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"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

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Lesh, E. W. 1980. A head-off method of measuring chinook and coho salmon. Calif. Fish Game, 66(1) : 59–62.

Page 60, 61. The coefficient of determination should be (r^2).

Page 61. The ordinate of Figure 3 should read: Fork length with head off in millimetres.

The abscissa of Figure 3 should read: Fork length with head on in millimetres.

IN MEMORIAM

J. BRUCE KIMSEY

J. Bruce Kimsey was born in Portland, Oregon on 18 July 1921 and died on 24 January 1980 at the Kaiser Hospital in Sacramento after a lengthy illness. Bruce leaves a wife and two grown sons and a legacy of devotion to his family and his career. He had a long and productive career as a professional biologist in fisheries research and management that spanned about 32 years.

Bruce received a B.A. degree from Chico State University in 1948 and an M.A. degree from the University of California at Berkeley in 1951. He served with the Armed Forces in the South Pacific during World War II. His first permanent position in fisheries was with the California Department of Fish and Game as a Junior Aquatic Biologist in 1948.

Bruce had wide ranging responsibilities with the Department on matters concerning inland fisheries. Probably the most challenging position during the 13 years he worked for the Department was as a leader of statewide warmwater fisheries coordination and research. It was during this period that most of his publications appeared.

His publications numbered about 45. Most appeared in either *California Fish and Game* or the Inland Fisheries Administrative Report series. Bruce's interest and enthusiasm for all aspects of natural history were reflected in his publications, some which concerned birds and appeared in the *Condor.*

Bruce's expertise in fisheries matters led to a long involvement and much overseas travel as a consultant for a number of foreign aid organizations. Bruce and his family spent an entire year at Lakes George and Edward in Uganda on an assessment of the fish stocks plus the training of African fisheries workers. This was just the begining and throughout the remainder of his career, Bruce took part in numerous short-term overseas assignments. Besides Uganda, Bruce traveled to Kenya, Tanzania, Rhodesia, Cameroon, Brazil, Colombia, El Salvador, Nicaragua, Philippines, and Indonesia.

After leaving the Department in 1961, Bruce went to work for the old U. S. Bureau of Commercial Fisheries as leader of a shrimp research project with headquarters at Galveston, Texas. He later moved to the Bureau's main office in Washington, D.C. where he assessed fisheries developments in various countries around the world. He transferred in 1961 to the old U. S. Bureau of Sport Fisheries and Wildlife where he became Chief of the Branch of Ecosystem Research. In this capacity he supervised six laboratories engaged in reservoir and marine sportfish research. Bruce returned to Sacramento in 1971 where he assumed the position of Regional Environmental Quality Officer for the Mid-Pacific Region of the Water and Power Resources Service. He remained at this post until he died.

Bruce was a fellow of the American Institute of Fishery Research Biologists and a member of various honorary and professional societies. He was President of the California-Nevada Chapter of the American Fisheries Society in 1976 and served as chairman or member of numerous national and regional committees of this organization.

Bruce will be sorely missed by his many friends and co-workers from around the world.—*Almo J. Cordone*

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IMPACT OF FLORIDA LARGEMOUTH BASS, *MICROPTERUS SALMOIDES FLORIDANUS,* INTRODUCTIONS AT SELECTED NORTHERN CALIFORNIA WATERS WITH A DISCUSSION OF THE USE OF MERISTICS FOR DETECTING INTROGRESSION AND FOR CLASSIFYING INDIVIDUAL FISH OF INTERGRADED POPULATIONS [1]

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Florida largemouth bass, *Micropterus salmoides floridanus,* had a notable genetic impact following their introduction into five northern California waters containing northern largemouth bass, *M. s. salmoides,* populations: Folsom Lake, New Hogan Reservoir, Lake Amador, Lake Isabella, and Clear Lake. Analysis of malate dehydrogenase isozyme patterns of fish systematically collected in years subsequent to the introduction indicated that intergraded populations developed at each of the waters. Incidence of the Florida allele at the study waters, based on malate dehydrogenase analyses, eventually ranged from 0.35 at Lake Amador to 0.52 at both New Hogan Reservoir and Clear Lake.

Discriminant function analysis of meristic data for fish of known electrophoretic phenotype showed that meristic values were not reliable for classifying individual fish from mixed populations as to Florida, northern, or hybrid bass categories. This was supported by meristic data for known F_1 hybrids. Hybridization could not necessarily be detected by an increase in mean meristic value or by unimodality of a frequency distribution of meristic values. The mode value of lateral line scale counts appeared to be the best meristic indicator of hybridization.

Information from this study and from a similar study at southern California waters indicates that introductions of Florida bass into northern bass populations have generally been beneficial through reducing high exploitation rates, increasing the mean size of bass in the catch, and providing exceptional fishing for trophy-sized bass at some waters.

Results of this study indicate that current largemouth bass populations at the study waters possess a wider spectrum of performance capabilities through the inclusion of desirable traits attributed to Florida bass. This is particularly advantageous in the reservoir setting where heavy angling pressure, water level manipulation, competition of prey species with small bass, and other factors work against the maintenance of a bass population.

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[1] This work was performed as part of Dingell-Johnson Project F-18-R, "Coldwater Reservoir and Special Experimental Reservoir Program," supported by Federal Aid to Fish Restoration funds. Accepted for publication.

INTRODUCTION

Northern largemouth bass were widely distributed to California's low- and mid-elevation waters in the years following their introduction from Quincy, Illinois[2] in 1891 (Shebley 1917). Florida largemouth bass were not introduced until 1959 when about 20,400 fingerlings from Holt State Fish Hatchery, Pensacola, Florida were liberated at Upper Otay Reservoir, San Diego County, which had been chemically treated to eradicate all fish and closed to public access (Sasaki 1961). These fish and their progeny were stocked at many southern California waters under the concept that Florida bass superiority in growth rate and longevity and possible lower vulnerability to angling would provide bass stocks with more large fish than northern bass were providing. While Florida bass were stocked into northern bass populations at most of these waters, Lake Hodges, San Diego County, which served as a source for some Florida bass plants in northern California, was dewatered and chemically treated prior to receiving Upper Otay fish in 1969 (L. Bottroff, Fishery Biologist, Calif. Dept. Fish and Game, pers. commun.).

Florida bass were first stocked in northern California (that portion of California north of the Tehachapi Mountains) in April 1969 at Clear Lake and Hidden Valley Reservoir, both in Lake County, from Upper Otay Reservoir (R. Wood, Fishery Biologist, Calif. Dept. Fish and Game, pers. commun.). Northern bass were present at Clear Lake, while newly impounded Hidden Valley Reservoir was devoid of bass at the time the introductions were made. From 1970 through 1973, Florida bass were stocked at a limited number of northern California waters containing northern bass of Illinois origin, including the five waters examined by this study (Figure 1). During that period, Florida bass were also stocked at a small number of waters that were devoid of bass including a farm pond in the San Joaquin Valley and Rancho Seco Reservoir, Sacramento County. These two waters served as sources for plants made later at the study waters (Figure 1).

The largemouth bass present at the study waters were considered descendants of northern bass brought to California from the northern part of their range in the United States. Based on a review of fish stocking records and communications with knowledgeable hatchery personnel and fishery biologists, northern

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[2] The earliest documentation of largemouth bass shipments into California gives 1891 as the year of introduction (Shebley 1917). According to Shebley the United States Commission brought largemouth bass and warmouth "bass" here for stocking at Lake Cuyamaca and the Feather River. While the source for largemouth bass is not given it was very likely Quincy, Illinois since this is given as the warmouth "bass" source.

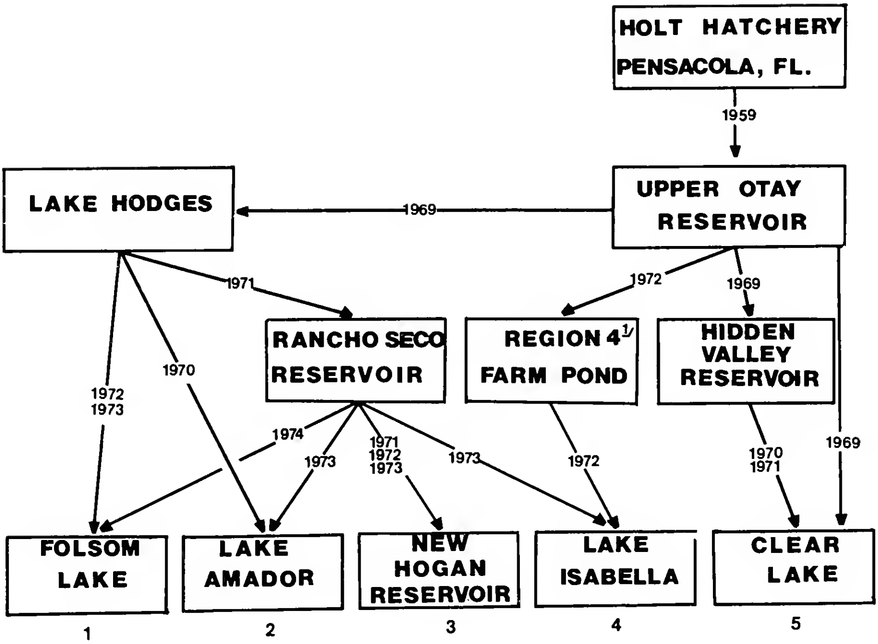


FIGURE 1. History of Florida largemouth bass stocking as related to the study waters (1–5).[1] Region 4 is one of six geographical areas of California designated by the Department for administrative and mangement purposes. It includes largely the San Joaquin Valley and adjacent foothills.

bass from other portions of their range were not stocked at the five study waters prior to the period of this study.

Apparent intolerance of Florida bass to 4° C in Missouri (Johnson 1975) and concern that maladaptive genes possibly related to this intolerance would be transmitted to northern bass populations (Childers 1975), prompted the Department to establish a moratorium in May 1974 on further stockings of the subspecies in northern California. Consequently, this study was initiated in July 1975 to evaluate the survival and genetic impact of Florida bass at northern California waters. Largemouth bass populations at Folsom Lake, Sacramento County; New Hogan Reservoir, Calaveras County; Lake Amador, Amador County; Clear Lake, Lake County; and Lake Isabella, Kern County were selected for evaluation. The largemouth bass population at Rancho Seco Reservoir was also analyzed since it served as a source for Florida bass plants at four of the study waters.

Identification of Florida and northern largemouth bass and their hybrids was critical to evaluating mixed populations at the study waters. Bailey and Hubbs (1949) first used scale counts for separation. Workers since have counted scales, pyloric caeca, and vertebrae, and made body measurements (Bottroff 1967; Buchanan 1968; Bryan 1969; Addison and Spencer 1971; Buchanan 1973; Chew 1975; Johnson 1975; and Bottroff and Lembeck 1978).

Physiological differences between Florida and northern largemouth bass were reported by Hart (1952). Bryan (1964) noted differences between serum electropherograms of the two subspecies. Differences in the electrophoretic mobility of isozymes (different molecular forms of enzymes) from tissues of largemouth and smallmouth bass and their hybrids were described by Whitt, Childers, and Wheat (1971). Chew (1975) reported that Dr. William Childers of the Illinois Natural History Survey, Urbana, Illinois, was able to separate Florida bass, northern bass, and fish thought to be their hybrids by isozyme analysis. Childers (pers. commun.) utilized starch gel electrophoresis and separated the fish on the basis of their different isozyme patterns of the enzyme malate dehydrogenase (MDH).

As related to this study, gel electrophoresis is a method for observing genetic variation of mixed populations by examining variant proteins (isozymes) manufactured by different individuals. A tissue sample from each individual to be studied is homogenized to release its cell contents, including isozymes. These are introduced into a gel made of starch and subjected to an electric current for a few hours. Each isozyme in the sample migrates through the gel in a direction and a rate that depends primarily on its net electric charge and, to some extent, on its molecular size and conformation. The gel is then treated with a solution containing a specific substrate, which is cleaved by the enzyme to be observed, and a salt, which couples with the cleavage products. This process yields a colored band at the zone to which the enzyme has migrated.

Because isozymes that are specified by different alleles may have different molecular structures and charges (and hence different mobilities in an electric field), the genetic makeup at the gene locus coding for a given enzyme can be established for each individual from the number and position of the electrophoretic bands (Ayala 1978). The advantage of data obtained through gel electrophoresis is that genetic interpretations can be made directly. Most variant alleles show codominant expression. This permits designation of the genotypes of individual samples based on staining patterns (Utter, Hodgins, and Allendorf 1974). When animals are crossed that are homozygous for different codominant alleles at the same locus, their offspring are heterozygous, receiving one allele from each parent. Because each allele codes for a slightly different protein, heterozygosity can be inferred from the presence of two variants of a given protein in a single individual (Ayala 1978). The simplest form of diploid variation is when two codominant alleles are present in a population, one specifying a fast-moving band and the other a slow-moving band. An individual homozygous for either allele will show a single band, whereas the heterozygote will have both bands (Gottlieb 1971).

Childers (pers. commun.) found that the MDH isozyme patterns (phenotypes) of Florida largemouth bass and northern largemouth bass (from the northern part of their geographic range) differed (Figure 2). Florida bass and northern bass were both homozygous for supernatant MDH-A and MDH-B. However, because of mutational differences in the makeup of the B gene locus, the most anodal band (B_m B_m; m = fast) of the Florida bass showed greater mobility than the most anodal band (B_s B_s; s = slow) of northern bass (Figure 2). The A gene locus and B gene locus of the northern bass each code for the production of a different subunit (A and B_s, respectively). These translated subunits randomly combine to form the various dimers which will migrate through starch gel differing distances in response to an electric current to produce a three-banded pattern. The Florida bass pattern is similarly produced by an A gene locus and a B gene locus, each coding for the production of a different subunit (A and B_m, respectively). When northern and Florida bass are crossed the genotype AA B_mB_s translates subunits that randomly combine to form six dimers (AA, AB_s, B_sB_s, AB_m, B_mB_s, and B_mB_m). This appears as a five-banded pattern, however, since two dimers (B_sB_s and AB_m) migrate the same distance in starch gel. The F_1 hybrid shows all bands found in Florida and northern bass plus an additional band (B_mB_s). For discussion of MDH phenotypes, MM is used for Florida bass, SS for northern bass, and MS for the hybrid.

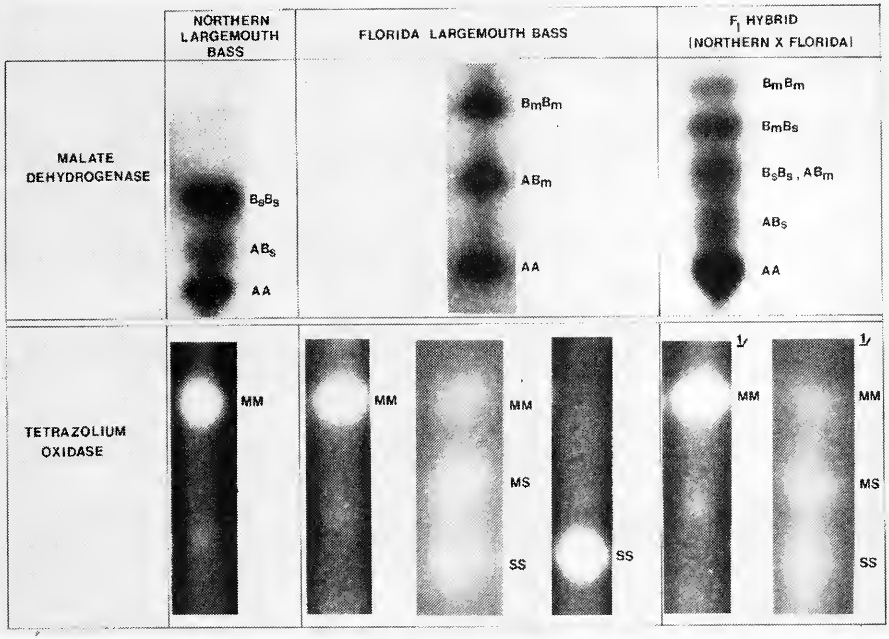


FIGURE 2. Malate dehydrogenase and tetrazolium oxidase phenotypes of northern and Florida largemouth bass and their F_1 hybrid. [1] Results from study waters showed all MS fish by MDH pattern to show only MM or MS by TO.

The frequency of alleles in a given population can be measured by direct counts from the electrophoretic expression of a representative sample (Utter and Allendorf 1977). In this study, the number of M alleles (coding for the B_mB_m band) and S alleles (coding for the B_sB_s band) in a population was determined (see Figure 3 for example). The number of MDH genes in a particular collection is twice the number of individuals sampled because a complementary pair of MDH genes are coded in each individual. A homozygous individual codes in duplicate for a given allelic form and the heterozygous individual codes for two different allelic forms.

Childers (pers. commun.) used an additional enzyme system, tetrazolium oxidase (TO), which permitted partial separation of Florida and northern bass (Figure 2). He found that northern bass were homozygous, showing a single fast-moving band (MM), whereas Florida bass showed either the fast-moving band (MM), or a single slow-moving band (SS), or a heterozygous three banded pattern (MM, MS, and SS). Fish thought to be first filial generation hybrids between Florida and northern bass showed the MM or MS pattern. Tetrazolium oxidase was used in this study to provide supportive data.

<table>
<tr><th>PHENOTYPE</th><th>SS</th><th>MS</th><th>MM</th></tr>
<tr><td>NO. OF FISH SHOWING PHENOTYPE</td><td>25</td><td>50</td><td>25</td></tr>
<tr><td>NO. OF FLORIDA BASS ALLELES IN SAMPLE</td><td>—</td><td colspan="2">$2 \times 25_{mm} = 50$
$+ \; 50_{ms}$
100</td></tr>
<tr><td>NO. OF NORTHERN BASS ALLELES IN SAMPLE</td><td colspan="2">$2 \times 25_{ss} = 50$
$+ \; 50_{ms}$
100</td><td>—</td></tr>
<tr><td>FREQUENCY OF FLORIDA ALLELE (M)</td><td colspan="3">$\frac{100}{200} = 0.50$</td></tr>
<tr><td>FREQUENCY OF NORTHERN ALLELE (S)</td><td colspan="3">$\frac{100}{200} = 0.50$</td></tr>
</table>

FIGURE 3. Calculation of gene frequency for a collection of 100 fish composed of 25 fish showing the SS phenotype, 50 showing the MS phenotype, and 25 showing the MM phenotype.

