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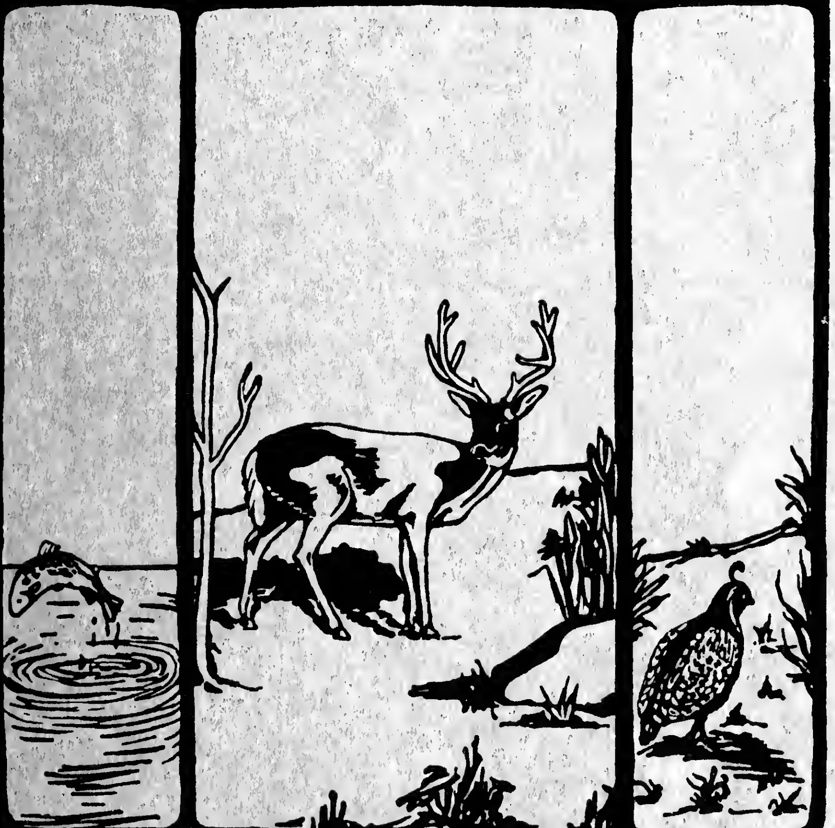

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LARGEMOUTH BASS, *MICROPTERUS SALMOIDES,* AND BLUEGILL, *LEPOMIS MACHROCHIRUS,* GROWTH RATES ASSOCIATED WITH ARTIFICIAL DESTRATIFICATION AND THREADFIN SHAD, *DOROSOMA PETENENSE,* INTRODUCTIONS AT EL CAPITAN RESERVOIR, CALIFORNIA [1]

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Growth rates of age I largemouth bass and bluegill decreased following introduction of threadfin shad in 1958. Decreased growth is attributed to competition for food between age I gamefish and threadfin shad. Growth rates of older largemouth bass and bluegill generally increased following the threadfin shad introduction, due to increased forage provided by threadfin shad. Growth rates of age I largemouth bass and bluegill increased from 1964 through 1966 during artificial destratification, possibly due to decreased competition with threadfin shad. Growth rate trends of older largemouth bass and bluegill during destratification were less distinct, but an initial increase during the first year or two of destratification was followed by declining growth rates for largemouth bass.

INTRODUCTION

Thermal stratification and oxygen depletion of deep waters often limits fish to shallow depths. In many eutrophic lakes, as much as 71% of the bottom area and 60% of the water volume are uninhabitable by fish due to thermal and chemical stratification (Ziebell 1969, Summerfelt 1981). Warm surface waters may further reduce the available habitat for trout and salmon, or even eliminate coldwater fish species (Fast 1976). Compression of fishes into a shallow zone not only reduces the water volume available to fishes, but can cause reductions in growth, reproduction, and "well-being" of those species which survive. Decreased bluegill growth rates and false annuli formation due to compression into warm, shallow water were observed by Bechman (1946), Sprugel (1954), and Mayhew (1963) and would also be expected for other warmwater species such as largemouth bass.

Artificial destratification through diffuse aeration can reduce or eliminate thermal and chemical stratification and is generally considered beneficial for warmwater fisheries (Fast 1968; Toetz, Wilhm, and Summerfelt 1972). Destratification allows increased fish depth distribution (Miller and Fast 1981), and may increase forage food densities (Fast 1973*b*). On the other hand, artificial destratification may adversely affect coldwater fish since it eliminates the cold waters required by these species (Fast and St. Amant 1971; Fast 1976).

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Effects of artificial destratification on depth distribution are easier to measure and better documented than effects on fish growth and survival. Many studies have documented habitat expansion and utilization of this habitat by fishes, as a result of artificial destratification (Summerfelt 1981); but only a few studies have documented changes in fish growth or survival rates through destratification. Johnson (1966) observed a 326% increase in coho salmon, *Oncoryhyncus kisutch,* survival during artificial destratification of Erdman Lake, Washington, while growth rates remained about the same; destratification more than tripled the habitable volume. The warmwater fish population doubled at Cox Hollow Lake, Wisconsin during 3 years of artificial destratification, although growth rates did not change (Wirth *et al.* 1970). Gizzard shad, *Dorosoma cepedianum;* white crappie, *Pomoxis* annularis; and freshwater drum, *Aplodinotus grunniens,* grew faster at Lake of the Arbuckles, Oklahoma when the lake was not stratified (Gebhardt and Summerfelt 1978). These studies indicate that artificial destratification can improve fish habitat, and that fish can respond by increased survival or growth.

From 1964 through 1966 we evaluated the effects of artificial destratification by diffuse aeration on the fishery and examined basic reservoir limnology at El Capitan Reservoir. Previous studies elsewhere largely evaluated the physical and chemical effects of destratification. This report describes changes in largemouth bass and bluegill growth rates associated with destratification of El Capitan. Other publications arising from the study describe the effects of aeration on physical and chemical properties, primary production, zoobenthos, zooplakton (Fast 1968, 1971*a*, 1971*b*, 1973*b*), fish depth distributions (Miller 1967, Miller and Fast 1981), and fish population sizes (Miller 1972, Bottroff and Lembeck 1978).

Incidental to the destratification evaluation, we also observed bass and bluegill growth before and following the establishment of threadfin shad at El Capitan Reservoir. Shad became established at El Capitan during 1958, whereas the reservoir was not destratified until 1965. A sufficient time interval between the two events permitted evaluation of their respective impacts.

Threadfin shad were introduced as forage for game fish into the Colorado River system, California at Lake Havasu in 1954 (Kimsey, Hagey, and McCammon 1957; Burns 1966). Only two plants, totaling 1,020 shad, were made in Lake Havasu. These threadfin and their offspring populated the entire Colorado River from Davis Dam southward to the Mexican border, the Salton Sea, and related irrigation canals within 18 months (Cole, Trenary, and Finkelstein 1958). This explosive invasion of favorable habitats is characteristic of shad (Burns 1966). Shad very rapidly spread via the Colorado River water aqueduct system throughout most southern California reservoirs which receive Colorado River water. Transplants further increased the spread of threadfin shad and they are now a dominant feature of many California reservoirs. Threadfin shad were probably introduced into El Capitan Reservoir during 1958 when imported Colorado River water was first stored there (Fast 1968). Although no statistics are available, shad almost certainly increased very rapidly in number following their introduction. They were reportedly common in 1958, and very abundant by 1960.

Threadfin shad are generally considered desirable forage for gamefishes (von Geldern and Mitchell 1975). However, there is growing evidence that in some cases shad may also compete for food with young centrarchids and thus limit their survival or growth (Miller 1971, von Geldern 1971). Our study sheds additional light on this thesis.

DESCRIPTION AND HISTORY OF EL CAPITAN RESERVOIR

El Capitan is a productive, warm, monomictic reservoir located 40 km east of San Diego, California. The San Diego River was impounded during 1934 and filled the reservoir to capacity by 1938. Maximum volume, area, and depth are 139 hm^3, 225 ha, and 60 m, respectively. Water volumes fluctuate widely, with less than 5% of total volume present during 1951 and 1957. Most of the water is from runoff, although Colorado River water is periodically imported and stored. Thermal stratification typically extends from February through November, and hypolimnetic oxygen is usually depleted soon after stratification commences. Surface water temperatures range from 1 to 26°C, while air temperatures range from −8 to 46°C (Fast 1968). Phytoplankton and natural stains typically limit secchi transparency to less than 3 m. A small littoral zone and fluctuating water levels greatly limit rooted and attached plants. El Capitan's water chemistry and management are typical of San Diego County reservoirs (Rawstron 1964).

The reservoir has a typical assemblage of warmwater fishes. Largemouth bass, bluegill, green sunfish, *L. cyanellus,* channel catfish, *Ictalurus punctatus,* and brown bullhead, *I. nebulosus,* dominate the sport fishery. White crappie, walleye, *Stizostedion vitreum vitreum,* and carp, *Cyprinus carpio,* are occasionally captured, although since 1970 walleye have been rarely taken. Threadfin shad have been abundant since 1958 (W. Simpson, dam keeper, pers. commun.). Northern largemouth bass, *M. s. salmoides,* and bluegill were first stocked in 1940, white crappie in 1950, walleye in 1962 and 1963, and channel catfish in 1961 and 1963; while green sunfish and brown bullheads were established in the watershed prior to impoundment.

Florida bass, *M. s. floridanus,* were first stocked in El Capitan Reservoir during 1961 (Bottroff and Lembeck 1978). At that time, 2,500 fingerlings were stocked. Yearling and subyearling Florida bass were stocked during 1968, 1969, and 1970. The Florida strain subsequently hybridized with resident northern largemouth bass; however, there is little evidence of hybridization before 1963, and even thereafter the rate of hybridization was likely much slower than that observed elsewhere (Bottroff and Lembeck 1978).

El Capitan was first opened to fishing during 1955 and has subsequently been open almost yearly. The fishery was considered "unbalanced" in favor of bluegill and an extensive chemical rejuvenation and stocking program was carried out between 1956 and 1962 (Beland 1960, Fast 1966). About a half million fish were killed during 1956 (mostly small bluegill) and more than 300,000 largemouth bass, 170,000 channel catfish, and 400,000 walleye were stocked during the program. Beland (1960), Fast (1966, 1968), Miller (1967, 1972), and Bottroff and Lembeck (1978) describe El Capitan Reservoir and its fisheries management in greater detail.

METHODS AND MATERIALS

Scales and fork length (FL) measurements were taken from 1955 through 1971 from fish captured principally by anglers, and to a lesser extent by seines, gill nets, and rotenone. Scales from 762 bluegill and 1,789 largemouth bass were used for growth analyses. Both fork length and total length were usually recorded; where only total length was recorded, conversion factors to FL were used following Carlander (1950). Before 1964, scales were generally taken above to the lateral line and anterior to the base of the dorsal fin. From 1964 on, scales were generally collected below to the lateral line and anterior to the base of the dorsal fin. Scale impressions were made in cellulose acetate strips using Campbell and Witt's (1953) technique with the following modifications: from four to six scales were mounted on plastic between two thin sheets of polished stainless steel and heated in a press at 55°C and 352 kg/cm² for about 1 min. They were then pressed at 55°C for 1 to 2 min at 1400 to 1680 kg/cm². Scale impressions were examined at magnifications of 23 or 48X.

Fish captured between 1 January and 31 May were assigned an annulus at the scale edge unless one was otherwise visible near the edge, whereas those fish captured between 1 June and 31 December were assigned only visible annuli. Scales from fish collected during the fall and winter typically lacked annuli at the edge. Bluegill formed visible annuli from March through May. For example, bluegill annuli formations during 1965 are as follows: 0% Jan., 0% Feb., 75% March, 100% April, 100% May. Largemouth bass formed annuli during mid-April, but some were formed during May and June. Annuli were considered true if they could be traced around the entire scale. Some false-annuli were well formed, but could usually be detected if they didn't completely cut circuli around the scale, or were spaced in a highly unusual manner between "true" annuli.

R. L. Miller and L. J. Bottroff read all bluegill scales and independently agreed on over 80%. Bottroff read all the largemouth bass scales without collaboration.

Back calculated lengths were estimated by the Lee method (Hile 1970), where intercept values of 20 mm and 34.7 mm were used for largemouth bass and bluegill, respectively. Scale length—fork length regressions yielded intercept values of 67.5 mm for largemouth bass and 34.7 mm for bluegill. All growth rates cited in this paper are yearly, incremental growth rates.

El Capitan Reservoir was artificially destratified during 1965, 1966, 1968, 1969, and 1970 by using a diffuse system of air injection. Air was injected through 31 m of PVC plastic pipe about 600 m upstream from the dam. Artificial destratification occurred from June through October 1965 and from March through October in other years, and resulted in a nearly isothermal reservoir during the summer. The temperature range between the surface and bottom was generally 2 to 3°C during destratification. Although this temperature range was small compared with non-aerated years, it was sufficient to permit considerable differences in oxygen concentrations between the surface and the bottom. Surface waters were usually saturated with oxygen, but bottom waters, especially in the upper end of the reservoir, often contained less than 3 mg/l of dissolved oxygen.

RESULTS

Largemouth bass age I growth rates always exceeded 130 mm before the threadfin shad introductions in 1958. Growth rates ranged between 131 and 199 mm per year (Table 1, Figure 1). This trend continued through 1960, after which age I growth declined precipitously. The greatest decrease occurred between 1961 and 1962 when growth decreased from 141 mm to 97 mm. Age I growth

TABLE 1. **El Capitan Reservoir largemouth bass average yearly growth rates in mm ($\bar{x}$), number of fish in each sample (N) and standard error (SE). Value within the step-down areas represent growth during artificially destratified conditions.**

Age group	*Year Classes*													*All years*
	1953	*1955*	*1956*	*1957*	*1958*	*1959*	*1960*	*1961*	*1962*	*1963*	*1964*	*1965*	*1966*	
I	$\bar{x}$ = 150	199	131	146	132	146	161	141	97	92	82	109	126	120
	N = 40	20	32	59	96	78	150	401	285	287	190	139	12	1,789
	SE = 5.3	7.8	4.6	6.0	4.7	5.2	3.6	2.2	2.5	2.2	2.3	3.4	11.6	1.2
II	72	117	124	114	125	115	90	150	160	165	190	171	157	149
	40	3	31	59	96	77	135	370	285	271	189	139	12	1,707
	5.2	47.6	6.4	5.0	3.5	4.8	2.0	2.1	2.0	2.4	2.3	2.4	6.5	1.1
III	100	101	92	84	85	76	86	77	96	113	107	93	70	93
	10	3	31	59	53	58	83	318	273	210	165	139	12	1,414
	6.2	21.0	6.2	4.6	4.6	3.5	3.1	1.6	1.9	2.8	2.0	2.3	5.3	0.9
IV	94	54	48	44	38	39	34	43	58	60	53	33	65	48
	2	3	31	38	35	43	35	303	145	181	154	138	11	1,119
	—	11.8	3.5	2.8	2.8	3.0	3.2	1.0	1.8	1.7	1.3	1.1	5.8	0.6
V	28	27	37	26	32	23	30	40	41	44	23	52	38	38
	2	3	10	23	23	31	11	194	119	158	137	128	5	844
	—	5.8	3.9	2.6	3.0	2.0	3.3	1.2	1.5	1.3	0.6	1.5	3.4	0.6
VI	28	19	18	24	22	20	29	30	26	16	47	28		29
	2	2	5	8	14	14	11	140	88	133	118	75		610
	—	—	4.3	2.9	2.8	1.4	3.0	1.0	1.3	0.6	1.4	1.4		0.6

VII	11 2 —	16 2 —	11 2 —		17 11 1.8	21 14 2.7	20 5 4.1	18 97 0.8	12 44 0.8	40 99 1.5	20 80 0.9			24 356 0.8
VIII			6 1 —		16 11 2.2	16 5 2.2	14 1 —	9 42 0.8	30 25 2.4	15 65 0.9				16 150 0.9
IX					8 5 2.4	9 1 —		16 17 2.1	11 15 1.8					13 38 1.3
X								7.9 10 1.2						8 10 1.2
Average age at capture	2.4	1.8	4.5	4.2	3.6	4.1	2.9	4.7	4.5	4.9	5.4	5.4	4.3	4.5

declined further thereafter, with a record low of 82 mm during 1964. This is the slowest growth for age I bass between 1953 and 1966.

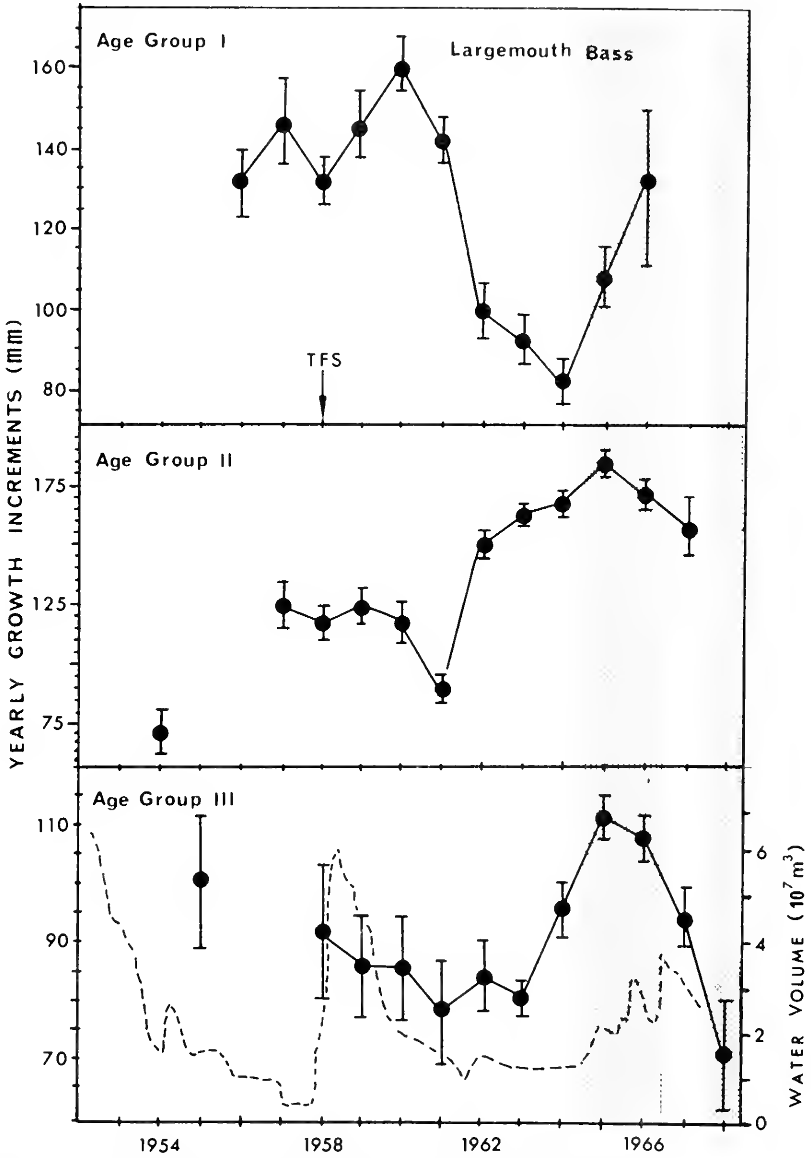

FIGURE 1. El Capitan Reservoir age groups I through III largemouth bass average yearly, incremental growth rates from 1954 through 1968, with 95% confidence interval about the average. No averages with less than 12 fish are shown. Threadfin shad (TFS) were introduced in 1958, and the reservoir was artificially destratified during 1965–66 and 1968 (shaded area). Water volumes are shown in the lower panel.

During the first year of artificial aeration, age I bass growth increased significantly. Age I growth increased from 82 mm in 1964 to 109 mm in 1965. Age I bass growth increased further to 126 mm during the second year of artificial aeration (1966).

Age II bass growth had a somewhat inverse pattern compared with age I bass. Age II growth prior to 1962, however, was never greater than 150 mm (Table 1, Figure 1). Age II averaged 126 mm between 1954 and 1962. After 1962, age II bass growth was never less than 157 mm, and it averaged 170 mm between 1963 and 1967.

An unusual feature of age I and II bass growth rates is that for all years combined, age II fish grew significantly faster than age I fish ($P < 0.01$, $t = 12.5$, d.f. = 3,488). This growth pattern is contrary to those cited by Carlander (1977; Table 1) where age I largemouth bass almost always grew faster than age II bass. The most interesting aspect of this situation is that all El Capitan year classes prior to 1961 had the usual growth pattern for age I and II fish; that is, age I always grew faster than age II (149 vs. 106 mm, respectively). All year classes from 1961 to 1966, however, showed the reverse pattern: Averages for ages I and II were 109 and 164 mm, respectively. That is, the ratio of (age I/age II) growth for year classes 1948 through 1960 was 1.4, but for year classes 1961 through 1966 this ratio was only 0.7.

Based on limited data available, Age III bass and older did not show much change in growth following the establishment of threadfin shad in 1958. Age III bass growth rates ranged from 92 mm in 1958, to 76 mm in 1961 (Table 1, Figure 1).

Growth rates of 2- and 3-year olds were greatest during the first year of destratification (1965), but declined greatly thereafter. The decline continued through 1968 for 3-year olds. Fish 4 years and older generally grew faster after aeration began, while 1969 was an especially favorable year for their growth. Excluding the 1953 year class, age group IV fish ($n = 2$), age groups IV through IX grew faster during 1969 than during any other year.

Significant ($P < 0.01$) compensatory growth occurred between age group I–II, V–VI, and VI–VII largemouth bass, while age group III–IV and IV–V growth were positively correlated (Table 2).

TABLE 2. Correlation Coefficients (r) for El Capitan Largemouth Bass and Bluegill Incremental Growth Rates Between Successive Age Groups. Successive growth rates of individual fish were correlated.

