "persimmon" in color. With these additional specimens, the known geographic range of *Maynea californica* is now from San Diego to Monterey Bay, California, and in water depths from 73 to 545 m (239 to 1787 ft); the majority taken shallower than 201 m (659 ft) (Table 1).

FIGURE 2. Right sagitta (otolith), 1.6 mm long, from *Maynea californica* (CAS 17623, No. 7, 182 mm SL). Photograph by Gary McDonald, October 1975.

Subsequent "habitat trap" sets produced even more specimens of *Maynea californica,* as well as several species of invertebrates. The April 5 set captured one *Maynea californica* and one *Octopus* sp., but was probably less successful due to the necessity of hauling it aboard by hand. The second set, on April 10, 1973, went more smoothly since a power winch was available, and resulted in the capture of 84 *Maynea californica,* three *Octopus* sp., one gastropod, *Pleurobranchaea californica,* and three bivalves, *Nuculana* sp. (all invertebrates were identified by Gary McDonald). The 84 *Maynea* captured in this last set ranged from 33.5 to 225.0 mm (1.3 to 8.9 inches) TL. The 21specimens preserved and later examined for stomach contents had been feeding primarily on amphipods. The lysianassid amphipod *Orchomene obtusa* occurred in 16 of the 21 stomachs examined and comprised 99% of all stomach contents both by number and volume. Unidentified gammarid amphipods were found in stomachs of three of these fish, but comprised a very small proportion of those stomach contents examined. Other prey items, of far lesser importance, were calanoid copepods, polychaete worms, fish eggs, and isopods.

All individuals of *Maynea* examined had heavy concentrations of acanthocephalan worms (genus *Echinorhynchus*) (R. Kliever, pers. commun.) embedded near the end of the intestine. In the 18 largest individuals examined [mean size 189 mm (7.4 inches) TL], there was an average of 38 acanthocephalan parasites per fish, with a maximum of 126 in one fish [177 mm (7.0 inches) TL]. Twelve of the 21 fish examined also had nematodes in the coelomic cavity, and one fish had a parasite copepod, *Acanthochondria cornuta* (R. Kliever, pers. commun.), attached to the gills.

Although *Maynea californica* has heretofore been considered rare, it now appears to be much more common than ever imagined. In subsequent collections from Monterey Bay, more than 1,100 individuals have been captured in only 58 habitat trap sets (Kliever 1976). However, in numerous otter trawl samples from the shelf area surrounding the canyon *Maynea californica* has never been taken (Cailliet, unpublished data). Our behavioral observations of *Maynea* in aquaria indicate that they will seek any structure available in which to "hide" rather than expose themselves. It is probably this behavior that has made our habitat trap so successful in capturing *Maynea.* The discovery of two individuals of *Maynea californica* in the Southern California Coastal Water Research Project trawl catches prompted the comment that "this species may actually occur more frequently off southern California and simply have been misidentified in the past" (Anon. 1973). From our results, however, it seems more likely that *Maynea* is generally not available to bottom trawls because it remains associated with clumps of drift kelp occurring in deep water, which, due to inaccessibility and rough terrain, is seldom trawled. The majority of the trawls in which *Maynea* was captured off Santa Barbara also had pieces of drift seaweed and kelp holdfasts in them, thus suggesting that the association of *Maynea* with drift seaweeds is consistent (R. Lee, pers. commun.).

Apparently, Monterey Bay, with its deep submarine canyon, provides an ideal habitat for a large population of *Maynea californica.* Although the coastline in the center of the bay, where the mouth of the canyon is located, has little in the way of kelp beds, there are dense stands of kelp both in the Monterey peninsula region south of the canyon and in the northern coastal area near Santa Cruz. Seaweeds must break off in these regions and be transported by currents into the head or main axis of the canyon, thus providing a supply of seaweed habitat for the *Maynea* population in the canyon. Since some seaweeds sink immediately and others float indefinitely or until they become beached and/or waterlogged, there are two means by which these drift seaweeds can reach the depths of the canyon. Evidence from southern California indicates that seaweeds do indeed break off (Rosenthal, Clarke and Dayton 1974) and could provide bottom drifting clumps of kelp in much the same way that they provide it to the beaches of San Diego County (Zobell 1971). Also, divers have observed considerable accumulations of kelp and other algae at the head of Monterey Submarine Canyon, which were swept down-canyon late in the year as a result of storm wave action (Oliver and Slattery 1973; Arnal, Dittmer and Shumaker 1973). Recently, a bottom photograph taken in the Monterey Submarine Canyon at 210 m (689 ft) by personnel from the United States Naval Postgraduate School exhibited a considerable amount of drift eelgrass partially buried in the sediment (R. Andrews, pers. commun.). In addition, Shepard and Dill (1966) have found concentrations of kelp in other submarine canyons along the Pacific coast. Off La Jolla, California, they (p. 50) proposed that "the canyon head is also a natural trap for marine plant detritus that is broken from its growth areas during periods of storm" and that "the same currents that transport the micaceous sands also carry large amounts of plant detritus into the canyon heads". Once there, they contend, "broken pieces of the giant brown algae *Macrocystis pyrifera* and *Egregia laevigata,* and the surf grass *Phyllospadix torreyi* (which) are the main constituents of the organic part of the canyon fill" become "intermixed with the sand" and build up in "large haystack-like layers". Therefore, it is not difficult to imagine the process by which bottom drift seaweeds reach the canyon and provide a habitat for *Maynea californica* in Monterey Bay.

The precise function that drift kelp serves in the natural history of *Maynea* is not known. Gooding and Magnuson (1967), in discussing the ecological significance of drifting objects to pelagic fishes, provide a list of possible functions that could equally apply to the importance of benthic drifting objects to demersal fishes. Drift seaweed could i) provide shelter from predators, ii) attract predatory fish by concentrating the food supply, iii) provide food for the fish in the seaweed itself, iv) provide a substrate upon which the fish could lay eggs, v) provide shade, vi) provide a background upon which a fish can better focus to its prey, and vii) provide a location to aid cleaner fishes. Obviously, in the case of *Maynea,* the last three functions do not apply, and the first suggestion is logically the most attractive. The real ecological function of drift kelp on the life of *Maynea californica* will require more detailed study. Gooding and Magnuson (1967) also pointed out that drift objects have three kinds of occupants: transients, visitors, and residents. The fact that *Maynea* are attracted to the new drift seaweed provided in the habitat trap indicates that they move between clumps of seaweed. Perhaps the drift seaweed, as it decomposes, becomes a less attractive environment for *Maynea* and they seek other fresher and perhaps more protective seaweed clumps. At any rate, it appears that *Maynea californica* is an abundant and true resident of the benthic drift seaweed habitat in the Monterey Submarine Canyon, and perhaps in canyons and deep basins elsewhere along the Pacific coast.

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FIRST RECORD OF MATING OF RIDLEY TURTLES IN CALIFORNIA, WITH NOTES ON COMMENSALS, CHARACTERS, AND SYSTEMATICS

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One of the several species of sea turtles that have been found to occur at times in California, currently named the Pacific ridley, *Lepidochelys olivacea* (Eschscholtz), has provided the initial record of the mating of any sea turtle in California. This mating occurred at La Jolla in August, 1973. The male, which was captured, hosted, chiefly as commensals, two remoras, a crab, sessile and stalked barnacles, parasitic copepods, and green algae. This individual displayed striking variations in the pattern of external horny plates (laminae) and bones, and in the intervening sutures, such as are often shown by the local form of *Chelonia* in the Gulf of California.

INTRODUCTION

Although several species of sea turtles (comprising the families Cheloniidae and Dermochelidae)—apparently including all of the commonly recognized genera and species other than *Eretmochelys imbricata*—are occasionally encountered along or just off the coast of California, and although one genus, *Chelonia,* appears to have taken up continuous residence in South San Diego Bay, in a channel warmed by a power-plant discharge, no record appears to have been published on the mating of any sea turtle species within or directly off the state—or farther north. It was, therefore, with keen interest that biologists of Scripps Institution of Oceanography, of the University of California, San Diego, observed in considerable detail a pair of rather large sea turtles mating, very close to shore, directly off the Institution. Inasmuch, furthermore, as details of sea-turtle mating anywhere are few, the observations are here recounted. The species that put on the show was later determined, as is indicated below, to have been the one generally called the Pacific ridley, *Lepidochelys olivacea* (Eschscholtz), which only recently has been authenticated as occurring in California.