METHODS AND MATERIALS

Fish from purportedly pure California sources of Florida bass (Upper Otay and Hidden Valley reservoirs) and northern bass (Central Valleys Warmwater Hatchery, Sacramento County; Shasta Lake, Shasta County; and Merle Collins Reservoir, Yuba County) were examined meristically and electrophoretically. Results for fish from Central Valleys Warmwater Hatchery were of particular interest. This hatchery had been involved for many years with stocking northern largemouth bass at northern California waters, including Folsom Lake, New Hogan Reservoir, and Lake Amador (M. Cochran, Fish Hatchery Manager, Calif. Dept. Fish and Game, pers. commun.). Also, hatchery brood fish had been obtained from several northern California sources.

Fish from mixed populations were analyzed using meristic and electrophoretic information for pure populations as baseline data. The study plan was to assess the degree of hybridization of Florida and northern bass by analyzing 100 young-of-the-year bass from each of the study waters annually. Electrophoresis was the primary method used; however, since no largemouth bass study involving both meristic and electrophoretic evaluations of the same fish was found in the literature, meristic data were collected through 1977 for fish analyzed electrophoretically. This provided a means to assess the value of meristic data for classifying individual fish from mixed populations and to determine if meristics could be used by fishery managers in their assessment of the degree of hybridization of mixed populations.

Fish were collected by electroshocking each fall from 1975 through 1978. So that samples would be representative of populations being evaluated, collections were made using the following guidelines:

(1) Sample at each of the four major compass directions.
(2) Sample representative cover types.
(3) Collect young-of-the-year of all sizes.
(4) Collect no more than 10 fish when encountering heavy concentrations of fish such as at the apex of coves, in brushy areas, etc.

Fish were sacrificed, individually enclosed in plastic bags, and transported in crushed ice to prevent breakdown of enzyme systems. At the laboratory they were retained in ice until each received an identifying tag and tissue was removed for analysis. When time did not permit this, fish were frozen and later thawed a few at a time for processing. Skeletal muscle tissue, used for MDH, was removed from an area just below the dorsal fin on the right side of the fish to facilitate scale counts. Liver tissue was taken for TO analysis. All utensils and the worker's hands were thoroughly cleaned after each fish was processed. Each fish and all samples removed from it received an identifying code which included information as to the year and water of collection. For example, F-III-1 was the first fish of the third year of collection at Folsom Lake, and F-III-2 was the second fish, etc. Tissue samples were frozen separately in vials until analysis could be made.

In some cases older fish were used and information from them was backlogged to their year of birth based on scale analysis. Use of older fish was generally avoided, however, because of possible differential survival and was done only to provide information for years prior to 1975 or to provide samples for years when drought conditions, scarcity of fish, or other factors limited or prevented collection of young-of-the-year fish.

Meristic data were collected following procedures outlined by Hubbs and Lagler (1949). The six counts made included the number of 1) scales along the lateral line, 2) scale rows above the lateral line, 3) scale rows below the lateral line, 4) scale rows around the caudal peduncle, 5) scale rows on the cheek, and 6) pyloric caeca. A pointer was used for making scale counts. A dissecting scope was used for counts on small fish. In most cases individual scale counts were made twice and if they were the same the value was accepted. If they were not identical an additional count was made and the dominant value was used. Pyloric caeca were counted once.

Each tissue sample was thawed to permit removal of a small portion which was homogenized in two volumes of 0.1 M tris-HC1 at pH 7.0 in a "Thomas" homogenizer for 6 to 10 s using a variable speed electric drill. The sample was then centrifuged for 20 minutes in a "Sorvall Superspeed RC 2-B "refrigerated centrifuge at 48,000 × g at 4°C. The supernatant was removed and held at 4°C until analysis was completed. The homogenizer and utensils were thoroughly cleaned after each sample.

A tris-citrate pH 6.8 stock buffer of 0.75 tris-(hydroxymethyl)aminomethane and 0.25 M citric acid (monohydrate) was diluted 1:30 for the gel and 1:7 for the electrodes. In preparing the gel, 195 ml of buffer was brought to a boil, and added to a solution composed of 30 g of potato starch and 55 ml of the same buffer. All air bubbles were extracted with vacuum drain by a waterjet aspirator and the warm solution was poured into a plastic frame (21.0 cm × 12.2 cm × 0.7 cm) positioned on a flat glass plate slightly larger in area. When the gel had cooled the frame was removed and plastic strips, half the thickness of the gel, were placed along each side of the gel. A length of monofilament line was placed tightly across the strips and drawn through the length of the gel, slicing it into equal layers. The upper layer could then be discarded or carefully positioned on another glass plate to provide two gels.

A small piece of filter paper was wetted with the supernatant sample and implanted in the gel. Up to 20 samples were implanted along a straight line 7 cm from one end of the gel, spaced far enough apart to prevent contamination. Utensils were thoroughly cleaned between implants. The gel was then covered with plastic wrap to prevent drying, except for an area about 2 cm wide along each end.

The gel was placed horizontally in an electrophoresis chamber such that the portion containing the samples was nearest the cathodal end of the chamber. The chamber was constructed of plastic and included reservoirs along opposite ends. Each of these contained a platinum wire electrode along its length and 150–200 ml of tris-citrate bridge buffer at pH 6.8. A nonwoven towel (made by "Masslinn") served as a wick and electrical conductor from reservoir to gel. Each wick was drawn up onto the gel to cover that portion of the gel not covered by plastic wrap. The wicks were also covered with plastic wrap. The chamber was then placed into a refrigerator and connected to a regulated power supply. The gel was subjected to 200-VDC (9.5V/cm) for 10 h at 4°C.

The zones of isozyme activity were stained for identification using 100 ml of tris-citrate buffer (Trizma 0.03 M and citric acid 0.005 M) at pH 8.5, 20 ml of malate-NaOH at pH 7.0 (0.5 M), 5 mg of nicotinamide adenine dinucleotide, 5 mg of nitro blue tetrazolium, and 3 mg of phenazine methosulfate. The gel was covered with this solution and incubated in the dark at 37°C until the banding patterns were interpretable. It was then rinsed with water and fixed with a solution of water (five volumes), methanol (four volumes), and acetic acid (one volume) to facilitate handling.

The procedure for tetrazolium oxidase was identical to that used for malate dehydrogenase with the exception of a different stain solution of 100 ml of 0.5 M tris-HCl at pH 9.0, 15 mg of nitro blue tetrazolium, and 15 mg of phenazine methosulfate.

Isozyme patterns of fish collected annually at the study waters were used to interpret the genetic impact of Florida bass. Presence of the MS pattern in a population indicated that hybridization had occurred, and the frequency of the Florida allele in a population indicated the extent of genetic influence of Florida bass on that population.

Reciprocal crosses of single pairs of Florida and northern largemouth bass were made in tanks at the Department's experimental management facility (Field Station) in Sacramento in spring 1978. This was done to confirm the isozyme pattern (MS) of suspected hybrids from mixed populations, to obtain meristic data for F_1 hybrids, and to eventually determine the frequency of isozyme patterns resulting from crosses of F_1 hybrids, and from backcrosses.

Meristic data for fish of known electrophoretic phenotype were statistically analyzed to determine if individual fish could be assigned to Florida bass, northern bass, or hybrid categories on the basis of five different scale counts and pyloric caeca counts. Group membership was examined using discriminant function analysis. This method finds an axis so that when the original variables are projected onto this new axis there will be minimum overlap of the groups. Grouping by electrophoretic pattern and using meristic measures as variables enabled an evaluation of the usefulness of meristics as group discriminators. Also, a stepwise procedure determined an economic subset of these measures. Inclusion into the subset was determined by an F-statistic based on a one-way analysis of variance test (Afifi and Azen 1972). The stepwise discriminant function analysis was an unmodified Biomedical Computer Program-BMDO7M (Dixon 1976). The program generates posterior probabilities for group membership. Prior probabilities for each group member were determined to be the fraction the group represented of the total sample. The first two canonical variables for each group were plotted to display the relationships of the groups.

RESULTS AND DISCUSSION

Electrophoretic Analysis-Malate Dehydrogenase

All largemouth bass electrophoretically analyzed from Upper Otay Reservoir (69 fish) and Hidden Valley Reservoir (114 fish) showed the MM phenotype. All bass from Central Valleys Warmwater Hatchery (100 fish), Merle Collins Reservoir (117 fish), and Shasta Lake (73 fish) showed the SS phenotype. Isozyme patterns for fish from these sources were consistent irrespective of the size of fish analyzed; larval fish provided patterns identical to those for fish weighing over 2.3 kg.

Known F_1 hybrids from reciprocal crosses of Florida and northern largemouth bass all showed the MS phenotype (Figure 4).

Fish of the MS phenotype appeared in collections from year classes spawned 1 year after the introduction of Florida bass at Folsom Lake and Clear Lake (Figures 5 and 9). Similarly, hybrid patterns were found within 2 years at Lake Isabella (Figure 8), within 3 years at New Hogan Reservoir (Figure 6), and within 4 years at Lake Amador (Figure 7). By 1975, fish of the MS phenotype were well represented in collections from all study waters. In 1978, the final year of the study, fish showing the MS phenotype constituted over 44% of collections from each of the study waters (Figures 5 through 9).

	NORTHERN ♀	FLORIDA ♂	F_1 HYBRIDS		
MDH PATTERN	S/S	M/M	ALL M/S		
NO. OF LATERAL LINE SCALES	65	68	66, 68,65,67, 64,66,68,66,64,68, 65,66,67, 64,69,65,62,66, 66,67, 67, 68,68,65,69,63,63,66,65,71, 70,58,65,60,61,58,66	$\bar{X}$= 65.4 RANGE = 58 – 71 n=37	GRAND MEAN= 65.7[2]
					RANGE= 58 – 72[2]
NO. OF LATERAL LINE SCALES	63	72	65,66,66,63,67,71,66,67, 66, 67, 67, 69,69,59,60,72,46[1], 47[1], 52[1]	$\bar{X}$=66.2[2] RANGE = 59 – 72[2] n=16[2]	N=53[2]
MDH PATTERN	S/S	M/M	ALL M/S		
	NORTHERN ♂	FLORIDA ♀	F_1 HYBRIDS		

FIGURE 4. Malate dehydrogenase phenotype and lateral line scale counts for F_1 hybrids from reciprocal crosses of northern and Florida largemouth bass. [1] Abnormally low counts. [2] Does not include low counts.

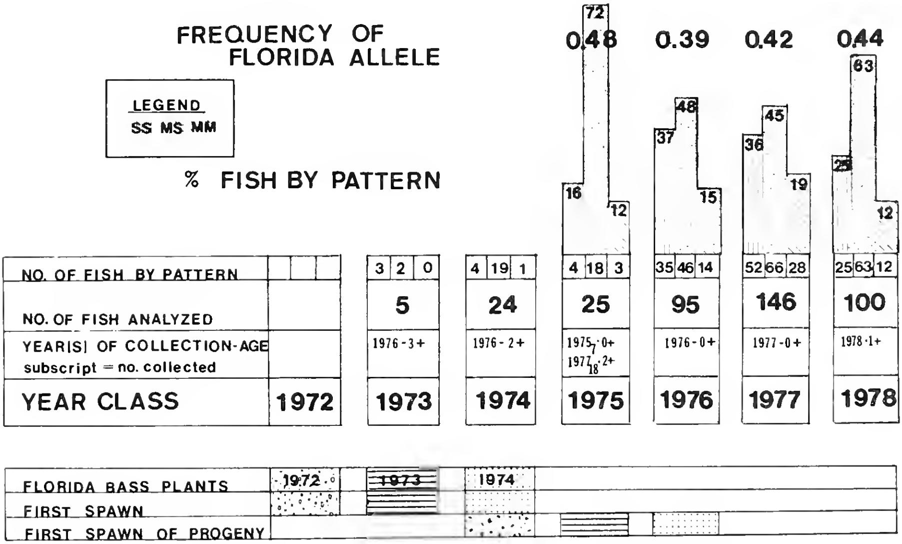


FIGURE 5. Results of malate dehydrogenase analyses of fish from Folsom Lake.

Results indicate that Florida bass survived and had an impact at each of the study waters. Fish showing the MS or MM pattern made up no less than 32% (Clear Lake—1975) and as much as 91% (New Hogan Reservoir—1977) of collections made from 1975 through 1978. Of 1,767 fish examined during this period, 1,168 (66%) showed the MS or MM pattern (Figures 5 through 9).

Fish showing the MS pattern only, made up no less than 10% (Lake Isabella—1976) and as much as 63% (Folsom Reservoir—1978; Lake Isabella—1978) of individual collections. Of 1,767 fish analyzed, 783 (44%) showed the hybrid pattern. The actual number of hybrid fish included in individual collections, however, likely exceeded the number of fish showing the MS pattern. According to Childers (pers. commun.) the offspring of a cross of two MS fish should show SS, MS, and MM patterns at a 1:2:1 ratio, respectively. A cross of MS and SS fish should yield fish showing MS and SS patterns at a 1:1 ratio. Similarly, MS crossed with MM should yield MS and MM at a 1:1 ratio. For this reason it is impossible to ascertain the incidence of hybrid fish in a population beyond the F_1 generation. Hybrid fish from subsequent generations may show an SS, MS, or MM pattern; results presented in Figures 5 through 9 almost surely include hybrid fish among those reported as SS or MM.

Collections of bass from Rancho Seco Reservoir, thought to contain a pure population of Florida bass, consistently contained fish of the MS phenotype. One fish, a member of the 1973 year class, was of the SS phenotype (Figure 10).

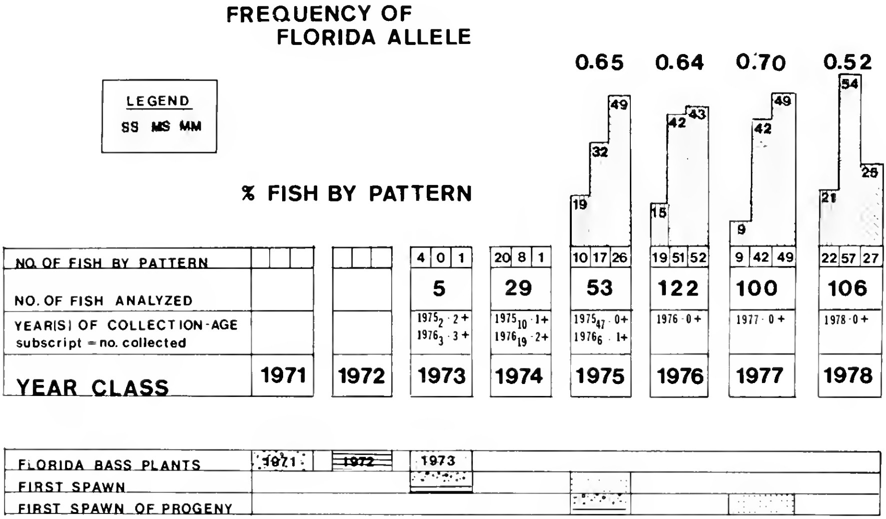


FIGURE 6. Results of malate dehydrogenase analyses of fish from New Hogan Reservoir.

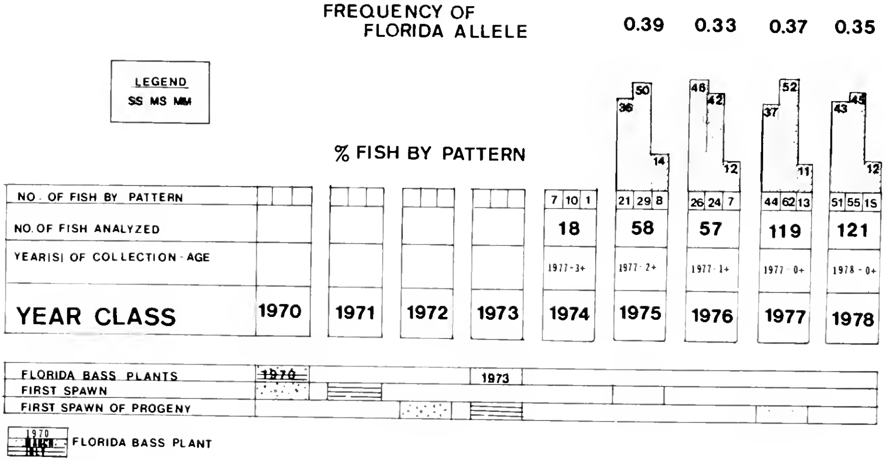


FIGURE 7. Results of malate dehydrogenase analyses of fish from Lake Amador.

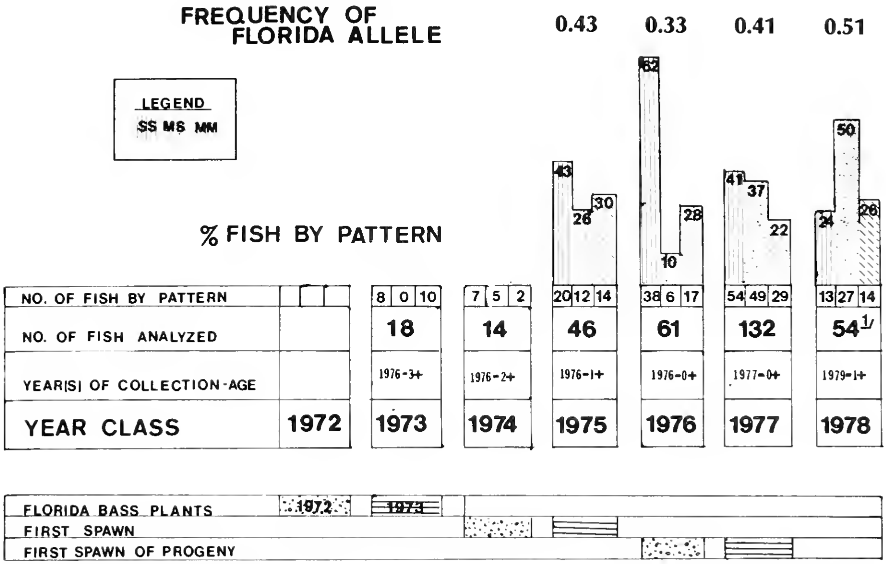


FIGURE 8. Results of malate dehydrogenase analyses of fish from Lake Isabella.[1] Twenty samples analyzed by Dr. D. Philipp of the Illinois Natural History Survey.

Frequency of the Florida Allele Based on Malate Dehydrogenase Analyses

Considering that the incidence of the Florida allele (M) was 0.00 in collections made at Central Valleys Warmwater Hatchery, Shasta Lake, and Merle Collins Reservoir, values recorded for the study waters indicate that Florida bass had substantial impact at these waters containing northern bass. Expectedly, there were differences in the incidence of the Florida allele in the study populations, based on collections from 1975 through 1978 year classes. The highest values recorded, 0.65, 0.64, and 0.70, were from New Hogan Reservoir fish of the 1975, 1976, and 1977 year classes, respectively (Figure 6). Fish from Lake Amador showed the most uniform values, ranging from 0.33 to 0.39 (Figure 7). Values for Clear Lake fish showed consistent increases from 0.17 in 1975 to 0.52 in 1978 (Figure 9). Values ranged from 0.39 in 1976 to 0.44 in 1978 at Folsom Lake (Figure 5), and from 0.33 in 1976 to 0.51 in 1978 at Lake Isabella (Figure 8). Sample sizes for 1975 were comparatively small at both waters.