	Largemouth bass		*Bluegill*	
Ages	*Correlation coef. (r)*	*n*	*Correlation coef. (r)*	*n*
I–II	−0.553 **	1,707	−0.173 **	672
II–III	0.005	1,414	0.121 **	539
III–IV	0.450 **	1,119	0.151 **	390
IV–V	0.150 **	844	0.292 **	167
V–VI	−0.153 **	610	0.268	22
VI–VII	−0.299 **	356		
VII–VIII	0.059	150		
VIII–IX	0.083	38		
IX–X	0.568	10		

** Significant correlation at 0.01 level.

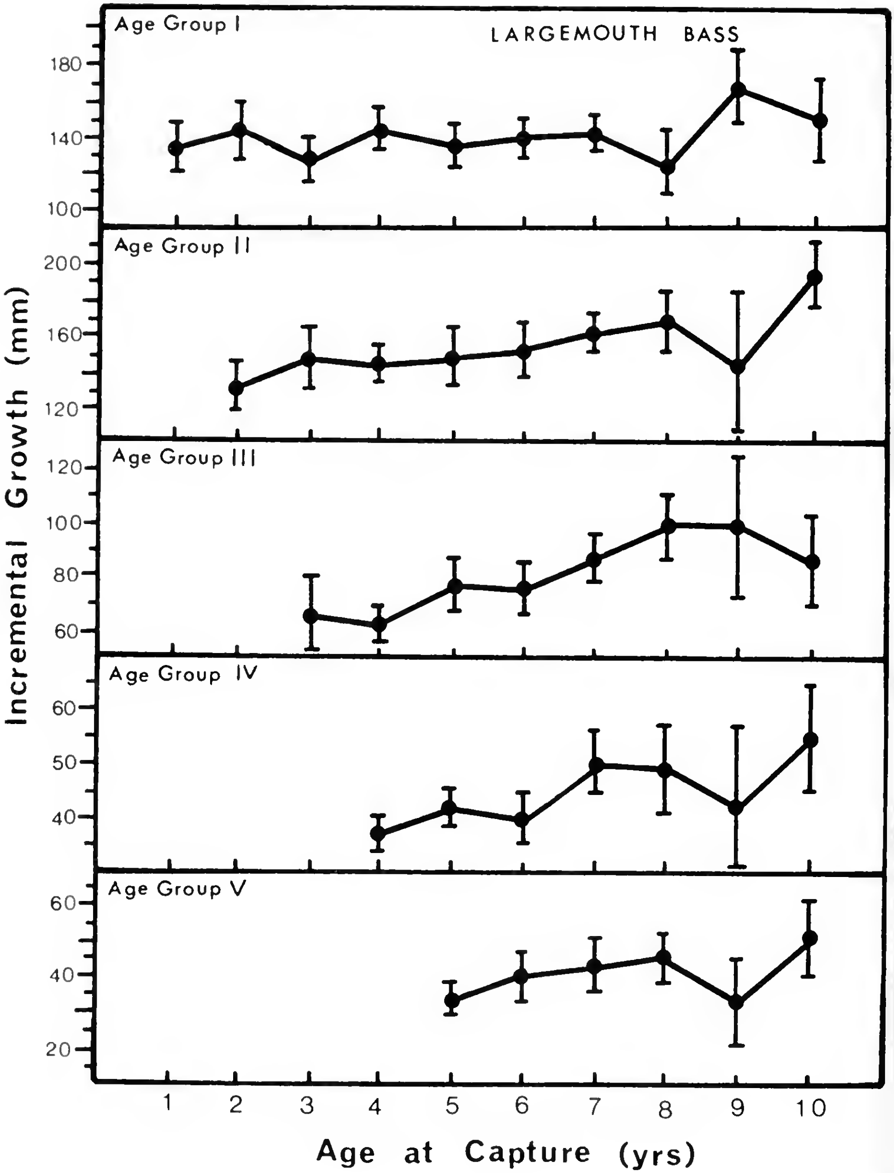

FIGURE 2. Calculated incremental growth rates of 1961 year class El Capitan largemouth bass collected between 1972 and 1971. Growth rates of each age group were calculated separately based on age at capture, as shown in Table 4.

Although largemouth bass average growth rates for each age group varied depending on age at capture for the 1961 year class (Figure 2, Table 3), there are no clear trends. Older fish tend to yield larger estimated average growth rates for age groups II through V than fish captured at an early age. This is contrary to Lee's phenomenon, where older fish (at capture) yield slower estimated growth rates as younger fish than do younger fish (Ricker 1958). Average age at capture varied from 1.8 years for the 1955 year class to 5.4 years for the 1964 and 1965 year classes (Table I). Based on the above analysis for the 1961 year class, we feel confident that our interpretations are not biased by Lee's phenomenon.

TABLE 3. Calculated Growth Rates (mm) of 1961 Year Class, El Capitan Reservoir Largemouth Bass and Bluegill Collected Between 1962 and 1971

Age at capture	*Largemouth bass—1961 year class*										
	n	*I*	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*	*IX*	
1	31	$\bar{x}$ = 134.1									
		STE = 6.5									
2	52	145.6	134.7								
		6.0	6.1								
3	15	123.1	148.3	68.9							
		7.9	7.1	7.4							
4	109	147.2	144.6	63.0	37.3						
		4.2	3.0	2.3	1.3						
5	55	135.8	148.2	77.5	43.9	34.5					
		6.3	6.0	3.6	2.1	2.1					
6	43	141.8	151.3	75.8	42.5	40.4	29.4				
		7.5	6.4	3.7	2.2	2.5	2.1				
7	55	144.3	160.9	89.2	51.2	42.4	28.1	18.0			
		6.0	5.2	3.5	2.4	2.2	1.3	1.0			
8	25	123.4	167.7	101.6	49.3	45.5	34.4	16.8	9.8		
		7.9	8.6	6.5	3.8	3.4	2.7	1.5	1.2		
9	7	170.9	144.0	98.6	43.9	33.6	28.3	18.1	8.3	13.9	
		12.0	19.2	12.8	6.3	5.4	3.7	4.6	1.3	2.9	
10	10	148.2	193.6	88.2	54.5	51.3	30.5	16.6	6.1	18.0	7.9
		10.2	6.5	8.0	5.2	4.9	2.9	2.5	1.8	3.0	1.2
Total		$\bar{x}$ = 141.5	150.0	76.6	43.4	40.3	29.7	17.5	8.7	16.3	7.9
		STE = 2.2	2.1	1.6	1.0	1.2	1.0	0.8	0.8	2.1	1.2
		n = 401	370	318	303	194	140	97	42	17	10
	Bluegill 1961 year class										
2	33	59.5	38.4								
		1.4	1.4								
3	8	51.8	47.9	25.7							
		2.6	4.8	1.7							
4	46	55.1	46.6	32.5	24.5						
		1.0	1.2	1.3	1.1						
5	38	54.8	40.7	28.2	23.5	13.9					
		0.9	1.4	1.0	0.9	0.7					
Total		$\bar{x}$ = 55.0	42.7	30.1	24.0	13.9					
		STE = 0.6	0.9	0.9	0.7	0.7					
		n = 125	125	92	84	38					

Bluegill average yearly growth rates varied widely during the study, but a steady decline in age group I growth occurred from 1959 through 1964, after the establishment of threadfin shad in 1958 (Table 4, Figure 3). Bluegill age group II and III growths increased during part of this period, but age group II decreased sharply during 1963, and age group III decreased during 1964.

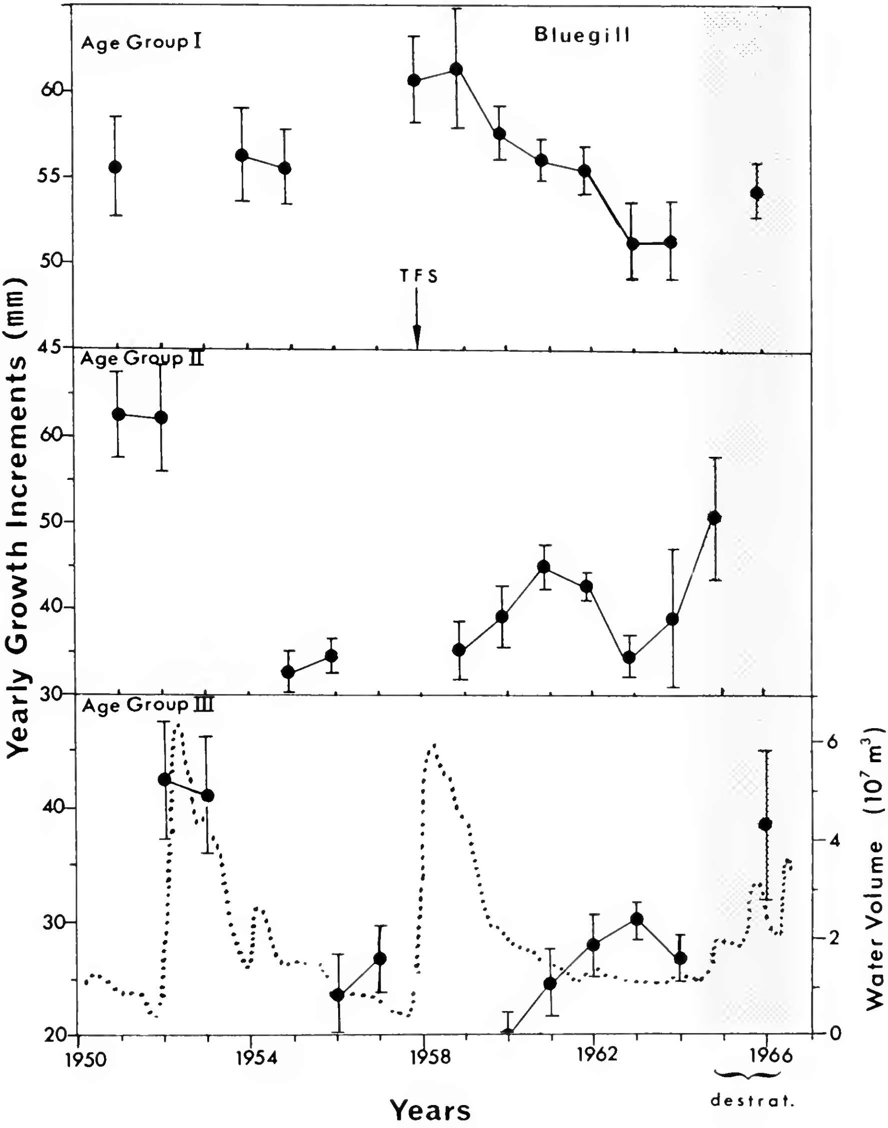

FIGURE 3. El Capitan Reservoir age groups I through III bluegill average yearly, incremental growth rates from 1952 through 1965. Only those averages with 20 or more fish are shown, with the 95% confidence interval about the average. Threadfin shad (TFS) were introduced in 1958, and the reservoir was artificially destratified during 1965–66 (shaded area). Water volumes are shown in the lower panel.

TABLE 4. **El Capitan Reservoir bluegill average yearly growth rates in mm ($\bar{x}$), number of fish in each sample (N) and standard error (SE). Value within the step-down area represent growth during artificially destratified conditions.**

Age	*Year Classes*																			*All*
group	*1948*	*1949*	*1950*	*1951*	*1952*	*1953*	*1954*	*1955*	*1956*	*1957*	*1958*	*1959*	*1960*	*1961*	*1962*	*1963*	*1964*	*1965*	*1966*	*years*
I	$\bar{x}$ = 61	48	56	55	48	49	56	55	64	62	60	61	57	55	55	51	51	51	54	54.2
	N = 1	8	43	44	12	10	40	49	18	14	40	38	71	125	115	28	22	11	73	762
	SE = —	2.5	1.6	1.5	1.3	2.0	1.4	1.1	2.9	2.7	1.3	1.8	0.8	0.6	0.7	1.0	1.0	2.5	0.8	0.25
II	46	51	62	62	43	30	32	34	37	35	35	39	44	42	34	39	50	44		41.6
	1	8	43	44	12	10	40	44	17	14	40	38	71	125	113	20	21	11		672
	—	5.2	2.5	3.1	4.7	2.7	1.2	1.0	2.0	2.7	1.7	1.8	1.3	0.9	1.2	3.8	3.4	4.2		0.48
III	54	41	42	41	30	27	23	26	33	25	19	24	28	30	26	39	38			30.0
	1	8	43	44	12	10	23	41	17	14	40	38	47	92	74	14	21			539
	—	5.6	2.6	2.6	3.3	4.5	1.6	1.5	3.1	2.6	1.1	1.5	1.4	0.9	1.0	4.3	3.1			0.48
IV	39	45	23	21	19		11	27	19	19	18	19	23	24	20	25				22.1
	1	8	43	44	8		13	31	17	13	40	22	24	84	28	14				390
	—	4.4	1.7	1.4	2.6		1.9	1.9	1.6	2.1	1.0	1.5	1.9	0.7	2.2	3.1				0.44
V	22	22	12	20			14	14	17	14		20	20	13	26					15.2
	1	8	43	14			2	22	1	13		2	19	38	4					167
	—	3.1	1.0	1.4			2.4	1.2	—	1.1		4.3	1.3	0.7	4.6					0.43
VI	22	8	13						15				11							10.7
	1	8	1						1				11							22
	—	0.9	—						—				0.9							0.62
VII	7																			7
	1																			1
	—																			—
Average age at capture	7.0	6.0	5.2	4.3	3.7	3.0	3.0	3.8	3.9	4.9	4.0	4.1	3.4	3.7	2.9	2.7	2.9	2.0	1.0	3.4

Age group I bluegill grew about the same during artificial destratification as during the preceding 2 years. Growth during 1965–66 was 51 mm (2.5 S.E.) and 54 mm (0.8 S.E.), respectively, compared with 51 mm (1.0 S.E.) for both 1963 and 1964. Age groups II and III, on the other hand, had large increases in growth during destratification. The 2-yr average (1965–66) for age group II was 47.0 mm (2.2 S.E.), compared with 36.5 mm (1.1 S.E.) for 1963–64. The 2-yr average for age group III (1965–66) was 38.5 (2.8 S.E.), compared with 28.0 (0.7 S.E.) for 1963–64.

Significant compensatory growth occurred between age groups I and II bluegill, while age groups II–III, III–IV, and IV–V growth were positively correlated (Table 2).

Although age I bluegill from the 1961 year class were not collected, there does not appear to be any significant difference in growth rates as a function of age at capture (Table 3). As with largemouth bass, Lee's phenomenon apparently did not occur with El Capitan Reservoir bluegill.

DISCUSSION

Conspicuous changes occurred in the growth patterns of largemouth bass and bluegill following the introduction of threadfin shad and during artificial destratification at El Capitan Reservoir. Both perturbances had major impacts and were separated sufficiently in time to allow us to witness their individual effects.

Although it is very difficult to demonstrate interspecific competition, we believe that our observations, plus evidence from studies conducted elsewhere about the habits of threadfin shad, largemouth bass, and bluegill, lead us to the conclusion that threadfin shad competed with the young-of-the-year bass and bluegill at El Capitan Reservoir. Furthermore, this competition led to reduced growth for young-of-the-year bass and bluegill. We observed substantially decreased growth of youth-of-the-year bass and bluegill following the shad introductions until 1964 (Figure 1 and 3). This growth reduction was most probably due to competition for food between these three species.

Young-of-the-year largemouth bass and bluegill, and all ages of threadfin shad are zooplanktivorous (Gerdes and McConnell 1963, Burns 1966, Emig 1966). Murphy (1950) found that largemouth bass are predominantly zooplanktivorous until 70 mm in length. Applegate and Mullin (1967) found that 40-mm largemouth bass consume mostly copepods. Bass larger than about 70 mm are largely piscivorous. Bluegill feed on zooplankton throughout their life, although larger bluegill also consume fish and other biota (Emig 1966). Threadfin shad feed largely on zooplankton throughout their life (Burns 1966).

Large populations of limnetic, zooplanktivorous fish such as threadfin shad, gizzard shad, or alewives, *Alosa pseudoharengus,* can greatly alter zooplankton composition and density (Brooks and Dodson 1965). Cramer and Marzolf (1970) found that gizzard shad can greatly alter zooplankton species composition through selective predation, and they speculate that this predation could have a deleterious effect on young-of-the-year gamefish growth rates. Johnson (1970) found that zooplankton abundance and threadfin shad population densities were inversely related, and that this apparently limited shad growth through intraspecific competiton for food. If shad can limit their growth rates by competition for food, then it is likely that they can also limit the growth of young-of-the-year bass and bluegill through competition.

Although threadfin shad may have reduced growth rates of young-of-the-year bass and bluegill at El Capitan Reservoir, we conclude that shad also caused an increased growth rate in older bass and bluegill. Growth rates of age II and older bluegill and largemouth bass generally increased following shad introduction. This is likely due to increased forage provided by shad. When threadfin shad are introduced into a reservoir, many piscivorous fishes will feed largely if not exclusively on shad. The piscivorous fish include largemouth bass; striped bass, *Morone saxatilis;* rainbow trout, *Salmo gairdneri;* coho salmon; channel catfish; and, to a lesser extent, bluegill (Burns 1966, Goodson 1965).

The abrupt dramatic reversal in relative growth rates of age I and II largemouth bass at El Capitan Reservoir during 1960/1961 is further evidence that threadfin shad competed with young-of-the-year bass for food, but themselves provided increased forage for age II and larger fish. It must be more than coincidence that age II bass always grew much slower than age I bass before 1961 and thereafter age II bass always grew much faster.

Both age I and II bass growth rates decreased at Millerton Lake after shad were established, but growth increased for older bass (Miller 1971). At Lake Nacimiento, age I bass growth did not change after shad were established, although growth increased for age II and III bass (von Geldern and Mitchell 1975). Although growth of age I fish was not reduced, von Geldern (1971) observed an inverse relationship between adult threadfin shad abundance and fingerling largemouth bass abundance. Taken together, these studies suggest that threadfin shad can adversely impact young bass by either reducing bass growth or survival, while at the same time shad can increase growth of older bass.

Bartholomew (1966) observed increased growth rates of age II and III white crappie following threadfin shad introductons at Lake Isabella, but age I growth and ages IV or older fish were not materially affected.

Hybridization of the Florida and northern strains of largemouth bass is another possible explanation for certain changes in bass growth rates at El Capitan Reservoir. Although this is a possible explanation for changes in bass growth following the threadfin shad establishment, we believe it is an unlikely explanation for several reasons. Most importantly, age I growth rates for the two strains are nearly equal. Bottroff and Lembeck (1978) found that pure northern and pure Florida age I bass (1961 year class) at El Capitan Reservoir grew 154.1 mm and 150.3 mm, respectively. They later observed an intermediate growth rate for apparent hybrids of these strains. Consequently, it is highly unlikely that the introduction of Florida bass in 1961 could account for the great decrease in age I bass growth between 1960 and 1964. During this period, age I bass growth decreased from 161 mm to 82 mm (Figure 1). Secondly, although age II and older Florida bass, and apparent northern X Florida hybrids grow faster than northern bass, we would not expect a significant impact on bass growth rates from this source until 1963 or later for age II bass, 1964 or later for age III bass, and so on. The single greatest increase in age II bass growth occurred between 1961 and 1962 when growth increased from 90 mm to 150 mm. These fish were from the 1961 year class, which could include some pure Florida bass, but no hybrids. Most of the bass (82%) that we used to calculate the 1961 year class, age II growth rates were captured in 1965 and after. If we assume that Florida bass: (i) were randomly sampled from the catch, (ii) had average annual exploitation rates of 17.7, 11.6, 11.4, 6.6, 4.8, 4.6, 2.9, and 0.6% for ages II through IX (Bottroff and Lembeck 1978), and (iii) the bass were all part of the catch reported by Bottroff and Lembeck (1978), then we estimate that less than 1% of our 1961 year class fish consisted of the Florida strain. Even though age II Florida bass grow from 8.5% to 23.0% faster than northern bass (Bottroff and Lembeck 1978), a 1% "contribution" could not account for the growth changes that we observed for any age group of the 1961 year class.

We cannot discount the possible long term impact of the Florida strain and hybrids on bass growth rates at El Capitan Reservoir. They undoubtedly had a significant impact through means that are not well understood or obvious. However, we can largely discount their impact on age I and II bass growth before 1963. It is during this period that we observed the greatest growth changes for bass following the introduction of shad, but before artificial aeration.

We are not surprised that largemouth bass showed a more clear cut response to shad introductions than did bluegill. This may be due to a more or less total shift in the diet of bass to fish as they grow larger; whereas bluegill feed on zooplankton throughout their lives. Consequently, bass would compete with shad for zooplankton only when small, while bluegill would compete with shad to some extent throughout their lives. Likewise, larger bass feed on shad more readily than bluegill would feed on shad. Thus the shad are a better forage source for larger bass than for larger bluegill.

Artificial destratification greatly altered conditions in El Capitan Reservoir. Anaerobiosis and conditions associated with it were eliminated (Fast 1968). Both phytoplanktonic primary production and zoobenthos numbers increased and zoobenthos readily invaded the depths (Fast 1971*b*). Zooplankton extended their distribution to maximum depth (Fast 1971*a*), as did certain fishes (Miller and Fast 1981). Following artificial destratification, threadfin shad and channel catfish distributed throughout the water column, while walleye, bluegill, largemouth bass, and other species extended their depth distribution slightly or were unaffected.

At El Capitan Reservoir, an increased growth rate of age I largemouth bass were clearly observed during the first 2 years of destratification. Effects on older bass are less definite, but an initial increase was followed by a substantial decrease in growth. Bluegill growth tended to increase for both young-of-the-year and older fish. We attribute these changes to decreased competition between shad and young-of-the-year bass and bluegill and decreased availability of shad to older bass and bluegill. That is, during artificial destratification, threadfin shad rapidly invaded the deeper waters and had a much deeper average depth distribution, but bass and bluegill still tended to remain in shallow water near shore (Miller and Fast 1981). Likewise, the zooplankton invaded the deeper waters at El Capitan Reservoir and were probably less vulnerable to shad predation because of much reduced illumination of the deep waters (Fast 1971*a*). Although we did not measure zooplankton densities, artificial aeration can cause increases in zooplankton population sizes and an increase in larger zooplankton species (Fast 1971*a*, Shapiro 1979). If these zooplankton changes occurred and if there was competition for the zooplankton as food between the shad and young bass and bluegill, then artificial destratification indirectly caused the increased growth rates of young bass and bluegill.

Destratification enlarged the available space for all species and in a sense created a "new" lake. Gamefish and their forage species were restricted to depths less than 8 m during periods of stratification, when more than 50% of the reservoir's volume was uninhabitable. They were, however, distributed to over 27 m during artificial destratification and utilized the entire volume. New impoundments are characterized by expanding fish populations and high growth rates (Kimsey 1958). If this same principle applies to destratified lakes, then we should expect increased growth rates during at least the first year of destratification due to the easing of competitive pressures. As the fish populations expand, the former constraints should again apply. Largemouth bass may have followed this trend, since during the first year of destratification (1965) all age groups grew well, but growth of age II and III fish declined thereafter.

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REFERENCES

Applegate, R. L., and J. W. Mullin. 1967. Food of young largemouth bass, *Micropterus salmoides,* in a new and old reservoir. Amer. Fish. Soc., Trans., 96: 74–77.

Bartholomew, J. P. 1966. The effects of threadfin shad on white crappie growth in Isabella Reservoir, Kern County, California. Calif. Fish and Game, Inland Fish. Admin. Rep. No. 66-6, 10 p. (mimeo).

Bechman, W. C. 1946. Further studies on the increased growth rates of the rock bass *Ambloplites rupestris* (Rafinesque), following the reduction in density of the population. Amer. Fish. Soc., Trans., 72: 72–78.