THE MATING

The mating pair, in nuptial embrace, was first observed at about 1130 hours on 29 August 1973, by Charles J. Farwell, of the Scripps Aquarium staff, about 20 m (66 ft) shoreward from the end of the Scripps Pier, which is about 300 m (1000 ft) offshore, in the northern part of La Jolla, San Diego County, California. The pair was then at the surface, close to the pier, on the south side, moderately outside of the surf zone, and was slowly drifting directly southward parallel with the shore. The depth here was probably somewhat less than 10 m (33 ft).

At about 1245 hours, on returning to my seaside office in the Scripps Building of Scripps Institution, I was informed by my associate Robert L. Wisner that for about 5 minutes he had been watching the pair through binoculars, as the two, with much flapping of their flippers, were slowly drifting southward together, very conveniently directly off our window viewpoint, still hardly 300 m (1000 ft) distant. Very soon both of us, using binoculars, relocated the pair, still (or again) in nuptial embrace, at the surface, outside of the breakers a short distance south of the southern boundary of the University campus.

Presently three of the many swimmers in the nearby surf moved out toward the turtles, which submerged when approached. The swimmers then took turns diving, as though striving to view the turtles underwater. About 15 minutes after the swimmers had returned to the surf zone, the two turtles reappeared, in union, at the surface, but soon disappeared again.

A skiff was launched from the Scripps Pier by Mr. Farwell and marine-biology student Edward B. Brothers, to attempt the capture of one or both of the turtles, to insure a definite identification of the species. They proceeded directly to the

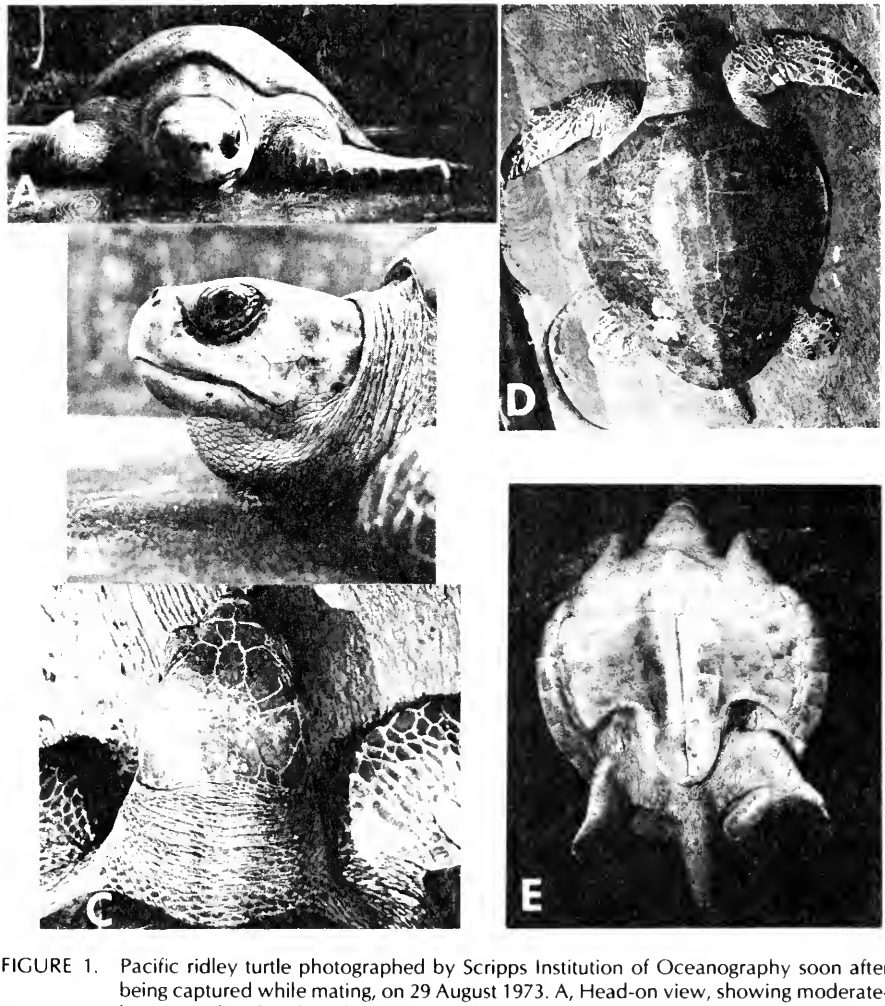

FIGURE 1. Pacific ridley turtle photographed by Scripps Institution of Oceanography soon after being captured while mating, on 29 August 1973. A, Head-on view, showing moderately massive head and moderately domed shell. B, Side view of head, showing, particularly, form of mouth and eyes. C, Top view of head, showing aberrant pattern of epidermal laminae and intervening sutures. D, Dorsal view, showing broad carapace, dully and rather evenly colored; the distinctive head size; and the 6 laterals (laminae) on each side. E, Ventral view, showing laminae, with 4 inframarginals on each side; also the strong hooks on the front flippers, by which this male firmly clasped its mate.

area where they had last seen the turtles, about one-fourth mile south of the pier. Soon, at about 1400 hours, the pair reappeared, in embrace, at the surface. Mr. Farwell noted that the male, riding atop, was then grasping the female firmly with the strong claws on the front edge of its fore flippers (Figure 1D), with the claw of each flipper attached at times to the carapace of the female; at other times the claw on one side was hooked over the carapace edge while the claw of the opposite flipper was attached onto the leading edge of the corresponding flipper of the female. As the male's flippers were thus otherwise engaged, the female had taken over swimming. She submerged out of sight at about 1410 hours, after the male had been dislodged by vigorous pulling and put into the boat.

Whether the male had clasped his mate throughout the nearly 3 hours of observation is of course not certain. Some intermissions occurred during the clasping of a pair of the loggerhead turtle, *Caretta caretta caretta,* observed for nearly 5 hours in Marineland of Florida (Wood 1953, p. 185 and plate).

ASSOCIATED ORGANISMS

At the conclusion of the observations from the skiff, the captured male (Figure 1) was promptly taken onto the Scripps Pier, where it was found to carry or conceal a considerable variety of other, more or less commensal creatures. It was then, for the first time, found that two small remoras had accompanied the turtle, unobserved. One was concealed in the pectoral axil, the other in the pelvic axil. The association of remoras with turtles was recorded by Columbus, who noted that West Indian natives used remoras, attached by line, to capture sea turtles (Gudger 1919). He perhaps dealt with the same widespread species, *Remora remora* (Linnaeus). The two specimens here reported (SIO 73–403), measuring 138 and 174 mm (5.4 and 6.9 inches) in standard length, are deposited in the Scripps Institution fish collection. One of the two, when removed onto the turtle's carapace, abruptly faded from blackish to pale blue. This species of remora, like the others, has on top of its head a spinous dorsal fin modified into a sucking disc, by which it attaches itself at will to other organisms, most commonly sharks, on which it hitches rides.

In addition to these two fish, a considerable number of invertebrates had been at home on this one turtle. One of these was a crab, which though capable of free swimming remained attached, concealed with a remora in the pectoral axil. It was kindly identified by John S. Garth, of the Allan Hancock Foundation of the University of Southern California, as an adult female of the well known pelagic species *Planes cyaneus* Dana (it is retained in the Hancock collection). Garth, by letter dated 17 September 1973, commented on the plausible significance of the association of this species of crab with sea turtles, as follows:

> Fenner Chace, whose paper "The oceanic crabs of the gunus *Planes* and *Pachygraspus*" (Proc. U. S. Nat. Mus., 101: 65–103, 1951) has this to say regarding their food (p. 77): "The only published record of the stomach contents of any of the species is that of Miss Crane (Zoologica, 22: 47–78, 1937) based on a large ovigerous female of *Planes cyaneus* taken from the tail of a green turtle. The stomach of this specimen contained finely digested animal matter. Miss Crane suggested the possibility that this food material might represent the excrement of the turtle. Some support is given to this theory by the fact that large specimens of *Planes* are commonly found around the tail and hind legs of turtles. Specimens living on other objects, however, must be able to assimilate less digested food.

Garth added another statement, that again brings Columbus into the picture:

> *Planes minutus* (Linnaeus), the western Atlantic counterpart of the eastern Pacific species, commonly occurs in *Sargassum* and is believed to have been the crab sighted by Columbus on September 17, 1492, when approaching America.