Comparison of the study populations based on these varying values is somewhat speculative considering the many variables related to the complex environments involved and the following factors that varied by water:

(1) Number of Florida bass planted (Figure 11).

(2) Number of Florida bass planted in relation to the number of northern bass present.

(3) Size of Florida bass planted (Figure 11).

(4) Surface acreage (Figure 11).

(5) Time of Florida bass plants (Figure 11).

(6) Supplemental stocking of northern bass (Figure 11).

(7) Morphometry.

Consideration of values obtained in the final year of the study, however, provides some measure of the comparative impact of Florida bass. Frequency of the Florida allele in the study populations based on fish analyzed from the 1978 year class was 0.44 at Folsom Lake, 0.52 at New Hogan Reservoir, 0.35 at Lake Amador, 0.41 at Lake Isabella (1977 value used because of the comparatively small sample size of the 1978 collection), and 0.52 at Clear Lake (Figure 11). The Lake Amador value, lowest of the five populations, was significantly different from that recorded for both New Hogan Reservoir and Clear Lake ($Z = 2.59$, $p < 0.05$), but was comparable to values for Folsom Lake ($Z = 1.36$, $p > 0.05$) and Lake Isabella ($Z = 0.98$, $p > 0.05$). All other values were equivalent when compared (Figure 11).

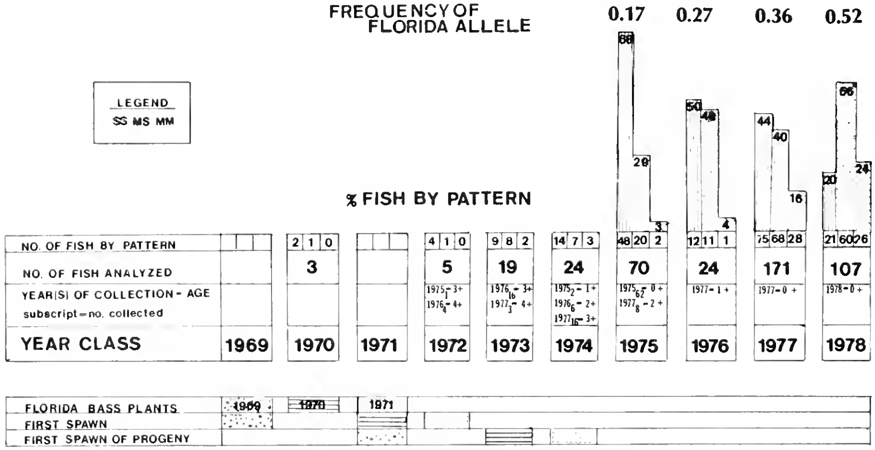


FIGURE 9. Results of malate dehydrogenase analyses of fish from Clear Lake.

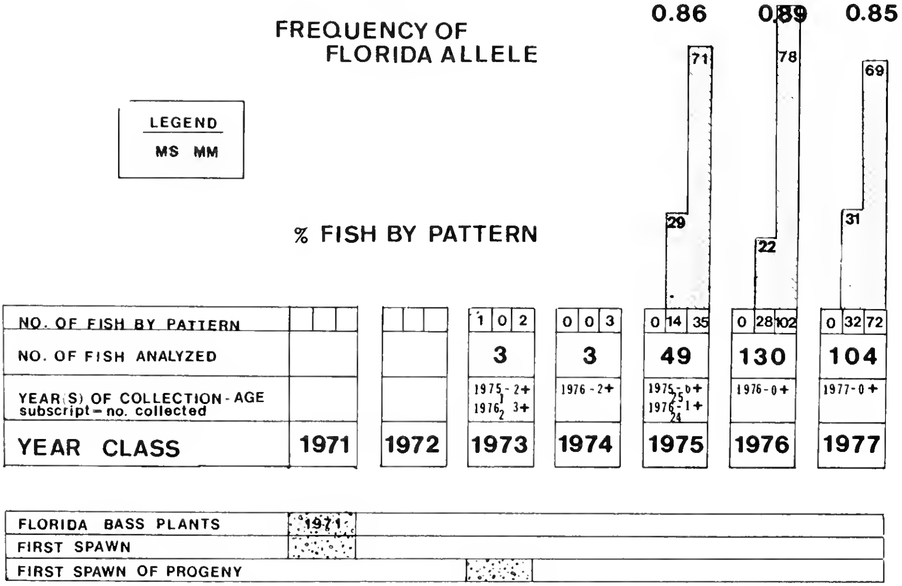


FIGURE 10. Results of malate dehydrogenase analyses of fish from Rancho Seco Reservoir.

WATER	Surface acreage maximum pool	Florida bass plants	No. of fish planted	Size of fish planted	Supplemental stocking of northern bass	Frequency of florida allele in 1978 collections	95% C.I. for frequency of florida allele		Z VALUES				
									1	2	3	4	5
FOLSOM LAKE (1)	11,450	APR 1972	160	1.5/LB	NO	0.44	034-054	1	—	—	—	—	—
		APR 1973	262	1.5/LB									
		MAR & APR 1974	245	1-1.5/LB									
NEW HOGAN RESERVOIR (2)	4,410	OCT 1971	990	32/LB	NO	0.52	042-062	2	1.15	—	—	—	—
		JULY & OCT 1972	2,967	5/LB									
		JULY 1973	1,430	480/LB									
LAKE AMADOR (3)	385	MAR & JULY 1970	259	0.75-4/LB	NO	0.35	0.26-045	3	1.36	2.59	—	—	—
		OCT 1973	942	64/LB									
LAKE ISABELLA (4)	11,400	JUNE 1972	3,000	~200/LB	NO	0.41[2]	031-051	4	048	1.69	0.98	—	—
		JUNE 1973	24,000	800/LB									
CLEAR LAKE (5)	43,800	APR 1969	136	1/LB	YES[1]	0.52	043-063	5	1.15	0	2.59	1.70	—
		MAY 1970	242	1/LB									
		OCT 1971	58	1/LB									

FIGURE 11. Relationship of surface acreage, Florida bass plants, supplemental stocking, and comparison of frequency of Florida allele in collections made at the study waters in 1978. [1] A total of 120,000 fish was stocked by a private group from 1975 through 1978 (L. Week, Fishery Biol., Dept. Fish and Game, pers. commun.) [2] 1977 value used due to the comparatively small 1978 sample.

According to Dr. David Philipp of the Illinois Natural History Survey (pers. commun.) evaluation of mixed populations by use of malate dehydrogenase may lead to overestimates as to the contribution of Florida bass genes to a given population of northern bass. The actual quantitative measurements of Florida bass influence at the study waters may be overestimated; however, he is of the opinion that this is likely a small and relatively constant error. Findings by Dr. Philipp show that isocitrate dehydrogenase and aspartate aminotransferase now provide more accurate estimates. These enzyme systems will be required for future examinations of bass populations at northern California waters since northern bass from states south of Illinois are now present here. Such fish have been federally stocked at military installations and Indian reservations in recent years. The Colorado River, which has had a long and complex history of bass stocking by adjoining states, likely also contains northern bass from sources south of Illinois. This is based on electrophoretic and meristic data collected from fish stocked from the Colorado River area into ponds at the Department's Imperial Wildlife Management Area in the Imperial Valley of southern California. Subsequent to the collection of fish from Central Valleys Warmwater Hatchery, Merle Collins Reservoir, and Shasta Lake, fish from the Imperial Valley ponds were brought to Central Valleys Warmwater Hatchery. These fish were then marked and stocked at Merle Collins Reservoir and Coyote Reservoir (Santa Clara County). Progeny of Imperial Valley fish that were retained at the hatchery were stocked at East Park Reservoir (Colusa County) and Salt Springs Reservoir (Calaveras County). They were likely also included with other bass stocked in 1978 at Shasta Lake, Biscar Reservoir (Shasta County), Mountain Meadows Reservoir (Lassen County), Lake Almanor (Plumas County), ponds at the Oroville Wildlife Area (Butte County), Clear Lake, Nicasio Reservoir (Marin County), and various farm ponds.

Electrophoretic Analysis-Tetrazolium Oxidase

All largemouth bass analyzed for tetrazolium oxidase from Central Valleys Warmwater Hatchery (100 fish), Shasta Lake (68 fish), and Merle Collins Reservoir (42 fish) showed the MM phenotype (Figure 12) as expected for northern bass. Of 68 fish analyzed from Upper Otay Reservoir, 43 (63.2%) showed the MM phenotype, 22 (32.4%) were MS, and 3 (4.4%) were SS. Of 83 fish analyzed from Hidden Valley Reservoir, 44 (53.0%) were MM, 36 (43.4%) were MS, and 3 (3.6%) were SS.

	WATER	YEAR CLASS	NUMBER OF FISH BY PHENOTYPE			NUMBER OF FISH ANALYZED
			MM	MS	SS	
NORTHERN BASS POPULATIONS	CENTRAL VALLEYS WARMWATER HATCHERY	——	100	0	0	100
	SHASTA LAKE	——	68	0	0	68
	MERLE COLLINS RESERVOIR	——	42	0	0	42
FLORIDA BASS POPULATIONS	UPPER OTAY RESERVOIR	——	43	22	3	68
	HIDDEN VALLEY RESERVOIR	——	44	36	3	83
STUDY POPULATIONS	FOLSOM RESERVOIR	1974	21	4	0	25
		1976	58	2	0	60
	NEW HOGAN RESERVOIR	1976	103	14	1	118
	LAKE AMADOR	——	——	——	——	——
	LAKE ISABELLA	1975	34	4	1	39
		1976	23	1	1	25
	CLEAR LAKE	1973	16	3	0	19
		1974	19	3	0	22
STUDY POPULATIONS COMBINED			274	31	3	308

FIGURE 12. Results of tetrazolium oxidase analyses of fish from northern bass populations, Florida bass populations, and study populations.

Predictably, MM was the most frequently found phenotype in fish analyzed from the study populations. Of 308 fish examined, 274 (89.0%) were MM, 31 (10.0%) were MS, and 3 (1.0%) were SS. Results for fish from Rancho Seco Reservoir were comparable to those for fish from Upper Otay and Hidden Valley reservoirs. Of 143 analyses, 81 (56.6%) were MM, 56 (39.2%) were MS, and 6 (4.2%) were SS.

Known F_1 hybrids by MDH were not analyzed for TO; however, of the 128 MS fish (MDH) from the study waters that were analyzed for TO, 109 were MM and 19 were MS.

Considering that northern or Florida bass or their subspecific hybrids can show the MM phenotype for tetrazolium oxidase (northern bass always MM, Florida bass may be MM, MS, or SS, and subspecific hybrids may be MM or MS), use of TO for classifying individual fish has limited value. This system is useful, however, for determining if Florida bass or subspecific hybrids are present in a population thought to contain northern bass only. In this regard, the presence of the MS or SS phenotype would indicate contamination. One would reasonably expect to find an MS phenotype (SS being in very low incidence even in Florida bass populations) in the collections from Central Valleys Warmwater Hatchery, Shasta Lake, or Merle Collins Reservoir if Florida bass or subspecific hybrids were present. For example, combining TO analyses for Upper Otay (68 fish) and Hidden Valley reservoirs (83 fish) showed that 58 fish, or about one out of every three fish, had the MS phenotype. Combining the TO analyses for fish from the study waters (308 fish) showed that 31 fish, or about one out of every 10 fish, had the MS phenotype (Figure 12). Therefore, it would not be unreasonable to expect to find at least one MS fish in the collections from Central Valleys Warmwater Hatchery, Shasta Lake, and Merle Collins Reservoir, considering the number of fish examined from each source.

Meristic Analysis

Results from discriminant function analysis of meristic data for fish of known MDH phenotypes showed that meristic values were not reliable for classifying individual fish from mixed populations as to Florida (MM), northern (SS), or hybrid bass (MS) categories. When meristic data for 69 MM fish from Upper Otay Reservoir, 271 MS fish from mixed populations, and a total of 167 SS fish from Central Valleys Warmwater Hatchery and Merle Collins Reservoir were analyzed as a whole, a considerable number of fish were categorized incorrectly. Only 32 Upper Otay fish were placed in the MM category, while 35 were classified as MS and two were classified as SS (Figure 13). Similar results were obtained when a total of 370 MM fish from Upper Otay and mixed populations, 271 MS fish from mixed populations, and a total of 427 SS fish from Central Valleys, Merle Collins, and mixed populations were considered as a whole. Of 370 MM fish, 261 were classified MM, 83 MS, and 26 SS. Of 271 MS fish, 115 were classified MS, 91 MM, and 65 SS. Of 427 SS fish, 369 were classified SS, 57 MS, and one MM. When 69 MM fish (Upper Otay) and 167 SS fish (Central Valleys and Merle Collins) were analyzed together, five of the former were categorized SS and four of the latter were classified MM.

Analysis also showed that the lateral line scale count was the most discriminating meristic character. Based on calculated values of the F-statistic, a measure of significant difference between groups for the character, the lateral line scale count was the most significantly different character ($F = 563.0770$), followed by pyloric caeca (50.3735), scale rows around the caudal peduncle (21.2659), scale rows above the lateral line (4.3975), scale rows on the cheek (3.4029), and scale rows below the lateral line (2.2009). For this reason, data are provided for lateral line scale counts only.

CLASSIFIED BY

	ELECTROPHORESIS		MERISTICS			
			MM	MS	SS	TOTAL
A 507 FISH	69_{MM}	UPPER OTAY RESERVOIR	32	35	2	69
	271_{MS}	MIXED POPULATIONS	52	183	36	271
	167_{SS}	CENTRAL VALLEYS W/W HATCHERY & MERLE COLLINS RESERVOIR	1	20	146	167
B 1,068 FISH	370_{MM}	UPPER OTAY RESERVOIR & MIXED POPULATIONS	261	83	26	370
	271_{MS}	MIXED POPULATIONS	91	115	65	271
	427_{SS}	CENTRAL VALLEYS W/W HATCHERY, MERLE COLLINS RESERVOIR & MIXED POPULATIONS	1	57	369	427
C 236 FISH	69_{MM}	UPPER OTAY RESERVOIR	64		5	69
	167_{SS}	CENTRAL VALLEYS W/W HATCHERY & MERLE COLLINS RESERVOIR	4		163	167

FIGURE 13. Results of discriminant function analysis-classification by meristic values of fish of known malate dehydrogenase phenotypes. The six meristic values used included number of 1) scales along lateral line, 2 and 3) scale rows above and below lateral line, 4) scale rows around caudal peduncle, 5) scale rows on cheek, and 6) pyloric caeca. A=507 fish considered as a whole (MM and SS fish from Florida and northern populations only). B=1068 fish considered as a whole (MM and SS fish from Florida, northern, and mixed populations). C=236 fish considered as a whole (classification of MM and SS fish only).

Northern largemouth bass lateral line scale counts ranged from 59 to 68 ($\bar{x}$ = 63.3, n = 100) for Central Valleys Warmwater Hatchery fish, from 59 to 69 ($\bar{x}$ = 64.0, n = 129) for Merle Collins Reservoir fish, and from 60 to 69 ($\bar{x}$ = 65.0, n = 73) for fish from Shasta Lake. Florida bass counts ranged from 66 to 75 ($\bar{x}$ = 70.5, n = 81) for Upper Otay Reservoir fish, and from 64 to 76 ($\bar{x}$ = 70.2, n = 93) for fish from Hidden Valley Reservoir.

Lateral line scale counts for all largemouth bass collected from the study waters following the introduction of Florida bass ranged from 53 to 79 ($\bar{x}$ = 66.2, n = 1,386). Counts made by Bottroff (1967) on largemouth bass from Folsom Lake prior to the 1972 introduction of Florida bass ranged from 56 to 69 ($\bar{x}$ = 63.4, n = 223). Post-introduction counts ranged from 53 to 78 ($\bar{x}$ = 65.6, n = 559) for fish collected from 1974 through 1977 (Figure 14).

Florida bass were introduced at New Hogan Reservoir in 1971. Counts made prior to that ranged from 57 to 68 ($\bar{x}$ = 63.4, n = 76). Post-introduction values for fish from 1975, 1976, and 1977 year classes ranged from 59 to 79 ($\bar{x}$ = 68.5, n = 278) (Figure 14).

No pre-Florida bass data were available for Lake Amador or Lake Isabella; however, post-introduction values ranged from 61 to 73 ($\bar{x}$ = 66.1, n = 155) and from 59 to 75 ($\bar{x}$ = 67.2, n = 114), respectively (Figure 14).

Pre-Florida bass introduction counts ranged from 58 to 68 ($\bar{x}$ = 63.7, n = 140) for Clear Lake fish (J. Broadway, M. Fairbank, and S. Morse, Univ. of California, Davis, unpublished data). Post-introduction values (1973 and 1975) ranged from 58 to 74 ($\bar{x}$ = 64.7, n = 280) (Figure 14).