Beland, R. D. 1960. History of the El Capitan Reservoir fishery, San Diego County, 1955–1959. Calif. Fish Game, Inland Fish. Admin. Rep. No. 60-20, 31 p. (mimeo).

Bottroff, L. J., and M. E. Lembeck. 1978. Fishery trends in reservoirs of San Diego County, California, following the introduction of Florida largemouth bass, *Micropterus salmoides floridanus,* Calif. Fish Game, 64(1): 4–23.

Brooks, J. L., and S. I. Dodson, 1965. Predation, body size, and composition of plankton. Science, 150: 28–35.

Burns, J. W. 1966. Threadfin shad. Pages 481–488. *in* A. Calhoun, ed., Inland fisheries management. Calif. Dept. Fish and Game, Sacramento, California.

Campbell, R. S., and A. W. Witt, Jr. 1953. Impressions of fish scales in plastic. Jour. Wildl. Mgmt. 17(2): 218–219.

Carlander, K. D. 1950. Handbook of freshwater fishery biology with the first supplement, William C. Brown Co., Dubuque, Iowa. 429 p.

______. 1977. Handbook of freshwater fishery biology. Iowa State Univ. Press. Ames, Iowa, II: 94–101, 228–243.

Cole, C. F., J. Trenary and S. Finkelstein. 1958. Experimental introduction of threadfin shad. Ark. Game and Fish Comm., Ann. Rep.

Cramer, J. D., and G. R. Marzolf. 1970. Selective predation on zooplankton by gizzard shad. Amer. Fish. Soc. Trans., 99: 320–332.

Emig, J. W. 1966. Largemouth bass (and) bluegill sunfish. Pages 332–353 and 375–392. *in.* A. Calhoun (ed.), Inland fisheries management. Calif. Dept. Fish and Game, Sacramento, California.

Fast, A. W. 1966. Fisheries management of El Capitan Reservoir, San Diego County, California, 1960–1962. Calif. Fish and Game, Inland Fish. Admin. Rep. No. 66-5, 29 p. (mimeo.).

______. 1968. Artificial destratification of El Capitan Reservoir by aeration, part I, effects on chemical and physical parameters. Calif. Dept. Fish and Game, Fish. Bull. 141: 97 p.

______. 1971*a.* Effects of artificial destratification on zooplankton depth distribution. Amer. Fish. Soc., Trans., 2: 355–358.

______. 1971*b.* Asiatic clam (*Corbicula manilensis* Philippi) invasion and distribution in a southern California reservoir. So. Calif. Acad. Sci. J., 70(2): 91–98.

______. 1973*b.* Effects of artificial destratification on primary production and zoobenthos of El Capitan Reservoir, California. Water Resources Res. 9(3): 607–623.

______. 1976. Hypolimnetic aeration as a fisheries management technique. Cal-Neva Wildlife, pp. 38–44.

Fast, A. W., and J. St. Amant. 1971. Nighttime artificial aeration of Puddingstone Reservoir, Los Angeles County, California. Calif. Fish and Game. 57: 213–216.

Gebhardt, G. E., and R. C. Summerfelt. 1978. Seasonal growth rates of fishes in relation to conditions of lake stratification. Okla. Acad. Sci. Proc., 58: 6–10.

Gerdes, J. H., and W. J. McConnell. 1963. Food habits and spawning of the threadfin shad in a small desert impoundment. Arizona Acad. Sci., J. 2: 113–116.

Goodson, Lee F., Jr. 1965. Diets of four warmwater game fishes in a fluctuating, steep-sided California reservoir. Calif. Fish Game, 51(4): 59–269.

Hile, R. 1970. Body-scale relation and calculation of growth in fishes. Amer. Fish. Soc., Trans., 99: 468–474.

Johnson, J. E. 1970. Age, growth and population dynamics of threadfin shad, *Dorosoma petenense* (Gunther), in central Arizona reservoirs. Amer. Fish Soc., Trans., 99: 739–753.

Johnson, R. C. 1966. The effects of artificial circulation on production of a thermally stratified lake. Washington Dept. Fish., Fish. Res. Papers, 2(4): 5–15.

Kimsey, J. B. 1958. Fisheries problems in impounded waters of California and the lower Colorado River. Amer. Fish. Soc., Trans., 87: 319–332.

Kimsey, J. B., R. H. Hagy, and G. W. McCammon. Progress report on the Mississippi threadfin shad, *Dorosoma petenensis atchafaylae,* in the Colorado River for 1956. Calif. Fish Game, Inland Fish. Admin. Rep. No. 57-23. 48 p. (mimeo).

Mayhew, J. 1963. Thermal stratification and its effects on fish and fishing in Red Haw Lake, Iowa. Iowa Cons. Comm., Biol. Sec., (April): 1–24.

Miller, E. E. 1971. The age and growth of centrachid fishes in Millerton and Pine Flat Reservoirs, California. Calif. Fish Game, Inland Fish. Admin. Rep. No. 71-4, 17 p. (mimeo.).

Miller, L. W. 1967. The introduction, growth, diet and depth distribution of walleye, *Stizostedion vitreum* (Mitchell), in El Capitan Reservoir, San Diego County. Calif. Fish Game, Inland Fish. Admin. Rep. No. 67-10, 14 p. (mimeo.).

______. 1972. Estimates of abundance for largemouth bass in El Capitan Reservoir. San Diego County. Calif. Fish Game, Inland Fish. Admin. Rep. No. 72-6, 10 p. (mimeo.).

Miller, L. W., and A. W. Fast. 1981. The effects of artificial destratification on fish depth distribution at El Capitan Reservoir, California. Pages 498–514 *in* F. L. Burns and I. J. Powling, eds. Destratification of lakes and reservoirs to improve water quality. Australian Government Publishing Service, Canberra, Australia.

Murphy, G. I. 1950. The closed season in warm-water fish management. North Amer. Wildl. Conf., Trans., 15: 235–251.

Rawstron, R. R. 1964. A limnological survey of selected California reservoirs. Calif. Fish Game, Inland Fish Admin. Rep. No. 64-3, 7 p. (mimeo.).

Ricker, W. E. 1958. Handbook of computations for biological statistics of fish populations. Can. Fish. Res. Bd., Ottawa, Canada, pp. 187–189.

Shapiro, J. 1979. The need for more biology in lake restoration. Pages 161–167, *in* Lake restoration: Proceedings of a national conference. U. S. Environmental Protection Agency, Washington, D.C.

Sprugel, G. Jr., 1954. Growth of bluegills in a new lake, with particular reference to false annuli. Amer. Fish Soc., Trans., 83(1953): 58–75.

Summerfelt, R. C. 1981. Fishery benefits of lake aeration: Pages 419–456 *in* F. L. Burns and I. J. Powling, eds. Destratification of lakes and reservoirs to improve water quality. Australian Government Publishing Service, Canberra, Australia.

Toetz, D., J. Wilhm, and R. Summerfelt. 1972. Biological effects of artificial destratification and aeration in lakes and reservoirs-analysis and bibliography. Bureau of Reclamation Report TEC-ERC-72-33, U. S. Department of the Interior, Denver, Colorado.

von Geldern, C. E., Jr. 1971. Abundance and distribution of fingerling largemouth bass, *Micropterus salmoides,* as determined by electro-fishing at Lake Nacimiento, California. Calif. Fish Game. 57: 228–245.

von Geldern, C. E., Jr. and D. Mitchell. 1975. Largemouth bass and threadfin shad in California. Pages 426–449. *in* R. H. Stroud and H. Clepper, ed. Black bass biology and management. Sport Fishing Institute, Washington, D. C.

Wirth, T. L., R. C. Dunst. P. D. Uttormark, and W. Hilsenhoff. 1970. Manipulation of reservoir waters for improve quality and and fish population responses. Wisc. Dept. Nat. Res., Madison, Wisc., Research Rep. No. 62, 23 p.

Ziebell, C. D. 1969. Fishery implications associated with prolonged temperature and oxygen stratification. Arizona Acad. Sci., J. 5(4): 258–262.

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HOME RANGE AND HABITAT PREFERENCES OF BLACK BEARS IN THE SAN BERNARDINO MOUNTAINS OF SOUTHERN CALIFORNIA[1]

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Nine bears were radio-collared in the San Bernardino Mountains of southern California. Approximately 400 telemetry locations were recorded from May 1976 to January 1979. Mean annual home ranges for five males and one female were 22.4 km^2 and 17.1 km^2, respectively. Mean total home ranges of males (36.4 km^2) were significantly larger than annual ranges. Mean seasonal ranges were small, with spring ranges being the largest (5.9 km^2). Elevational distribution indicated activity was higher on southern exposures than northern. Mean spring and summer elevation use was not significantly different at 1640 m and 1675 m, respectively. Fall activity was significantly higher (1822 m), as was the mean elevation for denning (2248 m).

The Canyon Oak Series was the preferred habitat type. This series provided year-round food and cover and winter denning sites. In addition to the Canyon Oak Series, other series used seasonally were: Spring—Ceanothus/Manzanita and Bigcone Douglas Fir; Summer—California Black Oak, Interior Live Oak, Alder, and Coulter Pine; Fall—Interior Live Oak and Ponderosa Pine. Seasonal utilization of habitats differed significantly from habitat availability within each home range. The Chaparral Formation was essentially avoided in summer and fall, but utilized in spring as a result of the use of the Bigcone Douglas Fir Series within this formation. The Conifer Forest Formation was not used differently than its seasonal availability, although it was marginally preferred in fall. The Woodland Formation was highly preferred in all seasons, particularly the Canyon Oak Series.

INTRODUCTION

The black bear, *Ursus americanus,* varies greatly in its habitat use throughout its geographic range. In the western United States it utilizes habitats ranging from desert scrub (Arizona), chaparral and woodland (Arizona and California), to open and closed coniferous forest (most western states) (Erickson 1965; Bray 1967; Jonkel and Cowan 1971; McCollum 1973; Poelker and Hartwell 1973; Amstrup and Beecham 1976; Lindzey and Meslow 1977; Kelleyhouse 1980; LeCount 1980; Reynolds and Beecham 1980). These researchers have reported on the food habits, denning characteristics, movements and home ranges of black bears in the West. Only a few, however, have examined the habitats utilized by western black bears (Jonkel and Cowan 1971—northwestern Montana; McCollum 1973—southwestern Oregon; Lindzey and Meslow 1977—southwestern Washington; Kelleyhouse 1980—northern California). The quality, quantity, and type of vegetation comprising California bear habitats are exceedingly variable, reflecting differences in latitude, elevation, slope, aspect, precipitation, and land-use patterns throughout the state. The black bear's use of these diverse habitats accentuates the need for determining local habitat preferences to provide a sound basis for management of this species.

The grizzly bear, *Ursus arctos,* was exterminated in California in the early

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1900's. The black bear was introduced into southern California from Yosemite National Park, California, in 1933 (Burghduff 1935). Sixteen bears were released into the San Bernardino Mountains and, for over 40 years, no information was gathered on this population. In 1974, a long-term study was initiated to gather baseline data. Reports have been completed on physical characteristics and health (Siperek 1979), food habits (Boyer 1976), denning (Novick, Siperek, and Stewart 1981), and the use of a new immobilizing drug (Stewart, Siperek, and Wheeler 1980). Presented here are the results of a 3-year investigation (January 1976 to January 1979) of home ranges and habitat preferences.

STUDY AREA

The study area encompasses approximately 170 km^2 of the Banning Canyon and Mill Creek drainages in the southeastern portion of the San Bernardino Mountains (Figure 1). Most of the area is within the San Bernardino National Forest. Detailed descriptions of the climate, topography and vegetation have been presented in previous reports (Boyer 1976; Novick 1979; Siperek 1979; Novick *et al.* 1981). The area is mountainous, with steep ridges and deep canyons. It has a heterogeneous mixture of Conifer Forest, Woodland, and Chaparral Formations with their component Series (Derby *et al.* 1978). The relative amounts of these Formations within the study area are approximately 38%, 24%, and 29%, respectively. Other habitats occupying the remaining 9% are the Barren, Grassland, Agriculture, and Riparian Series. The Canyon Oak Series occupies approximately 16% of the total study area.

The Conifer Forest Formation is found from 1600 to 2750 m. Lodgepole Pine, *Pinus murrayana,* Sugar Pine, *P. lambertiana,* and White Fir, *Abies concolor,* Series are found at the higher elevations; Mixed Conifer, Coulter Pine, *P. coulteri,* and Bigcone Douglas Fir, *Pseudotsuga macrocarpa,* Series at the lower elevations. In the Woodland Formaton, the Canyon Oak Series, *Quercus chrysolepis,* is found from 1600 to 2450 m on southern exposures and from 1200 to 1700 m on northern exposures, and often ranges into the Conifer Forest Formation. The Black Oak Series, *Q. kelloggii,* is found in more mesic conditions from 1450 to 2100 m. The Interior Live Oak Series, *Q. wislizenii,* occurs in more xeric, lower elevations, usually below or in association with canyon oak. Key foods, such as acorns, *Quercus* spp.; western chokecherry, *Prunus virginiana;* coffeeberry, *Rhamnus californica;* holly-leaved cherry, *P. ilicifolia;* and manzanita, *Arctostaphylos* spp., are present in the Woodland Formation (Boyer 1976; Novick 1979). The Chaparral Formation is found below 1650 m and includes the Ceanothus, *Ceanothus* spp./Manzanita Series and the Chamise Series, *Adenostoma fasciculatum.* The latter is generally below 1400 m. Bigcone Douglas fir is often regarded as a chaparral conifer due to its presence in canyon bottoms down to 1200 m.

The U.S. Forest Service's Pacific Southwest Forest and Range Experiment Station provided 75 years of fire history for the study area. Approximately 20 to 25% has burned within the last 75 years. Most of this was from large fires occurring in 1924, 1943, and 1951, and burning predominantly in chaparral and oak woodland.

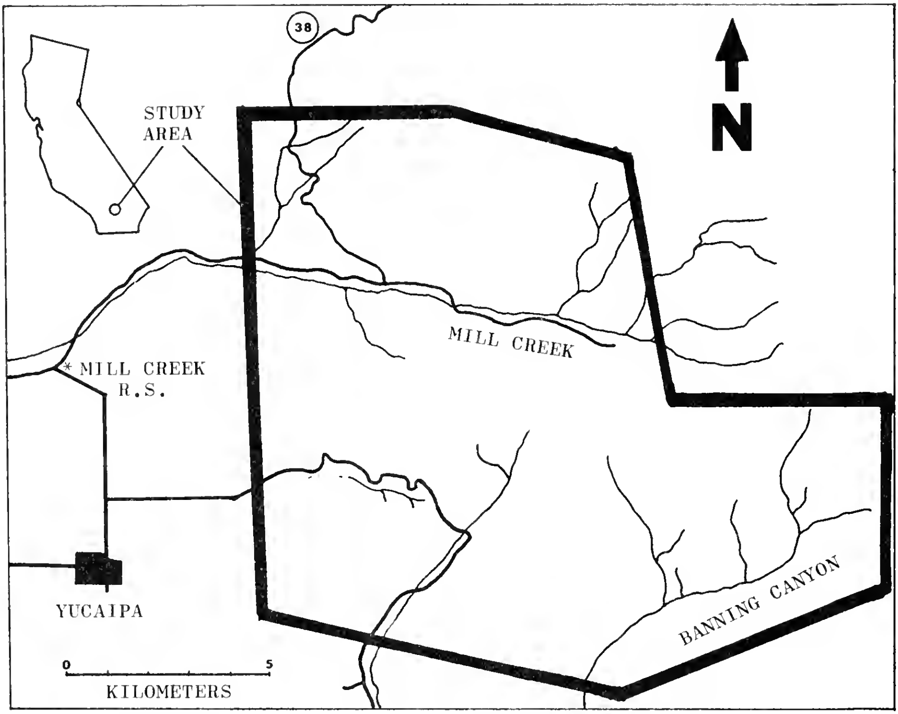

FIGURE 1. Geographic location of the study area in the San Bernardino Mountains, California.

METHODS AND MATERIALS

The methods and materials used during the course of this investigation have been reported elsewhere (Novick 1979; Siperek 1979; Novick *et al.* 1981). Radio-telemetry collars (Telonics) were attached to nine bears between May 1976 and December 1977. Monitoring of each bear was achieved on the ground and from fixed wing aircraft. Telemetry locations, determined by triangulation or with close range monitoring, were plotted on 7½ min topographic maps. The 1000-m Universal Transverse Mercator system was used to assign grid coordinates to each location.

Home range has classically been described as that area which provides all the essential elements (food, water, cover, denning sites, breeding and nursery areas, etc.) to fulfill an individual's requirements, ensuring its survival. Functionally, seasonal, annual, and total home ranges are recognized here. These were determined by connecting the outermost telemetry locations, but excluding a few extreme and unusual movements or sallies (Lindzey and Meslow 1977). Total home ranges were based on more than one full year of data. Annual home ranges consisted of three consecutive seasons, usually including a denning location and defined by at least 25 locality fixes. Seasonal ranges, which are essentially components of annual home ranges, were based on a minimum of five locations distributed throughout each season. A compensating polar planimeter was used to calculate the area within each range. Calculated in this way, annual and total home ranges usually are larger than the sum of the seasonal ranges because they are based on a greater number of locality points.

Seasonal ranges were arbitrarily set as follows: Spring—den emergence (if known) or 1 April to 30 June; Summer—1 July to 30 September; and Fall—1 October to den entrance (if known) or 31 December.

The U.S. Forest Service provided a "Wildlands Recreation Study Map, 1978" which delineated vegetation types from aerial color photographs. The boundaries of these vegetation types were re-checked and modified to more closely approximate vegetation within the study area. This vegetation map was overlaid on bear ranges and the amount of habitat available in each seasonal range was calculated. Habitat use was determined from telemetry locations and bear sign. When more than one vegetation type described a use area, such as in an ecotone, each type was assigned an equal portion and use for that area.

For statistical comparisons, the Student's t-test and the Chi-Square Goodness-of-Fit test were used (Zar 1974). Confidence limits, for preference or avoidance of habitats used in relation to their availability, were determined as described by Neu, Byers, and Peek (1974). A stratified Chi-Square analysis was performed to further refine the comparison of seasonal bear use within each Formation. Since the number and distribution of telemetry locations can affect the size of seasonal, annual, or total home ranges, weighted means were calculated to give more importance to those ranges based on many locations. Weighted means were calculated by taking the sum of the ranges multiplied by the number of their respective telemetry locations and divided by the sum of these telemetry locations.

RESULTS

Three hundred ninety-seven telemetry locations were recorded from May 1976 to January 1979. Seven of the nine bears collared provided home range and habitat preference information. The other two bears (A483 and 890) provided only denning information because their radio-collars malfunctioned shortly after attachment.

Home Ranges

Thirty-one seasonal, 9 annual, and 4 total home ranges were recorded for one female and six male bears. Three total home ranges of males averaged 36.4 km ^{2} (range 19.8 to 64.3) (Table 1). Six annual home ranges of males varied considerably, but were significantly smaller ($P<0.05$), with a mean of 22.4 km ^{2} (range 7.4 to 53.6). One female (886) was monitored for 3 years. Her mean annual home range (17.1 km^2) was not significantly different ($P>0.10$) from her total home range (24.6 km^2).

Spring ranges for males averaged 4.9 and 8.1 km^2 for 1977 and 1978, respectively. Summer ranges were smaller, with means of 2.9 and 5.0 km^2 for 1977 and 1978. Fall ranges varied considerably with means of 1.7, 5.3, and 3.3 km^2 for 1976, 1977, and 1978, respectively. The mean cumulative spring range of males was 5.9 km^2 (range 1.0 to 12.8). The mean cumulative summer and fall ranges were smaller at 3.2 km^2 (range 1.1 to 8.0) and 3.7 km^2 (range 1.0 to 12.7), respectively. These mean seasonal ranges for males were not significantly different in size ($P > 0.10$). The seasonal, annual, and total home ranges of all individuals overlapped considerably.

TABLE 1. Seasonal, Annual, and Total Home Range Sizes of Black Bears.

Bear	*Sex*	*Age (1978)*	*Year*	*Season (km²)*			*Annual (km²)*	*Total home range*
				Spring	*Summer*	*Fall*		
880	M	7	1976	—	—	2.5	—	—
			1977	12.4	8.0	12.7	53.6	64.3
882	M	4 (est.)	1978	7.3	—	—	—	—
883	M	10	1976	—	—	1.3	—	—
			1977	4.4	1.3	—	17.1	—
884	M	12	1976	—	—	2.4	—	—
			1977	1.1	1.1	4.5	13.2	19.8
885	M	3	1977	—	1.4	1.9	—	—
			1978	2.4	—	—	7.4	—
886	F	7	1976	0.1 *	3.7	6.3	9.7	—
			1977	2.8	1.1	3.5	19.6	—
			1978	6.2	5.9	3.5	18.9	24.6
890	M	4 (est.)	1977	—	—	—	—	—
A483	M	5	1976	—	—	—	—	—
A489	M	5	1976	—	—	1.0	—	—
			1977	1.0	2.7	2.3	11.3	—
			1978	12.8	5.0	3.3	18.2	25.7

* less than five locations per season.

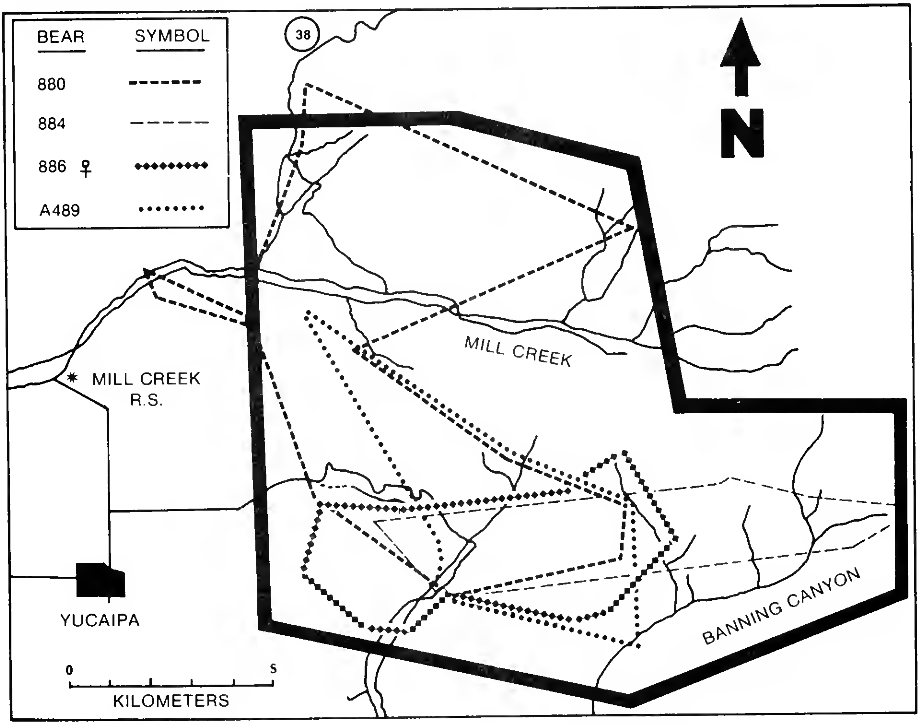

FIGURE 2. Total home ranges of one female and three male black bears.