The other associated organisms were organically attached to the turtle. The numerous barnacles have been identified by Arnold Ross, the cirripedian specialist of the Natural History Museum of the San Diego Society of Natural History, as comprising two species: the sessile barnacles as *Cylindrolepis darwini* Pilsbry and the stalked barnacles as *Conchoderma virgatum* (Splengler). The sessile form was widely attached, largely to exposed parts of the head, body, and flippers, whereas most of the stalked barnacles were attached in the loose area of the pelvic axil, oddly with the normally free end embedded.

Some parasitic copepods were attached to the turtle. Two smaller ones, each with a black strand, were attached in the crease of the carapace, one on each side.

The carapace was covered incompletely with a fine, short growth of green algae (not identified). After being held in a shallow, open pond at Sea World in San Diego for some time, the turtle had become densely covered with algae.

SIZE, CHARACTERS, AND IDENTIFICATION

Promptly after its capture the male turtle (Figure 1) tipped the scales at just 50 lb (ca. 23 kg) and the broadly rounded carapace (Figure 1D) was measured with calipers as 661 mm (26.0 inches) in greatest length and 546 mm (21.5 inches) in maximum width (definitely in advance of mid-length). The female was judged to be of about the same size. The head measured about 157 mm (6.2 inches) in greatest width. These measurements, along with the only moderately arched (Figure 1A) and broadly rounded (Figure 1D) carapace are compatible with the identification of the mated turtles with the species currently called the Pacific ridley, *Lepidochelys olivacea* (Eschscholtz). The head (Figure 1) is appreciably smaller than in the loggerhead genus *Caretta,* much more massive than in the green turtle genus *Chelonia,* and vastly larger than in the hawksbill turtle genus *Eretmochelys.* The specimen has, appropriately for *Lepidochelys,* six lateral laminae (horny scutes) on each side of the carapace (Figure 1D) and four large inframarginals on the bridge of the plastron (Figure 1E), disregarding the smaller laminae adjoining the pectoral axil. There are, as in the diagnoses of *Lepidochelys,* two pairs of prefrontal laminae, though these are subject to irregularities (discussed below).

The general coloration (Figure 1D) of the male seemed definitely too dull for the loggerhead turtle, especially about the head. The color was light purplish gray, with, on the head, only a bare trace of dusky brown blotching medially. The dull color was reminiscent only of the peculiarly dark color of the common turtle of the Gulf of California, which has been named *Chelonia mydas carrinegra* by Caldwell (1962), but many other characters, internal as well as external, negate that identification, or indication of close relationship.

Reference of the turtles in question to *Lepidochelys* is based further on skeletal characters. The skeleton of the male (deposited along with the dried carapace and plastron in the San Diego Society of Natural History Museum, SDSNH 56548) agrees with the diagnostic characters emphasized by Carr (1952, p.

341–343 and figures 23–24). However, the skeletal features as well as the epidermal laminae and sutures are, as noted below, subject to much variation and gross bilateral asymmetry.

Although cheloniid systematics seems to rest on somewhat insecure basis, as far as species and races are concerned, the genera appear to be rather firmly established, despite the variability mentioned below. However, allocation of the mated specimen under discussion to *Lepidochelys* seems secure, but the reference of the species to *olivacea* (Eschscholtz), is merely inferential.

Lepidochelys olivacea has been recorded from California, for instance by Houck and Joseph (1958) from Mendocino County, on the basis of a stranded specimen indicated as representing a northward extension of range of about 800 miles (1300 km); and by Morejohn (1969), from Monterey Bay, on the basis of a photograph of a living individual (identification indicated as having been confirmed by Archie Carr, Victor B. Scheffer, and Clifford Fiscus). Other material that I have accumulated, from the San Diego area and elsewhere, and have identified as of this species, has now been deposited in the San Diego Natural History Museum (some of the specimens, especially of juveniles, may need reidentification).

REMARKS ON VARIATION IN *LEPIDOCHELYS* AND *CHELONIA*

The breeding male recently taken in La Jolla illustrates the vast variation that may exist, even in one individual, in the epidermal horny laminae, in the intervening sutures, and in the underlying skeletal elements. For example, some peculiarities, including bilateral asymmetries, may be noted in the laminae of the head (Figure 1C): the posterior left prefrontal is almost entirely divided, along an oblique line, into two plates, whereas the two right prefrontals are not completely separated to the median longitudinal suture. Various other irregularities and asymmetries are evident in the interocular, postocular, and nuchal regions.

Even more striking are the gross irregularities, including bilateral asymmetries, seen in the skeletal preparation of the same specimen.

Considerable variation in the pattern of the laminae was noted by Caldwell (1962) in describing, on the basis of the observation of large numbers of adult specimens, the peculiar high-domed, uniformly dark, form of *Chelonia* in the Gulf of California, under the odd new name, *Chelonia mydas carrinegra*. Soon before he made this study I had conducted detailed variational studies of laminal variation at the same locale (Bahía de los Angeles, Baja California), also utilizing large numbers of this peculiar race, in holding pits. I was amazed at the tremendous variation shown by the large series examined in the flesh, of this peculiar form of *Chelonia*. Perhaps it is unusually variable.

In describing "*Chelonia mydas carrinegra*" Caldwell rather briefly referred to *Chelonia agassizii* Bocourt, which was described from the Pacific coast of Central America and has been treated as a regional subspecies of *Chelonia mydas* by Carr (1952, p. 357) and others. I have examined the excellent plate of the type of *C. agassizii* and have studied a number of adult specimens from the eastern tropical Pacific, especially at the Galápagos, without, so far, coming to any clear result other than confusion. I can aver, however, that the Gulf of California form, largely I believe endemic, is not matched by the consistently flatter and more colorful green turtles that I have seen in Hawaii, Japan, Australia, southeastern Africa, Curaçao, etc.

Obviously there is much yet to be learned about sea turtles!

ACKNOWLEDGMENTS

For sharing their observations of the sea-turtle mating herein described, I am very grateful to staff members and students, including Robert L. Wisner, Edward B. Brothers, and, particularly, Charles J. Farwell. For the identification and interpretation of the commensal organisms found on the captured male, I am deeply grateful to John S. Garth, of the Allan Hancock Foundation of the University of Southern California (on the pelagic crab), and to Arnold Ross of the Museum of the San Diego Society of Natural History (on the barnacles). Sea World of San Diego maintained the male for some time and donated it to the San Diego Natural History Museum, where it was nicely processed by Curator of Herpetology Thomas H. Fritts, who has made the specimen available and has helpfully advised me in the preparation of this report. The staff of the Scripps Institution Photography Laboratory cooperated by taking picutres and in processing the negatives for the figure. Elizabeth Noble Shor has helped to put the manuscript into shape for publication, and my wife Laura Clark Hubbs has been, as usual, of patient help during this sojourn into another field. I thank David K. Caldwell for reviewing the manuscript and offering a helpful suggestion.

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NOTES

ACANTHOCEPHALAN PARASITES OF THE SEA OTTER, *ENHYDRA LUTRIS*, OFF COASTAL CALIFORNIA

A recent survey of parasitism in marine mammals (Dailey and Brownell 1971) reviewed the important literature concerning helminth parasites of the sea otter. These studies as well as the recent work of Margolis and Dailey (1972) are concerned with parasites of the sea otter off Alaska, the Aleutian archipelago, and islands of the Bering Sea. The present paper provides the first comprehensive study of acanthocephalan parasites of the sea otter off coastal California.

MATERIALS AND METHODS

Most dead or moribund sea otters recovered by coastal residents and Department of Fish and Game personnel from the central California coast between Santa Cruz and Morro Bay have been necropsied over several years (Morejohn, et al. 1975). The gastrointestinal tracts of 80 of these sea otters were examined for parasites.

Each tract was placed in a large dissecting tray and flooded with running water. The stomach and intestines were opened, washed, and carefully examined for acanthocephalan parasites.

Acanthocephalans attached to the intestinal mucosa were gently excised, placed in freshwater, washed, and relaxed. Unattached acanthocephalans found floating in intestinal fluids also were collected, washed, and preserved in 70% alcohol.