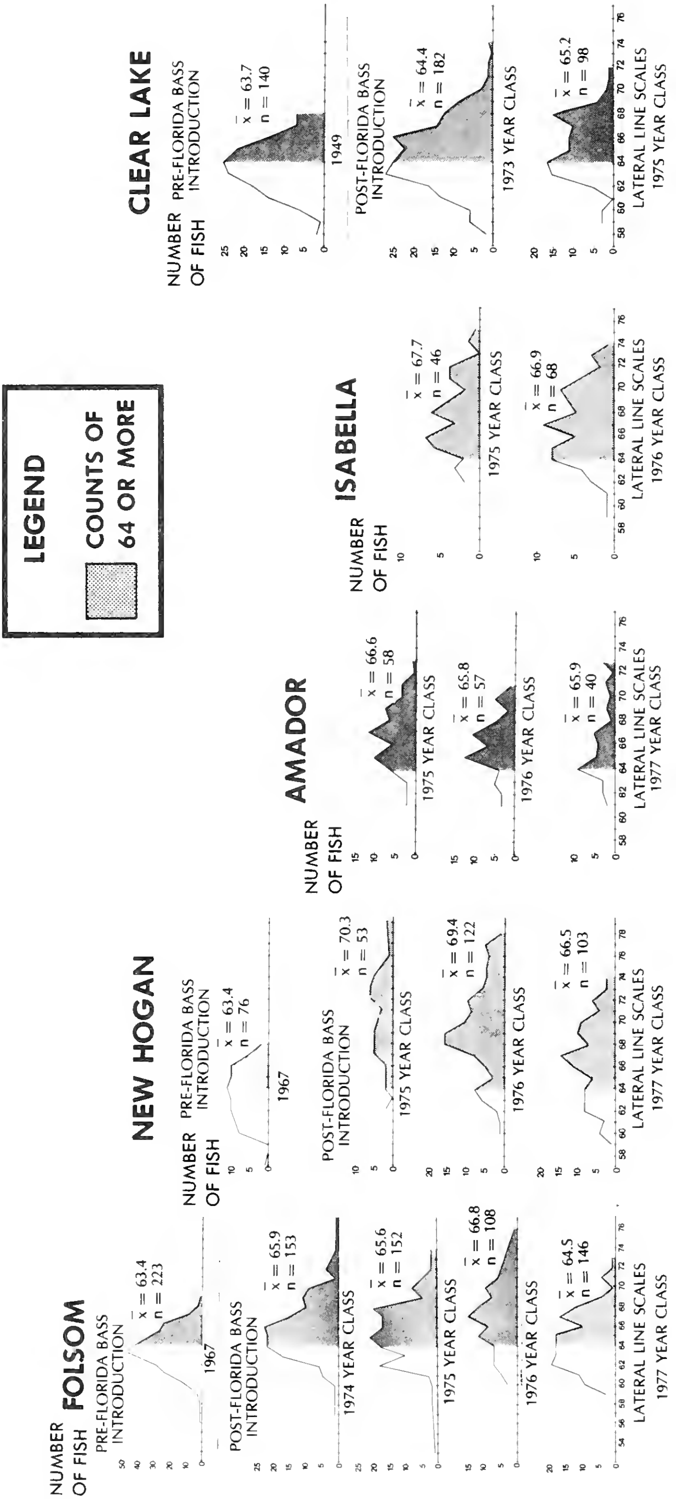


FIGURE 14. Frequency distributions of lateral line scale counts for fish from the study waters.

Counts for known F_1 hybrids ranged from 58 to 72 ($\bar{x} = 65.7$, $n = 53$), excluding abnormally low counts of 46, 47, and 52 (Figure 4). Values for fish from the study waters showing the MDH hybrid pattern ranged from 59 to 77 ($\bar{x} = 66.9$, $n = 313$).

Scale counts for Rancho Seco Reservoir fish (1975 and 1976) ranged from 62 to 82 ($\bar{x} = 72.8$, $n = 284$).

Use of Meristic Data in Evaluating Study Populations

Electrophoretic data were collected because meristic data appeared to be of limited value in meeting the objectives of this study:

(1) Categorization of individual fish from mixed populations would be difficult because of overlaps in ranges of meristic values for the subspecies and their hybrids.

(2) Hybridization could probably not be demonstrated by increases over time in mean meristic values for study populations since such increases would likely occur with no hybridization because of higher survival by longer-lived, less vulnerable Florida bass.

(3) Hybridization could not necessarily be demonstrated by a frequency distribution of meristic values for fish sampled from a mixed population because of its possible similarity to a distribution postulated for a comparable population of the two subspecies spawning independently and with differing annual mortality rates.

(4) While changes in meristic values may have provided indications that hybridization had occurred (extended ranges and/or unimodal distribution of values, etc.), determination of the extent of hybridization was unlikely.

Bailey and Hubbs (1949) reported a range of lateral line scale counts of 59 to 69 for northern bass from the Great Lakes and the Mississippi River, a range of 65 to 75 for Florida bass from the Florida Peninsula, and an overall range of 58 to 76 for apparent hybrids from various Florida and Georgia waters. Lateral line scale counts for fish identified electrophoretically by this study as northern bass ranged from 59 to 69. Counts for Florida bass ranged from 64 to 76. Counts for fish from mixed populations ranged from 53 to 78, and those for known F_1 hybrids ranged from 58 to 72. It is apparent from these overlapping ranges that one cannot expect to classify individual fish from mixed populations as to subspecific or hybrid categories with reasonable accuracy on the basis of a lateral line scale count. Similar overlaps occurred for other scale counts and for pyloric caeca counts.

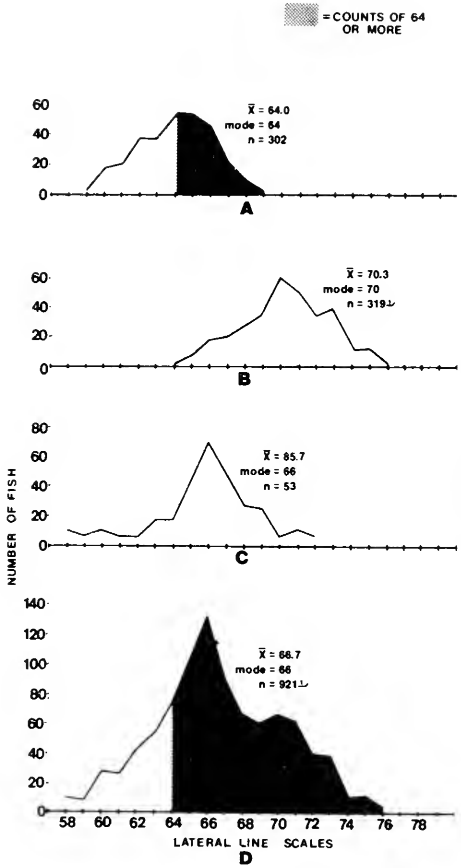
Mean lateral line scale counts for northern bass populations reported by Bailey and Hubbs (1949) ranged from 62.6 to 64.6. Bottroff (1967) reported mean counts of 61.2 to 63.9 for several California populations. Lateral line scale counts for Central Valleys Warmwater Hatchery fish averaged 63.3, and those for fish from Merle Collins Reservoir averaged 64.0. Fish from Shasta Lake averaged 65.0. While this mean was abnormally high for a northern bass population, no individual count exceeded the range typically reported for northern bass. The mean lateral line count for fish collected prior to introduction of Florida bass was 63.4 at Folsom Lake and at New Hogan Reservoir, and 63.7 at Clear Lake. Mean counts for fish collected at the study waters following the introduction of Florida bass ranged from 64.5 to 66.8 at Folsom Lake, 66.5 to 70.3 at New Hogan Reservoir, and 65.8 to 66.6 at Lake Amador. Post-introduction values were 67.7

and 66.9 at Lake Isabella and 64.4 and 65.2 at Clear Lake. This would suggest that hybridization could be detected by an increase in mean lateral line count to a value of 65 or more. Such an increase, however, would likely have occurred at the study waters with no intersubspecific spawning, considering the differing annual mortality rates of 0.55 for northern bass and 0.25 for Florida bass reported by Bottroff and Lembeck (1978). Considering that Florida bass were stocked into established populations of northern bass at the study waters at a ratio of at least one Florida bass for every 50 northern bass, an increase in the mean lateral line scale count to 65 scales for fish representatively collected from the study populations would likely not have occurred for several years. However, if young Florida bass survived at a disproportionate rate that time would have been substantially reduced.

One might expect the frequency distribution of lateral line scale counts for fish from an intergraded population to show a unimodal distribution (Figure 15D). Conversely, the frequency distribution of a population of Florida and northern bass spawning independently and with differing mortality rates should eventually show a bimodal distribution. Bimodality would most likely occur at 67, 68, or 69 scales, which are at the upper end of the northern range and near the lower end of the Florida range (combining A and B of Figure 15). Bimodality would be most apparent in populations having equal numbers of the two subspecies. At the study waters, however, Florida bass were initially outnumbered by northern bass by a wide margin. For this reason, bimodality would likely not be detected in representative samples for several years (Figure 16).

Figure 16 provides frequency distributions of lateral line scale counts that one might expect to find if a yearling population of 15,950 northern bass and 319 Florida bass, a 50 to 1 ratio (a conservative estimate of the initial ratio at the study waters), was examined each year over a 5-year period when: 1) the two subspecies were dying at the differing rates (0.55 for northern bass and 0.25 for Florida bass) reported by Bottroff and Lembeck (1978); 2) within the respective groups, no scale count was being removed disproportionately; and 3) all fish were marked for separation. Northern bass scale counts were expanded proportionally from the 302 counts recorded for fish from Central Valleys Warmwater Hatchery, Shasta Lake, and Merle Collins Reservoir. Counts for fish from Upper Otay and Hidden Valley reservoirs were used for Florida bass. In this hypothetical exercise in which there was no intersubspecific spawning and recruited fish were not considered, bimodality began to appear among the surviving fish at 69 scales in the fourth year.

Given the same initial population, the frequency distributions of Figure 16 likely also approximate the scale counts of fish representatively sampled from that population (including recruited fish) each year over a 5-year period when: 1) no intersubspecific spawning occurred; 2) the two subspecies were dying at the differing rates reported by Bottroff and Lembeck (1978); 3) survival to sampling of young fish of each subspecies was comparable; and 4) the incidence of each lateral line scale count for fish recruited into the population was proportional to the incidence of that count in the initial population. Under these conditions, bimodality could conceivably be detected as early as the fourth year. If, however, fish with lateral line scale counts of 67, 68, or 69 were recruited into a population at a disproportionate rate, bimodality may not be detected and the frequency distributions for sampled fish would likely show a unimodal distribu-



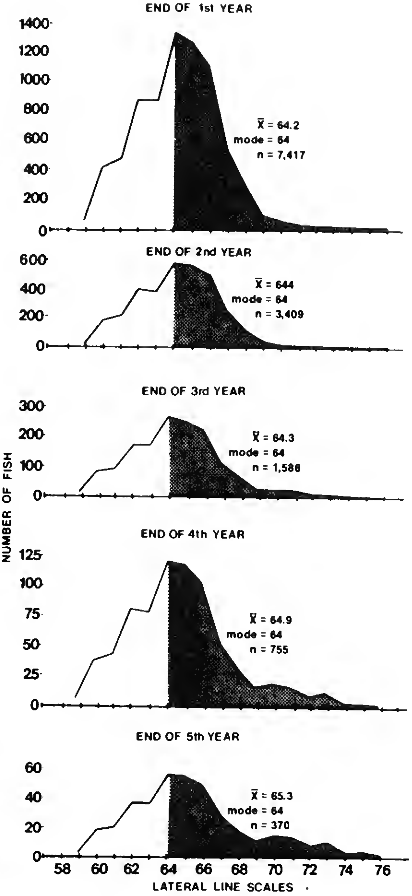


FIGURE 15. Frequency distributions of lateral line scale counts for: (A) northern bass from Central Valleys Warmwater Hatchery, Shasta Lake, and Merle Collins Reservoir combined; (B) Florida bass from Upper Otay and Hidden Valley reservoirs combined; (C) known F_1 hybrids; and (D) A+B+C (53 counts expanded to 300 on a proportional basis). [1] Includes 145 counts made by L. Bottroff (unpubl. data).

FIGURE 16. Frequency distributions of lateral line scale counts for an initial population composed of 15,950 northern bass and 319 Florida bass (a 50 to 1 ratio), and applying the annual mortality rates of 0.55 for northern bass and 0.25 for Florida bass reported by Bottroff and Lembeck (1978) over a 5-year period. Northern bass counts were expanded proportionally from the 302 counts recorded for fish from Central Valleys Warmwater Hatchery, Shasta Lake, and Merle Collins Reservoir. Counts for fish from Upper Otay and Hidden Valley reservoirs were used for Florida bass.

tion. Inadequate sample size or sampling error may also give frequency distributions falsely suggestive of an intergraded population.

Various changes in lateral line scale count values following the introduction of Florida bass into a northern bass population such as 1) an increase in mean count, 2) the occurrence of individual values that exceed the combined ranges of the two subspecies, and 3) the unimodality of a frequency distribution of values may suggest that intersubspecific spawning has occurred. These indicators do not provide, however, a measure of the extent of hybridization or an insight into the makeup of the resultant population.

Compilation of meristic, as well as electrophoretic data for study populations, for populations of Florida and northern bass, and for known F_1 hybrids provided an opportunity to assess the value of meristics for detecting hybridization. In this regard, the mode value of lateral line scale counts for fish of a mixed population where a comparatively few Florida bass were stocked, appeared to provide greater insight than other indicators. The mode value of a distribution of lateral line scale counts is typically 63 or 64 for a northern bass population (Bottroff 1967 and Figure 15A), and 70 for a Florida bass population (Bottroff 1967 and Figure 15B). Mixed populations typically exhibit a mode ranging from 65 to 70 (Bottroff 1967). Consistent with this, a hypothetical population composed of equal numbers of northern bass, Florida bass, and known F_1 hybrids had a mode of 66 (Figure 15D). While distributions for fish from the study waters were generally multimodal because of comparatively small sample sizes (Figure 14) it is apparent that the mode for larger samples from these waters would fall within the aforementioned range. For example, combining collections from Folsom Lake ($n = 559$) gives a mode of 65. Combining collections from New Hogan Reservoir ($n = 278$) gives a mode of 69. Also, a comparison of the percentage of fish with counts of 64 or greater in a northern bass distribution (darkened portion of Figure 15A) with the percentage of fish with those counts in the hypothetical mixed population (darkened portion of Figure 15D) and in the study populations (darkened portions of Figure 14 post-Florida bass) indicates that the mode value for most study water collections lies between 65 and 70. The percentage of values 64 or greater in a northern population distribution is usually about equal to or less than the percentage of values less than 64 (Bottroff 1967 and Figure 15A). Contrastingly, the percentage of fish with values of 64 or greater in distributions of the hypothetical mixed population and actual collections made at the study waters exceeds the percentage of fish with values less than 64. Bottroff's (1967) distributions were equivalent in this respect.

Population Sampling

Two major factors related to sampling could have affected the evaluations:

(1) A correlation between isozyme pattern and susceptibility to electrofishing.

(2) Differences in the makeup of collections between years being a reflection of sampling error rather than changes within the populations.

Most fishery workers involved with comparative tests report that Florida bass are considerably more wary than northern bass (Zolczynski and Davies 1976; Rieger, Summerfelt, and Gebhart 1978). For this reason, one would expect Florida bass to be more difficult to capture by electrofishing. Consistent with the findings of Zolczynski and Davies (1976) that Florida bass ceased feeding and moved into deeper water in response to fishing, Florida bass should move from shallow water into deeper water in reaction to an approaching electrofishing boat with its associated bright lights and noisy generator (or alternator). I found, however, that adult Florida bass were no more difficult to capture at Hidden Valley Reservoir and Rancho Seco Reservoir (mostly Florida bass present), than northern bass were at Merle Collins Reservoir and other waters. If Florida and northern bass differ in susceptibility to electroshocking the age group least likely to demonstrate this would probably be young-of-the-year fish. Most fish collected at the study waters were young-of-the-year. While these fish ranged considerably as to size, no correlation was found between a given MDH pattern and size. Considering the incidence of the three MDH patterns in collections from the study waters, over time and when comparing one water with another, I do not believe that MM, MS, or SS fish showed appreciably different susceptibilities to the electrofishing gear.

It is possible that sampling error was responsible for some differences in the makeup of collections between year classes. There are indications, however, that through rigid adherence to collection guidelines previously listed, these differences were mostly a reflection of actual changes in the population makeup rather than changes falsely represented through sampling error. For example, the incidence of fish showing the three MDH isozyme patterns in collections from Lake Amador remained relatively constant from 1975 through 1978 (Figure 7). Appreciable sampling error would have caused noticeable differences between two or more of these years.

Rancho Seco Reservoir

A small pond at the eventual site of Rancho Seco Reservoir was chemically treated to eradicate all fish life prior to inundation of the reservoir basin. It is likely that this treatment was successful and that northern bass were not present when Florida bass were introduced in 1971. The presence of one fish of the northern bass MDH phenotype among fish analyzed from the 1973 year class, however, showed that the Rancho Seco Reservoir population included northern bass alleles. It is possible that a small number of northern bass were inadvertently pumped into the reservoir from the nearby Folsom South Canal or were transplanted by anglers from another source.

While no SS (northern bass) phenotypes were found in collections from the 1975, 1976, and 1977 year classes, MS (hybrid) phenotypes were represented (Figure 10). It is probable that the Rancho Seco Reservoir population contained hybrid fish at the time it was utilized as a source for some of the study waters (Figure 1). The incidence of hybrid fish in groups stocked from the reservoir from 1971 through 1974 was likely low, however, considering that comparatively few northern bass were initially involved. An indication that Rancho Seco Reservoir contained few hybrids in the early years comes from a comparison of the frequency of the Florida allele in 1978 at New Hogan Reservoir (0.52) and Clear Lake (0.52). New Hogan Reservoir was the only study water that received fish from Rancho Seco Reservoir only. Clear Lake was planted from Upper Otay and Hidden Valley reservoirs. Also, it is unlikely that the high incidence of the Florida allele at New Hogan Reservoir in 1975 (0.65), 1976 (0.64), and 1977 (0.70) would have occurred if an appreciable number of hybrids were present in plants made there from Rancho Seco Reservoir.

Maladaptive Genes

Apparent intolerance of 4° C by Florida bass reported by Johnson (1975) prompted concern that maladaptive genes possibly related to this intolerance would be transmitted to northern bass populations through Florida bass introduction. Quoting from Johnson:

> "Low temperature stress was suspected as the cause of poor survivorship of Florida bass in the Ashland ponds and Phillips Lake. As a preliminary test, three Florida and three northern bass were subjected to rapid temperature decreases (acclimated to 21°C for 48 hours and then exposed to a reduction in temperature from 21° to 4° within 12 hours). Florida bass mortality was 100% in the two replicates over a 7-day test period. Only one of the six northern largemouth bass died. Although the experimental design was limited, the results point to a greater sensitivity for Florida largemouth bass than for the northern subspecies. A subsequent investigation of this question utilized a large outside tank which held 20 Florida and 20 northern largemouth. The fish were acclimated at 15°C (59°F) and then subjected to gradually decreasing temperatures. Mortality was similar in the two subspecies until the ninth day at a temperature of 5°C (41°F). The temperature was held at 4°C (39°F) for 5 days. Fourteen days after the inception of the experiment, all Florida bass were dead while only three northern bass had died. While these data do not prove winter mortality in ponds is caused by low temperature, it does indicate a difference in temperature tolerance between the two subspecies. The Florida bass is much more sensitive to a rapid decline in temperature."

Results of these tests suggest that Florida bass are more sensitive to a rapid decline in temperature than are northern bass. These tests should have included, however, control fish of both subspecies held in comparable tanks at optimal temperature. My experience with Florida bass has been that they initially are more wary and, as a result, more stressed by handling than are northern bass. For this reason, one might expect that Florida bass, disproportionately stressed before entering comparative, stressful tests with northern bass, would show a higher mortality. Colby (1973) cautioned against extrapolating laboratory results to explain natural events. He cited laboratory tests of temperature tolerance of alewives, *Alosa pseudoharengus,* and endemic species that showed differential mortalities of alewives at temperatures <3°C, suggesting that they were likely vulnerable to the low temperatures which occur in the Great Lakes. The fact that alewives were captured in trawls in the Great Lakes in waters colder than 2°C suggested that captivity may reduce low temperature tolerance.