Seasonal ranges of female 886 varied in size (Table 1). Her mean cumulative seasonal ranges were 4.0, 2.9, and 4.7 km^2 for spring, summer, and fall. Although these ranges are not significantly different in size ($P > 0.05$), the smaller ranges in the spring and summer of 1977 may reflect a limitation imposed on her activities by the pair of cubs she had this year.

The elevational distribution of radio-collared bears indicated that activity was significantly higher ($P < 0.001$) on southern exposures than on northern ones (Figure 3). Bears emerged from their dens in spring and moved to low or middle elevations ($\bar{x} = 1640$ m, south aspects; $\bar{x} = 1391$ m, north aspects). Summer activity averaged slightly higher in elevation ($\bar{x} = 1675$ and 1450 m on south and north aspects, respectively). These elevations were not significantly different ($P > 0.05$) from spring elevations. Fall ranges were significantly higher in elevation ($P < 0.001$) than spring and summer ranges ($\bar{x} = 1822$ and 1486 m on south and north aspects, respectively). In December, as the time for denning approached, bears moved to significantly higher elevations ($P < 0.001$) in their home ranges ($\bar{x} = 2248$ m on south aspects).

Habitat Use

The habitats used by black bears varied seasonally (Table 2, Figure 4).

TABLE 2. Seasonal Use of Habitats by Black Bears.

		Spring		*Summer*		*Fall*	
Habitat type[1]	*Code*	*Use*[2]	*Available*[3]	*Use*	*Available*	*Use*	*Available*
Bigcone Douglas Fir	1	17.16	7.54	6.25	3.44	6.16	2.79
Ponderosa Pine	2	1.49	4.33	0.78	1.03	7.53	3.23
White Fir	4	1.49	4.35	0.78	0.36	4.79	3.73
Sugar Pine	7	0.75	0.39	0	0	1.37	4.48
Lodgepole Pine	8	0	0	0	0	0	0.84
Coulter Pine	11	8.21	6.26	7.81	4.00	6.16	6.39
Mixed Conifer	35	2.99	3.86	1.56	1.81	2.74	2.90
California Black Oak	16	9.70	10.35	21.88	15.05	8.90	9.29
Canyon Oak	17 c	29.85	22.11	32.82	19.08	43.17	29.07
Interior Live Oak	17 w	7.46	3.84	8.59	0.88	8.22	1.70
Coast Live Oak	17 l	0.75	0.20	0	0	0	0
Ceanothus/Manzanita	19	14.18	19.74	10.16	24.13	8.90	16.52
Chamise	20	3.73	7.87	1.56	6.86	1.37	6.71
Alder	27	2.24	0.93	7.81	1.86	0	1.62
Sycamore	28	0	0.34	0	1.29	0	0.63
Grassland	30	0	1.20	0	4.73	0	1.70
Orchard	31 o	0	5.21	0	15.48	0.69	7.77
Barren	31 b	0	1.48	0	0	0	0.63
No. of telemetry locations		95		94		115	
No. of seasonal ranges			11 (7 bears)		9 (6 bears)		15 (9 bears)

[1] Series based on USFS "Wildlands Recreation Study Map, 1978", with modifications, and Derby *et al.* (1978)

[2] Percent of telemetry locations in each habitat type.

[3] Percent of each habitat type available in the combined seasonal ranges of the bears monitored.

Spring: As bears emerged from their dens and moved to lower elevations, they utilized habitats predominantly in the Woodland and Chaparral Formations.

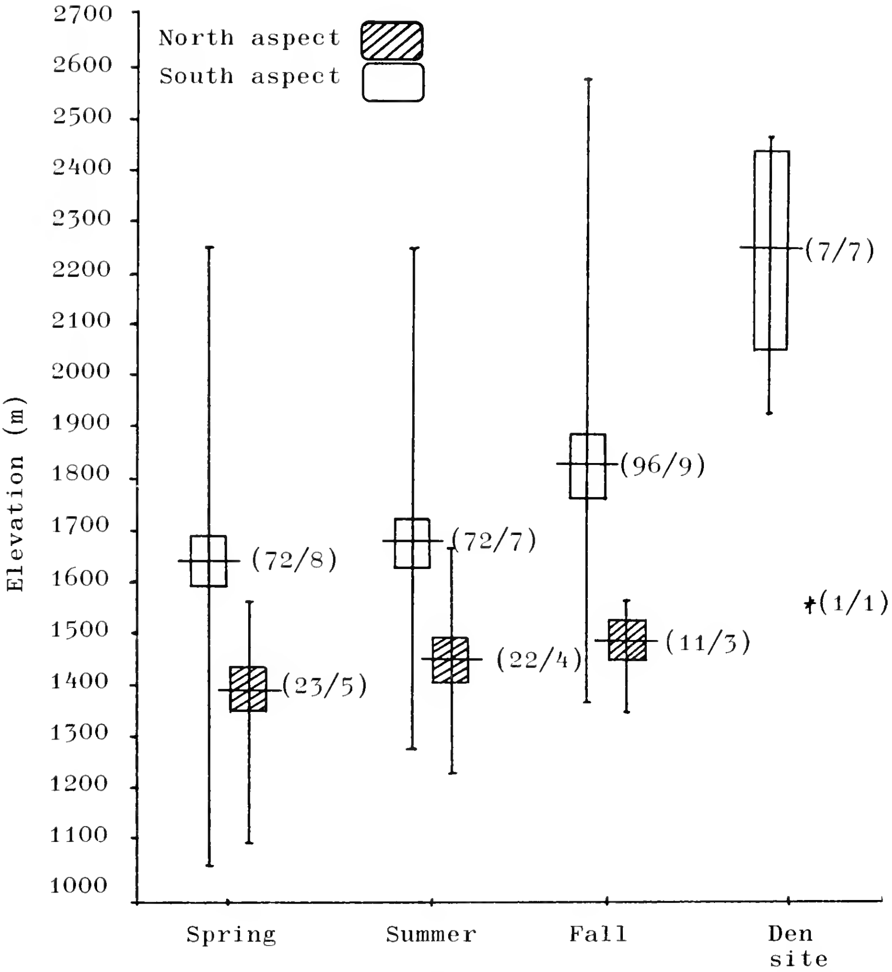

FIGURE 3. Elevational distribution of radio-collared black bears in the San Bernardino Mountains (horizontal axis = mean, rectangle = ±2 standard errors, vertical axis = range, () = no. of telemetry locations/no. of bears monitored).

These formations comprised 82.08% (47.01% and 35.07%, respectively) of the spring habitat use, while Conifer Forest and riparian habitats received only 14.93% and 2.24% of the spring use.

The Canyon Oak Series was the most important spring habitat type. Ceanothus/Manzanita and Bigcone Douglas Fir Series were the next most used habitats. The Bigcone Douglas Fir Series was found in the Conifer Forest, Woodland, and Chaparral Formations. Occupying moist canyon bottoms in the Chaparral Formation, it often provided the cover, intermittent water, grasses, and forbs necessary for chaparral use at this time. The Alder Series while not seeming too important, provided water, grasses, and forbs for bears emerging from their dens.

Summer: The Woodland Formation had the greatest use in summer (63.29%). Conifer Forest and Chaparral Formations decreased from spring use to 10.93%

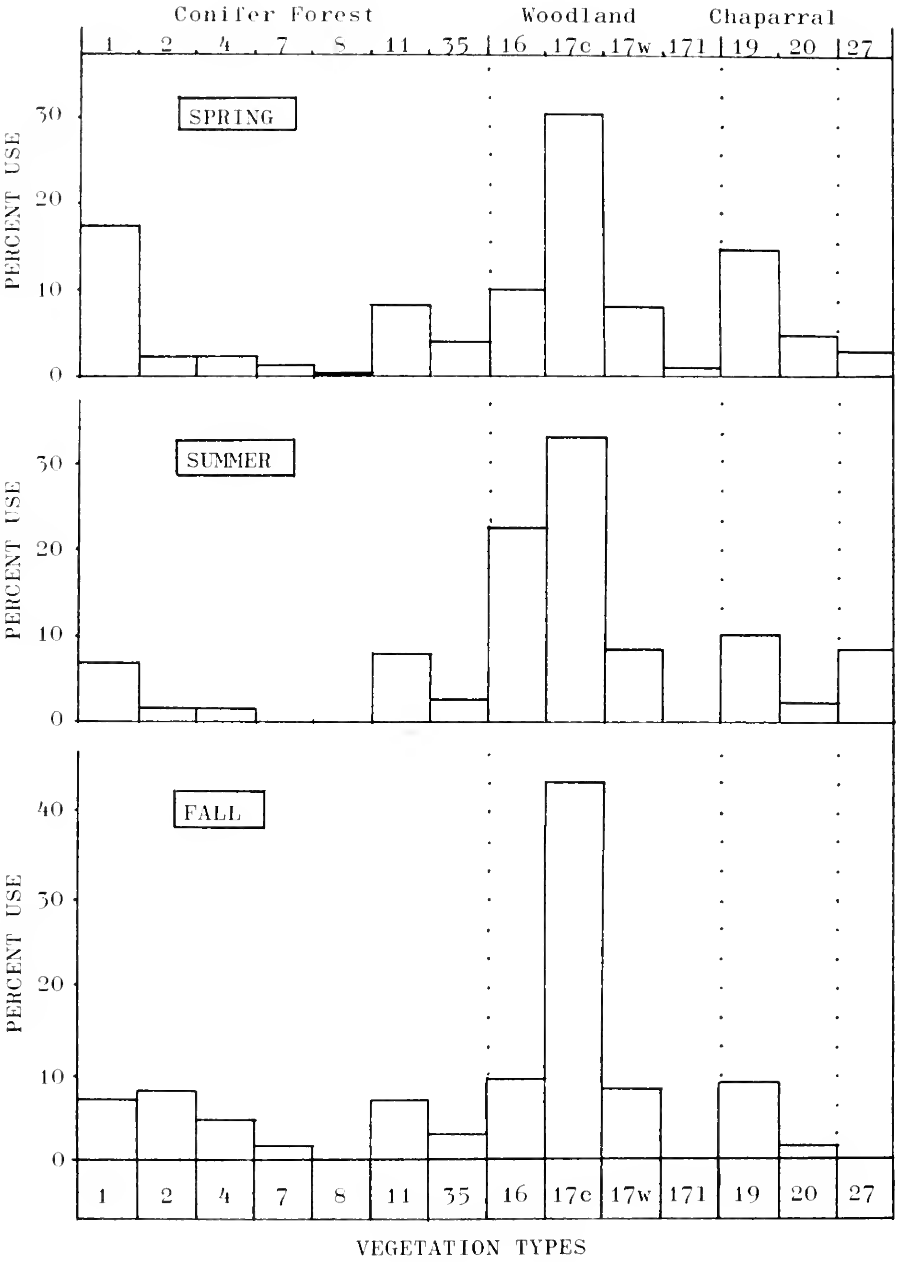

FIGURE 4. Seasonal use of habitats by black bears. (See Table 2 for habitat codes.)

and 17.97%. The Canyon Oak Series was utilized most frequently. California Black Oak and Interior Live Oak Series were used more heavily than in spring. The increased use of the California Black Oak Series was not only in response to available food, but also to water, which is often present in ravines within this type. Limited use of lower elevations was observed in the Ceanothus/Manzanita Series, occurring mostly on xeric locations adjacent to or within the Woodland Formation. Use of the Bigcone Douglas Fir Series decreased, but the use of riparian habitat (Alder Series) increased probably as intermittent water supplies dried up. Middle elevation conifer habitats, such as the Coulter Pine and Mixed Conifer Series, were used as in spring. Use of high elevation conifer habitats, such as the Ponderosa Pine, White Fir, Sugar Pine, and Lodgepole Pine Series, declined.

Fall: The Woodland Formation continued to have the highest use (60.29%), followed by the Conifer Forest (22.59%) and Chaparral (16.43%) Formations. The Canyon Oak Series had its greatest seasonal use in fall. Not only does this Series provide acorns, a very important late fall food item, but other key foods such as coffeeberry, holly-leaved cherry, and to a lesser extent in mesic areas, western chokecherry. The use of high elevation conifer series—Ponderosa Pine, White Fir and Sugar Pine—increased, while use of Coulter Pine, a middle elevation conifer series, remained relatively high as before. This indicates that middle elevations were used most, but excursions to higher elevations, especially as denning approached, became more common.

Denning: Novick *et al.* (1981) described the denning characteristics of this population. The Canyon Oak Series, alone or co-dominant with a conifer series (Coulter Pine, Mixed Conifer, or Black Oak), was chosen for seven of the eight den sites monitored. Most bears denned in remote areas at the higher elevations of their home ranges ($\bar{x} = 2248$ m south aspects). Dens were dug either under very large boulders or beneath the bases of dead or living trees. Most dens were located within 100 m of a creek bottom, possibly indicating that water is important upon den emergence.

Habitat Preferences

The percent use of several habitat types differed significantly ($P < 0.05$) from their availability in spring, summer, and fall ranges (Figure 5). The Chaparral Formation was used differently than its availability ($P < 0.01$) in each season. While preferred in spring, as a result of the high use of the Bigcone Douglas Fir and Ceanothus/Manzanita Series, it was avoided in summer and fall. Use of the Woodland Formation was significantly greater ($P < 0.001$) than its availability in summer and fall. In the spring it was only marginally preferred ($0.10 > P > 0.05$). The Conifer Forest Formation was not used differently ($P > 0.05$) from its availability in spring and summer. Fall use was marginally greater ($0.10 > P > 0.05$).

The Canyon Oak Series was preferred in all seasons (Figure 5). Other habitats used significantly more than their availability were: Bigcone Douglas Fir Series in spring; California Black Oak, Interior Live Oak, and Alder Series in summer; Interior Live Oak and Ponderosa Pine in fall. Those habitats used significantly less than their availability were the orchards, Ceanothus/Manzanita and Chamise Series. Orchards are known to have been used in summer and fall, as apples were present in scats. However, few telemetry locations were found in orchards. Those habitats completely avoided were the Lodgepole Pine, Sycamore, Grassland and Barren Series. All of the remaining habitats were used in proportion to their availability ($P > 0.10$).

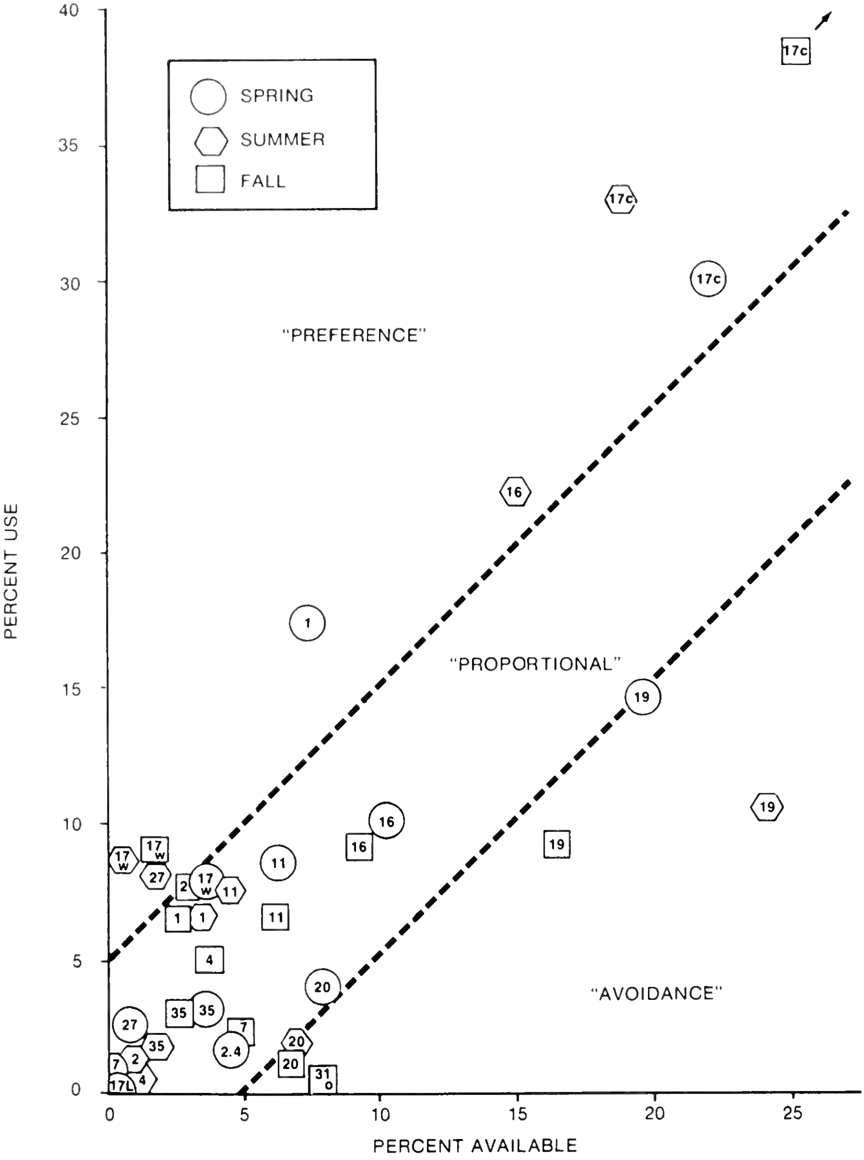

FIGURE 5. Habitat use in relation to availability. Dashed lines define the 90% confidence limits. (See Table 2 for habitat codes.)

DISCUSSION

Habitat quality is known to influence home range size, productivity and survival of black bears, as well as other wildlife. Amstrup and Beecham (1976) felt that the quantity, quality, and distribution of food, as influenced by climate and topography, probably set minimums on the sizes of bears' home ranges. Habitat diversity and quality have been described by others as important in allowing small home ranges for black bears (Jonkel and Cowan 1971; Amstrup and Beecham 1976; Lindzey and Meslow 1977; LeCount 1980). While bears inhabit diverse habitats, the quality of these habitats differs not only within each type, but also between types.

Home Range Comparisons with Other Studies

The total home ranges of bears monitored in the San Bernardino Mountains are relatively small (36 km^2 for three males and 25 km^2 for a female). In comparison with other studies (Table 3), Arizona home ranges are the most similar. Lindzey and Meslow (1977) state that the richness of the habitat and diversity of food-producing plants allow small home ranges of about this size. Jonkel and Cowan (1971) found that Montana Bears had small home ranges and noted that habitat diversity was great, but quality was not necessarily high. These bears were living under suboptimal nutritional conditions, as shown by small body weight, smaller litter sizes, late minimum breeding age, and reduced frequency of litters. Their small home ranges were more likely the result of estimates based on a few capture-recapture locations than a reflection of superior habitat quality. Conversely, in Pennsylvania (Alt *et al.* 1980) bears have very large home ranges, which may be primarily a function of little topographic relief (0 to 100 m), not necessarily poor habitat quality.

TABLE 3. Comparison of Home Range Sizes (km^2) in This and Other Black Bear Studies.

	Male	*Female*	*Reference*
Michigan	52	26	Erickson and Petrides (1964)[1]
Pennsylvania	173	41	Alt *et al.* (1980)[2]
Montana	31	5	Jonkel and Cowan (1971)[1]
Washington	49	5	Poelker and Hartwell (1973)[2]
Washington	5	2	Lindzey and Meslow (1977)[2]
Idaho	112	49	Amstrup and Beecham (1976)[2]
Idaho	105	18	Reynolds and Beecham (1980)[2]
Arizona	29	18	LeCount (1980)[2]
California	36	25	This study[2]

[1] from capture-recapture locations
[2] from radio telemetry locations

The shapes of home ranges essentially followed the east-west orientation of the Yucaipa/Mill Creek Ridge (Figure 2). This area has great topographic relief (elevation 1200 to 2750 m), and the Chaparral, Woodland, and Conifer Forest Formations tend to form vegetation belts on this elevational gradient. The linearity of these home ranges probably also reflects the avoidance of low elevation Chaparral (Chamise Series) and high elevation Conifer Forest (Lodgepole Pine and Sugar Pine Series). Lindzey and Meslow (1977) found their bears' home ranges to be linear due to the shape of Long Island and the juxtaposition of recent clearcuts, which were avoided.

Seasonal Movements

Spring appears to be a difficult time for bears. Available foods (grasses and forbs) are less nutritious than berries or acorns and, consequently, bears lose weight (Jonkel and Cowan 1971). Furthermore, grasses and forbs are well dispersed throughout lower elevations. Spring ranges, therefore, need to be relatively large. In our study they averaged 46% and 37% larger than summer and fall ranges, respectively. Average seasonal ranges for female 886 were smaller than those of males. In part, this reflected her greater use of apple orchards and a garbage dump, especially when she had cubs.

Movements of bears are often in response to available food (Bray and Barnes 1967; Amstrup and Beecham 1976; Reynolds and Beecham 1980). Rogers (1976) found that, during berry and mast crop failures, bear damage to farm crops, beehives, and livestock increased. The manzanita crop failed in 1977 within the study area, and there was an increase in depredation problems throughout the summer. Bear 886 with cubs moved 2 km out of her normal range to an apiary that summer. Artificial food sources, like garbage dumps and apple orchards, supplement natural foods during mast failures (Novick 1979). However, these unnatural food sources may tend to increase bear densities and associated problems locally, and thus may be undesirable.

Home range and habitat selection by black bears could be influenced by a dependence upon garbage. However, the use of garbage by radio-collared bears in this study, and its influence upon home range activity, was low and varied seasonally (Novick 1979). Boyer (1976) found that garbage comprised only 6.4% of the total diet of bears in the study area. The limited amount of garbage use reflected the availability of natural foods.