The acanthocephalans were processed by a modification of the methods described by Van Cleave (1953), Olson and Pratt (1971), and Olson (pers. commun.), then removed from the preservation fluid and stained in a solution of 70% ethanol and Semicohn's acetocarmine stain, dehydrated in an ethanol series and cleared by slow addition of xylene to a small amount of 100% ethanol. Uncatalyzed Ward's Bio-Plastic synthetic resin was added to the clearing solution until nearly 100% synthetic resin was reached. The resin saturated specimens were mounted then in thin sections of the catalyzed synthetic resin.

These specimens were passed through several dilutions of ethanol to distilled water and then placed in a warm solution of 0.5% trisodium phosphate (Van Cleave 1953) until the worms became plump and pliable. The specimens then were transferred to distilled water with repeated changes to ensure complete removal of the trisodium phosphate. The restored specimens then were passed through the dehydration series to 70% ethanol.

RESULTS AND DISCUSSION

Parasite Description

The sea otter was found to be infected with *Corynosoma enhydri* as described by Morosov (1940) and Neiland (1962). Neiland considered the Alaska sea otter the definitive host for *C. enhydri*, and there is no published evidence of this parasite occurring in its adult form in any other mammalian host.

The *C. enhydri* of the sea otter off California appears to be identical to the *C. enhydri* of the sea otter of the Alaska region except for smaller size. The length of the worms from Alaska sea otters ranged from 18.5 to 26.0 mm (0.7 to 1.0 inch) for females compared to the range of 16.5 to 28.0 mm (0.6 to 1.1 inches) for the female worms from California sea otters. The length of the male parasite from the Alaska sea otters ranged from 12.5 to 17.0 mm (0.5 to 0.7 inch) as compared to the 9.0 to 18.5 mm (0.4 to 0.7 inch) range for the male worms from California sea otters.

The most common species of *Polymorphus* observed parasitizing the California sea otter was *P. kenti* Van Cleave, 1947. This species was first found in the intestines of the Herring gull, *Larus argentatus,* collected at Kent Island in the eastern north Atlantic Ocean off New Brunswick, Canada. The occurrence of *P. kenti* in the sea otter is a new host and distributional record.

Polymorphus major Lundstrom, 1942 was the smallest species found infecting California sea otters. All were immature and thus sexes were indistinguishable. This species was described from the sea duck *Clangula clangula* in Sweden. The appearance of this acanthocephalan in the California sea otter also represents a new host and distributional record.

Polymorphus altmani was observed from a single sea otter only. This parasite was described originally by Perry (1942) from surf scoters, *Melanitta perspicillata,* and white-winged scoters, *M. deglandi,* found on Carmel Beach, Monterey County, California. The sex of the *P. altmani* specimens infecting the sea otter was indistinguishable due to immaturity. The occurrence of *P. altmani* in the sea otter represents a new host record. The one otter infected with this parasite had six specimens in its intestinal tract.

Parasite Infection Rate

Twenty-nine of 30 (97%) immature and adult female otters surveyed were infected by *Corynosoma enhydri* while 30 of 37 (81%) immature and adult male otters were infected with this parasite. Four of seven (57%) female pup sea otters were infected and 1 of 6 (17%) male pup sea otters contained this worm.

The number of *C. enhdri* found in immature and adult female sea otters ranged from 0 to 4,864 parasites per sea otter. The immature and adult male sea otter parasite load ranged from 0 to 4,972 worms per sea otter. The average *C. enhydri* load of the female sea otter (exclusive of pups) was 638 worms per sea otter while the parasite load of the same age grouping of male sea otters was five. A monthly tabulation of the number of parasites recorded for a 5-year period (Table 1) revealed no definite monthly trend in parasitism of the sea otter. However, it is clear that the heaviest parasite loads were found January to May. This may only reflect larger sample sizes during those months, but it may also indicate seasonality of infection based on availability of the intermediate host at a previous time.

Polymorphus kenti was the most common worm of this genus in both occurrence and rate of infection. Four sea otters (2 males, 2 females) had *P. kenti* infections with infection rates of 3, 6, 8, and 206 worms per otter.

P. major was the next most common species occurring in three male otters with infection rates of 2, 2, and 6 worms per sea otter. *P. altmani* was the least common member of this genus observed in only one sea otter (six specimens).

TABLE 1. Monthly *Corynosoma enhydri* numbers from sea otter intestinses over a 5-year period.*

	Months										
	January	*February*	*March*	*April*	*May*	*June*	*July*	*August*	*September*	*October*	*December*
	3397m	481m	3179f	3433f	3315f	225fp	105f	150f	0fp	511f	200f
	6m	0fp	200m	75m	50f	100m	2m	2f	1m	43f	57m
	24f	88f	34m	40f	4864f	25m	672m	30f	0f	—	211f
	202f	6m	472m	10m	144f	85f	0m	150f	0m	—	23f
	34m	10m	32f	4972m	0fp	0m	810f	0m	—	—	92f
	12m	33m	30f	47m	0m	2m	0m	25m	—	—	—
	58m	30fp	55fp	0mp	16m	—	—	0m	—	—	—
	7mp	54f	0mp	147f	—	—	—	—	—	—	—
	512f	0mp	0mp	0mp	—	—	—	—	—	—	—
	30m	0mp	—	60f	—	—	—	—	—	—	—
	210f	21m	—	117f	—	—	—	—	—	—	—
	—	—	—	5f	—	—	—	—	—	—	—
	—	—	—	0m	—	—	—	—	—	—	—
Month sum	4492	723	4002	8906	8371	437	1589	357	1	554	583
Otter sum	11	11	9	13	7	6	6	7	4	2	5
Mean load	408.4	65.7	444.6	685.1	1195.8	72.8	264.8	51.0	—	227.0	116.6

* Each number represents an individual sea otter. Letter following numbers indicates the following: *m*, male; *f*, female; *p*, pup. Note that no sea otters were examined for parasites for the month of November.

Significance of Otter Parasitism

In general, Rausch (1953) found *C. enhydri* to have little effect on the otter. Other species, however, have deleterious effects on their hosts.

Petrochenko (1956) considered in detail the pathological, anatomical, and histological changes in the intestines of ducks caused by infection of *Filicollis anatis,* an acanthocephalan closely related to those observed in this study. He found that *F. anatis* completely penetrated the intestine of the ducks and concluded that most of the pathological effects were caused by the penetration of the parasite into the intestinal wall, resulting in ulcers and necrosis with eventual perforation of the wall. Disruption of intestinal innervation as well as secretory and motor function thus resulted. Additionally, toxic compounds were found secreted by the parasite at the height of the infection. Petrochenko (loc. cit.), therefore concluded that *Filicollis* had a definite pathological effect on the duck and suggested a strong invasion of this parasite would cause death to the host.

In our study *Corynosoma* was removed easily from the intestinal mucosa where it penetrated only slightly. Ulcerative lesions were observed in the intestinal walls of some otters.

The harm caused to the total sea otter population by *Polymorphus* would probably be small due to their rare occurrence, but individual sea otters infected by the worm may be seriously affected. The *Polymorphus* species attach securely to the intestine with their large, bulbous proboscis deeply embedded in the intestinal wall. The one otter infected with 206 *P. kenti* had a necrotic ulceration which had perforated the intestinal wall with many *P. kenti* attached. This heavy infection may have contributed to the eventual death of this sea otter.

Suspected Intermediate Hosts

Reish (1950) recorded *P. kenti* at Coos Bay, Oregon, in the western gull, *Larus occidentalis,* and the glaucous gull, *L. glaucescens.* He then examined the sand crab, *Emerita analoga,* at Coos Bay and found juvenile acanthocephalans free in the mid-gut near the digestive gland. A number of these juvenile forms were fed to laboratory rats which, after 25 days, were found to be infected with immature *P. Kenti.* The length of these immature forms was from 10 to 15 mm (0.4 to 0.6 inch).

A survey was then made by Reish (loc. cit.) of 109 *E. analoga* collected at Coos Bay. Of this total, 94 were infected with a range of infection from 1 to 17 parasites per crab.

The habitat of the sand crab, the intermediate host, is the intertidal sand of beaches. The probable life cycle of *P. kenti* as described by Reish (loc. cit.) is as follows: the eggs of the parasite are passed in the feces of the gull; the filter-feeding sand crabs pick up the eggs and act as the intermediate host; the gull becomes infected by eating the infected sand crab. However, Reish found no remains of the sand crab in nine gulls examined post mortem.