Several points should be considered in relating Johnson's findings to Florida bass in northern California waters:

(1) It is unlikely that temperature declines at rates comparable to those used by Johnson would occur at California's low- and mid-elevation reservoirs.

(2) Florida bass survived outdoor temperatures (including freezing conditions in which only aeration of the holding tanks prevented them from freezing over) for two winters (1977–78, 10 fish; 1978–79, 13 fish) at the Department's Field Station.

(3) No mortalities occurred among 61 F_1 hybrids held in outdoor tanks at the Field Station during winter 1978–79.

(4) Considering the obvious genetic impact of the comparatively few Florida bass stocked at the study waters, it is unlikely that they or their progeny suffered appreciable wintertime mortalities.
(5) No unusual wintertime dieoffs of bass at the study waters were reported by fishery workers, marina operators, or anglers.

Results of this study indicate that considerable variation exists among fish of the intergraded populations. Of particular interest here are variant forms of enzymes related to temperature compensation. The enzyme reactions which exhibit the highest degree of temperature compensation are primarily those involved in generating the energy "currency" (ATP, NADH, etc.) needed by the cells at all times (Hochachka and Somero 1973). Malate dehydrogenase is such an enzyme. According to Hochachka and Somero (1971) for an organism experiencing changes in habitat temperature over daily or hourly time spans, it would seem advantageous to have two or more variants of a given enzyme in its tissues which, by acting together, could promote thermally independent enzyme function over a wider range of temperatures than would be possible if only a single form of the enzyme were present.

Performance Capabilities of Fish of Intergraded Populations

Malate dehydrogenase isozyme patterns used to identify northern and Florida bass, for which some performance capabilities have been described, have limited use in predicting the performance of individual fish of intergraded populations. A fish showing a Florida bass enzyme pattern, for example, may or may not spawn earlier, grow faster, live longer, or demonstrate other attributes assigned to Florida bass. The performance capability of a fish is ultimately determined by its biochemical makeup (Hochachka and Somero 1973). While MDH, an enzyme involved in energy transfer, is a part of that makeup, isozyme patterns of MDH do not necessarily indicate the behavioral, anatomical, or physiological characteristics of fish. Results of this study showed, however, that the heterozygote of Florida bass x northern bass possesses MDH isozymes of both parents plus an additional isozyme found in neither parent. Similarly, Dr. Philipp (pers. commun.) identified heterozygous patterns for two additional enzymes, isocitrate dehydrogenase and aspartate aminotransferase, in Lake Isabella fish of the 1978 year class. Several workers have reported variant isozymes for several enzymes in hybrids resulting from inter- and intraspecific crosses (Goldberg 1966; Aspinwall and Tsuyuki 1968; Bailey and Wilson 1970; Whitt, Childers, and Wheat 1971; Metcalf, Whitt, and Childers 1972; Wheat, Whitt, and Childers 1973; Whitt, Childers, and Cho 1973; Whitt et al. 1973; Avise and Smith 1974).

Umbarger (1961) proposed that additional isozymes provide auxiliary routes for energy transfer. According to Ayala (1978) the manufacture of slightly variant proteins by the heterozygote may enable it to adapt to a broader range of conditions and individuals that are heterozygous at a number of loci are usually stronger and reproductively more successful than individuals homozygous at a large number of loci. Several workers have reported that progeny from crosses between species or inbred lines show increased vigor termed heterosis (Hubbs and Hubbs 1930; Shull 1948; Whitt et al. 1973; Wheat, Childers, and Whitt 1974; Ayala 1978). Utter, Hodgins, and Allendorf (1974) pointed out that studies of interspecific variation can be extended through studies of species hybrids because of the greater amount of genetic variation that exists between any two species than that which exists within either of them. Ayala (1978) stated that a population that has considerable variation may be hedged against future changes in the environment.

Results of this study indicate variability of characteristics among fish of the intergraded populations in two major ways. Firstly, the range of meristic values for fish sampled from the mixed populations typically equalled, and in some cases overlapped, the combined ranges for the subspecies involved. Fish of given MDH isozyme patterns had quite variable meristic values, particularly those collected in the latter years of the study. For example, some fish showing the northern bass pattern had counts as high as 75, while some fish showing the Florida bass pattern had counts as low as 62. Meristic values for MS fish typically showed the greatest variability. Lateral line scale counts of MS fish collected in 1976 from Folsom Lake ranged from 60 to 76. Similarly, MS fish from New Hogan Reservoir in 1976 had counts ranging from 60 to 78. It is, therefore, reasonable to assume that if variability exists between isozyme pattern and meristic values this variability could extend to other characteristics.

Secondly, since fish of the study populations exhibited one of three MDH isozyme patterns, and some fish from Lake Isabella demonstrated heterozygous patterns for two other enzymes, it is likely that fish of the intergraded populations exhibit variant forms of other enzymes. The possible combinations resulting from this are considerable.

It is reasonable to assume that the current largemouth bass populations at the study waters possess a wider spectrum of performance capabilities than that previously present. This is consistent with the original intent of introducing Florida bass which were reported to grow faster, live longer, spawn earlier, and be more difficult to catch than northern bass. Inclusion of these and other traits likely yielded populations composed of individuals ranging from those showing mostly Florida bass traits to those showing mostly northern bass traits. This variability would be particularly advantageous in the reservoir setting where heavy angling pressure, water level manipulation, competition of prey species with small bass, and other factors work against the maintenance of a bass population.

Management Implications

Indications of the management implications of Florida bass introduction come from Bottroff and Lembeck (1978) in relating their findings at San Diego County reservoirs where Florida bass were introduced into established populations of northern bass:

> . . . populations with Florida-like characteristics are resistant to overharvest by anglers. The mean size of bass caught and the incidence of trophy specimens has increased in reservoirs where Florida bass have been established. Increased bass yields were associated largely with the development of hybridized populations although one impoundment containing bass with Florida-like characteristics provides angling of exceptional quality.

Pre- and post-Florida bass introduction census data were not available for the study waters. There are indications, however, that Florida bass had a positive impact at some of these waters. According to R. Lockhart, Sr. (Operator, Lake Amador Resort, pers. commun.) bass fishing has been excellent at Lake Amador in recent years. In spring 1978 anglers caught over 100 largemouth bass weighing between 3.2 kg and 5.9 kg. During the first 9 months of 1979, anglers caught over 100 bass weighing between 3.2 kg and 4.9 kg. Lockhart pointed out that his records include only the catches of anglers who voluntarily stop at the resort headquarters prior to departing.

B. Burke (Marina Owner, New Hogan Reservoir, pers. commun.) reports that largemouth bass fishing has been good at the reservoir in recent years. Highlighting catches made during the first 9 months of 1979 were four bass, each weighing over 4.5 kg.

In 1976 L. Week (Fishery Biologist, Calif. Dept. Fish and Game, pers. commun.) verified the weight of a 4.6 kg largemouth bass, establishing a new record weight for bass at Clear Lake. According to Week, bass fishing has improved considerably at the lake since early 1978, after more than a decade of poor fishing. He does not relate this to the heavy supplemental stocking of northern bass conducted at the lake for several years by a private group. Electrofishing surveys directed at assessing the survival of these fish, mostly fingerlings, have yielded very low returns. For example, the marked fingerlings (110,000) stocked in July 1979 made up only 3.8% of young-of-the-year bass collected one month later. Week also reports that largemouth bass reproduction has increased considerably. Electrofishing surveys in August 1978 and 1979 yielded 123 and 243 young-of-the-year per kilometre, respectively.

Loss of habitat in the form of underwater trees and brush is thought to be responsible for the decline in largemouth bass catches at Folsom Lake, which began in the early 1960's. Since then, smallmouth bass, *M. dolomieui,* have dominated bass catches (Pelzman, Rapp, and Rawstron 1980). No information was obtained that would indicate that this trend was reversed by the introduction of Florida bass. In 1965 largemouth bass constituted only about 3% of the sport catch at Lake Isabella (Hayden 1966). No information was obtained that would suggest that Florida bass substantially improved this situation. While in the long term, the introduction of Florida bass may increase bass catches at Folsom Lake and Lake Isabella, it is perhaps unrealistic to expect Florida bass to markedly improve bass fishing at waters where conditions are such that established northern bass populations are providing only marginal fishing.

Results of this study and of the study at San Diego County reservoirs (Bottroff and Lembeck 1978) showed that:

(1) There is considerable overlap in the spawning periods of northern and Florida bass, and intersubspecific spawning will likely occur when the two are present in the same water.
(2) Introduction of Florida bass provides a method for reducing the high harvest rates typically recorded for northern bass populations in California.
(3) Anglers may catch fewer bass following the introduction of Florida bass; however, the mean size of bass in the catch is greater.
(4) The incidence of trophy-sized bass increased at most waters where Florida bass were introduced.

For these reasons, consideration should be given to stocking Florida bass into northern bass populations at additional, selected northern California waters. Also, intergraded populations should serve as a source for stocking at newly created reservoirs and for restocking dewatered reservoirs.

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Calif. Fish and Game 66(3): 163–171

EXPLOITATION, NATURAL MORTALITY, AND SURVIVAL OF SMALLMOUTH BASS AND LARGEMOUTH BASS IN SHASTA LAKE, CALIFORNIA [1]

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To obtain information on mortaility and survival of black bass in Shasta Lake, $5 reward trailer tags were attached to smallmouth bass, *Micropterus dolomieui,* in 1973 and 1975 and to largemouth bass, *M. salmoides,* in 1975.

First-year exploitation of 203 to 356 mm (8 to 14 in.) smallmouth bass tagged in 1973 was 0.68, natural mortality was 0.24, and survival was 0.08. First-year exploitation of 254- to 305-mm (10- to 12-in.) smallmouth bass tagged in 1975 was 0.70, natural mortality was 0.28, and survival was 0.02. First-year exploitation of 254- to 406-mm (10- to 16-in.) largemouth bass tagged in 1975 was 0.50, natural mortality 0.28, and survival 0.22.

First-year exploitation of both species probably was lower than that indicated by tag returns since anglers were known to release some small bass after removing the tag. Survival of both species may have been underestimated since high turbidity levels in 1974 and the beginning of a 2-year drought in 1976 may have reduced angler use and/or success.

High exploitation of smallmouth bass in Shasta Lake is the result of heavy angling pressure and high vulnerability of young smallmouth bass to natural baits. This high exploitation appears to be responsible for the large population of small smallmouth bass in Shasta Lake.

INTRODUCTION

Fishery management efforts at Shasta Lake have centered primarily on the stocking of salmonids large enough to utilize the large population of threadfin shad, *Dorosoma petenense,* (Weidlein 1971), but a substantial warmwater fishery is also present. Largemouth bass were introduced in 1948 and smallmouth bass in 1952. Largemouth bass fishing was excellent in the 1950's and early 1960's, but more recently, largemouth bass fishing has declined. Smallmouth bass have become the most frequently caught warmwater species (Weidlein 1971). In 1973, smallmouth bass outnumbered largemouth bass in the catch by about 13 to 1 (Healey, MS9).

Weidlein (1971) noted a decline in both total catch and catch/h of smallmouth bass in Shasta Lake from 1968 to 1969 and recommended that the fishery be closely examined to see if this species was being overharvested. Creel checks conducted in 1968 and 1969 (Weidlein, unpubl. data) and 1972 and 1973 (Van Woert, unpubl. data) showed that the mean length of smallmouth bass in the catch ranged from 274 to 287 mm (10.8 to 11.3 in.). During these 4 years, 64.3% to 74.5% of the smallmouth bass in the catch were under 305 mm (12 in.). Relatively few smallmouth bass larger than 356 mm (14 in.) entered the catch or were found during electrofishing surveys.

Studies by Rawstron (1967), Rawstron and Hashagen (1972), and Rawstron

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and Reavis (1974) showed that largemouth bass were heavily exploited in some California waters; however, mortality and survival of smallmouth bass have received little attention in California. Rawstron's (1967) findings also suggested that the harvest of smallmouth bass might be as high or higher than that of largemouth bass in Folsom Lake.

As part of a program designed to collect the basic biological information needed to develop a management plan for warmwater fishes, smallmouth bass were tagged in Shasta Lake in 1973 and both smallmouth and largemouth bass tagged in 1975 to determine exploitation, natural mortality, and survival rates. Smallmouth bass were tagged in 1975 to obtain comparable estimates of mortality and survival for 254- to 305-mm (10- to 12-in.) smallmouth and largemouth bass in the Pit River Arm of Shasta Lake and for comparison with smallmouth estimates obtained in 1973 in the Sacramento River Arm of Shasta Lake. The tagging studies would provide the information needed to evaluate current angling regulations, particularly the bag limit and possible need for a minimum length limit. This report summarizes the results of the 1973 and 1975 tagging studies and discusses some future management possibilities for black bass in Shasta Lake.

DESCRIPTION OF SHASTA LAKE

Shasta Lake is located on the Sacramento River 11 km (7 miles) upstream from Redding, Shasta County, California (Figure 1). Completed in the early 1940's, this reservoir is operated by the U.S. Water and Power Resource Service for irrigation, power generation, and flood control.

Shasta Lake has three long, narrow arms named for its major tributaries; the Sacramento, McCloud, and Pit Rivers. At full pool the Lake has a surface elevation of 325 m (1,067 ft), impounds 5,551 hm^3 (4.5 million acre-ft) of water, covers 11,947 ha (29,500 acres), and has 587 km (365 miles) of shoreline. Maximum water storage is generally reached about May and summer drawdown begins by early June.

Surface water temperatures range from about 10°C (50°F) in winter to 27°C (80°F) in summer. Thermal stratification takes place usually in June. Lake margins have mostly moderately steep to steep slopes, with very little vegetation in the fluctuation zone.

Shasta Lake is open year-round to fishing for all species. Daily bag limit during the study was five black bass, with no minimum length limit. Boat anglers have good access to the Lake from numerous public boat launching ramps and privately-owned resorts. A relatively small portion of the shore is accessible by road for shore fishing.

METHODS

Tagging studies were designed to study each major arm of the Lake separately because of Shasta Lake's large size. Smallmouth and largemouth bass were tagged by length groups and returns analyzed by length groups and age classes in an effort to determine an optimum length limit by evaluating the effects of incremental increases in minimum length on maximum yield. All bass were collected with an electrofishing boat usually operated within 3 m (9.8 ft) of the shore and in water under 2 m (6.6 ft) deep. Pulsating direct current was used.

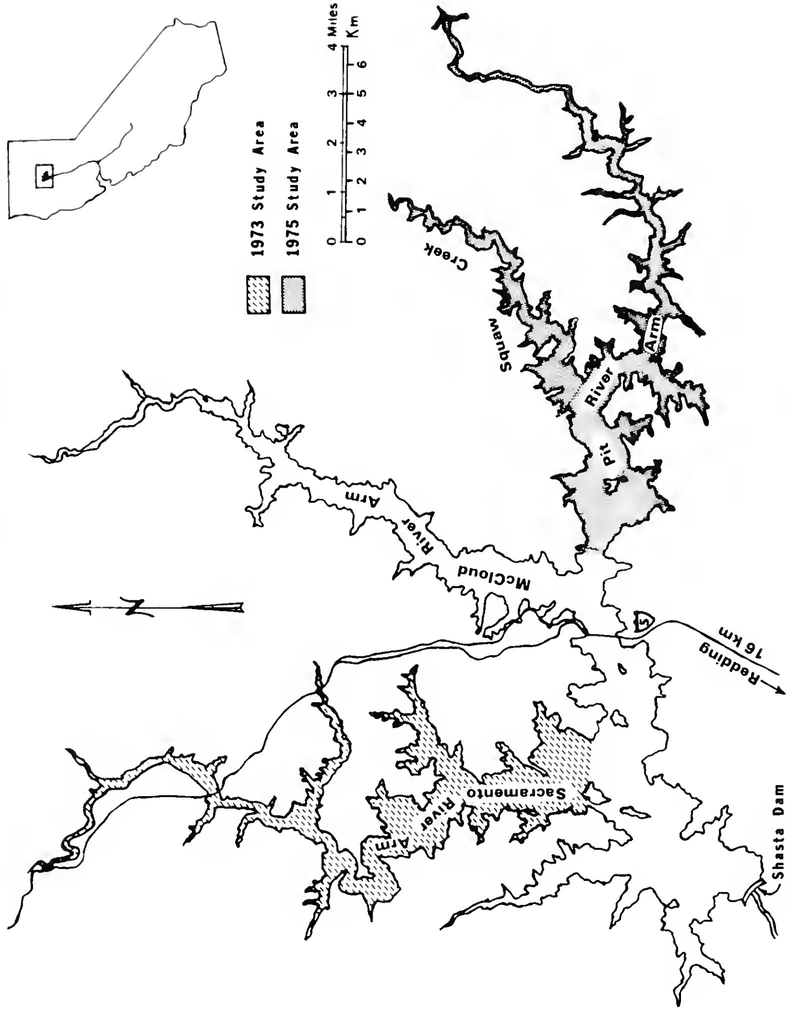

FIGURE 1. Shasta Lake showing areas where black bass were tagged in 1973 and 1975.

All electrofishing was done at night during March, April, and May.

In 1973, electrofishing was conducted along 156 km (97 miles) of shoreline in the Sacramento River Arm in an effort to tag 203- to 356-mm (8- to 14-in.) smallmouth bass.

In 1975, electrofishing was conducted along 208 km (129 miles) of shoreline in the Pit River Arm in an effort to tag 254- to 406-mm (10- to 16- in.) largemouth bass and 254- to 305-mm (10- to 12-in.) smallmouth bass.

Smallmouth bass larger than 356 mm (14 in.) were not tagged in 1973 because previous bass tagging studies in California suggested that too few large bass would be tagged to give significant returns after the second year. Early electrofishing in 1975 indicated that few largemouth bass under 254 mm (10 in.) were available for tagging while largemouth bass 356 to 406 mm (14 to 16 in.) were fairly abundant. Only 254- to 305-mm (10- to 12-in.) smallmouth bass were tagged in 1975 because of limited reward tag funds.

As the electrofishing boat moved along the shoreline, stunned bass were netted, measured to the nearest 2.54 mm (0.1 in.), tagged, and a scale sample, for use in aging fish, taken near the tip of the pectoral fin. Stunned bass generally recovered in less than 5 minutes and were released as soon as they appeared to be recovered. An effort was made to release tagged bass close to where they had been captured.