Amstrup and Beecham (1976) noted that bears used lower and middle elevations for succulent grasses and forbs, then followed the phenological progression of berry-producing plants, particularly huckleberries, *Vaccinium globulare*, and cherries, *Prunus* spp., to higher elevations. The sequence of events in the San Bernardino Mountains was somewhat different. Upon emergence from their dens (mid March), bears remained at high to middle elevations (predominantly Woodland Formation) and fed on the previous year's acorn crop, if available. Bears then moved to middle and lower elevations in the Canyon Oak or Bigcone Douglas Fir and Ceanothus/Manzanita Series. There, they fed on grasses, forbs, and garbage, when present (Boyer 1976). Movements followed elevational progressions of manzanita and chokecherry from July to early September. During drought and years of berry failures, however, unripe acorns and holly-leaved cherries were utilized, particularly from the Interior Live Oak Series (Novick 1979). In late summer and fall, many berry and mast crops were available at middle elevations in the Woodland Formation. Movements no longer followed an elevational pattern there, but shifted to concentrated food sources. From October through December, acorns or coffeeberries, depending on their production, dominated the diets (Boyer 1976; Novick 1979).

Habitat Preferences

Bray and Barnes (1967), summarizing earlier studies, characterized black bear habitats as areas of mixed conifer forests and brush interspersed with meadows and open hillsides. Habitat diversity, and the resulting ecotones and "edges", are important. Jonkel and Cowan (1971) found that the spruce-fir *(Picea-Abies)* forest provided year-round habitat for Montana bears. Lindzey and Meslow (1977) found that Sitka spruce *(Picea sitchensis)* zones with western hemlock *(Tsuga heterophylla)*, red cedar *(Thuja plicata)* and Douglas fir *(Pseudotsuga menziesii)* were preferred by bears in southwestern Washington. In Oregon, McCollum (1973) found coniferous forests were utilized somewhat (25%), but most use occurred in the Douglas fir—sclerophyll forest (49%). This habitat was used year-round and provided acorns, manzanita and salal, *Gaultheria shallon* berries. Oaks begin to play an increasingly important role in the more southerly regions of bear habitat. In northern California, Kelleyhouse (1980) and Piekielek and Burton (1975) noted that they provided important food (acorns) and also cover, when associated with conifers such as Douglas fir and ponderosa pine. In southern California (this study) and Arizona (LeCount 1980), oaks were preferred, especially when associated with chaparral or yellow pine forest.

Lindzey and Meslow (1977) found that the availability and juxtaposition of food and cover were the ultimate factors in the selection of vegetation types. Vegetation types within their bear's home ranges were used disproportionately to their availability, as we also found in this study. The Woodland Formation, dominated by oaks, was the physiognomic unit preferred by bears in our study area. Canyon oak is the most widely distributed oak in California and appears in a large number of vegetation types (Sawyer, Thornburgh, and Griffin 1977). In the San Bernardino Mountains, the Canyon Oak Series was considered year-round bear habitat, providing denning sites and food, as well as cover. Homogeneous stands of canyon oak were used, but ecotones of this species with black oak, bigcone Douglas fir and interior live oak were equally important. Ecotones increased plant species diversity and the amount of "edges" available. Kelleyhouse (1980) noted that fingers of mixed conifer forest extending into oak woodland, and their ecotonal associations, were important for northern California bears.

Use of Chaparral

In Arizona, LeCount (1980) found bears inhabiting Petran chaparral. This "chaparral", with its great diversity of berry and mast producing species, provides a wide variety of bear foods and is used throughout the year when bears are active. The Series of the California Chaparral Formation were not used continuously or uniformly. The Chamise Series occurring at low elevations, was essentially avoided. The Ceanothus/Manzanita Series was important in spring, although not as important as its availability would suggest. This was probably a function of lack of suitable cover, accessibility and food, though lack of water also may have contributed to seasonal limitations on chaparral use. However, islands of bigcone Douglas fir and oaks did provide cover and access. The association of these trees with canyon bottoms, where grasses and forbs usually were plentiful, probably was the most important factor allowing spring and early summer use of chaparral.

The fire history of the study area indicates that this was mature chaparral (greater than 20 yrs. old). It was nearly impenetrable, and poor in plant diversity and understory vegetation. Recently burned chaparral is rich in plant diversity (Hanes 1977), but probably lacks cover and may not be used by bears. Other studies have shown that recently logged conifer forests were avoided while clearcuts 8 to 15 yrs old were used (Jonkel and Cowan 1971; McCollum 1973; Lindzey and Meslow 1977).

Management Considerations

The plant communities in southern California have adapted to two primary environmental stresses, fire and drought. Canyon oak, a good sprouter, is very fire sensitive. In areas frequented by fires, it is usually a bush or low thicket with multiple trunks (Minnich 1976; Sawyer *et al.* 1977). It is tree-like in areas unable to carry intense burns (cliffs or deep canyons) and in areas with no recent fire history. Due to the steep topography and the U.S. Forest Service's past policy of total fire suppression, much of the preferred canyon oak habitat in the study area is in the tree form. Such habitat should continue to be protected throughout the San Bernardino Mountains, especially in the canyons and for several hundred metres on either side, as it provides valuable denning sites, food and escape cover.

We further recommend that management of bear habitat in the San Bernardino Mountains employ prescribed burning of chaparral to increase species diversity and age-class heterogeneity, reduce the build-up of undesirable fuels, and create a mosaic of vegetation types and wildlife openings. These wildlife openings should be situated away from roads and campgrounds to minimize human disturbance. Broad corridors of chaparral should separate these managed areas and steep slopes (greater than 60%) should be left untreated (Neff *et al.* 1979). Again, the cover provided by bigcone Douglas fir and canyon oak, especially near canyon bottoms and managed areas, should be protected from fire. The importance of large tracts of diverse habitat, with suitable escape cover, water and foods used seasonally, cannot be overemphasized.

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REFERENCES

Alt, G., F. Matula, F. Alt, and J. Lindzey. 1980. Dynamics of home range and movements of adult black bears in northeastern Pennsylvania. Pages 131–136. *In:* C. Martinka and K. McArthur, eds. Bears—their biology and management. February 1977. Kalispell, Montana.

Amstrup, S., and J. Beecham. 1976. Activity patterns of radio-collared black bears in Idaho. J. Wildl. Manage. 40(2): 340–348.

Boyer, K. 1976. Food habits of black bears (*Ursus americanus*) in the Banning Canyon area of San Bernardino National Forest. M.S. Thesis. California State Polytechnic University, Pomona. 63p.

Bray, O. 1967. A population study of the black bear in Yellowstone National Park. M.S. Thesis. Colorado State University, Fort Collins. 102p.

Bray, O., and V. Barnes. 1967. A literature review on black bear populations and activities. National Park Service and Colorado Cooperative Wildlife Research Unit. 34 p.

Burghduff, A. 1935. Black bears released in southern California. Calif. Fish and Game 21(1): 83–84.

Derby, J., I. Parker, T. Paysen, V. Bleich, H. Black, J. Mincks, and B. Harvey. 1978. Vegetation classification system for southern California. U.S. Forest Service and California Dept. of Fish and Game Interagency Publ. 44p.

Erickson, A. 1965. The black bear in Alaska—its ecology and management. Alaska Dept. of Fish and Game. Fed. Aid in Wildl. Restoration Project Report. Project W-6R-5, Work Plan 7. 19p.

Erickson, A., and G. Petrides, 1964. Population structure, movements and mortality of tagged black bears in Michigan. Pages 46–67. *In:* The Black Bear in Michigan. Michigan St. Univ. Res. Bull. 4.

Hanes, T. 1977. California chaparral. Pages 417–469. *in:* M. Barbour and J. Major, eds. Terrestrial Vegetation of California. John Wiley and Sons.

Jonkel, C., and I. McT. Cowan. 1971. The black bear in the spruce-fir forest. Wildl. Monogr. 27. 57p.

Kelleyhouse, D. 1980. Habitat utilization by black bears in northern California. Pages 221–227. *in:* C. Martinka and K. McArthur, eds. Bears—their biology and management. February 1977. Kalispell, Montana.

LeCount, A. 1980. Some aspects of black bear ecology in the Arizona chaparral. Pages 175–179. *in:* C. Martinka and K. McArthur, eds. Bears—their biology and management. February 1977. Kalispell, Montana.

Lindzey, F., and E. Meslow. 1977. Home range and habitat use by black bears in southwestern Washington. J. Wildl. Manage. 41(3): 413–425.

McCollum, M. 1973. Habitat utilization and movements of black bears in southwest Oregon. Thesis. California State University, Arcata. 61p.

Minnich, R. 1976. Vegetation of the San Bernardino Mountains. Pages 99–124. *in:* J. Latting, ed. Plant Communities of Southern California. Symposium Proceedings, California Native Plant Society, Berkeley, California.

Neff, D., C. McCulloch, D. Brown, C. Lowe, and J. Barstad. 1979. Forest, range, and watershed management for enhancement of wildlife habitat in Arizona. Arizona Game and Fish Department and Arizona Water Commission. Special Report No. 7. 109p.

Neu, C., C. Byers, and J. Peek. 1974. A technique for analysis of utilization—availability data. J. Wildl. Manage. 38(3): 541–545.

Novick, H. 1979. Home range and habitat preferences of black bears (*Ursus americanus*) in the San Bernardino Mountains of southern California. Thesis. California State Polytechnic University, Pomona. 58p.

Novick, H., J. Siperek, and G. Stewart. 1981. Denning characteristics of black bears in the San Bernardino Mountains of southern California. Calif. Fish and Game 67(1): 52–61.

Piekielek, W., and T. Burton. 1975. A black bear population study in northern California. Calif. Fish and Game 61(1): 4–25.

Poelker, R., and H. Hartwell. 1973. The black bear of Washington. Washington State Game Dept. Biol. Bull. 14. 180p.

Reynolds, D., and J. Beecham. 1980. Home range activities and reproduction of black bears in west-central Idaho. Pages 181–190. *in:* C. Martinka and K. McArthur, eds. Bears—their biology and management. February 1977. Kalispell, Montana.

Rogers, L. 1976. Effects of mast and berry crop failures on survival, growth and reproductive success of black bears. Trans. N. Am. Wildl. Nat. Resour. Conf. 41: 431–438.

Sawyer, J., D. Thornburgh, and J. Griffin. 1977. Mixed evergreen forest. Pages 359–382. *in:* M. Barbour and J. Major, eds. Terrestrial Vegetation of California. John Wiley and Sons.

Siperek, J. 1979. Physical characteristics and blood analysis of black bears (*Ursus americanus*) in the San Bernardino Mountains of southern California. Thesis. California State Polytechnic University, Pomona. 63p.

Stewart, G., J. Siperek, and V. Wheeler. 1980 Use of the cataleptoid anesthetic CI-744 for chemical restraint of black bears. Pages 57–61. *in:* C. Martinka and K. McArthur, eds. Bears—their biology and management. February 1977. Kalispell, Montana.

Zar, J. 1974. Biostatistical analysis. Prentice-Hall, Inc., Englewood Cliffs, N.J. 620p.

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COMPARISON OF AGE, GROWTH, AND FEEDING OF THE TAHOE SUCKER FROM SIERRA NEVADA STREAMS AND A RESERVOIR [1]

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The Tahoe sucker, *Catostomus tahoensis,* grew faster in a reservoir than in two tributary streams. Growth rates were evaluated both by comparison of back-calculated lengths using pectoral fin rays and by comparison of standard lengths at capture of age V suckers. Digestive tract fullness and energy content of the diets were not significantly different for fish in the streams or the reservoir, which indicated food availability was not a factor influencing the growth differential. Growing season length or increased maintenance metabolic costs for stream residents are likely temperature-related phenomena explaining observed growth rate differences.

INTRODUCTION

Growth rates of fishes inhabiting streams commonly differ from those in lacustrine systems. Carlander (1969) summarized the vast literature on growth of rainbow trout, *Salmo gairdneri,* with the observation that growth is slower in streams than in lakes. Brasch, McFadden, and Kmiotek (1958) report similar findings for brook trout, *Salvelinus fontinalis.* Ball and Jones (1960) compared growth rates of brown trout, *Salmo trutta,* in Llyn Tegid, Scotland, and neighboring streams and found growth rates were faster in tributary streams than moorland streams but lower than in the lake. Brown trout that migrated from streams into Llyn Tegid exhibited an accelerated growth rate. Finally, Tahoe suckers, *Catostomus tahoensis,* grew faster in Lake Tahoe, California/Nevada, than in a tributary stream (Willsrud 1966). In none of these cases was the underlying mechanism responsible for growth differences investigated.

Tahoe suckers have been reported to reach a maximum size of 600 mm in Pyramid Lake, Nevada (LaRivers 1962). However, collections of Tahoe suckers in 1978 in Sagehen Creek, a small stream in the Pyramid Lake watershed, yielded no suckers greater than 250 mm standard length (SL) (Vondracek unpubl. data). The objectives of the present study were to measure and evaluate growth rate differences among Tahoe suckers found in two small streams (Sagehen Creek and the Little Truckee River) and the reservoir (Stampede Reservoir) into which they drain and determine what factor(s) influence growth rate. In this system, four potential factors could account for differences in growth rates: 1) genetic differences, 2) extra energy costs of maintaining station in flowing systems, 3) quantitative or qualitative food availability, and 4) environmental temperature regime.

METHODS

Study Sites

Tahoe suckers were collected from Sagehen Creek, the Little Truckee River,

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[1] Accepted for publication October 1980.

and Stampede Reservoir. These waters are located in Sierra and Nevada counties, California. The collection site in Sagehen Creek was approximately 2 km in length, beginning 100 m above Stampede Reservoir and extending upstream (Figure 1). In the Little Truckee River collections were made from a point approximately 1.2 km from Stampede Reservoir and extending upstream 2 km. In Stampede Reservoir fish were collected in the Sagehen and the Little Truckee arms between 200 and 800 m from the influx of the tributary streams.

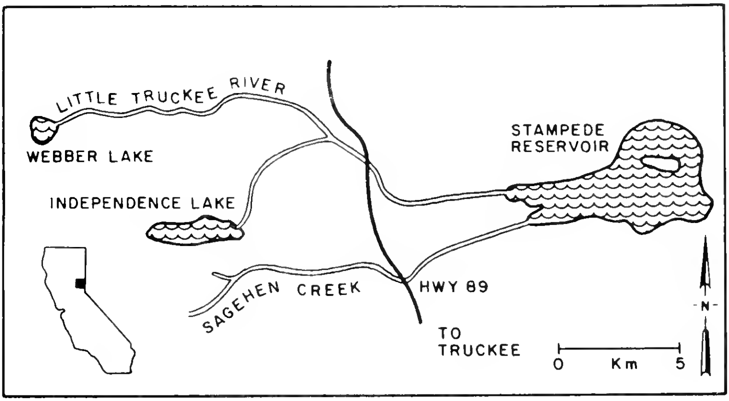

FIGURE 1. Watershed of Stampede Reservoir and the two tributaries, Sagehen Creek and the Little Truckee River.

Collection of Species

Suckers from the streams were captured with a backpack electroshocker (Smith-Root, Type V). Collection, proceeding upstream, generally occurred between 0800 and 1100 on an irregular basis throughout July, August, and early September. After collection, fish were transported alive to the University of California Sagehen Creek Field Station in an aerated fish tranport box with heavy insulation. Transport time was always less than 30 min and no evidence of egested food was found in the transport box. Fish were sacrificed upon return to the Field Station. Fish used for age and growth and stomach analysis were weighed to the nearest gram with a spring balance and standard length (SL) measured to the nearest millimetre. The left pectoral fin ray was removed and all visceral organs were removed and preserved in 10% formalin.

Suckers from Stampede Reservoir were taken with a hoop net and two experimental gill nets (33 m long, 3 m deep, 5 panels) of various mesh sizes (1 cm to 8 cm bar mesh). The gill nets were generally set so that one was parallel to shore and one was perpendicular to shore at depths of 3–5 m. The hoop net was generally set within 100 m of the gill nets. Nets were set at dusk and retrieved early the following morning. Fish were transported on ice to the Field Station for analysis.

Age Analysis

Pectoral fin rays were used to determine age using techniques described by Vondracek (1977). A microprojector was used to project an image of the transverse fin ray sections. Only fin rays with all annual rings clearly visible along the long axis of the section were used for back-calculation of growth rate. Difficulties in sectioning and mounting fin rays precluded growth rate determinations in four fish from Sagehen Creek, one from the Little Truckee River, and two from Stampede Reservoir. Back-calculation was based on the proportion method and employed a formula modified from Tesch (1971):

$$l_t = L + \frac{l - L}{FM} \cdot A_t$$

where:

l_t = calculated length at age t (mm)
L = intercept value determined by regression of pectoral fin ray radius vs. fish length (SL)
l = standard length at capture (mm)
A_t = distance from focus to annulus t (mm)
FM = distance from focus to the margin along the longest axis of the fin ray (mm)

A regression of pectoral fin ray radius and fish length was linear, validating the calculation formula. Back-calculated lengths at each age were used in a one-way analysis of variance (Steel and Torrie 1960) to determine if growth rates were similar in each area of collection.

Stomach Analysis

Length of the alimentary tract from esophagus to anus was measured to the nearest millimetre, blotted dry, and the volume of the alimentary tract determined by displacement. The anterior one-third of the intestine was then removed and the contents sorted. The remaining two-thirds of the intestine was dissected open and scraped. The entire intestinal wall was blotted dry and the volume of the intestine determined by displacement. The volume of the ingested material was calculated by subtracting the volume of the intestinal wall from the volume of the intact intestine. All contents were preserved in 10% isopropanol. Each food item was identified to order and to family, if possible, using keys by Merritt and Cummins (1978) and Pennak (1978), and enumerated. Each category was pooled from stream-caught and reservoir fish, weighed, and divided by the number of food items to obtain an average weight per individual food item. The average weight was then multiplied by the number of items per gut. The caloric equivalent of all food items as determined by Cummins and Wuycheck (1971) was calculated for each fish. Fish caloric equivalents were divided by fish weights to obtain the caloric equivalents, per gram of fish. Numbers and caloric equivalents of ingested food items for fish from each system were compared with a one-way analysis of variance.

Temperature Data

Temperatures at the Stampede Reservoir collecting site were measured at the bottom (4 m) and at 1 and 2 m depth with a YSI model 51 telethermometer and model 401 thermistor probe. These data were collected at approximately 2-week intervals beginning 5 July and ending 14 September 1979. The reservoir remained unstratified during this period, except near the dam (Marrin 1980). Despite the absence of a sharply-defined thermocline, a vertical temperature gradient was measured in the reservoir.

Temperature was continuously recorded using a Rustrak recorder and YSI model 401 thermistor during six diel cycles in lower Sagehen Creek 1.2 km above the reservoir at the mid point of the fish collection site. The six cycles are a composite of three 2-day intervals (20 and 21 July, 14 and 15 August, and 28 and 29 August). These data were compared to water temperatures continually recorded at the Sagehen Creek Field Station, 6 km upstream from the collection area. Correlations between temperatures from lower Sagehen and the Field Station allowed estimations of lower stream temperatures from Field Station temperature records during 30 June to 12 September 1979. Water temperature measurements taken during collection of suckers in the Little Truckee River were always within 1° C of temperatures in lower Sagehen Creek.

Length-Weight Relationship

A separate length-weight relationship was determined for fish collected in Sagehen Creek, Little Truckee River, and Stampede Reservoir. The equation used was log weight = a + b log length. The parameters a and b were determined by linear regression. The length-weight relationships were compared with a test of homogeneity of regression coefficients (Steel and Torrie 1960).

RESULTS

Growth Rates

A total of 60 fish, 17 from Sagehen Creek, 15 from the Little Truckee River and 28 from the reservoir, between ages I and VII was collected for analysis of growth rate (Tables 1 and 2). No statistical difference was found between the lengths of the two stream groups for age classes II and older (ANOVA $P > 0.05$). Thus, for statistical analysis, data from the two sreams were combined. Comparisons of lengths from the reservoir fish compared with the stream fish showed that suckers in each age class older than age class I were growing faster in the reservoir than in the streams (Table 1, Figure 2). Growth acceleration in the reservoir fish seems especially apparent from age class II through V (Table 1, Figure 2). These back-calculated results are corroborated by the complete lack of overlap of the ranges of standard lengths (at capture) of age V stream vs. reservoir suckers, the age class which contained the greatest number of individuals from both streams and reservoir (Table 2). The adequate numbers of Tahoe suckers collected over a 10-week period and the demonstrated statistical differences among zoogeographic groups preclude the necessity of larger samples, which may adversely affect abundance of the species in the watershed. The allometric relationship of length to weight among the three groups was virtually identical across all age classes (Figure 3).

Age I individuals were collected only in streams. From back-calculated lengths, no significant differences ($P > .05$) in first year growth were found between fish collected in Sagehen Creek and in Stampede Reservoir. This suggests that young Tahoe suckers (young-of-year and age I) initially inhabit streams and later move into the reservoir.

TABLE 1. Mean Lengths and (Sample Sizes) of Tahoe Suckers at Each Age, Determined by Back-Calculation Using Pectoral Fin Rays.

Collection site	*Age* *I**	*II*	*III*	*IV*	*V*	*VI*	*VII*
Sagehen Creek	65(13)	88(12)	109(12)	126(12)	138(11)	137(4)	
Little Truckee R.	58(14)	81(14)	99(14)	115(14)	135(14)	144(7)	154(3)
Stampede Reservoir	64(26)	101(26)	134(26)	160(26)	171(25)	178(14)	200(7)

* The only age class in which lengths of Tahoe suckers from stream populations did not differ significantly ($P < 0.05$) from individuals taken from the reservoir.

TABLE 2. Mean (± SD) and Range of Standard Lengths for Age V Tahoe Suckers at Capture.

Collection site	*Standard length* *Mean*	*Range*	*Number of fish*
Sagehen Creek	150 ± 9	141–162	11
Little Truckee River	146 ± 23	114–179	8
Stampede Reservoir	212 ± 13	191–228	13

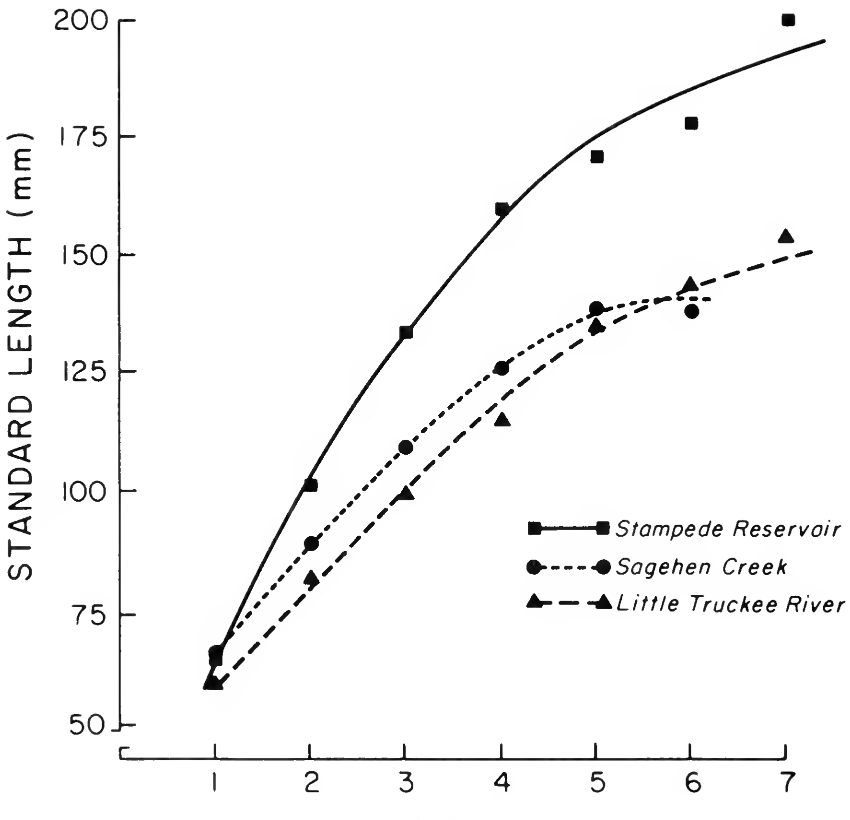

FIGURE 2. Back-calculated lengths of Tahoe suckers at each age in Stampede Reservoir, Sagehen Creek, and the Little Truckee River (curves fitted by eye).