In a study of food habits based on gastrointestinal contents of *California sea otters,* we found both anomuran sand crabs, *Emerita* and *Blepharipoda,* to be eaten by sea otters (Morejohn and Hennessy 1977). We have also observed surf scoters, *M. perspicillata,* to feed along sandy beaches on *E. analoga* and have collected scoters to verify sand crab consumption by stomach content analysis.

California sea otters, therefore, may become infected with acanthella larvae of *P. kenti* and *P. altmani* by consumption of *Emerita* or perhaps *Blepharipoda.* As evidence of the role as intermediate host of *Emerita,* acathella larvae were recently found in *Emerita* off coastal California (Eric Hochberg, pers. commun.). *P. altmani* probably also has an intermediate host in a related crustacean.

The study of Reish (1950) clearly showed that *P. kenti* has a low definitive host specificity as indicated by infection of laboratory rats with acanthellae from *E. analoga*. We are of the opinion, therefore, that *Enhydra* may become the definitive host of *P. kenti* (or related species) by ingestion of infected intermediate hosts such as *E. analoga*.

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We gratefully acknowledge the assistance provided by several individuals during this study. Paul Wild and Jack Ames of the California Department of Fish and Game kindly provided the sea otter materials for study. Gerald Schmidt verified our acanthocephalan identifications and provided useful comments on the study. This investigation was funded in part by NOAA, Office of Sea Grant, Department of Commerce, under Grant # NOAA-04-5-158-20.

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—Scott L. Hennessy and G. Victor Morejohn, Moss Landing Marine Laboratories, P. O. Box 223, Moss Landing, California 95039. *Accepted March 1977.*

NOTES ON SHARK SPECIES IN NEARSHORE WATERS NEAR POINT CONCEPTION, CALIFORNIA

Ongoing quarterly biological surveys of the marine biota associated with a kelp bed near Point Conception have yielded data on local shark species inhabiting waters less than 18-m (60-ft) deep. Since September 1974, monofilament-multimesh and nylon twine singlemesh surface and bottom gill nets have been deployed at three distinct depths: 7.6 m (25 ft), 12.1 m (40 ft), and 16.7 m (55 ft) near Cojo Anchorage, approximately 5 nautical miles southeast of Point Conception (Figure 1). Each "set" was 12-hr duration and each station was sampled for 2 days (~4 sets/station) every 3 months. Mesh sizes were 1.3 to 6.5 cm (0.5 to 2.5 inches) in 1.3-cm (0.5-inch increments). Each net was 24.2-m (80-ft) long and 2.4-m (8-ft deep). One surface and one bottom net were deployed simultaneously at each station.

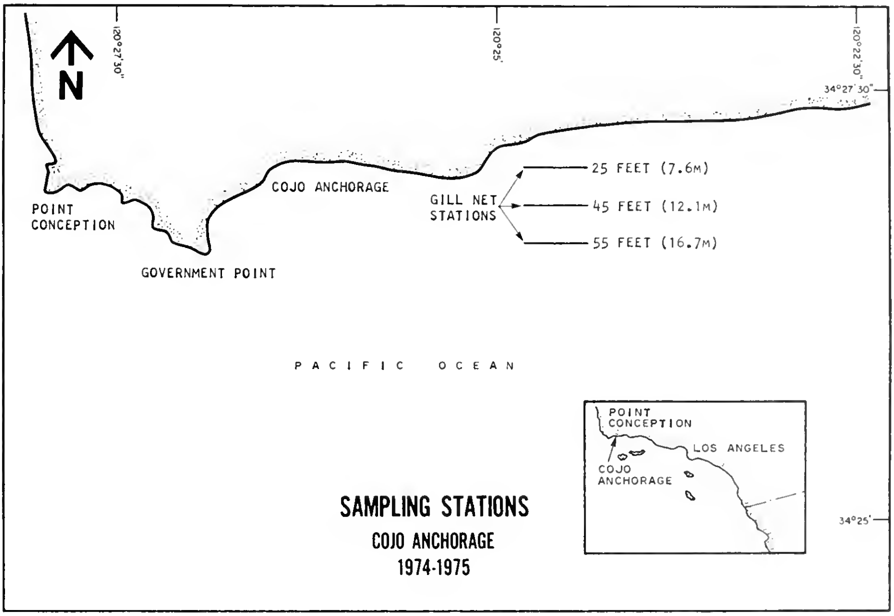

FIGURE 1. Sampling Stations, Cojo Anchorage—1974–1975

This discussion is based on 1-year's data. Continuing studies in the Cojo Anchorage area may well yield additional data, therefore, no conclusions will be drawn from this interim data synopsis. Only five shark species have been collected thus far. In order of overall abundance, they are: (i) *Squalus acanthias,* (ii) *Cephaloscyllium ventriosum,* (iii) *Galeorhinus zyopterus,* (iv) *Triakis semifasciata,* and (v) *Squatina californica.*

The data indicate that spiny dogfish, *S. acanthias,* is present in varying numbers throughout the year (Table 1). Except in December 1974 and March 1975, females were more abundant than males. In June 1974, females outnumbered males 8.6 to 1, and in September, 5.3 to 1. Females were consistently larger than males with a mean total length of 94.4 cm (37.2 inches) compared to 79 cm (31.1 inches) for males, and were taken in varying numbers during every survey.

Swell sharks, *Cephaloscyllium ventriosum,* the second most abundant species were most prevalent in the summer (June and September) collections. Males outnumbered females 2.3 to 1 and were consistently larger, with a mean total length of 64.2 cm (25.3 inches) compared to 52.2 cm (20.6 inches) for females. This species was most abundant at the 12.1-m (40-ft station), which is at the outer extent of the *Macrocystis* kelp.

The Soupfin shark, *Galeorhinus zyopterus,* constituting only 6.8% of the total years catch, contributed the largest individuals; two 170-cm (66.9-inch) males. Males and females were about equal in number, however, males were consistently larger with a mean total length of 102.8 cm (40.5 inches) compared to 87.3 cm (34.4 inches) for females.

Leopard sharks, *Triakis semifasciata,* were never numerous and females were more abundant than males. Mean total length for females was 85.7 cm (33.7 inches) and males 68.8 cm (27.1 inches).

Only two angel sharks, *Squatina californica,* were collected: 105-cm (41.3 inch) male and a 109-cm (42.9-inch) female. Both were collected at the 12.1-m (40-ft) station.

Diver observations along the same depth transects indicate angel sharks were more abundant than the gill net data show as they have been observed throughout the area in groups of two to four at depths of 7.6 to 37.4 m (25 to 95 ft).

Swell sharks, predominantly a nocturnal species, have been observed clustered under rocks during daylight dives from 4.5 to 27.3 m (15 to 90 ft).

No soupfin or spiny dogfish sharks have been observed during the 100 dives completed thus far in this study region.

Blue sharks, *Prionace glauca,* observed in the water further offshore have not been collected in the gill nets or observed in the nearshore waters.

—*Leray A. DeWit, Dames and Moore, 1100 Glendon Ave., Los Angeles, CA. 90024* *Accepted October 1976.*

HARVEST, SURVIVAL, AND WEIGHT RETURNS OF TAGGED EAGLE LAKE AND COLEMAN RAINBOW TROUT STOCKED IN LAKE BERRYESSA IN 1972

Annual stocking of catchable-sized rainbow trout *(Salmo gairdneri)* is an established management practice in California's low and mid-elevation reservoirs that possess threadfin shad *(Dorosoma petenense)* and are limnologically suited for salmonids. Rawstron (1972, 1973, 1977) has shown that domesticated Coleman rainbow trout consistently produced higher weight returned to weight planted ratios than Whitney and Shasta strains, two other domesticated stocks, and was more economical to use in the creation of this type of fishery.

In 1972, 5,000 Eagle Lake trout *(Salmo gairdneri aquilarum)* became available to compare with Coleman rainbow. Trailer tags (modified Carlin) (Nicola and Cordone 1969) offering a $5 reward were placed on 400 Eagle Lake trout and 500 Coleman rainbow and stocked in Lake Berryessa in May. The remaining

TABLE 1. Relative Abundance of Sharks in the Cojo Anchorage Area.