All bass were tagged with trailer tags. The method of attachment was described by Nicola and Cordone (1969). Tags used in this study were 16-mm (⅝-in.) long, 6-mm (¼-in.) wide, 0.8-mm (.030-in.) thick, and made of laminated green vinyl plastic. Tags had a number and $5 REWARD on one side and instructions for returning the tag on the other side. Tag frame and link were made of 0.3-mm (.012-in.) diameter soft stainless steel wire.

Bass caught from zero through 365 days from the date of tagging were considered first-year returns. Bass caught from 366 to 730 days and 731 to 1,095 days after the date of tagging were considered second- and third-year returns, respectively. The computation of mortality and survival rates follow Ricker (1958).

Age determinations were made by counting annuli on scale impressions made on cellulose acetate strips with the aid of a binocular microscope and an Eberbach scale projector.

RESULTS

Smallmouth Bass—1973

Between 8 March and 25 April 1973, 530 smallmouth bass were tagged in the Sacramento Arm of Shasta Lake. Anglers returned a total of 391 (73.8%) of these tags within 3 years. Only first- and second-year tag returns were used in calculations of mortality and survival because muddy water in 1974 may have adversely affected fishing success. Since no tags were returned during the fourth year, tag returns were considered complete. First-year exploitation for all length groups combined amounted to 0.68, natural mortality was 0.24, and survival from the first to the second year was 0.08 (Table 1).

When calculated for 25.4-mm (1-in.) length groups, first-year exploitation increased from 0.59 to 0.79 for bass 203 mm (8 in.) to 279 mm (11 in.) and decreased from 0.79 to 0.52 for fish 279 mm (11 in.) to 356 mm (14 in.) (Table

.1). A chi-square test of homogeneity showed a significant difference in exploitation by length at the 5% level ($X^2 = 18.78$; d.f. = 5; $p < 0.01$).

Analysis by age class showed that younger smallmouth bass were exploited at higher rates than older fish (Table 2). First-year exploitation amounted to 0.72 for Age II, 0.58 for Age III, and 0.47 for Age IV fish. Length at any given age was highly variable. Age II smallmouth bass ranged from 208 to 307 mm (8.2 to 12.1 in.) and averaged 254 mm (10.0 in.). Age III fish ranged from 221 to 350 mm (8.7 to 13.8 in.) and averaged 305 mm (12.0 in.). Age IV smallmouth bass were incompletely represented in the study since only fish under 356 mm (14 in.) were tagged.

TABLE 1. Exploitation, Natural Mortality, and Survival of Tagged Smallmouth Bass by Length Groups in 1973 at Shasta Lake.

Fork Length at tagging (mm)	*Number tagged 1973*	*Number of tags returned*			*Total*	*First-year exploitation (u)*	*Natural mortality (v)*	*Annual survival* (s)*
		First year	*Second year*	*Third year*				
203–228	44	26	2	–	28	0.59	0.34	0.07
229–253	156	109	9	–	118	0.70	0.22	0.08
254–279	133	105	4	1	110	0.79	0.17	0.04
280–305	67	47	3	1	51	0.70	0.24	0.06
306–330	67	41	4	–	45	0.61	0.30	0.10
331–356	63	33	6	–	39	0.52	0.30	0.18
Total	530	361	28	2	391	–	–	–
Mean	–	–	–	–	–	0.68	0.24	0.08

* Based on ratio of second-year to first-year returns.

TABLE 2. Exploitation, Natural Mortality, and Survival of Tagged Smallmouth Bass by Age Classes in 1973 at Shasta Lake.

Age	*Mean length (mm)*	*Number tagged 1973*	*Number of tags returned*			*Total*	*First-year exploitation (u)*	*Natural mortality (v)*	*Annual survival* (s)*
			First year	*Second year*	*Third year*				
II	254	346	250	16	1	267	0.72	0.21	0.07
III	305	70	41	6	1	48	0.58	0.27	0.15
IV †	–	45	21	3	–	24	0.47	0.40	0.14
Total	–	461 ‡	312	25	2	339	–	–	–

* Based on ratio of second-year returns to first-year returns.
† Age group incompletely sampled because bass over 356 mm (14.0 in.) were not tagged.
‡ Scales in 69 samples could not be aged.

Smallmouth Bass—1975

Between 11 March and 9 May 1975, 200 smallmouth bass were tagged in the Pit River Arm of Shasta Lake. Anglers returned a total of 143 (71.5%) of the tags within 2 years after tagging (Table 3). Since no tags were returned during the third year, tag returns were considered complete. Total first-year exploitation was 0.70, natural mortality was 0.28, and survival from the first to the second year was 0.02. Mortality and survival rates by age class were not calculated for this group of fish because of the narrow length range of fish tagged.

TABLE 3. Exploitation, Natural Mortality, and Survival of Tagged Smallmouth Bass by Length Groups in 1975 at Shasta Lake.

Fork length at tagging (mm)	*Number tagged 1975*	*Number of tags returned*		*Total*	*First-year exploitation (u)*	*Natural mortality (v)*	*Annual survival* (s)*
		First year	*Second year*				
254–279	100	73	–	73	0.73	0.27	0.0
280–305	100	68	2	70	0.68	0.29	0.03
Total	200	141	2	143	–	–	–
Mean	–	–	–	–	0.70	0.28	0.02

* Based on ratio of second-year to first-year returns.

Largemouth Bass—1975

Between 11 March and 9 May 1975, 461 largemouth bass were tagged in the Pit River Arm of Shasta Lake. Anglers returned a total of 309 (67.0%) tags within 5 years after tagging. Only first- and second-year tag returns were used in calculations of mortality and survival because of possible changes in fishing use and/or success during the 1976–77 drought. Total first-year exploitation amounted to 0.50, natural mortality was 0.28, and survival was 0.22 (Table 4).

A chi-square test of homogeneity showed no significant difference in exploitation by length groups at the 5% level ($X^2 = 3.06$; d.f. = 5; p = −0.69).

Natural mortality showed considerable variation among length groups, ranging from 0.15 for fish 331 to 356 mm (13 to 14 in.) to 0.35 for fish 306 to 330 mm (12 to 13 in.) (Table 4).

TABLE 4. Exploitation, Natural Mortality and Survival of Tagged Largemouth Bass by Length Groups in 1975 at Shasta Lake.

Fork Length at tagging (mm)	*Number tagged 1975*	*Number of tags returned*					*Total*	*First-year exploitation*	*Natural mortality (v)*	*Annual survival * (s)*
		First year	*Second year*	*Third year*	*Fourth year*	*Fifth year*				
254–279	68	38	4	3	–	1	46	0.56	0.34	0.10
280–305	100	51	10	3	–	1	65	0.51	0.29	0.20
306–330	100	52	7	1	1	3	64	0.52	0.35	0.13
331–356	67	31	12	4	–	1	48	0.46	0.15	0.39
357–381	72	33	9	3	1	–	46	0.46	0.27	0.27
382–406	54	23	9	6	1	1	40	0.43	0.18	0.39
Total	461	228	51	20	3	7	309 †	0.50	–	–
Mean	–	–	–	–	–	–	–	–	0.28	0.22

* Based on ratio of second-year to first-year returns.
† Returns through January 1980.

Analysis by age class showed a 0.51 and 0.50 first-year exploitation for Age II and Age III largemouth bass, respectively (Table 5). Age IV and V fish were incompletely represented in the study because only fish under 406 mm (16 in.) were tagged. Some small Age II fish may not have been included in the study since fish under 254 mm (10 in.) were not tagged.

Age II largemouth bass ranged from 254 to 353 mm (10.0 to 13.9 in.) and averaged 300 mm (11.8 in.) in length. Age III largemouth bass ranged from 300 to 401 mm (11.8 to 15.8 in.) and averaged 358 mm (14.1 in.).

TABLE 5. Exploitation, Natural Mortality, and Survival of Tagged Largemouth Bass by Age Classes in 1975 at Shasta Lake.

Age	Mean length (mm)	Number tagged 1975	Number of tags returned					Total	First-year exploitation	Natural mortality (v)	Annual survival[*] (s)
			First year	Second year	Third year	Fourth year	Fifth year				
II	300	271	139	24	10	1	6	180	0.51	0.32	0.17
III	358	110	55	14	5	1	–	75	0.50	0.25	0.25
IV[†]	–	43	15	8	4	1	1	29	0.35	0.12	0.53
V[‡]	–	2	1	–	–	–	–	1	–	–	–
Total	–	426[‡]	210	46	19	3	7	285	–	–	–

[*] Based on ratio of second-year returns to first-year returns.

[†] Age group incompletely sampled because bass over 406 mm (16.0 in.) were not tagged.

[‡] Scale samples from 35 fish could not be aged.

DISCUSSION

Exploitation rates of smallmouth bass in Shasta Lake appear to be much higher than those reported by Coble (1975) for northern lake populations of this species.

Annual fishing mortality rates compiled by Coble (1975) (assumed by the author to be "m" as defined in Ricker 1958) show fishing mortalities of 28 to 35 for the Great Lakes (Latta 1963, Fry 1964, and White 1970), 35% for Oneida Lake (Forney 1972) and 38% for Lake Opeongo (Christie 1957). Annual fishing mortality (m) of smallmouth bass in Shasta Lake, computed for fish tagged in 1973, was 85%. However, this figure may be an over-estimate since in order to obtain an accurate estimate of annual fishing mortality, fishing effort and catchability should remain constant during the study period. In the case of smallmouth bass tagged in 1973, effort was down by 31% in 1974 as compared to 1973, (USDA 1973–1977) with vastly different water conditions. During the spring of 1973, water was relatively clear, while in the spring of 1974 the water was turbid because of large inflows during the winter. Also, the number of smallmouth bass observed in the catch during 1974 was down 27% over 1973 (Healey, MS). Creel census effort each year was comparable.

An annual expectation of death from fishing for smallmouth bass tagged in 1973 (first-year exploitation, u) of 68% was a more accurate estimate of fishing mortality, and still indicated that exploitation of smallmouth bass in Shasta Lake was considerably higher than that reported for northern populations.

First-year exploitation of largemouth bass (50%) in Shasta Lake was similar to that reported for other California waters. Exploitation of largemouth bass was 40% in Folsom Lake (Rawstron 1967), 49% in Merle Collins Reservoir (Rawstron and Hashagen 1972), and 47% and 58% in Folsom Lake and Lake Berryessa, respectively (Rawstron and Reavis 1974). These authors consider exploitation rates over 0.50 to be excessive for black bass (R. R. Rawstron, Fish Mgmt Supervisor, Calif. Dept. Fish and Game, pers. commun.). In small Missouri lakes and ponds, a 40% harvest of adult largemouth bass appeared to be the maximum that could be allowed and still maintain a balanced sunfish population and adequate growth and recruitment of bass (Graham 1974, Ming 1974, and Redmond 1974). Preliminary results of tagging studies in progress at Shasta Lake show that many anglers release largemouth bass, particularly fish under 305 mm

(12 in.), although there is no minimum length limit. Since no adjustment of exploitation rates was made for fish released at Shasta Lake and apparently was not made for earlier tagging studies conducted on largemouth bass in California, the true rate of exploitation of largemouth bass populations studied in California waters was probably somewhat less than that computed from tag returns.

About 60% of the anglers checked at Shasta Lake between April and September 1973, fishing for species other than trout, were found to be using natural baits (Van Woert, unpubl. data). These anglers caught 71% of the smallmouth bass and 9% of the largemouth bass in the creel samples. Anglers who used only crickets for bait caught 42% of the smallmouth bass and 3% of the largemouth bass sampled, while those using artificial lures caught 78% of the largemouth bass observed. In recent years, overexploited bass populations in many California waters have been managed by the imposition of a 305-mm (12-in.) minimum length limit.

A minimum length limit may not be an efficient means of reducing exploitation of smallmouth bass at Shasta Lake because the extensive use of natural baits may result in excessive hooking mortality. Pelzman (1978) observed a 56% mortality of largemouth bass less than 305 mm (12 in.) as a result of esophageal hooking; however, fish hooked in other parts of the mouth experienced little mortality.

First-year exploitation of largemouth bass (0.53) between 254 and 305 mm (10 and 12 in.) tagged in 1975 was substantially lower than that for smallmouth bass (0.70) of the same size tagged the same year. Some of this difference in exploitation may be caused by the difference in vulnerability of the two species to the different angling techniques noted above. Hooking mortality probably would not be a critical factor in imposing a length limit on largemouth bass since this species is caught mainly (78%) on artificial lures (Van Woert, unpubl. data).

While high exploitation resulted in a small average size of smallmouth bass in the catch at Shasta Lake, recruitment generally was good and smallmouth bass were abundant during most years. Since smallmouth bass were relatively easy to catch on natural bait, they helped satisfy a high angling demand during the spring and summer months. Any attempt to improve the quality of smallmouth bass fishing by protecting smallmouth bass until they reach larger sizes may require restrictions on bait, as well as a minimum length limit.

Although smallmouth and largemouth bass may be overexploited in Shasta Lake, there does not appear to be a serious imbalance between bass and sunfish populations. Electrofishing surveys indicate that recruitment of bluegill, *Lepomis machrochirus,* and green sunfish, *L. cyanellus,* is low. Analysis of stomach contents indicate that bass in Shasta Lake rely more heavily upon threadfin shad as a food source than upon other sunfishes. Examination of scales has shown that black bass appear to be achieving normal growth patterns in Shasta Lake (Charles E. von Geldern, Jr., Sr. Fish. Biologist, Calif. Dept. Fish and Game, pers. commun.).

Electrofishing surveys conducted at Shasta Lake indicated that recruitment of largemouth bass is low. To increase production and survival of young largemouth bass in Shasta Lake, bass spawning and nursery habitat should be restored. If efforts to enhance shelter for largemouth bass are not feasible, the combination of low recruitment, good growth, and high exploitation strongly suggests that a minimum length limit would provide better fishing for largemouth bass.

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DIET AND BEHAVIORAL ASPECTS OF THE WOLF-EEL, *ANARRHICHTHYS OCELLATUS,* ON SANDY BOTTOM IN MONTEREY BAY, CALIFORNIA [1]

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We studied the diet and behavior of wolf-eels occurring near artificial structures on a sandy bottom in Monterey Bay, California, to obtain information about their biology and natural history. Diet was determined by examining stomach contents. The principal prey items consumed were the slender crab, *Cancer gracilis,* and the sand dollar, *Dendraster excentricus.* Other species were of minor importance in their diet. Our data suggest that wolf-eels, in our study area, are nocturnal predators which forage over wide areas for food.

Scuba divers observed wolf-eel behavior. The individuals observed displayed strong territorial, homing, and itinerant behaviors.

Based on the numbers of individuals collected and observed at our stations, the wolf-eel population of Monterey Bay may be quite large.

INTRODUCTION

We examined the diet and behavior of a population of wolf-eels on a subtidal sandy bottom in Monterey Bay, California, to obtain information about the biology and natural history of the species.

Wolf-eels occur in shallow areas along the west coast of North America from Imperial Beach in southern California (Radovich 1961), through Oregon and Washington (Schultz and DeLacy 1936), and as far north as the Aleutians (Quast and Hall 1972). A few specimens have been reported as far west as the Sea of Okhotsk and the Sea of Japan (Popov 1933, Schmidt 1965). They inhabit relatively shallow rocky areas (Gill 1911; Schultz 1930; Barsukov 1959; Miller and Gotshall 1965; Burge and Schultz 1973, p. 161) although Fitch and Lavenberg (1971) reported a specimen caught as deep as 400 ft. The sandy bottom environment of the population in this study is a habitat not previously reported for wolf-eels in the Pacific.

MATERIALS AND METHODS

Twenty-five wolf-eels were collected randomly from August 1974 to July 1975 by scuba divers using hand spears. All specimens were obtained from two sites in central Monterey Bay at Moss Landing, California (Figure 1). The collecting sites were permanent stations established on sandy bottom in 18 m and 24 m of water where various artificial structures had been emplaced. They were designated M-4 and M-5, respectively. All specimens were collected during the morning hours, generally between 0700 and 1100 h. Most were collected during August 1974 and June and July 1975.

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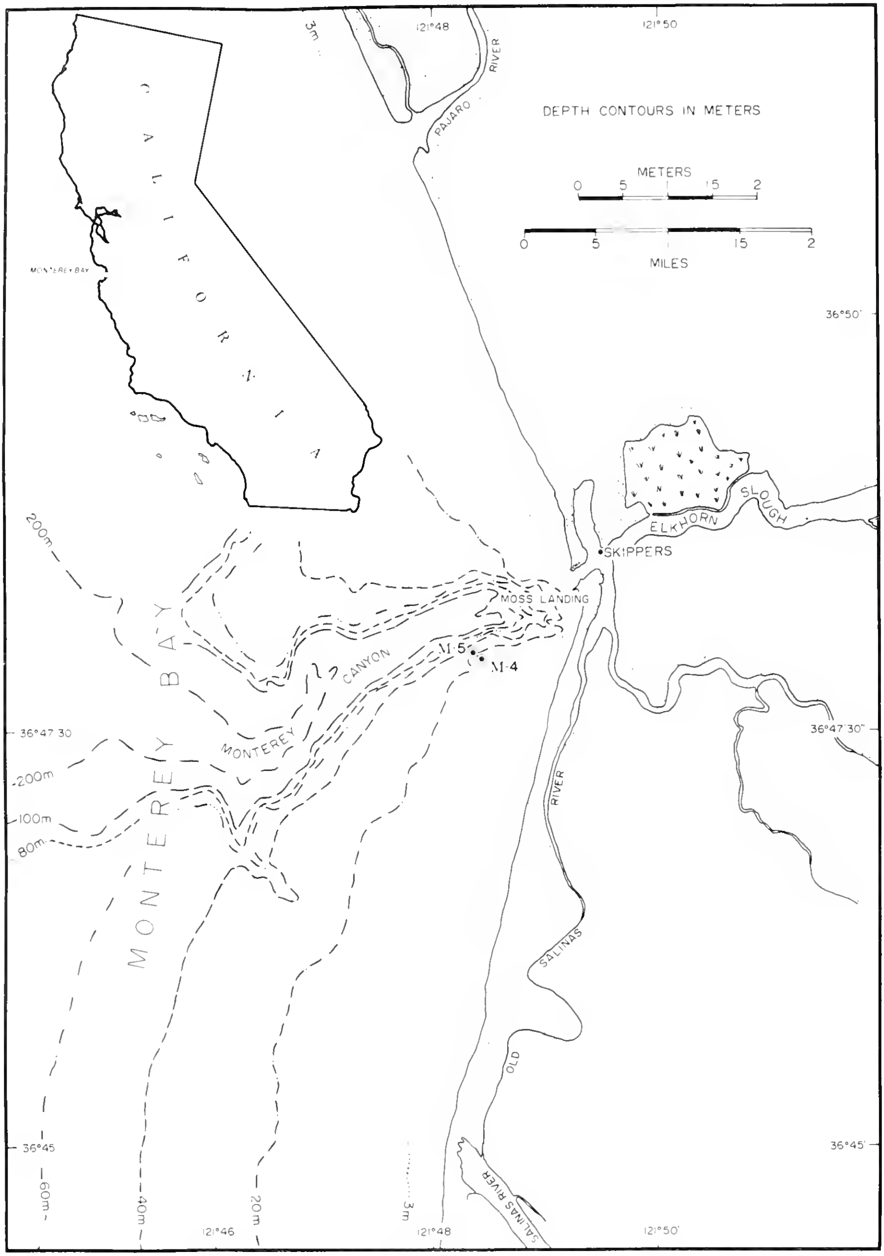

FIGURE 1. *Anarrhichthys ocellatus* collecting sites M-4 and M-5.