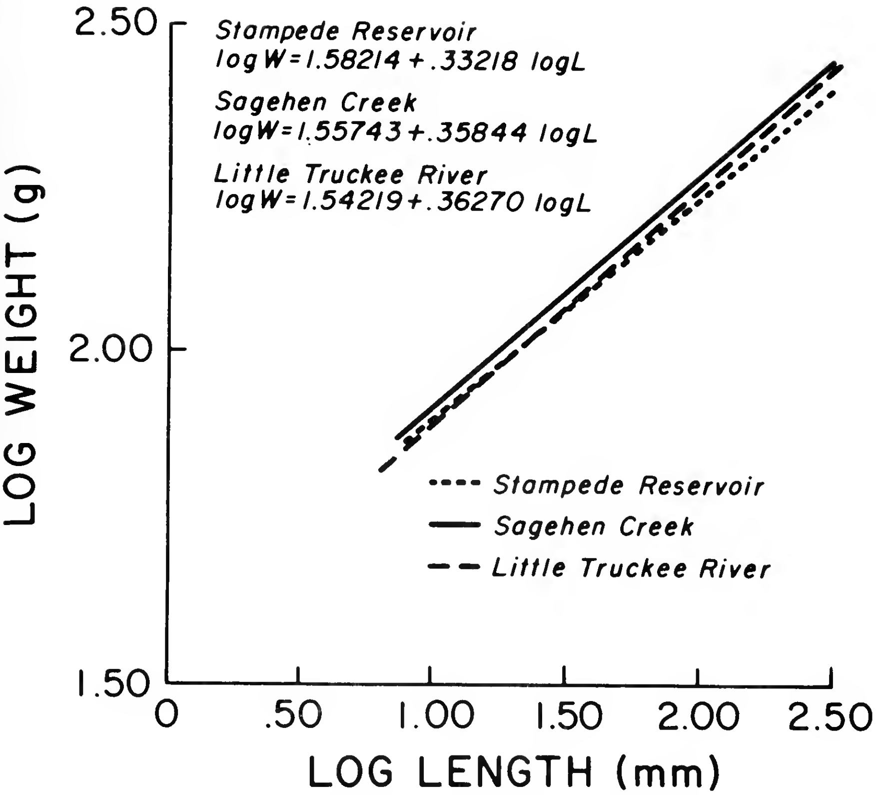

FIGURE 3. Length-weight relationships of Tahoe suckers from Stampede Reservoir, Sagehen Creek, and the Little Truckee River.

Despite concerted attempts, no age II and only two age III fish, were collected from all three locations. No fish younger than age IV were collected in the reservoir.

Food Habits

The major components of the sucker diet in both streams and reservoir are algae, detritus, and chironomid larvae (Table 3). However, the chironomid larvae eaten by reservoir suckers averaged three times larger by weight than those eaten by stream fish. It was also noted that the diet of stream-dwelling Tahoe suckers encompassed a wider variety of taxa than the diet of the reservoir fish. Ephemeroptera, Trichoptera, Plecoptera, Megaloptera, and Coleoptera were absent in the guts of Stampede Reservoir suckers (Table 3). Benthic samples in Stampede Reservoir collected simultaneously with our study (Marrin 1980) revealed that the suckers were not selective in their feeding habits in the reservoir. The number of taxa available in the reservoir was lower and the average size of available chironomid larvae was larger (Marrin 1980). Although benthic samples were not collected from Sagehen Creek or the Little Truckee

River, dietary items from the resident fishes closely paralleled previous stream invertebrate collections made in 1974 (G. Grossman, Post-graduate Research Biologist, University of California, Davis, unpubl. data) and 1978 (Cech, unpubl. data). The fullness of the digestive tract of suckers in the present study from each location on various summer collecting dates (Table 4) revealed no significant differences among the locations (ANOVA $P > 0.05$). Based on caloric equivalents per gram of fish, there was no difference ($P > 0.05$) in energy content of the food items from each collection site.

TABLE 3. Stomach Contents of Tahoe Suckers as Percent Volume, Average Number, and Percent Occurrence with (Number of Fish).

	Stampede Reservoir (14)			*Sagehen Creek (12)*			*Little Truckee River (12)*		
	Mean % Vol.	*avg. #*	*Mean % Occur.*	*Mean % Vol.*	*avg. #*	*Mean % Occur.*	*Mean % Vol.*	*avg. #*	*Mean % Occur.*
Algae & detritus	73	N.A.	100	70	N.A.	100	59	N.A.	100
Chironomidae	20	146	92	8	193	100	11	247	93
Diptera	3	14	8	<1	7	29	3	137	29
Simuliidae	0	–+	0	<1	3	14	<1	9	29
Diptera pupae	<1	11	80	2	5	86	4	8	79
Ephemeroptera	0	–	0	10	29	79	18	52	71
Trichoptera	0	–	0	2	16	57	3	27	57
Plecoptera	0	–	0	2	10	64	1	15	50
Megaloptera	0	–	0	5	4	29	<1	3	21
Coleoptera									
adult	0	–	0	<1	4	29	0	–	0
larvae	0	–	0	<1	43	29	<1	16	<1
Pelecypoda	<1	1	12	<1	8	50	<1	2	<1
Gastropoda	0	–	0	<1	2	36	0	–	0
Oligochaeta	3	8	48	<1	3	29	<1	1	14
Hydracarina	<1	8	8	<1	1	7	<1	9	14
Cladocera	<1	*	44	<1	+	7	<1	–	29
Other	<1	1	12	<1	—	1	<1	–	1

* = present in small volumes, but not counted.
\+ = absent or negligible
N.A. = not applicable

TABLE 4. Mean Digestive Tract Fullness of Tahoe Suckers.

Collection site	*Date of collection*	*Number of fish*	*Average fullness **
Stampede Reservoir	26 July 1979	3	15.60
	8 Aug. 1979	4	13.98
	23 Aug. 1979	7	7.28
Sagehen Creek	7 Aug. 1979	5	15.45
	15 Aug. 1979	5	16.20
Little Truckee R.	7 July 1979	4	16.06
	6 Sept. 1979	8	20.89

* Average fullness is presented as millilitres of digestive track content/gram of fish body weight $\times 10^{-3}$.

Temperature

The temperature regime at the collecting sites in Sagehen Creek and the Little Truckee River fluctuated on a diel cycle, with temperature maxima occurring at about 1600 h and minima at about 0800. Daily mean stream temperature increased from near 15° C in early July to a peak of about 17° C in late July and early August (Figure 4). Mean temperature then decreased to about 13° C in mid-September.

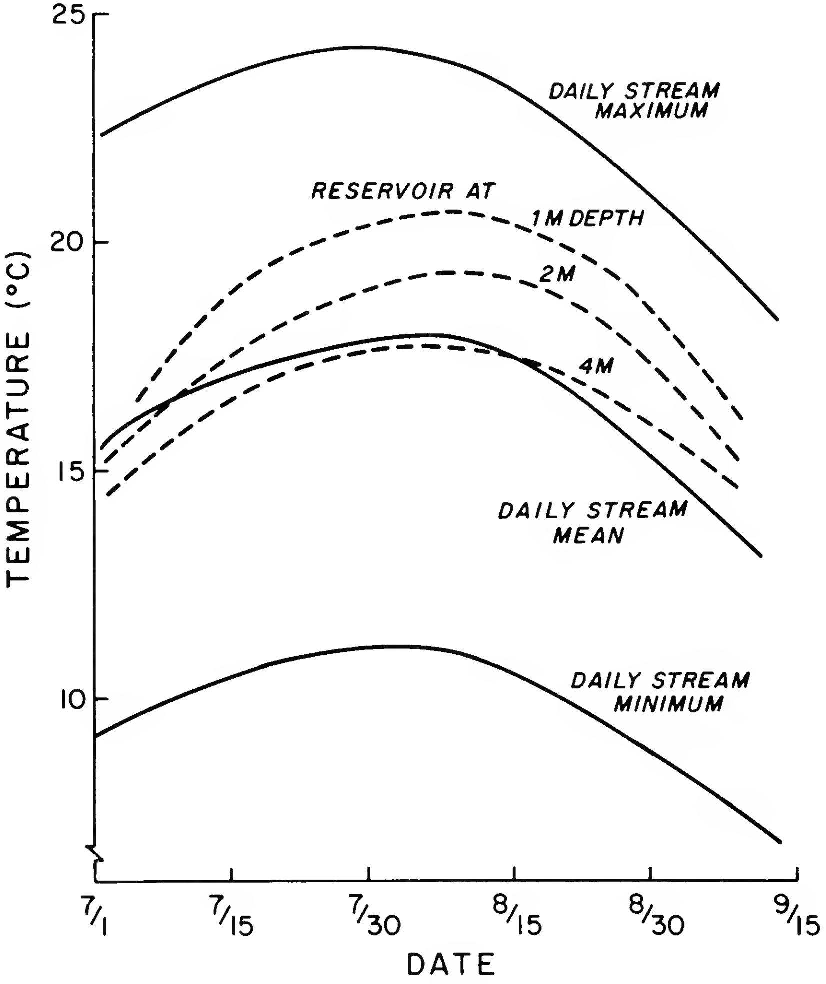

FIGURE 4. Maximal, mean, and minimal water temperatures in Sagehen Creek, and water temperatures at 1, 2 and 4-m depths in Stampede Reservoir.

Vertical temperature profiles at the Stampede Reservoir collecting sites generally ranged less than 3° C through a diel cycle (Marrin 1980), whereas 12° C fluctuations characterized Sagehen Creek (Figure 4). Mean creek temperatures and bottom temperatures in the reservoir followed a similar pattern through the summer sampling period.

DISCUSSION

Faster growth of Tahoe suckers in Stampede Reservoir was demonstrated by lengths determined from back-calculation (Table 1, Figure 2) and the observed difference in standard length (without overlap) at capture of age V suckers (Table 2). We were unable to capture sufficient numbers of fish and aged II, III and IV for direct comparisons of each age. Consecutive age-classes, age II, III, and IV were weak or missing in the stream samples and age I, II, and III were absent in collections from the reservoir. The absence of age I suckers in the reservoir, and the comparable growth of all age I suckers caught provides evidence that Tahoe suckers spend their first 1+ years in streams. Tahoe suckers migrate into streams for spawning (Willsrud 1966). The missing age II and weak age III year classes may well represent a consequence of poor spawning associated with two of the most severe drought years (1976, 1977) in California during the past two decades. Drought-induced reduction in stream flow may have impeded the spawning migration and/or influenced survival of young-of-the-year.

Several factors could influence the observed differential growth. Evidence indicates that the observed differences in growth are not due to genetic differences between stream and reservoir groups. The allometric relationship between length and weight is not significantly different (Figure 3), the streams and reservoir are contiguous, with no man-made barriers to prevent gene flow, and collection areas were less than 6 km apart and suckers now inhabiting Stampede Reservoir are from the parental stock from Sagehen Creek and the Little Truckee River.

Microdistribution of Tahoe suckers in streams has not been investigated quantitatively. However, observations of the bottom-dwelling sucker suggest that energy expenditures to mantain station in a flowing system may be low. During collections of Tahoe suckers for this and other studies, we have found suckers generally prefer pools and areas of low flows. Suckers situated in an instream observation tank at the Sagehen Creek Field Station maintain position without apparent swimming motion at flow rates approximating 17 cm/s or one body length/s for large individuals. Suckers selected areas of low flow, such as behind rocks and in depressions of the stream bed. Further, suckers in Brett-type respirometers (Brett 1964), subjected to water velocities of one body length/s, did not swim and had metabolic rates virtually identical to those measured in static respirometers (Vondracek and Cech 1980).

Fullness of the digestive tract and caloric equivalents of the major food items of Tahoe suckers suggest that food availability does not explain growth differences between stream and reservoir suckers, although absolute feeding rates in each system remain to be studied. Other factors which should be considered are the digestibility and nutrient composition of specific food items. For example, the increased dietary diversity of the stream suckers may make available a wider variety of essential amino acids, fatty acids, and trace elements. The absolute importance of this difference, however, may be negligible as the stream suckers consumed the more diverse diet, yet grew more slowly than the reservoir fish (Table 1).

Temperature regimes in streams and lacustrine systems can differ in three important ways. First, mean stream temperatures, especially high mountain streams, can be several degrees cooler than the epilimnion of lakes in the same region. Second, small streams, especially those receiving substantial solar radiation, generally exhibit marked diel temperature fluctuations, e.g. 6°C (Hynes

1970). Needham and Jones (1959) reported an average daily July temperature fluctuation of 12°C in Sagehen Creek at the Field Station. Third, small streams are isothermous throughout their depth profile at a particular point, eliminating vertical behavioral thermoregulation by resident fishes.

The mean temperatures of the streams approximated those at the bottom of the reservoir, where suckers reside throughout the summer (Figure 4). However, reservoir temperature data from the rest of the year are not available. Because of the greater thermal inertia, this large body of water probably stays warmer than the streams through the autumn (Wetzel 1975). It is also possible that the reservoir warms more slowly than the streams in the spring. Migrations of spawning suckers into the streams in the spring could allow a longer growing season in warmer water for those individuals which later return to the reservoir. In contrast, the spawning runs upstream may be of short duration, and some Tahoe suckers may spawn in the reservoir (A. J. Cordone, Fishery Biologist, Calif. Dept. Fish and Game, pers. commun.).

In contrast to streams, lacustrine systems may become thermally stratified. Thus, behavioral thermoregulation for energetic advantage by the resident fishes is possible (McLaren 1963, Brett 1971). Diel movements of Tahoe suckers in Stampede Reservoir have not been studied. However, Marrin (1980) investigated their migration patterns in nearby Webber Lake, where the pattern is nocturnal inshore movements and diurnal offshore movements along the bottom. If movements are similar in Stampede Reservoir, Tahoe suckers would experience only small changes in temperature (Figure 4). In contrast, stream populations are always subjected to a wide diel temperature cycle.

Hokansen, Kleiner, and Thorslund (1977) found growth differences between juvenile rainbow trout exposed to cyclic temperatures and those subjected to constant temperatures equivalent to the mean of the cycles. Vondracek and Cech (1980) have found that Tahoe suckers display a higher routine metabolic rate when exposed to Sagehen Creek fluctuating temperatures than when exposed to constant mean temperature. Increased maintenance energy demands should leave less energy for growth and other non-maintenance demands (Winberg 1956).

The observed growth differences of Tahoe suckers between Stampede Reservoir and its tributary streams (Sagehen Creek and the Little Truckee River) are probably due to temperature characteristics of the environments rather than genetic, current flow, or dietary differences. The ability of suckers to lengthen their growing season by movements in their natural habitat and/or to avoid lengthy exposure to wide temperature fluctuations characteristic of streams seems especially important in maximizing growth. A worthwhile objective for future research would be to investigate the partitioning of these two effects for Tahoe suckers as well as the other native and introduced fishes.

ACKNOWLEDGMENTS

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REFERENCES

Ball, J. N., and J. W. Jones. 1960. On the growth of the brown trout of Llyn Tegid. Lond. Zool. Soc., Proc. 134: 1–41.

Brasch, J., J. McFadden, and S. Kmiotek. 1958. The eastern brook trout: its life history, ecology, and management. Wisc. Cons. Dept. Publ. 226. 11 p.

Brett, J. R. 1964. The respiratory metabolism and swimming performance of young sockeye salmon. Can., Fish. Res. Bd., J., 21: 1183–1226.

______. 1971. Energetic response to salmon to temperature: a study of some thermal relations in the physiology and freshwater ecology of sockeye salmon (*Oncorhynchus nerka*). Am. Zool., 11: 99–113.

Carlander, K. 1969. Handbook of freshwater fisheries biology, Vol. 1. Iowa State Univ. Press, Ames, Iowa 752 p.

Cummins, K. W., and J. C. Wuycheck. 1971. Caloric equivalents for investigations in ecological energetics. Mitt. Internat. Verin. Verh., 18: 1–158.

Erman, D. C. 1973. Upstream changes in fish populations following impoundment of Sagehen Creek, California. Am. Fish. Soc., Trans., 102: 626–629.

Hokanson, K. E. F., C. F. Kleiner, and T. W. Thorslund. 1977. Effects of constant temperatures and diel temperature fluctuations on specific growth and mortality rates and yield of juvenile rainbow trout, *Salmo gairdneri*. Can., Fish. Res. Bd., J., 34(5): 639–648.

Hynes, H. B. N. 1970. The ecology of running waters. Univ. of Toronto Press. 555 p.

LaRivers, I. 1962. Fishes and fisheries of Nevada. Nev. Fish Game Comm. 782 p.

Marrin, D. L. 1980. Food niche and habitat utilization of introduced trouts and two native non-game fishes in sub-alpine lakes. Thesis. Univ. of Calif., Berkeley, Calif. 80 pp.

McLaren, I. A. 1963. Effects of temperature on growth of zooplankton and the adaptive value of vertical migration. Can., Fish. Res. Bd., J., 20(3): 658–727.

Merritt, R. W., and K. W. Cummins. 1978. An introduction to the aquatic insects. Kendall/Hunt Publishing Co., Dubuque, Iowa. 441 p.

Needham, P. R., and A. C. Jones. 1959. Flow, temperature, solar radiation, and ice in relation to activities of fishes in Sagehen Creek, California. Ecology, 40(3): 465–474.

Pennak, R. W. 1978. Fresh-water invertebrates of the United States, 2nd Ed. John Wiley & Sons. New York. 803 p.

Steel, R. G. D., and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Co. Inc., New York. 480 p.

Tesch, F. W. 1971. Age and growth. Pages 98–130 *in* W. E. Ricker, ed. Methods or assessment of fish production in fresh waters. IBP handbook No. 3. Blackwell Scientific Publications, Oxford. 348 p.

Vondracek, B. 1977. Characteristics of suckers in Green Bay and Lake Michigan, with special reference to white suckers. Thesis. Univ. Wisconsin. 60 p.

Vondracek, B., and J. J. Cech, Jr. 1980. A preliminary study of stream fish respiration in cycling temperatures and its potential influence on growth rates. Cal-Neva Trans. (in press).

Wetzel, R. G. 1975. Limnology. W. B. Saunders Co., Philadelphia, Pennsylvania. 743 p.

Willsrud, T. 1966. A study of the Tahoe sucker, *Catostomus tahoensis* Gill and Jordan. Thesis. California State Univ., San Jose, California. 77 p.

Winberg, G. G. 1956. Rate of metabolism and food requirements of fishes. Can. Fish Res. Bd. Transl. Serv. No. 194: 1–202.

NOTES

AN UNDERWATER FISH TAGGING METHOD

INTRODUCTION

Fish tagging is an invaluable means of acquiring specific information on growth and movement. Fishes are usually captured by hook, net, or trap, brought to the surface, pertinent data recorded, and the fish tagged and released. However, there are potential problems for the captured fish. First, hooks can cause tissue damage in the head region. Nets or traps can also cause injury. Second, the rapid ascent to the surface from depth has inherent risks. Gas bladder volume can not rapidly be regulated in physoclistous species and rapid ascent often causes over-inflation with subsequent stomach eversion. Such internal distention can cause physical trauma. Gotshall (1969) partially solved the over-inflation problem by deflating the gas bladder through the body wall using a hypodermic needle. However, there remains the possibility of damage due to the initial gas bladder over-inflation as well as possible needle trauma. Third, rapid pressure change resulting from rapid ascent could cause gas embolism. Finally, it is difficult to ascertain the immediate survival success due to predation resulting from potential short-term behavior changes in stressed fish.

Underwater tagging equipment and tags vary widely. Yamashita and Waldron (1958) used a hollow needle carrying a barbed tag. The needle was used onboard a boat with conventionally captured fish. The insertion and removal of the needle left the tag implanted. This tagging method has the advantage of speed, but fish must still be captured and brought to the surface. Ebert (1964) developed a tagging gun which thrust a shaft holding a barbed tag. This method was employed underwater, thereby eliminating some stress to the fish. However, there are some disadvantages. First, the diver must be in close proximity to the target fish and this is often difficult with many species. It is also possible to improperly penetrate a fish with a needle if angle or distance are misjudged or if the fish moves. Furthermore, length data can not be collected.

Matthews and Bell (1979) used a modification of the Waldron device to tag fish underwater. A hand spear was modified to hold a hollow needle which accepted a Floy dart tag that remained in the fish following penetration. The procedure was also carried out underwater, but has disadvantages similar to Ebert's method. Length data can not be collected and improper penetration could cause injury and/or mortality.

This paper describes a tagging method which minimizes potential trauma to fish and has proven successful for various species.

METHODS AND MATERIALS

Target species were *Sebastes chrysomelas,* black-and-yellow rockfish; *S. carnatus,* gopher rockfish; *Hexagrammos decagrammus,* kelp greenling; *Scorpaenichthys marmoratus,* cabezon; and *Ophiodon elongatus,* lingcod. Using a method apparently similar to Hallacher's (1978), fish were readily caught underwater by divers using fabricated fishing poles. A pole consisted of a 30 to 50 cm long, 1.3-cm diameter PVC pipe with an equally long piece of stainless steel wire attached firmly to one end. A swivel and feathered rockfish jig were attached to the other end of the wire. The pipe was scribed in centimetres and a stainless steel, 5-cm bolt was inserted through the pipe at the base at the zero centimetre mark to serve as a stop for ease in measuring fish (Figure 1).