	September 1974	*December 1974*	*March 1975*	*June 1975*	*September 1975*	*Total No.*
Squalus acanthias						
Males	0	5 (80.8)	3 (53.6)	8 (85.8)	10 (80.3)	26 (79.0)
Females	3 (93.3) *	2 (98.0)	1 (40.0)	69 (95.7)	53 (93.6)	128 (94.4)
						154 (47.5) **
Cephaloscyllium ventriosum						
Males	26 (63.5)	0	3 (53.6)	36 (65.4)	29 (64.4)	94 (64.2)
Females	15 (54.6)	0	1 (40.0)	13 (58.5)	12 (55.8)	41 (55.8)
						135 (41.7)
Galeorhinus zyopterus						
Males	0	2 (170)	0	0	10 (89.4)	12 (102.8)
Females	0	1 (157)	0	0	9 (79.5)	10 (87.3)
						22 (6.8)
Triakis semifasciata						
Males	1 (67.0)	0	0	3 (70.6)	0	4 (69.5)
Females	2 (77.0)	0	0	5 (91.2)	0	7 (85.7)
						11 (3.4)
Squatina californica						
Males	0	0	0	0	1 (105)	1 (105)
Females	0	0	0	0	1 (109)	1 (109)
						2 (0.6)
TOTAL						324 (100)

* Mean Total Length (TL) in centimeters.
** Percentage of total catch (1 year).

TABLE 2. Tag Returns, Exploitation and Survival Rates, Weight Returns, and Mean Weight at Capture of Coleman and Eagle Lake Rainbow Trout, 1972–1976, Lake Berryessa, California

Rainbow trout strain	*Number tagged*	*Number returned*	*Total harvest (%)*	*Mean annual exploitation (weighted)*	*Mean annual survival (weighted)*	*% Weight returned/ Weight planted*	*Mean weight at capture (kg)*
Coleman	500	163	32.6	0.25	0.28	127	0.55
Eagle Lake	399	171	42.9	0.31	0.32	190	0.60
Total	899	334					

Eagle Lake trout and 20,000 Coleman rainbow were marked with distinctive fin clips for future identification in growth studies. This note compares harvest and survival rates and the weight returned of these tagged fish from 1972 to 1976.

TABLE 1. Tag Returns by Strain, Month, and Year for Coleman and Eagle Lake Trout Planted in Lake Berryessa in 1972

	Coleman				*Eagle Lake*			
Period	*1972–73 Year 1*	*1973–74 Year 2*	*1974–75 Year 3*	*1975–76 Year 4*	*1972–73 Year 1*	*1973–74 Year 2*	*1974–75 Year 3*	*1975–76 Year 4*
May	18	1	1	0	10	0	1	0
June	18	0	0	0	9	0	0	0
July	11	3	0	0	5	2	1	0
August	1	1	0	0	7	1	0	0
September	0	1	0	0	1	2	0	0
October	27	12	0	0	15	17	1	1
November	33	14	0	0	42	14	1	0
December	1	12	0	0	8	12	1	0
January	3	0	0	0	9	0	0	0
February	3	0	0	0	5	1	0	0
March	1	0	0	0	1	0	0	0
April	2	0	0	0	4	0	0	0
Total	118	44	1	0	116	49	5	1

A creel survey on three weekends in October 1972 revealed similar growth for both trout strains after 6 months in the lake. Mean weight of 26 Eagle Lake trout was 0.43 kg (0.94 lb) ± 0.06 kg (0.13 lb) and 106 Coleman rainbow averaged 0.39 kg (0.87 lb) ± 0.05 kg (0.11 lb). No subsequent growth information was obtained. Since no significant differences ($\alpha = 0.05$) between strains existed at that time and growth rates closely paralleled those from my previous studies, a growth curve developed for my 1977 report was used to assign mean monthly weights. These weights, multiplied by the number of tags returned in a month for each strain and then summed, provided estimates of the relative total weight of tagged trout landed.

Anglers landed 190% of the originally planted weight of Eagle Lake trout and 127% of the Coleman rainbow (Table 2). Similarly, Eagle Lake trout returned at a significantly higher mean weight (0.60 kg or 1.33 lb) than Coleman trout (0.55 kg or 1.22 lb).

Since Coleman rainbow had shown a clear superiority over two other strains in my other studies and Eagle Lake trout outperformed Coleman trout in this trial, Eagle Lake trout should also rank high in experimental management plans for lakes similar to Lake Berryessa.

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—Robert R. Rawstron, Inland Fisheries, California Department of Fish and Game, 987 Jedsmith Dr., Sacramento, CA. 95819. Accepted December 1976.

A RANGE EXTENSION FOR MISSISSIPPI SILVERSIDES IN CALIFORNIA

Mississippi silversides (*Menidia audens*) were first introduced into California in the fall of 1967 (Cook and Moore 1970). The introduction, associated with the biological control of the Clear Lake "gnat", occurred in Clear Lake and in Upper and Lower Blue lakes in Lake County. Moyle, Fisher, and Li (1974) report a range extension to Putah and Cache creeks in Yolo County and further introductions into eight reservoirs in Alameda and Santa Clara counties.

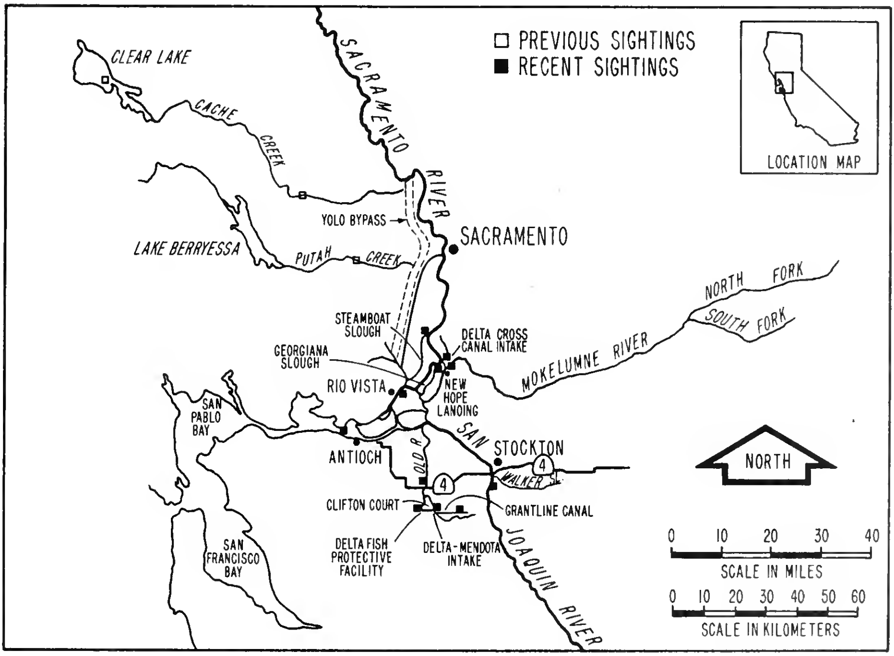

Figure 1. Locations of recent and previous sightings of Mississippi silversides, *Menidia audens,* in California.

On December 10, 1975, a Mississippi silversides 77 mm (3.0 inches) fork length (FL) was taken at the Delta Fish Protective Facility near Byron on the California Aqueduct (Figure 1). Other specimens were caught there; 2 in January, 3 in February, and 11 in March 1976.

On April 21, 1976, one female Mississippi silversides 94 mm (3.7 inches) FL was taken in a beach seine on Old River opposite the Central Valley Project's Delta-Mendota Canal intake. Dissection revealed ovaries in an early development stage.

In July and August 1976, numerous young-of-the-year silversides were beach seined throughout the Sacramento-San Joaquin River Delta (Figure 1). In the San Joaquin region of the Delta, silversides were caught near Walker Slough, in Grantline Canal, in Old River at the Highway 4 crossing, and at Antioch. On the Sacramento River side of the Delta, silversides were found in Steamboat Slough, the Delta Cross Canal, Georgiana Slough, and at Rio Vista. Silversides were also captured in the Mokelumne River at New Hope Landing.

The number of silversides per seine haul varied from zero to 2,500. On July 27, approximately 2,500 young-of-the-year silversides were collected in one haul from Grantline Canal. These fish ranged in size from 23 to 58 mm (0.9 to 2.3 inches) FL and averaged 40.5 mm (1.6 inches). More young-of-the-year were collected during August 1976 at the Tracy Fish Collection Facility of the Central Valley Project.

The occurrence of a sexually developing female in Old River during April 1976 and the collection of numerous young-of-the-year in the Delta in July and August 1976 indicate Mississippi silversides are reproducing within the Sacramento-San Joaquin Delta.