All wolf-eels were weighed and measured (standard length). Their stomachs were removed, fixed in 10% formalin, and later stored in 50% isopropyl alcohol. Subsequently, prey items were identified to the lowest taxa possible and their volumes determined by liquid displacement. Since stomach contents consisted primarily of hard parts of ingested prey, they were reassembled as much as possible to determine the total number of whole individuals consumed.

An index of relative importance (IRI) (Pinkas, Oliphant, and Iverson 1971) was used to show the total contribution of each prey species to the diet of the wolf-eel. This index was calculated as IRI =FO (N+V) where N is the numerical percentage a food type contributed to the total diet, V is its volumetric percentage, and FO is its percent frequency of occurrence (that proportion of stomachs containing the food item). To calculate this index, data from all specimens were combined and treated as a single sample.

Behavioral aspects of wolf-eels were observed by scuba divers during approximately 100 dives. In addition, seven specimens were tagged to document behavior patterns of specific individuals.

RESULTS AND DISCUSSION

The specimens obtained ranged from 109 to 145 cm length (X = 131 cm). Their weights ranged from 1400 to 4230 g (X =2977 g), with much variation depending upon the amount of food present in the stomachs.

The slender crab, *Cancer gracilis,* was the most frequently consumed species and, by far, the most important volumetrically (Figure 2). The sand dollar, *Dendraster excentricus,* was occasionally consumed in large numbers. Other items were taken less frequently (Table 1). The only evidence of fish predation was the presence of several fish vertebrae in the stomach of a single specimen. The stomachs of most wolf-eels contained an appreciable amount of food; only four wolf-eels had empty stomachs.

In general, our findings on the diet of *A. ocellatus* agree with those of other studies. Clemens and Wilby (1961) reported a diet of crustaceans, sea urchins, mussels, clams, and other hard shelled invertebrates as well as fishes; Fitch and Lavenberg (1971) reported a preponderance of crab remains in the stomachs, and also found sea urchin fragments, small snails including abalones, and an occasional piece of fish; Jordan and Evermann (1898) found stomachs containing sea urchins and sand dollars; Jordan and Starks (1895) reported a diet of chiefly crustaceans and mussels. In our study, however, bivalves and gastopods were taken rarely.

Wolf-eels probably forage over large areas for *Cancer* spp. because we did not observe many large crabs during hundreds of day and night dives in our study area for another project. We did observe an abundance of small flatfishes in the area but, evidently they were not a major food item (Table 1). Apparently, *A. ocellatus* is capable of capturing only relatively slow moving prey on an open sandy bottom. Fishes may be easier prey in rocky areas where they might be trapped more readily.

Of nearly 50 wolf-eels observed, all were sedentary (but alert) and in close proximity to an artificial structure. They were never observed on an open sandy bottom away from structures. Thus, there appears to be strong attraction to structures of some kind. In addition, all individuals observed exhibited strong territoriality. When a wolf-eel was approached it would rear its head back and open its mouth to prominently display its teeth. It would continue this aggressive display for several minutes, occasionally advancing toward the intruder in a threatening manner. A wolf-eel could be approached to approximately 30 cm before it would leave. When it did leave the area, it did so at a slow, apparently unhurried, pace. Despite their aggressive displays, none ever attacked, even when provoked. They did not possess the viciousness reported by Miller and Gotshall (1965), nor that reported for related species by Goode (1884).

TABLE 1. Prey Items Consumed by Individual *Anarrhichthys ocellatus.*

Specimen #	*Cancer gracilis*	*Dendraster excentricus*	Octopus	*Isocheles pilosus*	Bivalves	*Polinices* spp.	*Cancer anthonyi*	*Cancer antennarius*	*Cancer productus*	*Randallia ornata*	Barnacles	Fish vertebrae
1		8						1				
2	6			4								
3	2											
4	7											
5			1									
6												
7	3											
8			1									
9	1	1	2			2						
10	2	12		1								
11	8											
12	5											
13	11											
14	9											
15	1						1			1		
16	1		1		1							
17	7	13										
18	1		1		1	1			1		1	
19												
20												
21												1
22	11											
23												
24	17											
25	9		1									

Of seven wolf-eels tagged and released at station M-5, two were observed at the same location on subsequent dives. One of these was observed in exactly the same spot (in an open cylinder placed on the bottom) for nearly a month.

Other individuals, not tagged but recognizable by anatomical characteristics and scars, were observed at particular sites for up to a month. Wolf-eels probably forage over wide areas during their occupation of a territory because nearly all of those collected contained an appreciable amount of food in their stomachs and the abundance of major prey in any given area was low. By returning repeatedly to specific sites for periods of several days to several weeks, the fish displayed a strong homing behavior.

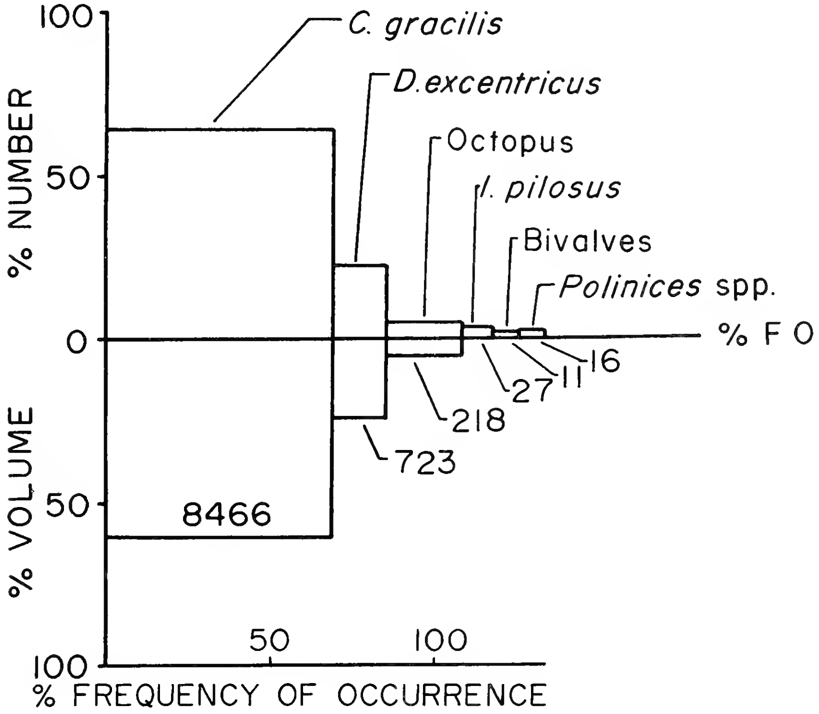

FIGURE 2. Index of relative importance (Pinkas, Oliphant, and Iverson 1971) for major prey items found in *Anarrhichthys ocellatus* stomachs.

Because all wolf-eels encountered during our daylight (morning) dives were sedentary and consistently ignored food items (such as crabs) offered to them, and because most of those collected had relatively full stomachs, we believe that this species, at least in our study area, is a nocturnal feeder. On the other hand, they are often caught during the day by hook and line fishermen (Fitch and Lavenberg 1971). Also, because locations vacated by individuals we collected were reoccupied by other individuals, generally within 1 or 2 days, we concluded that they are itinerant.

The wolf-eel population in Monterey Bay may be quite large if the numbers we collected and observed at our stations are any indication of abundance.

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DECLINE OF THE LAKE GREENHAVEN SACRAMENTO PERCH POPULATION

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Fish populations at Lake Greenhaven were monitored by fall surveys from 1973 through 1978. The Sacramento perch has undergone a decline in abundance, growth, and condition, and has failed to reproduce in 3 of the last 4 years of the study. Other species, particularly the bluegill, have increased in abundance since 1973. Competitive interference by the bluegill population is suggested as the primary reason for the decline of the Sacramento perch population.

INTRODUCTION

Lake Greenhaven is a 24-ha eutrophic lake located in a suburban area in southwestern Sacramento, California (T8N, R4E). In 1973, the fish population in this Lake was dominated by the Sacramento perch, *Archoplites interruptus,* the only native centrarchid west of the Rocky Mountains (Aceituno and Vanicek 1976). This species, endemic to the lower Sacramento-San Joaquin drainage system and the Pajaro and Salinas River systems has undergone a marked decline in abundance in its native range, although it has been successfully introduced beyond its original range (Aceituno and Nicola 1976). According to Aceituno and Nicola (1976), Lake Greenhaven was one of only two natural waters in the state reported to contain Sacramento perch in both 1955 and 1973 statewide surveys, and it provided the stock for Sacramento perch introductions to numerous waters in the state by the Department of Fish and Game since 1955 (J. Ryan, Assoc. Fish. Biol., Calif. Dept. of Fish and Game, pers. commun.). This paper reports on changes that have occurred in the Lake Greenhaven Sacramento perch population since 1973.

DESCRIPTION OF STUDY AREA

Lake Greenhaven, formerly known as Brickyard Pond, was dredged and enlarged to its present size in 1965 to enhance a new housing development. Before this alteration, the Lake contained hitch, *Lavinia exilicauda;* Sacramento blackfish, *Orthodon microlepidotus;* carp, *Cyprinus carpio;* Sacramento perch; tule perch, *Hysterocarpus traski;* and sculpin, *Cottus* sp. Just prior to enlargement the Lake was chemically treated with rotenone and subsequently restocked with carp, mosquitofish, *Gambusia affinus;* channel catfish, *Ictalurus punctatus;* Sacramento perch; largemouth bass, *Micropterus salmoides;* and bluegill, *Lepomis macrochirus.* In addition, the following species have been found in the Lake: golden shiner, *Notemigonus crysoleucas;* white catfish, *Ictalurus catus;* green sunfish, *Lepomis cyanellus;* and white crappie, *Pomoxis annularis.* Fishing pressure on the Lake has been very light since 1973.

A description of the Lake's physical and chemical characteristics is provided by Aceituno and Vanicek (1976). Water quality analyses conducted in July 1979 (dissolved oxygen, pH, hardness, alkalinity, and specific conductance) showed little change in the chemical nature of the water from 1973 conditions, although secchi disk transparency readings were higher than in 1973 when the water was turbid due to phytoplankton blooms resulting from the addition of commercial fertilizer to control submergent vegetation. In 1973 approximately 50% of the Lake's shoreline had been dredged and rip-rapped; in 1977, work to dredge and rip-rap the rest of the shoreline began, and by October 1978 virtually all of the Lake's shoreline had been altered.

METHODS AND MATERIALS

To monitor changes in the Lake's fish fauna, the Fishery Principles class at California State University, Sacramento, conducted a fall population inventory of Lake Greenhaven from 1974 through 1978, using the following types of sampling gear: a 30.5-m (100-ft) × 1.8-m (6-ft) bag seine with 2.5-cm (1.0-inch) mesh wings and a 1.3-cm (0.5-inch) mesh bag; a 12.2-m (40-ft) × 1.8-m (6-ft) bag seine with 1.3-cm (0.5-inch) mesh; a 7.6-m (25-ft) × 1.8-m (6-ft) bag seine with 3-mm (0.1-inch) bobbinet mesh; 1.8-m (6-ft) × .8-m (2.6-ft) fyke nets with 19-mm (0.75-inch) mesh; multifilament nylon experimental gill nets, 45.6-m (150-ft) × 1.8-m (6-ft), with mesh sizes (square measure) of 19, 25, 38, 50, and 76 mm (0.75, 1.0, 1.5, 2.0, and 3.0 inches). Additional collections were made in May, June, and July 1978. Comparisons were made with fish collections from Aceituno and Vanicek's (1976) study which were taken from March 1973 through January 1974 and which utilized the same types of sampling gear.

All fish were measured to the nearest millimetre, fork length (FL). Scale analysis techniques for age and growth determination described by Aceituno and Vanicek (1976) were used in this study.

SPECIES COMPOSITION AND RELATIVE ABUNDANCE

Eight species of fish were collected in Lake Greenhaven in 1978: golden shiner, mosquitofish, largemouth bass, bluegill, white crappie, Sacramento perch, white catfish, and channel catfish. White catfish were not collected in 1973, while carp and goldfish, both collected in 1973, were not taken in 1978.

In 1973 Sacramento perch dominated the species complex, as they comprised 96% of the total catch from all sampling methods combined. In 1978, however, they comprised only 2% of the total catch. In contrast, bluegill increased from less than 3% of the total catch in 1973 to 94% in 1978. To make more specific comparison of changes in abundance of the species between the 2 years, I contrasted the average number of fish by species caught per overnight gill net set of the 11 sets made in 1973 with the 9 sets in 1978 (Table 1). The most striking contrast was the decrease of the Sacramento perch from an average of 53.0 fish per set in 1973 to only 10.9 in 1978. For the same years, bluegill increased from 0.7 fish per set to 6.8 fish. White catfish, golden shiner, and white crappie showed slight increases. During the 1974–1977 period, when gill net collections were made only in September or October, the Sacramento perch decline was indicated by the abrupt drop in catch per set from 99.0 fish in 1975 to 17.0 and 7.3 fish in 1976 and 1977, respectively. Comparisons of catches with fyke nets and seines were limited since the shoreline areas where these nets were used have been altered, and the nets, especially the fyke nets, could not be used effectively after 1976. September fyke net catches of Sacramento perch dropped from an average of 11 and 13 fish per net in 1973 and 1974, respectively, to 7 fish per net in 1975 and again in 1976. The 1975 figure may be misleading since several of the fyke nets had been disturbed by intruders. Small bluegills (age 0 and I) dominated minnow seine collections in 1975, 1977, and 1978, whereas young Sacramento perch were the most abundant fish in the 1973, 1974, and 1976 collections.

TABLE 1. Average Number of Fish Caught per Overnight Gill Net Set, 1973 and 1978, Lake Greenhaven.

	Average no. fish per set	
Species	*1973 (11 sets)*	*1978 (9 sets)*
Sacramento perch	53.0	10.9
Bluegill	0.7	6.8
Largemouth bass	0.7	0.6
White crappie	0.0	1.3
Golden shiner	0.1	0.3
White catfish	0.0	0.4

SACRAMENTO PERCH POPULATION CHANGES

The size and age structure of the Sacramento perch population has changed radically since 1973. Length-frequency histograms (Figure 1), based on all fish collected during fall collections from 1973–1978, indicated a constant reduction in range of sizes, with the disappearance of large and small fish. In 1973 perch in the samples ranged from 35 to 265 mm FL, while in 1978 the size range was reduced to 130 to 155 mm FL. There had also been a loss of younger age groups due to reproductive failure in 1975, 1977, and 1978. Although successful reproduction did occur in 1976, no survivors of this year class were collected in 1977 or 1978. Mean size of these young-of-the-year perch in September 1976 was considerably smaller than at this time in 1973 and 1974 (Figure 1).

Scale analysis of fish collected in 1978 revealed three age groups: IV, V, VI. In contrast, in 1973 seven age groups (0 through VI) were present. Growth histories of 1978 fish were not back-calculated because I had difficulty in establishing a body-scale relationship; however, mean lengths at time of capture were much shorter in 1978 than the respective age group from 1973 (Table 2). I conclude that the annual growth of the Sacramento perch has been dramatically reduced over the past 4 years (Figure 1).

TABLE 2. Comparisons of Mean Fork Length (Millimetres) at Time of Capture of Sacramento Perch by Age Group, 1973 and 1978, Lake Greenhaven (Number of Fish in Parentheses).

	Year of capture	
Age	*1973 **	*1978*
IV	241 (17)	145 (20)
V	305 (1)	151 (9)
VI	319 (1)	164 (3)

* Data from Aceituno and Vanicek (1976)

Condition factors, K_{FL} ($= W_3/L \times 10^5$), were calculated for fish collected in fall surveys (September or early October) from 1973 through 1978 (Table 3).

The mean K_{FL} value dropped considerably from 1973 to 1974, and has remained below 2.00 since. Throughout 1973, the mean K values never fell below 2.00 (Aceituno and Vanicek 1976). The difference between the mean K values from 1973 and subsequent years is significant at the 99% level.

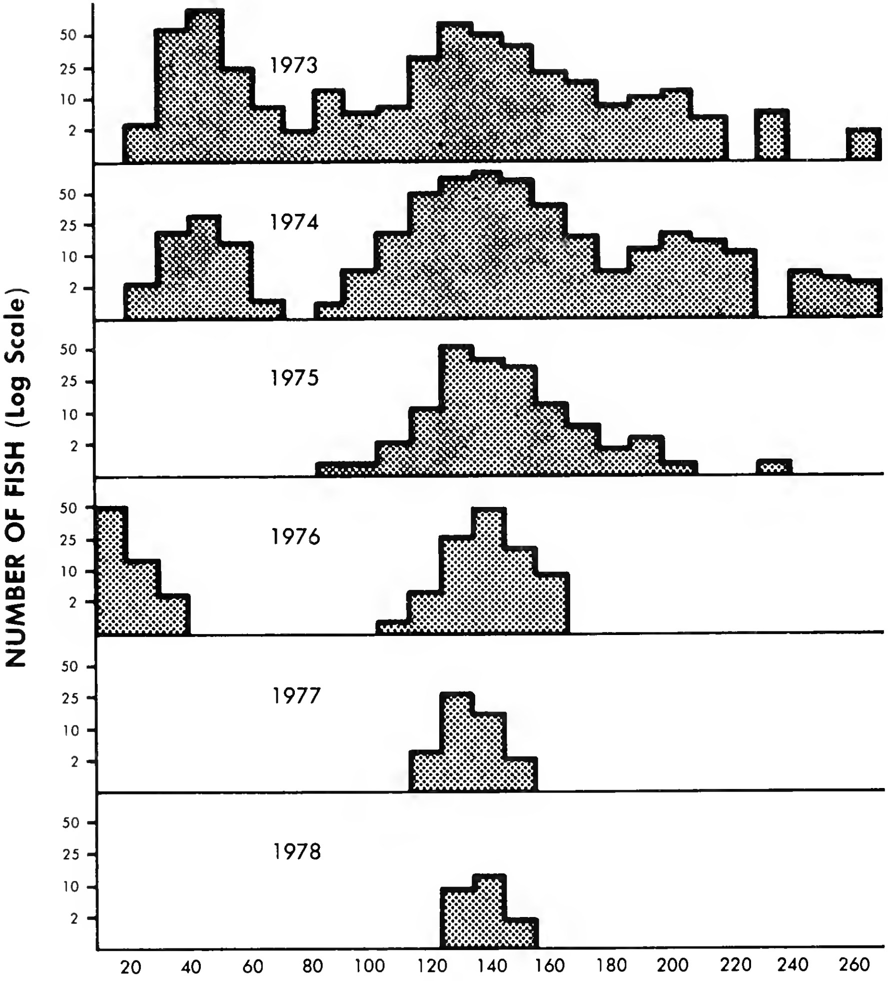

FIGURE 1. Length frequencies of all Sacramento perch captured in September–October, 1973 through 1978, in Lake Greenhaven.