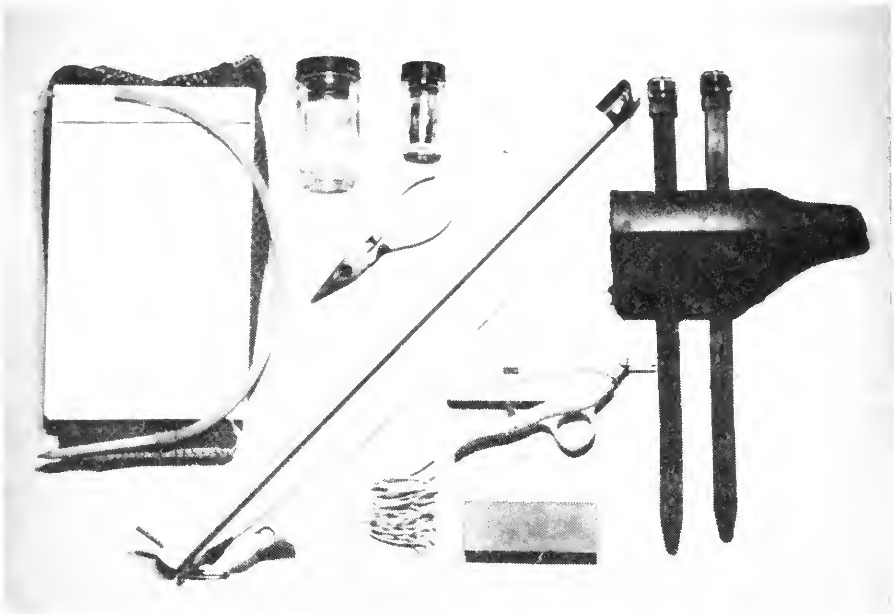

FIGURE 1. Fish tagging equipment carried by diver includes slate and bag, jars with bait and hooks, wire cutters, fishing pole marked in centimetres, tagging gun with arm sheath, tags, and needle sharpening stone. *Photograph by T. C. Wilson,* March 1980.

The tagging equipment consisted of a continuous feed FLOY MARK II tagging gun with needle and FD-67C type anchor tags.

Two divers, each carrying a fishing pole, a small nylon mesh bag, additional bait and hooks, small wire cutters, a tagging gun loaded with tags and a slate (Figure 1), did the tagging. If a fish accepted the hook, the hook was set by a slight tug. The fish was grasped carefully in one hand and tagged beneath the dorsal fin with the free hand (Figures 2 and 3). The fish was then measured, unhooked, and released. If the hook was not easily removed without tissue damage, the wire cutters were used to cut off the barb and tip. Each diver operated without assistance.

DISCUSSION

This underwater tagging technique has several advantages. When compared to tagging methods utilizing usual capture techniques, this method offers minimal chance of injury since nets and traps are not involved and hook placement is constantly observed, thereby decreasing the possibility of hook ingestion. Gas bladder expansion is not a problem. Territorial species are not removed from their home range and most important, when compared to other underwater

FIGURE 2. Underwater tagging procedure. Diver has set tag and removed gun. *Photograph by T. C. Wilson,* March 1980.

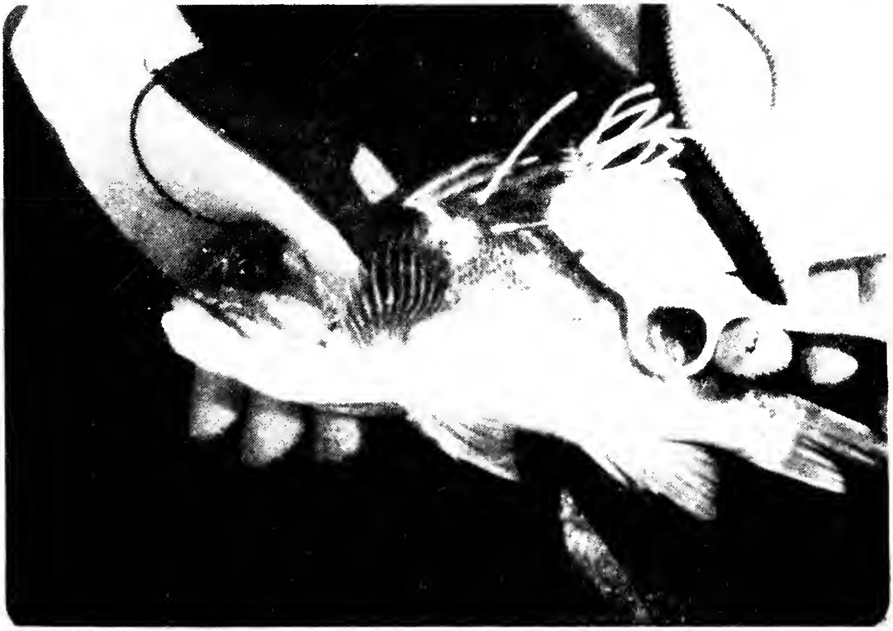

FIGURE 3. Underwater tagging procedure. Close-up of properly placed tag. *Photograph by T. C. Wilson,* March 1980.

methods, tags may be carefully placed and set to decrease excess trauma and chance of tag loss. Data collection is also increased since length data can be recorded.

Stress is apparently minimal since over 20 fish have been rehooked immediately following capture, tagging, and release. Furthermore, fish have been observed and recaptured up to 1.5 years following capture and tagging. Using the technique described, several hundred fish in the area of Diablo Canyon, San Luis Obispo County, have been tagged. The technique should be useful for any species which readily accepts bait or artificial lures and does not show an avoidance to scuba divers.

REFERENCES

Ebert, E. E. 1964. Underwater tagging gun. Calif. Fish Game, 50(1): 29–32.

Gotshall, D. W. 1969. A tagging study of the blue rockfish, *Sebastodes mystinus*. Arcata, CA: Humboldt State College; 66p. thesis.

Hallacher, L. E. 1978. Patterns of space and food use by inshore rockfishes (Scorpaenidae: Sebastes) of Carmel Bay, California. Berkeley, CA: Univ. of Calif. Berkeley; Dissertation.

Matthews, J., and J. D. Bell. 1979. A simple method for tagging fish underwater. Calif. Fish Game, 65 (2): 113–117.

Yamashita, D. T., and K. D. Waldron. 1958. An all-plastic dart-type fish tag. Calif. Fish Game, 44 (4): 311–317.

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CONCURRENT SEXUAL BEHAVIOR IN THREE GROUPS OF GRAY WHALES, *ESCHRICTIUS ROBUSTUS,* DURING THE NORTHERN MIGRATION OFF THE CENTRAL CALIFORNIA COAST

On 23 March 1979, north of Pecho Rock, San Luis Obispo County, sexual behavior was observed in gray whales, *Eschrictius robustus,* during their northern migration. An increasing number of gray whales had been observed during March, indicating a peak in migration for the central California nearshore area. During the early afternoon, three groups of whales were observed floating in nearshore areas. One group was approximately 400 m offshore, while the remaining two groups were located in two small *Nereocystis* (bull kelp) beds in approximately 15 m of water approximately 200 m offshore. All three groups exhibited similar behavior. Initially, a fluke was observed perpendicular to the sea surface and flippers were frequently observed upright above the water surface (Figure 1). Two whales were observed venter-to-venter. Water turbulence and surface thrashing that resulted from fluke movement was substantial. Typically, two whales were visible at the surface while a third was only occasionally visible. However, it was difficult to determine the relative positions of each whale since they continued to roll and submerge just beneath the surface. Two groups involved three whales while the third group apparently involved only two whales. Walker (1971) reported that the third whale of the mating triad is a male whose function is to stabilize the copulating pair. During his studies in Scammon's Lagoon, Baja, California, Samaras (1974) noted that only one observation was made of two whales mating in the absence of a third. Two of the observations described in this paper indicate the close association of a third whale which might possibly serve in a stabilizing role.

FIGURE 1. Copulatory behavior in venter-to-venter gray whales north of Pecho Rock, San Luis Obispo County, California.

Similar behavior was exhibited concurrently in all groups. The boat from which observations were made drifted close to two of the groups and a series of photographs was taken. Shortly after Figure 1 was taken, a pair rolled apart and a penis became visible (Figures 2 and 3). The duration of the activity from first observation until the northern migration resumed was approximately 60 min.

On 25 March 1979, Joseph Gibson (San Francisco State Univ., pers. commun.) observed similar whale behavior while directing a whale watching cruise from Princeton Harbor, San Mateo Co., California. Between 1200 and 1600 h, he observed the copulatory behavior of two males with a single female 2 miles south of Pillar Point, San Mateo Co. and 2 miles offshore. He noted similar behavior in the same general area five times during March and April 1979. His description was similar, with the observer's attention drawn to floating whales with flippers perpendicular to the water surface.

It is commonly accepted that breeding behavior in gray whales takes place at the southern end of their migration, in waters off Baja, California. However, Orr (1972) noted that nonpregnant females are impregnated during the southern migration or close to the calving areas on the west side of Baja and in lagoons of the Mexican mainland. In fact, these southern lagoons are commonly known as the gray whale breeding grounds. Scammon (1974), Gilmore (1960) and Norris, et al. (1977) reported gray whale sexual behavior in southern Baja, typically at lagoon mouths. However, breeding behavior is not limited to the southbound migration and Mexican waters.

FIGURE 2. Separation of whales, with venters to surface. Penis became visible as the pair rolled apart. Smaller organ in foreground may be the semi-flaccid penis of the second male.

FIGURE 3. Lone male following sexual encounter. Female has dived and left immediate area.

Samaras (1974) observed mating behavior in a trio of northbound gray whales near the Palos Verdes Peninsula, Los Angeles Co., California in 1973. He further noted that mating has been observed during both the southern and northern migrations. Newman (1976) observed whales exhibiting sexual behavior in a bay at La Push, Washington. Apparently only two whales were involved and both were males, each with an erect penis. He then suggested homosexual behavior. Initially, we found it difficult to distinguish a third whale in two of the three groups observed, and it is possible that Newman failed to observe a female that was actually present. Hart (1977) noted sexual behavior in pairs of whales near Pachena Point, British Columbia during northern migration. Baldridge (1974) noted sexual behavior in migrating whales near Carmel and Monterey, California. His description of the sexual activity was similar to that in our own observations. Houck (1962) described what appeared to be sexual activity in gray whales near Arcata, California, and Sauer (1963) noted mating behavior in the Bering Sea.

The observations described in this paper provide additional evidence for sexual activity of gray whales away from calving areas. Furthermore, it is of particular interest to note that in this case, sexual activity in three spatially separated groups was taking place concurrently. Such observations have not apparently been previously reported.

REFERENCES

Baldridge, A. 1974. Migrant gray whales with calves and sexual behavior of gray whales in the Monterey area of central California, 1967–73. U. S. Fish Wildl. Serv., Fish. Bull. 72(2): 615–618.

Gilmore, R. M. 1960. A census of the California gray whale. U. S. Fish. Wildl. Serv., Spec. Sci. Rep. Fish. 342: 1–30.

Hart, G. F. 1977. Observations on the spring migration and behavior of gray whales near Pachena Point, British Columbia. Murrelet, 58(2): 40–43.

Houck, W. J. 1962. Possible mating of grey whales on the northern California coast. Murrelet, 43(3): 54.

Newman, J. R. 1976. Observations of sexual behavior in male gray whales, *Eschrictius robustus.* Murrelet, 57(2): 49.

Norris, K., R. M. Goodman, B. Villa-Ramirez, and L. Hobbs. 1977. Behavior of California gray whale, *Eschrictius robustus,* in southern Baja California, Mexico. Fish. Bull., U. S. 75(2): 159–172.

Orr, R. T. 1972. Marine mammals of California. Univ. Calif. Press, Berkeley. 64p.

Samaras, W. F. 1974. Reproductive behavior of the gray whale, *Eschrictius robustus,* in Baja California. Bull. Southern Calif. Acad., Sci., 73(2): 57–64.

Sauer, E. G. F. 1963. Courtship and copulation of the gray whale in the Bering Sea at St. Lawrence Island, Alaska. Psychol. Forsch., 27: 157–174.

Scammon, C. M. 1974. The marine mammals of the north-western coast of North America. John H. Carmany and Co., San Francisco. 319p.

Walker, T. J. 1971. The California gray whale comes back. Natl. Geogr. Mag. 139: 394–415.

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MORPHOLOGY AND GROWTH OF A PUGHEADED BROWN ROCKFISH, SEBASTES AURICULATUS

During a population study on brown rockfish, *Sebastes auriculatus,* in San Francisco Bay, a pugheaded brown rockfish (Figure 1) was caught four separate times. The study, which included the taking of morphometric, tagging, and growth data, provided an opportunity to statistically test certain characteristics of the pugheaded fish against normal brown rockfish. The morphometric comparisons describe the effects of the pugheaded condition on growth of other parts of the body. Tagging data show the effects of pugheadedness on overall growth. This is the only instance known to us of a direct measurement of growth of a pugheaded fish. These data can be used to answer the question: Is this fish handicapped by its pugheadedness and, if so, how much?

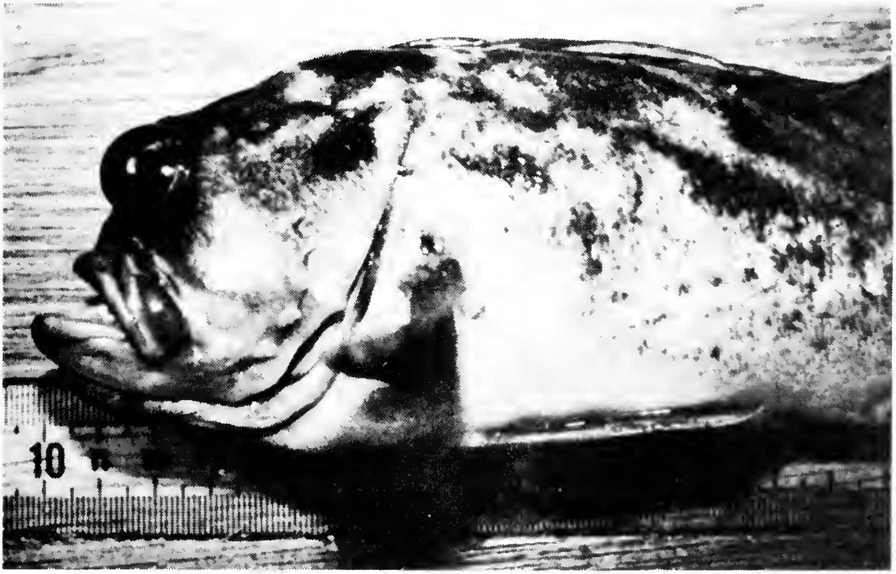

FIGURE 1. A pugheaded brown rockfish, *Sebastes auriculatus,* caught in San Francisco Bay near Tiburon, California.

Morphometrics of over 100 normal fish were regressed against total length (tip of lower jaw to the maximum length of the caudal fin). Measurement definitions were the same as those used by Phillips (1957). These regressions were used to estimate morphometrics for an "average" fish with a total length of 240 mm. The morphometrics of the pugheaded fish were compared with those of the "average" fish using *t*-tests.

The three morphometrics associated with pugheadedness—head, snout, and upper jaw lengths—were significantly smaller ($P > 0.05$) than the expected values (Table 1). The least depth of the caudal peduncle is significantly larger than expected normally. However, regression of the caudal peduncle against other parts of the body indicate that this is the result of random variations in the data. No other body parts differ significantly from those expected.

TABLE 1. Morphometrics and *t*-Test Statistics for Pugheaded and "Average" Brown Rockfish, *Sebastes auriculatus.*

Measurements	*Pugheaded fish (mm)*	*Estimated "average" fish (mm)*	*t-test value*	*Degrees of freedom*
Head length	63.5	71.5	−2.31*	109
Body depth at ventral fin	68.6	67.2	0.24	79
Body depth at anal fin	53.4	52.1	0.33	103
Length of anal fin base	29.2	29.8	−0.20	115
Length of snout	13.2	17.5	−1.73*	109
Width of orbit	16.2	17.1	−0.46	114
Width of interorbital space	12.9	12.8	0.11	106
Length of upper jaw	30.0	34.6	−2.38*	107
Width of base of pectoral fin	20.4	19.2	0.99	111
Longest pectoral fin ray	49.9	52.5	−0.78	110
Longest pelvic fin ray	37.8	41.7	−1.14	108
Length of pelvic spine	27.6	26.8	0.35	107
Length of first anal spine	15.2	14.0	0.69	107
Length of second anal spine	30.1	28.0	0.64	90
Length of third anal spine	27.1	25.9	0.48	107
Longest anal fin ray	35.7	37.5	−0.80	107
Longest dorsal fin spine	37.3	33.9	0.66	76
Longest dorsal fin ray	31.4	33.2	−0.71	94
Least depth of caudal peduncle	22.0	19.5	1.74*	77
Posterior of anus to origin of anal fin	10.4	11.2	−0.31	56

* Significant at the 95% probability level.

Body parts other than those directly stunted by the pugheadedness grew in normal proportion to each other. The orbit and interorbital space were not significantly different from normal, indicating that the pugheadedness and exophthalmic condition (bulging eye) are the results of a shortened snout and upper jaw and are not independent conditions.

During a period of 15 months, the pugheaded brown rockfish was caught four times (Table 2). The fish was double-tagged with Floy [1] T-bar tags at the first capture date. The fish has been deposited in the fish collection at the California Academy of Sciences (CAS 46146). The daily growth rates for both the pugheaded and normal fish were calculated for all of the six possible time periods (Table 3). Only those fishes caught during the same time interval as the pugheaded fish, and with total lengths between 150 and 260 mm, were used to calculate the normal daily growth of the population. The *t*-tests were used to compare the daily growth rate of the pugheaded fish with the average growth rate of normal fish in the population.

TABLE 2. Capture Dates and Total Lengths of a Pugheaded Brown Rockfish, *Sebastes auriculatus,* from Tiburon, California.

Capture date	*Total length (mm)*
10 December 1976	173
7 June 1977	198
2 December 1977	232
18 April 1978	240

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[1] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

TABLE 3. Growth Periods and Daily Growth Rates for Pugheaded and Normal Brown Rockfish, *Sebastes auriculatus*.

Growth period number	*Date start*	*Date stop*	*Daily growth for pugheaded fish (mm)*	*Daily growth for normal fish (mm)*	*t-test value*	*Degrees of freedom*
1	10 Dec 1976	7 Jun 1977	0.1117	0.1927	−9.10*	20
2	10 Dec 1976	2 Dec 1977	0.1657	0.1495	1.55	4
3	10 Dec 1976	18 Apr 1978	0.1359	—	—	—
4	7 Jun 1977	2 Dec 1977	0.1932	0.1768	1.34	12
5	7 Jun 1977	18 Apr 1978	0.1342	0.1460	−1.28	6
6	2 Dec 1977	18 Apr 1978	0.0588	0.1517	−8.85*	32

* Significant at the 99% probability level.

The *t*-tests indicate that there were two periods (one and six) when the pugheaded fish's daily growth rates were significantly less than the average growth rates of the population (Table 3). The differential in growth between the pugheaded and normal fishes averaged −2.4, 0.5, and −2.8 mm per month during period 1 (December 1976 to June 1977), period 4 (June 1977 to December 1977), and period 6 (December 1977 to April 1978). Although the pugheaded individual grew more slowly than normal brown rockfish during the winter, its growth rate was the same during other times of the year.

The winter quarter (January, February, and March) is a period of limited food resources and stress for brown rockfish in San Francisco Bay, as demonstrated by major reductions in their fat reserves (unpublished data). The period of population stress and the period of growth reduction coincide, indicating that the pugheaded brown rockfish is not as efficient as normal fish when the population is under stress.

The possibility that pugheadedness reduces the ability of an individual to compete has been investigated for other species (Mansueti 1960, Leggett 1969). The growth rate of a pugheaded striped bass, *Morone saxatilis,* was compared to that of normal individuals by Mansueti (1960). He found the pugheaded individual to be relatively fit, but smaller than its normal counterparts at each age group. A similar comparison was made of a pugheaded Atlantic salmon, *Salmo salar,* by Leggett (1969) who found little indication (only a reduced length-weight ratio) that the pugheaded individual was unable to compete with normal fish in its population. Both of these studies and our data suggest that while a pugheaded fish may be relatively fit, pugheadedness limits the fish's growth. The reduced growth rate of the pugheaded brown rockfish and the timing of the reduction of fat reserves in the population suggests to us that the fish is relatively fit during periods of food abundance, but during periods of population stress and increased intraspecific competition, the pugheaded fish's fitness is lowered probably through reduced feeding efficiency.

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REFERENCES

Leggett, W. C. 1969. Pugheadedness in landlocked Atlantic salmon (*Salmo salar*). Can., Fish. Res. Bd., J. 26(11): 3091–3093.

Mansueti, R. J. 1960. An unusually large pugheaded striped bass, *Roccus saxatilis,* from Chesapeake Bay, Maryland. Chesapeake Sci. 1(2): 111–113.

Phillips, J. B. 1957. A review of the rockfishes of California (Family Scorpaenidae). Calif. Dept. Fish and Game, Fish. Bull., (104): 1–158.

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RELATION BETWEEN SIZE OF CHINOOK SALMON, *ONCORHYNCHUS TSHAWYTSCHA,* RELEASED AT HATCHERIES AND RETURNS TO HATCHERIES AND OCEAN FISHERIES

We used recovery data for fall-run chinook salmon, *Oncorhynchus tshawytscha,* released from three hatcheries on tributaries to the Sacramento River between 1955 and 1973 (Table 1) to describe the relation between survival and size at release from hatcheries. The sum of estimated catch in the ocean and adults returning to the hatchery was our index of survival.

Survival increased, although at a decreasing rate, as the size of juvenile salmon at release increased (Figure 1*a*). We described similar relations for groups of 1970 and 1971 brood fall-run chinook salmon released into Washington waters between January and July (Figure 1*b*) for comparison. Estimated catch in the ocean was our survival index for Washington fish; returns to the hatchery were excluded because some groups were released at a site remote from the hatchery and few adults were expected to return to the hatchery. Although different groups of Washington fish consisted of different stocks, represented different studies, were reared at different locations, and were released at different locations, the large number of data points appear to subsume much of this variation and to show an increase in survival as a function of size at release. Although the curves differ between states and between broods, the similarity in their general shape suggests that these relations can be useful in predicting the relative survival of juvenile chinook salmon released at different sizes.

Marked fall-run chinook salmon were also released from Coleman National Fish Hatchery during March and April and during October in 1945, 1946, 1948, and 1949 (Cope and Slater 1957); size at release ranged from 0.7 to 28 g. Although returns to the ocean fisheries were not available, returns to the Sacramento River gill-net fishery alone averaged 19%—well above the highest survival estimated for fish released in more recent years. We are unable to explain the discrepancy between the present data and those of Cope and Slater.

In applying the present results (Figure 1), one should recognize that yield (total weight of adults) may not increase as rapidly as survival when size at release is increased: when increased size at release results from extended rearing, mean weight at maturity is often reduced (Cope and Slater 1957; Warner, Fry, and Culver 1961).