Appearance of these species on fish screens at both the California Aqueduct and the Delta-Mendota Canal suggests a future range extension to San Joaquin Valley waters and southern California reservoirs.

ACKNOWLEDGEMENTS

Thomas Macy and Thomas Scoville did much of the collecting described by this paper. Frank Fisher of the California Department of Fish and Game provided valuable assistance in examining the first specimens described in this paper. Nanci Dong drew the accompanying map. To them, we give our gratitude.

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Moyle, Peter B., Frank W. Fisher, and H. W. Li. 1974. Mississippi silversides and logperch in the Sacramento-San Joaquin River system. Calif. Fish Game, 60(3): 144–149.

—Mike Meinz and W. Lee Mecum, California Department of Fish and Game, 4001 North Wilson Way, Stockton, California 95205. Mr. Meinz's present address is California Department of Fish and Game, 1001 Jedsmith Drive, Sacramento, California 95819. *Accepted October 1976.*

FIRST RECORD OF THE STRIPED MULLET (*MUGIL CEPHALUS*) IN THE SACRAMENTO-SAN JOAQUIN DELTA OF CALIFORNIA

On February 11, 1977 a striped mullet, *Mugil cephalus* (Linnaeus), 26 mm (1.02 inch) SL, 32 mm (1.26 inch) TL, was collected at the State's Delta Fish Protective Facility near Byron, Contra Costa County, California.

This Facility is located at the head of the California Aqueduct and diverts water from the Sacramento-San Joaquin Estuary via Old River. *M. cephalus* have been observed as far north as Monterey Bay (Miller and Lea 1972), but this is the first record of occurrence in the Sacramento-San Joaquin Delta.

The specimen was identified and submitted to W. I. Follett, California Academy of Sciences, San Francisco, who confirmed it as *Mugil cephalus* (Linnaeus). The following data are taken from a radiograph of the specimen: Fin ray count, D IV-I,8; A III,8; principal caudal rays (branched rays + one above and one below), 7+7; Midlateral scale count, 39; Vertebral count, 11+13=24.

The specimen was deposited at the California Academy of Sciences, Department of Ichthyology (Catalog Number CAS 38891).

Chuck Brock, a Fish and Wildlife Assistant at the Delta Fish Protective Facility, deserves special commendation for his alertness in recognizing and saving this specimen. The author also wishes to thank W. I. Follett for the radiograph, his help in confirming the identification, and reviewing the manuscript.

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—Brian D. Quelvog, California Department of Fish and Game, 4001 N. Wilson Way, Stockton, California 95205. *Accepted April 1977.*

BOOK REVIEWS

Coastal Fishes of Southern Japan.

By Hajime Masuda, Chuichi Araga, and Tetsuo Yoshino; Tokai University Press, Tokyo, 1975; 379 pp., $60.00.

This is an important book for anyone interested in the systematics or biology of Western Pacific marine fishes. The geographic limits include the Pacific coast of Honshu Island south of Sagami Bay, Shikoku and Kyushu Islands, the Isu and Bonin groups, and the chain of Ryukyu Islands. The depth limit is not stated, but judging from the species covered, extends to about 200 m.

About half of the book comprises color photographs of fresh specimens of 1,252 species of fishes (151 species are indicated as new records for Japan). The species included in this book were apparently determined by what could be collected and photographed while still fresh by the authors. There are no keys or lists of related Japanese species. The text generally consists of very brief diagnostic notes and the distribution for each species. Various remarks on the biology, ecology, color, morphs, and frequency of occurrence are also included for many species.

In addition to descriptions of six new species (*Bodianus masudai, B. izuensis, Trimma caudomaculata, Etelis nudimaxillaris, Odontanthias flagris,* and *Pikea rubre*) and one new subspecies (*Doryrhamphus melanopleura japonica*), a remarkable new myctophiform family, genus, and species (Pseudotrichonotidae, *Pseudotrichonotus altivelis*) is described. The authors (Yoshino and Araga) promise another paper "soon" discussing the osteology and systematic position of *P. altivelis.* This interesting species is described from four specimens, 6–9 cm SL, collected in 30 m, off the Izu Peninsula. The absence of an adipose fin, six branchiostegal rays, seven ventral fin rays, 17 principal caudal rays, and 33 dorsal fin rays are among the several features that distinguish this new family from other myctophiform fishes.

Some 42 fishes are identified only to genus, and in the text accounts for these illustrations various reasons for omitting the species names are given.

The accuracy of the identifications in this book seems pretty good and reflects not only the ichthyological competence of the authors, but also the wide range of other ichthyologists they consulted. A few of the misidentifications are corrected in a loose-leaf list of errata supplied with the book. In addition, prospective purchasers of this book may wish to note the following corrections: The fish identified as *Dipterygonotus leucogrammicus* is certainly not that species, which incidentally is a junior synonym of *D. balteatus* (Valenciennes); this fish is almost certainly *Emmelichthys struhsakeri* Heemstra and Randall, 1977. The fishes identified as *Plectorhynchus orientalis* are *P. picus* (Cuvier). *"Myripristis pralinus"* is *M. violaceus* Bleeker, and *"M. melanostictus"* is *M. adustus* Bleeker. *"Assessor macneilli"* is *A. randalli* Allen & Kuiter, 1976. *"Meiacanthus herlihyi"* is *M. atrodorsalis* (Günther); *"Dasson trossulus"* is *Petroscirtes (Dasson) breviceps* (Valenciennes). *"Chromis isharai"* is *C. chrysura* (Bliss); *"C. margaritifer"* is *C. bicolor* (Macleay). *"Pomacentrus melanopterus"* is *P. brachialis* Cuvier. *"Anampses* sp." is *A. caeruleopunctatus* Rüppell. *"Labroides* sp." is *L. pectoralis* Randall & Springer, 1975. *"Halichoeres melanurus"* is *H. biocellatus* Schultz. *"Centropyge fisheri"* is *C. flavicauda* Fraser-Brunner; *"C. multispinis"* is *C. bispinosus* (Günther). *"chaetodon chrysurus"* is *C. xanthurus* Bleeker; *"C. collare"* is *C. aureus* Temminck & Schlegel; *"C. miliaris"* is *C. guentheri* Ahl. *"Canthigaster amboinensis"* is *C. janthinopterus* (Bleeker).

A few nomenclatural errors or misspellings were noted: The invalid family name Histiopteridae is used instead of its senior synonym Pentacerotidae. "Carchariidae" should be replaced by Odontaspididae, "Dasytidae" by Dasyatidae, "Family Drosomatidae" by Dorosomatidae (or Subfamily Dorosomatinae), *"Konosirus punctatus"* by *Clupanodon punctatus,* "Synodontidae" by Synodidae, "Gerridae" by Gerreidae, *"Grabrilutjanus nematophorus"* by *Symphorus nematophorus,* "Opisthognathidae" by Opistognathidae, "Labae" by Labridae, "Antigoniidae" by Caproidae, "Moldae" by Molidae, and Cephalacanthidae" by Dactylopteridae.

One serious oversight in this book is the absence of size data for the fish illustrated. Although for a few species both juvenile and adult forms are shown, even these are not labelled with their lengths. In the text account for each species, the maximum known size is given. Most of the photographs are good, and the color rendition generally seems quite accurate; but several of the illustrations are so small (one only 25 mm long) that much detail is lost. The small size of some photographs is difficult to understand in view of the large format (29 × 20 cm) and the vast amounts of blank space on some of the plates.

The list of references is a useful compilation of recent papers dealing with the taxonomy of Japanese fishes; unfortunately some recent papers cited in the text are not included in this list.

The book is printed on good quality paper, sturdily bound, and supplied in an attractive box.—*Phillip C. Heemstra, CSIRO Division of Fisheries and Oceanography, P.O. Box 21, Cronulla, NSW, Australia.*

Fishes of the World

by Joseph S. Nelson; John Wiley and Sons, New York, 1976; xiii + 416 p., illustrated.

According to the author, "One purpose dominated in the writing of this book—to provide a modern introductory systematic treatment of all major fish groups." Toward this end, he has presented a brief account of each of the various fish groups down to the level of family. for families, for instance, a common name, if available, is presented and the preferred zoogeographical habitat of the family members is mentioned. An outline drawing of a typical, if there be such a creature, family member usually is given, along with a few salient, though rarely diagnostic, characters. Maximum or average sizes may be mentioned, and genera and species belonging to the family are enumerated. Some, but not all, genera are listed. If an important revisionary or similar work is known to the author, he usually has listed it.