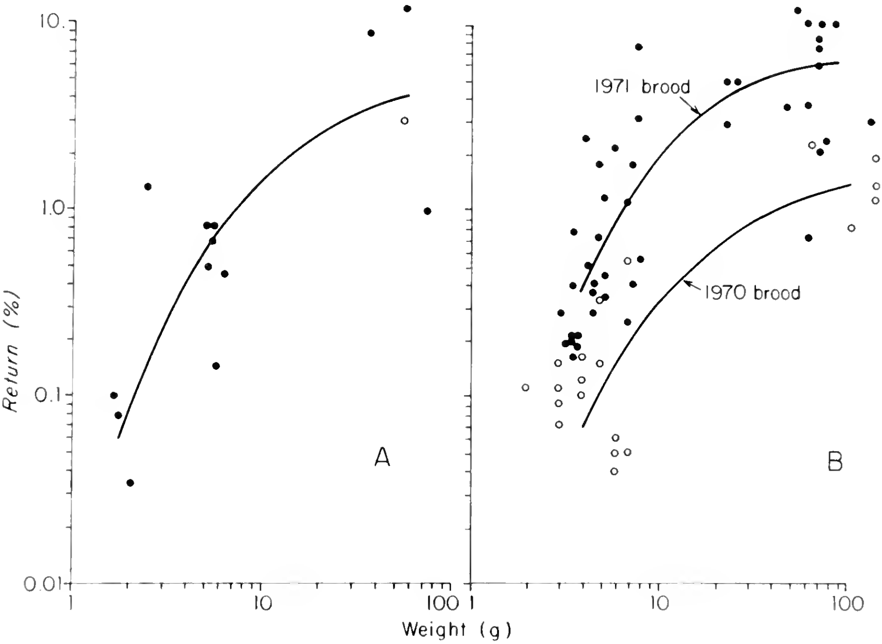

FIGURE 1. (A) Percent recovery in the ocean fisheries and at the hatchery of marked groups of fall-run chinook salmon released into the Sacramento River system at different sizes. (Curve fitted by inspection.) Open circle represents the 1955 brood, for which there was no estimate of return to the ocean sport fishery (Warner, Fry, and Culver 1961). (B) Percent recovery in the ocean fisheries through 1976 of marked groups of fall-run chinook salmon released into Washington waters at different sizes. (Curves fitted by inspection.) Open circles represent the 1970 brood and solid circles the 1971 brood. Data summarized by Garrison and Rosentreter-Peterson (1979) and R. L. Garrison (unpublished data).

REFERENCES

Cope, O.B., and D.W. Slater. 1957. Role of Coleman Hatchery in maintaining a king salmon run. U.S. Fish Wild. Serv. Res. Rep. 47. 22 p.

Garrison, R.L., and N. Rosentreter-Peterson. 1979. Stock assessment and genetic studies of anadromous salmonids. Oregon Dept. of Fish and Wildlife, Annual Progress Report. AFS-23-2. 82 p.

Hallock, R.J., and R.R. Reisenbichler. 1979. Evaluation of returns from chinook salmon, *Oncorhynchus tshawytscha,* released as fingerlings from Coleman and Nimbus hatcheries and in the Sacramento River estuary. California Department of Fish and Game. Anadromous Fisheries Branch Office Report. 10 p.

Sholes, W.H., and R.J. Hallock. 1979. An evaluation of rearing fall-run chinook salmon, *Oncorhynchus tshawytscha,* to yearlings at Feather River Hatchery, with a comparison of returns from hatchery and downstream releases. Calif. Fish Game, 65(4): 239–255.

Warner, G.H., D.H. Fry, Jr., and A.N. Culver. 1961. History of yearling king salmon marked and released at Nimbus Hatchery. Calif. Fish Game, 47(4): 343–355.

TABLE 1. Release and Recovery Data for Marked Groups of Fall-run Chinook Salmon from Hatcheries in the Sacramento River System. All fish except the 1958 brood were released at the hatcheries; the 1958 brood was released into the Sacramento River 130 km downstream from Coleman National Fish Hatchery. Data are from Warner, Fry, and Culver (1961), Hallock and Reisenbichler (1979), and Sholes and Hallock (1979).

*Fish hatchery * and brood year*	*Release data*			*Recovery (%)*		
	Mark †	*Average weight (g)*	*Date*	*Ocean fisheries*	*Hatchery*	*Total*
Coleman						
1958	D-RM	2.5	Apr–Jun 1959	1.15	0.15	1.30
1959	D-LV	2.1	Mar–May 1960	0.03	<0.01	0.03
1960	D-LV-RM	1.8	Apr–Jun 1961	0.07	<0.01	0.08
1961	D-LV-LM	1.7	Mar–May 1962	0.08	0.02	0.10
1968	Ad-LV	6.4	Apr–Jun 1969	0.38	0.06	0.44
1969	Ad-LV	5.2	Apr–Jun 1970	0.77	0.06	0.82
1970	Ad-LV	5.5	May–Jun 1971	0.61	0.05	0.67
Feather River						
1967	Ad-RP	38	Jan 1969	8.2	0.8	9.0
1969	An-LP	60	Feb 1971	12.1	0.5	12.6
1970	An-LP	76	Feb 1972	0.9	0.1	1.0
Nimbus						
1955	Ad-LV	56	Mar–Apr 1957	0.4‡	2.5	2.9‡
1968	An-LV	5.9	Jun 1969	0.11	0.03	0.14
1969	LV-RP	5.3	May–Jun 1970	0.46	0.02	0.49
1970	An-LV	5.6	May–Jun 1971	0.73	0.08	0.81

* Coleman National Fish Hatchery (near Anderson) and Feather River (near Oroville) and Nimbus (near Rancho Cordova) salmon and steelhead hatcheries.

† Abbreviations: L=left; R=right; Ad, adipose; An, anal; D, dorsal; M, maxillary; P, pectoral; V, ventral. Fish of the 1969 and 1970 brood years released from Feather River hatchery were additionally marked with coded-wire tags.

‡ Does not include an estimate of the ocean sport catch.

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A MICROSPORIDIAN INFECTION IN MOSQUITOFISH, *GAMBUSIA AFFINIS,* FROM ORANGE COUNTY, CALIFORNIA

Mosquito abatement personnel reported diseased fish among wild populations of mosquitofish, *Gambusia affinis* (Baird and Girard), in Orange County, California. The infected fish were characterized by extremely distended abdomens. Upon dissection, the abdominal cavity was found to contain one or more cysts ranging in size to 4 mm in diameter (Crandall 1980). These contained a white pus-like fluid comprised primarily of spores. According to the proposed taxonomic system of Sprague (1977), the organism was identified as a member of Order Microsporida (*Microspora* ph. n.). Further, we identified the organism as *Glugea* sp., based upon the characteristics of the parasite's developmental cycle: sporogony within a membrance-bound vacuole in the host cell cytoplasm, sporonts giving rise to two sporoblasts, and the formation of cell hypertrophy tumors or xenomas. This type of lesion is characteristic of other *Glugea* spp., which infect the smelt, *Osmerus mordax,* (Dechtiar 1965; Nepszy, Budd, and Dechtiar 1978) and the European stickleback, *Gasterosteus aculeatus,* (Weissenberg 1968). Upon entry into the host cell, this intracellular parasite increases in number and ultimately fills the cell to produce a xenoma tumor. In some cases, xenomas made up as much as 35% of the body weight of an infected fish.

We are reporting on a limited survey conducted in Orange County to locate mosquitofish populations infected with *Glugea* sp. and to subsequently determine the severity of infection of these populations.

Sixty fish (30 female, 30 male) were collected from each of six sites suspected to contain infected fish. The sampling sites were: 1) Riverview Golf Course pond, Santa Ana, 2) Mission Viejo Golf Course pond, Mission Viejo (two collections), 3) Casa Del Sol Golf Course pond, Mission Viejo, 4) Meadowlark Golf Course pond, Huntington Beach, 5) West Street Basin, Garden Grove (Crandall 1980). All sites were located in Orange County, California. Since these waters had not been supplementally stocked with fish for several years, we thought that data collected would be representative of established infections, not ones recently introduced. All fish were weighed, measured, and sexed. Presence of xenomas was determined by careful examination of viscera of each fish under a dissecting microscope at 60X.

Fish at five collection sites were infected with *Glugea,* with an incidence of infection ranging to 25% (Table 1). Males generally showed a higher incidence of infection than females (Table 1). Our data reflect infections that had progressed to a stage where xenomas were visible under a low power dissecting microscope; the actual number of infected fish may have been greater. There was little or no difference in length-weight relationships between infected and noninfected fish of the same sex.

TABLE 1. Percent of Gambusia affinis Infected with *Glugea* sp. from Six Sites in Orange County, California

	Percent infected		*Percent total population infected*
Site	*male*	*female*	
1	20	6.7	13.3
2A	23.4	10	16.7
2B	13.4	6.7	10
3	20	30	25
4	16.7	3.4	10
5	0	0	0

While this *Glugea* sp. has caused mosquitofish mortalities under field and laboratory conditions (Crandall 1980), the extent of its impact on mosquitofish populations is unknown. Our investigation involved locations where conditions appeared quite favorable to mosquitofish. Less favorable environmental conditions may result in much higher rates of infection.

In the most advanced infections, fish appear to have a reduced swimming ability. Also, there appears to be an atrophy of internal organs, as many are displaced by the mass of xenomas. Nepszy *et al.* (1978) suggests that a mass mortality of smelt infected with *Glugea hertwigi* was due to changes in the host's center of gravity, thus reducing swimming ability; malformed organs, resulting in physiological stress; and probable intestinal occlusion, resulting in starvation or absorption of toxic wastes. Cause of death in mosquitofish may be similar.

There is much to be learned about this *Glugea* sp. Of particular interest is its impact on mosquitofish populations, considering that mosquitofish are being evaluated for even more intensive culture for mosquito control in California.

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REFERENCES

Crandall, T.A. 1980. The biology of a parasite found in the mosquitofish, *Gambusia affinis*. Thesis. University of California, Davis. 45 p.

Dechtiar, A.O. 1965. Preliminary observations on *Glugea hertwigi* Weissenberg, 1911 (Microsporidia: Glugeidae) in American smelt, *Osmerus mordax* (Mitchell) from Lake Erie. Can. Fish Cult., 34: 35–38.

Nepszy, S.J., J. Budd, and A.O. Dechtiar. 1978. Mortality of young-of-the-year rainbow smelt (*Osmerus mordax*) in Lake Erie associated with the occurrence of *Glugea hertwigi*. J. Wildl. Dis., 14: 233–239.

Sprague, V. 1977. Classification and phylogeny of the microsporidia. Pages 1–30 *in* L.A. Bulla and T.C. Cheng, eds. Comparative pathobiology, Vol. 11. Plenum Press, New York.

Weissenberg, R. 1968. Intracellular development of the microsporidia *Glugea anomala* Moniez in hypertrophying migratory cells of the fish *Gasterosteus aculeatus* L., an example of the formation of "xenoma" tumors. J. Protozool., 15: 44–57.

—T.A. Crandall and P.R. Bowser, Aquaculture Program, Agriculture Experiment Station, University of California, Davis, California 95616. Current address of P.R. Bowser is College of Veterinary Medicine, Mississippi State University, P.O. Drawer V, Mississippi State, MS 39762. Accepted for publication January 1981.

RESPONSE OF THE MOHAVE CHUB, *GILA BICOLOR MOHAVENSIS,* TO DEWATERING OF AN ARTIFICIAL IMPOUNDMENT

The Mohave chub once inhabited the Mojave River, but this endangered species now survives in only a few man-made refugia in the southwest (Miller 1968, St. Amant and Sasaki 1971, Pister 1980). The Fort Soda refugium, San Bernardino County, has provided habitat for "pure" populations of this species for the past 50 years. The Bureau of Land Management and the Department of Fish and Game have been evaluating the various aquatic habitats at Fort Soda for the past several years to identify habitat requirements of the Mohave chub and to develop a management plan.

During May 1979, over 3,500 Mohave chub were transferred from a temporary holding pond to their historic pond habitat at Fort Soda. This transfer was the final phase of a coordinated effort between the Department and the Bureau to improve one of the existing habitats for this species. The fish had been temporarily transferred while their historic pond was dredged to remove sediments washed in over the past several years. These sediments had not only reduced the available surface habitat by approximately 30% but also permitted the encroachment of aquatic vegetation.

Draining of the temporary pond required 1 day. The majority of fish were seined from the pond as the waters receded. As the water level dropped a series of smaller pools were exposed, each containing several fish. Channels were subsequently dug between the higher pools and the sump area to speed the draining process. This afforded an opportunity to observe the response of chub to declining water levels within these smaller pools.

Initially, fish in the higher pools were quiescent. As the water level dropped to a depth of about 8 cm, swimming movements increased until the outflow to the interconnecting channel was located. Once the fish found the outflow they actively swam down the channel with the current. It is unlikely that the flow within the channel (approximately 100 ml/s) physically moved the fish downstream. When the fish reached a pool area within the channel they stopped and swam slowly around as if again seeking the outflow. Once the outlet was located the fish again actively moved down the channel, often exposing much of the body. This behavior continued until all fish (24–30) either reached the downstream trap net or the main pool.

While the Mohave chub may have moved to safety in response to temperature change (Alder 1975), it is very likely that lateral line detection of subtle water current prompted the downstream movement (Dijkgraaf 1963). Survival of the species in the desert for centuries has likely hinged on this behavioral response. The author believes this behavior may be unique to desert species, and is unaware of similar behavior by other species documented in the literature.

REFERENCES

Alder, H.E. 1975. Fish behavior; why fishes do what they do. T.F.H. Pub., Inc. Neptune City, N.J. 271 p.

Dijkgraaf, S. 1963. The functioning and significance of the lateral line organs. Biol. Rev. 38: 51–105.

Miller, R.R. 1968. Records of some native freshwater fishes transplanted into various waters of California, Baja California, and Nevada. Calif. Fish Game, 54: 170–179.

Pister, E.P. 1980. A summary of the proceedings of the tenth annual symposium. Desert Fishes Council, Bishop, CA 93514. Jan. 30, 1980.

St. Amant, J.A. and S. Sasaki. 1971. Progress report on reestablishment of the Mohave chub, *Gila mohavensis* (Snyder), an endangered species. Calif. Fish Game, 57: 307–308.

—Louis A. Courtois, California Department of Fish and Game, 1701 Nimbus Road, Rancho Cordova, CA 95670. *Accepted for publication May 1980.*

BOOK REVIEWS

Assessing the Effects of Power-Plant Induced Mortality on Fish Populations

Edited by Van Winkle; Pergamon Press, Inc., New York; 1977; 401 p; $25.00

This volume presents the proceedings of the conference sponsored by the U. S. Energy Research and Development Administration, Oak Ridge National Laboratory, and the Electric Power Research Institute. In the United States most concerns dealing with fish and power plants have historically concentrated upon the impacts of discharges of heated effluents. Recently, however, concerned scientists have begun to concentrate upon entrainment-induced mortalities of eggs and larvae.

The fundamental question asked at the conference was "How do mortality rates imposed by power plants on young fish affect adult population size?" During the conference five areas of activity germane to this question were considered: case histories; estimating population sizes and natural mortality rates, especially for young-of-the-year fish; evidence for and magnitude of compensation; design of monitoring programs and statistical analysis of data; and, assessing power plant impacts with simulation models. The participants were chosen because of their research contributions in one or more of these five areas.

Three of the papers deal with problems of west coast anadromous fish populations: salmon in the Columbia River, and striped bass in the Sacramento-San Joaquin Estuary, California.

The state-of-the-art being what it is, the fundamental question remains unanswered. The papers presented, however, do provide important guideposts for these scientists and administrators faced with the problems inherent in attempting to lessen the biological impacts of power plants.

This volume, while dealing with a specialized area of research, represents an important reference for fishery scientists working with population estimation techniques, larval survival rates, sampling techniques, and population modeling, as well as the basic problems of power plant entrainment of eggs and larvae.—*Michael L. Johnson.*

Wild Geese

By M. A. Ogilvie, Buteo Books, Vermillion, SD; 1978; 350 p; illustrated; $25.00

Wild Geese is a veritable compendium of biological data pertaining to the true geese, *Branta* and *Anser,* of the world. With the exception of the atypical Hawaiian Goose, *Branta sandvicensis,* Ogilvie provides the reader with a thorough treatment of these genera, ranging in scope from etymology to exploitation. He has accomplished this by presenting material in a comparative format, rather than using the systematic approach of individual species accounts. The book consists of eight chapters, each dealing with a selected aspect, or several aspects, of goose biology including: Classification; Identification; Ecology, Food, and Feeding; Breeding; Counting; Ringing, and Population Dynamics; Distribution and Status; Migration; and Exploitation and Conservation.

Overall the book is excellent; however, I enjoyed several chapters in particular. For example, in the chapter on breeding Ogilvie presents a thorough review of the breeding ecology of wild geese. Factors such as nest placement and construction, timing of breeding, nesting behavior, courtship, and copulation are described in detail. Discussions of predation, social ecology, and fledging and add further to this excellent chapter.

The chapter on "Counting, Ringing and Population Dynamics," is also an excellent chapter and will be of at least some practical value to almost all waterfowl biologists who read it. Included is an historical review of the study of goose population biology, beginning with the 1930 Black Brant census organized by James Moffitt of the California Department of Fish and Game. Modern day techniques, including rotary-wing and fixed wing aircraft surveys are described, and the merits of each method are evaluated. Also included are hints on how to make accurate and productive counts. The descriptions of methods of capturing, banding, and collaring wild geese are also of value. The chapter terminates with a good discussion of goose population dynamics, including such topics as recruitment and mortality, and those factors which appear most often to influence populations.

"Exploitation and Conservation" presents a very good discussion of the legislative history which has influenced the protection and management of waterfowl in North America and Europe. Many of the problems which continue to hinder adequate management are discussed. These problems are particularly common outside of North America. The problems encountered in Europe are primarily related to the complex political patterns existing there. In Asia, political problems, rather than patterns, appear to be a major hinderance to sound research and management. Ogilvie also discusses management regulations, crippling losses, future research and management goals, current refuge systems and their objectives, transplanted populations, and depredation problems and solutions. A species-by-species account of the current status and population trends of the various geese of the world concludes the chapter.

In all, M. A. Ogilvie has produced an excellent work which pulls into one volume much of the existing knowledge on the geese of the world. Including the Hawaiian Goose in this book would have made the work more complete, but would not necessarily have added much to the usefulness of the book. The text is well written, easily read, and is laced with British vernacular. It terminates with a philosophical statement reminiscent of Aldo Leopold: "The appeal of geese is to the senses of man, to his eyes, his ears, and to an inner feeling of aesthetic pleasure. That pleasure can come from the thrill of seeing a goose fall to one's gun, a fitting climax to a battle of wits between the geese and yourself. Alternatively it can stem from an emotion that combines the sheer delight to be gained from watching and hearing them with something less tangible yet somehow deeply gratifying, the sense of contact with the wildest of all wild birds, wild geese."

The reader, whether a professional waterfowl biologist, birdwatcher, naturalist, or waterfowler, will find a great deal of valuable information in this book. I strongly recommend this work as an addition to the literature on waterfowl biology and as a source of fascinating reading for interested laymen and professionals alike. In this day and age it is unusual to find something worth the price placed upon it; this book is well worth the $25.00 asked by the publisher.—*Vernon C. Bleich.*

River Channel Changes

Edited by K. J. Gregory; John Wiley and Sons; New York, NY; 1977; 450 p; $39.95.

The subject of this book was the theme of a 1-day symposium organized by the British Geomorphological group in 1976. Aside from the original symposium contributors, many contributions from Australia, Europe, and North America are included.

The book is divided into four major sections; I: Mechanics and Sedimentation, II: Channel Geometry Changes, III: River Channel Pattern, and IV: Network Change and Theory. Some of the more valuable and interesting chapters include: Channel Pattern Change; Man-induced Changes in Stream Channel Capacity; Channel Response to Flow Regulation; Peak Flows, Low Flows, and Aspects of Geomorphic Dominance; Changeable Rivers; The Context of River Channel Changes; Channel Changes in Ephemeral Streams; Urbanization, Water Redistribution, and Their Effect on Channel Processes; and Meander Migration.

The book is free of noticeable typographical errors. The graphics are neat and readable. Each chapter is well referenced and the volume contains a short but adequate index. Many biologists may find the mathematics and geomorphology nomenclature difficult. With the rather high price tag, many workers may be reluctant to add this volume to their personal libraries; however, those scientists working with streams will find this volume a valuable reference for state-of-the-art in geomorphology.—*M. L. Johnson.*

Coyotes

Edited by Mark Bekoff; Academic Press Inc., New York, NY; 1978; 384 p; $34.50.

Professional wildlife biologists have long awaited a volume which would present a synthesis of the known literature of the most versatile predator in North and Central America. Recent coyote literature has proliferated at an astounding rate (a recent bibliography on coyotes by Dolnick, et al. 1978, lists over 4100 references). For all this astounding amount of verbiage, large gaps still exist in our knowledge of this elusive canid. The primary value of this excellent volume is that it brings together a valuable cross-section of recent coyote research.

The volume is divided into four major sections—I: Basic Biology; Evolution, Pathology, and Reproduction; II: Behavior; III: Ecology and Systematics; and IV: Management. Each of the sections is divided into topical chapters, written by specialists in each respective field, presenting a unique, multi-disciplinary approach.

The coyote has long been the center of a controversy typified by a bumper sticker popular among western stockmen, "Eat Lamb, 10,000 Coyotes can't be wrong." Predator control programs and the use of biocides for coyote control have come under fire by environmentalists, with a strong antipathy developing over the coyote control programs between stockmen and environmentalists. This controversy may last for decades.

The photos are mostly too small for good clarity and the graphics are not generally of the quality expected in a book of this type. The volume is well indexed, a rarity with many multi-authored volumes. The book will be a welcome addition to the libraries of the many people involved in understanding and working with this remarkable canid, as well as predator biology in general.—*M. L. Johnson.*

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INSTRUCTIONS TO AUTHORS

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The editorial staff will consider for publication original articles and notes dealing with the conservation of the fauna and flora of California and its adjacent ocean waters. Authors may submit two copies, each, of manuscript, tables, and figures for consideration at any time.

MANUSCRIPTS: Authors should refer to the *CBE Style Manual* (fourth edition) for general guidance in preparing their manuscripts. Some major points are given below.

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TABLES: Each table should be typewritten double-spaced throughout with the heading centered at the top. Number tables with arabic numerals and place them together in the manuscript following the references. Use only horizontal rules. See a recent issue of *California Fish and Game* for format.

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