The volume contains a wealth of information, but the latest references are dated 1973. I'd like to have seen a bit more space between family accounts so that I could annotate my copy as pertinent literature is published. I'd also liked to have seen a listing of all genera within a family where there are fewer than 10. As it is, a family containing seven genera might have all listed or only three or four, etc.

In his introductory chapter, the author estimates that there are 18,818 living species of fish in the world, and these belong to 4,032 genera in 450 families. In a 14-page appendix, he lists the 450 families in their respective classes, orders, and suborders. A second appendix contains 45 fish distribution maps, 40 of which pertain to specific families. The bibliography, through 1973, is excellent, and the volume is well-indexed. It is the type of reference that should be kept within easy reach on bookshelf or desk, as it will be referred to often by those who invest in a copy.—*John E. Fitch.*

WATERFOWL OF NORTH AMERICA

by Paul A. Johnsgard; Indiana University Press, Bloomington & London, 1975; 575 pp., 104 black and white photos, 32 color photos, 63 drawings, 46 maps. $25.00

Dr. Johnsgard has successfully developed a volume that should prove useful to the greatest number of people. Without seriously overlapping the great works of Bent, Kortright or Delacour, the author has compiled up-to-date series accounts dealing with reproductive biology, identification, and ecology of every waterfowl species presently known to breed on the North American continent. Emphasis is on possible application in conservation and management of each species.

The all new photographs and anatomically correct drawings by Dr. Johnsgard are excellent. Included are rare and questionable records, such as the Smew, Tufted duck, Bahama Pintail, Garganey, Baikal Teal, Falcated Duck and others. The twenty five pages of sources of information at the back of the book are particularly useful for further studies.

Waterfowl of North America is understandable to the nonprofessional, but still retains sufficient specific information to make it a useful reference for students and professional wildlife biologist. Ornithologists, bird lovers, waterfowl hunters and decoy carvers will also appreciate this new book.—*W. F. "Bill" Hart.*

Advanced Bass Fishing

by John Weiss; E. P. Dutton and Co., New York. 1976. XXViii + 256 p. Illustrated. $11.95.

As the title would indicate, *Advanced Bass Fishing* is not a book the beginning black bass angler could readily digest. Mr. Weiss begins with an introduction to the various species of black bass and how each relates to his environment. From there the author goes into factors affecting bass behavior such as lake structure, light penetration, oxygen content in the water, and water temperatures.

The largemouth species, being the most sought after, receives the lion's share of attention with separate chapters devoted to the small-mouth, spotted-bass, and Florida-strain bass. At all times the tactics and theories are geared toward the experienced bass fisherman who is looking to increase the size or quantity of his catch or maybe turn some of those inevitable water-hauls into a more productive or educational experience.—*Gary Miller*

Fly Tackle

by Harmon Henkin. J. B. Lippincott Co., N. Y., N. Y., 1976. 240 p. Illustrated. $9.95.

"Fly Tackle—A Guide to the Tools of the Trade" is a different kind of book. It is well written, interesting, and the author is knowledgeable about his subject. There is something for everyone; facts, philosophy, and personal opinion. The first one hundred pages are devoted to rods—rod buying and building, a history of rods and rod builders; bamboo, glass, graphite, saltwater, ultralight, and repairs. I do take exception to the prices he quotes for used bamboo rods. I don't think you can find rods in good shape made by the name builders for the prices he quotes. He does indicate used rod prices have fluctuated incredibly recently; I think more incredibly than he is aware. There are three short chapters on gear needed for fishing spring creeks, warm water, and salmon, steelhead and saltwater; I felt the section on steelhead was somewhat weak. Reels, lines, leaders, and all the other paraphernalia used by the fly fisherman are the subjects of additional brief but thoughtful chapters. Appendices list sources of fly fishing tackle, books, and fly tying materials. The illustrations by Jeff Johnson add a great deal to the enjoyment of reading this book.—*K. A. Hashagen, Jr.*

Classic Rods and Rodmakers

by Martin J. Keane; Winchester Press, N. Y., N. Y., 1976; 246 p., illustrated with both color and black and white photos. $15.00.

It is obvious from the very first page that Martin Keane knows his subject thoroughly and *Classic Rods and Rodmakers* is a labor of love. The material was compiled by digging through old fishing catalogues, patent files, correspondence, and through many personal interviews.

The history of the classic rod is detailed from the earliest days, when rods were made of various woods, through the development of the bamboo rod. Various stages of rod evolution are described (materials, reel seats, ferrules, and guides). The greatest portion of the book describes the lives and works of the great rod makers, explaining, often for the first time, the theory and execution of an individual builder's expertise. The Eastern builders—Leonard, Payne, Orvis, Edward, Gillum, and Garrison are covered comprehensively, as are the middle-American rod builders Dickerson and Young and our well-known western builders E. C. Powell, Walton Powell, R. L. Winston Company, and G. Howells.

I found the book fascinating and educational. The quality of the photographs are the book's only drawback. Frequently they are too small and taken from too great a distance to show the desired detail.—*K. A. Hashagen, Jr.*

The Essential Fly Tier

by J. Edson Leonard; Prentice-Hall, Inc., Englewood Cliffs, N. J., 1976; 262 p., illustrated. $12.95.

Purportedly, *The Essential Fly Tier* "cuts through the fog of irrelevancies that so often surrounds discussions of the art and science of fly tying." The author, J. Edson Leonard, "discards both the rule book and a host of fly tying myths." In my opinion, however, the book fails to live up to its fly leaf.

Starting with an exhaustive and exhausting discussion of hooks, the book continues with the obligatory chapters on fly tying tools, materials, and fly nomenclature (a glossary of the parts of a fly). The remaining chapters discuss in detail various types of flies for various types of fish (trout, panfish, bass, salmon, steelhead, shad, pike). Line drawings throughout the book illustrate techniques described in the text. Two fold out color plates by the author depict many of the fly patterns described in the text.

I was a bit perplexed by the overall approach of the book. The "fog of irrelevancies" and "discarded rule book and fly tying myths" is more accurately the author's philosophy, which appears to be to not get too hung up on rules and books, but constantly analyze and do what is necessary to catch fish. I'm not sure for whom—beginner or expert—the book was written. Much of the material in the initial chapter is obviously directed at the beginner. In the chapters on the fly types, however, the descriptions are quite technical and complex and, I'm sure, would be of value to only the advanced tier.

I'd rate this one, at $12.95, as a competent, well written book which contains little new or innovative material.—*K. A. Hashagen, Jr.*

INDEX TO VOLUME 63

AUTHORS

SCIENTIFIC NAMES

SUBJECT

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FISH AND GAME COMMISSION
NOTICE OF MEETINGS RELATIVE TO
1977 SPORT FISHING REGULATIONS

NOTICE IS HEREBY GIVEN that the Fish and Game Commission, pursuant to the authority vested by Sections 200–221 of the Fish and Game Code, will meet on October 7, 1977, at 9:00 a.m. in Room 1138 of the State Building, 107 S. Broadway, Los Angeles, California to receive recommendations as to what regulations should be made relating to fish, amphibia and reptiles for 1978.

Notice is also given that the Fish and Game Commission will meet on November 4, 1977, at 9:00 a.m. in Room 303, 1600 Pacific Highway, San Diego, California, for public discussion of and presentation of objections to the proposals presented to the commission on October, 7, 1977, and after considering such discussion and objections, the commission shall announce the regulations which it proposes to make relating to fish, amphibia and reptiles.

Notice is also given that the Fish and Game Commission will meet on December 9, 1977 at 9:00 a.m. in the Auditorium of the Resources Building, 1416 Ninth Street, Sacramento, California to hear and consider any objections to its tentative approvals in relation to fish, amphibia and reptiles for the 1978 sport fishing season.

Environmental plans with respect to the Department's proposals will be on file and available for public review in the commission office, 1416 Ninth Street, Sacramento, California 95814 after October 7, 1977.

The Fish and Game Commission has determined that there are no new costs to local government, pursuant to Section 2231 of the Revenue and Taxation Code.

FISH AND GAME COMMISSION

Leslie F. Edgerton
Executive Secretary