DISCUSSION AND CONCLUSIONS

The Lake Greenhaven Sacramento perch population is stressed and declining, as evidenced by the reproductive failures, reduced growth, and low condition coefficients in recent years, and by decreased relative abundance. Concurrently the bluegill population has increased and is now the domimant species in the Lake. Catch per unit effort statistics are not valid for comparing relative abundance of different species due to differences in vulnerability to gear, but the major changes in catch per gill net set for bluegill and Sacramento perch undoubtedly do reflect changes in abundance over the 5-year period. Moreover, the catches in the minnow seine hauls reflect this trend as no Sacramento perch young-of-the-year were collected in 3 of the last 4 years when young bluegill dominated the catches.

TABLE 3. Mean Condition Factors of Sacramento Perch Collected in Lake Greenhaven, September–October, 1973–1978.

Date of collection	*Mean K factor (number of fish in parentheses)*
9/21/73	2.40 (22)
9/21/74	1.84 (43)
9/13/75	1.74 (38)
9/11/76	1.64 (52)
10/6/78	1.83 (18)

Competition with exotic centrarchids, especially the bluegill, has been suggested as a major cause of the decline of the Sacramento perch in its native waters (Moyle, Mathews, and Bonderson 1974; Aceituno and Nicola 1976). The mechanism of this competition may involve interference. Observations in aquaria indicate that in interspecific encounters, bluegill consistently dominate and displace Sacramento perch (Mary Bacon, California State University, Sacramento, pers. commun.; Moyle et al. 1974). Although Imler, Weber, and Fyock (1975) concluded that Sacramento perch can compete successfully with a variety of species, bluegill were either scarce or absent in their study ponds in Colorado. Murphy (1948) attributed decline of the Sacramento perch to its failure to guard its eggs; however, more recent investigators have reported that perch do defend their nests against potential egg predators (Mathews 1965, Aceituno 1974).

While bluegill and Sacramento perch were both stocked in Lake Greenhaven after it was renovated in 1966, it is not clear why bluegill did not become abundant until 1975, the time when the Sacramento perch began to decline. By this time the bluegill may have become abundant enough to interfere with the perch by displacing them from preferred habitats and spawning sites.

No major changes in water quality that might be detrimental to the Sacramento perch were noted between 1973 and 1978. Commercial fertilizer was not added to the Lake after 1973, and subsequently, primary productivity has probably decreased, as the increase in water transparency suggests. However, this decrease in productivity would be expected to affect all species. Perhaps the reduced food supply intensified interspecific competition between the bluegill and Sacramento perch. I feel that it is unlikely that the decrease in turbidity in itself was responsible for the perch decline, since thriving populations have been reported from Lake Almanor (Aceituno and Vanicek 1976), Pyramid Lake (Johnson 1958), and Crowley Lake (E. P. Pister, Assoc. Fish. Biol. Calif. Dept. Fish and Game, pers. commun.) where water clarity was high. The only other apparent environmental change has been the shoreline alteration and creation of new bays along the northwest shore, but the decline of the perch population was in evidence in 1975, well before the alterations began in 1977.

In summary, observations on these changes in the Lake Greenhaven fish fauna support the hypothesis that Sacramento perch are negatively affected by introduced centrarchids, particularly the bluegill. If the present trend continues, the Sacramento perch will soon become extinct in Lake Greenhaven, one of the few locations where this species has sustained a population in its native range.

ACKNOWLEDGMENTS

I wish to extend my appreciation to the following for assisting in this project: Peter B. Moyle and Martin R. Brittan, for reviewing the manuscript; Gary Grossman, for collecting the 1977 data; the numerous California State University, Sacramento students who assisted in the field collections; and the Lake Greenhaven Homeowner's Association for allowing us free access to the Lake.

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NOTES

A POPULATION OF THE ENDANGERED SANTA CRUZ LONG-TOED SALAMANDER, *AMBYSTOMA MACRODACTYLUM CROCEUM,* FROM MONTEREY COUNTY, CALIFORNIA

On 12 October 1973, we found a juvenile Santa Cruz long-toed salamander, *Ambystoma macrodactylum croceum,* under a wooden box at the edge of an agricultural field 3.2 km north of Moss Landing, Monterey County, California. This was the first of numerous specimens found in the same general area under debris and represented the discovery of a third breeding population of *A. m. croceum.* Previous to the discovery of these specimens, *A. M. croceum* was known to occur at only two localities, both in Santa Cruz County; one population breeding at Valencia Lagoon near Aptos, and another at Ellicott Pond near Watsonville (Russell and Anderson 1956; Anderson 1967).

In an attempt to discover the breeding pond of this new population of *A. m. croceum,* we examined three wetlands located within 1 km of the original discovery site (Figure 1). Initially, we concentrated our efforts on studying wetland no. 2. In late October and early November, 1973, we placed drift fences and can traps, constructed as described by Ruth and Tollestrup (1973), on all sides of wetland no. 2. These traps were monitored daily through December 1973. From January through June 1974, we periodically examined each of the three wetlands by walking the shorelines and searching for adult and juvenile salamanders under logs, debris, and emergent vegetation. Throughout this period, we used dipnets to search for larval salamanders in each wetland. We found *A. m. croceum* in all three wetlands.

Wetland no. 1, an area of about 3 ha, is on the south side of California State Highway No. 1 near its junction with Struve Road. The wetland is surrounded on three sides by a salt water marsh and on the fourth by agricultural land. Willows, *Salix* sp., grow along the northern side of the wetland and emergent vegetation grows throughout most of the wetland.

An abundance of larval *A. m. croceum* were found in wetland no. 1. Most larval salamanders were found on the east end of the wetland in what appeared to be a man-made ditch approximately 100 m long, 5 m wide, and 1 m deep at its greatest depth. Many juvenile salamanders were found under logs and debris around this wetland. Pacific treefrog tadpoles, *Hyla regilla,* and red-legged frog tadpoles, *Rana aurora,* were common in the wetland.

Wetland no. 2, covering an area of about 8 ha, is a pond on the north side of California State Highway No. 1 approximately 100 m NE of wetland No. 1. Willows are scattered around the wetland but are most concentrated at the east and west ends. Cattail, *Typha* sp., and bulrush, *Scirpus* sp., form dense stands in the northern half of the wetland. The wetland is surrounded on three sides by agricultural land and on the fourth side by a salt water marsh.

Numerous migrating *A. m. croceum* were captured in can traps near willow groves on the east and west ends as they entered wetland no. 2. Although numerous mature *A. m. croceum* migrated into the pond, we captured only one

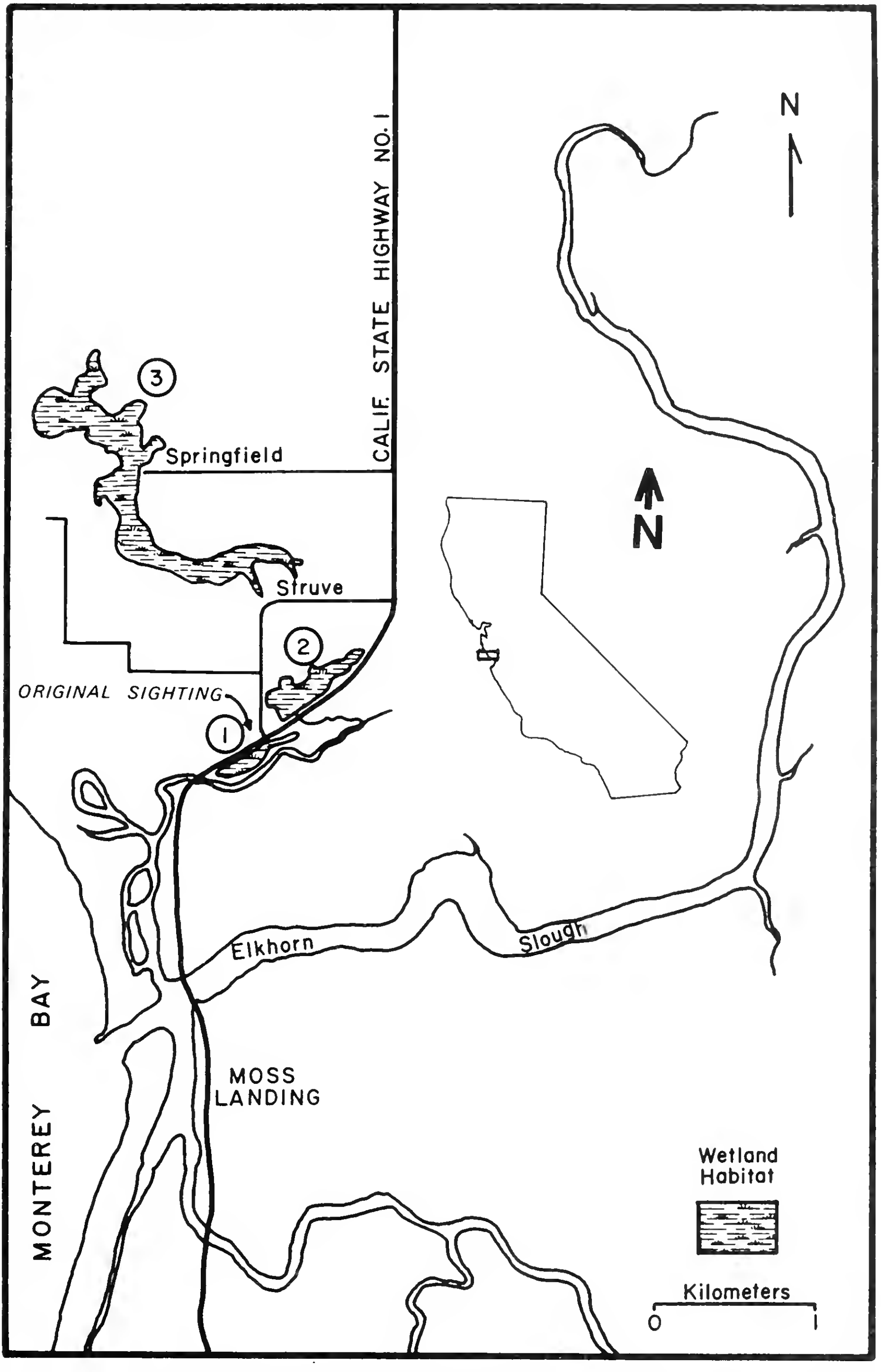

FIGURE 1. Three wetlands in Monterey County, California, where Santa Cruz long-toed salamanders, *Ambystoma macrodactylum croceum,* were discovered.

larval salamander throughout the season. Possibly the dense growth of emergent vegetation in the wetland prevented additional captures. Other amphibians observed in the wetland were Pacific treefrogs, red-legged frogs, and one tiger salamander, *Ambystoma tigrinum californiense.*

Wetland no. 3, a large wetland area of about 40 ha, is approximately 1 km northwest of wetlands 1 and 2 and is almost completely surrounded by agricultural land. Dense stands of cattail and bulrush cover much of the wetland. Willows are scattered around the wetland and two small groves are present in the northwest end of the wetland.

Many mature and juvenile *A. m. croceum* were found under debris and dead emergent vegetation on the northwest end of wetland no. 3, near the end of Springfield Road, throughout the spring and summer. The presence of adult salamanders in the wetland during the summer indicates that many salamanders did not migrate into a separate terrestrial habitat after the breeding season. Although many transformed salamanders were found under vegetation, we were unable to capture any larval salamanders. Pacific treefrogs were the only other amphibians seen in the immediate area.

It seems probable that the Santa Cruz long-toed salamanders occurring in wetlands nos. 1, 2, and 3 represent what remains of a formerly larger population. The lack of native terrestrial habitat in the vicinity of the three wetlands is presumably a major factor limiting the population size of *A. m. croceum* in the area. It appears that the most suitable habitat is now restricted to the wetlands themselves and many salamanders may not migrate into separate upland habitat. Additional research is needed to evaluate the relative importance of the three wetlands to *A. m. croceum.* In addition, the area in the vicinity of Elkhorn Slough should be examined for additional breeding ponds and to determine if the uplands around the slough serve as terrestrial habitat for *A. M. croceum.*

ACKNOWLEDGMENTS

We thank Stephen Ruth and Michael Johnson for their advice. The California Department of Fish and Game supplied the materials used to construct drift fences.

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REPEAT SPAWNING OF PACIFIC LAMPREY

Accounts of the life history of Pacific lampreys, *Entosphenus tridentatus,* state that adults die after spawning (Hart 1973, Scott and Crossman 1973). The appearance of kelt lampreys at the Snow Creek and Salmon Creek downstream migrant traps led to the marking of these fish and the subsequent recapture of two of them.

The Washington Department of Game operates permanent fish traps near the mouths of Snow and Salmon creeks. The creeks are located on the northeastern corner of the Olympic Peninsula and drain into the Strait of Juan de Fuca. The traps operate year around and trap upstream and downstream migrants. Lamprey kelts captured in the traps are measured to the nearest millimeter total length (TL) and marked by cutting a notch in the dorsal fin. All lampreys are subsequently examined for marks.

During the springs of 1978 and 1979, eight lamprey kelts between 291 and 451 mm TL were marked in Salmon Creek. Most of the kelts were in good condition; they swam strongly and did not appear to be debilitated. On 5 March and 25 October 1979, two marked lampreys measuring 575 mm and 470 mm TL, respectively, were captured in the upstream migrant trap in Salmon Creek. A more detailed and extensive study will be needed to determine the extent of the ability of lampreys to spawn more than once and what effect this has on their population dynamics.

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A DIVER-OPERATED SNAGGING DEVICE FOR CAPTURING LINGCOD, *OPHIODON ELONGATUS*

During field operations to obtain lingcod for a tagging study, diving observations revealed that large numbers of lingcod were present in a given area but few were being taken by hook-and-line. Also, it was found that lingcod, either in the open or concealed in caves, could be approached closely by divers without being frightened away. Based on this knowledge and in order to improve the catch-per-unit-of-effort of this species, a diver-operated snagging device (Figure 1) was invented by Reinhold Banek (Fish and Wildlife Seasonal Aid, Department of Fish and Game, Monterey, California), which causes little injury to the fish.

One part of the device consists of a hollow, fiberglass fishing pole, about 2.5-cm of which was cut off from the tip. The outside diameter of the pole's butt is 2.5 cm and that of the cut-off tip is 0.6 cm. The pole has one eyelet about 10 cm from its tip and another just above the handle. A female electrical fitting was placed inside the tip end of the pole and bonded with epoxy.

The other part of the device consists of a 10.2-cm long, 0.3-cm diameter metal shaft, onto one end of which was bonded a male electrical fitting, and onto the other end was soldered a 12/0 double fish hook with barbs removed. One end of a 90-cm long stainless steel wire was looped through the eye of the hook and fastened to itself with a crimp-type cable clamp. The other end of the wire was threaded through the upper eyelet of the pole and attached by a ring and snap to a 30.5-cm long, 9.5-mm diameter piece of surgical tubing, which was threaded through the lower eyelet and secured to the handle of the pole.

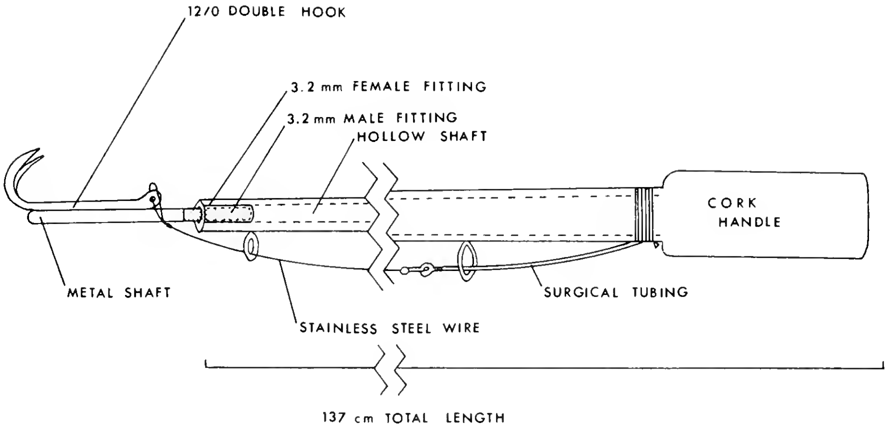

FIGURE 1. Snagging device used to capture lingcod, *Ophiodon elongatus.*

By inserting the male shaft fitting into the female pole fitting, hooks pointed upward, the snagging device was ready to use. When a lingcod was located, the diver would position the hooks under the lower jaw of the fish. A quick jerk backward would both set the hook in the jaw and release it from the end of the pole. The fish was then played, much like one would be with hook-and-line. The surgical tubing maintained tension on the line but provided sufficient elasticity to minimize injury to the fish. Only one lingcod sustained a major injury from the device; the fish was inadvertently hooked posteriorly to the lower jaw, in the gill region, causing excessive bleeding.

When snagged, a fish would fight furiously for 10–15 s, then sink to the bottom, usually with mouth agape. A second diver would quickly bag it and remove the hook before the fish recovered and began to fight again. The fish was then taken to the surface, tagged, and released.

During 200 d of hook-and-line fishing for lingcod in the Hopkins Marine Life Refuge kelp beds, the catch-per-day (c/d) was 0.32. Using the device, 45 fish were captured in 3 d for a c/d of 15.0. At Chase Reef, in open water, hook-and-line c/d was 0.82 compared to 6.0 for the snagging device. The highest c/d for the device was 24, and lingcod in this group ranged in size from 400 mm to 900 mm total length.

The "snagger" is an inexpensive device that can be used on other demersal fishes such as cabezon, *Scorpaenichthys marmoratus,* and kelp greenling, *Hexagrammos decagrammus.* By altering hook size, it may be possible to use the device on many other fishes.

—James L. Houk, Operations Research Branch, California Department of Fish and Game, 2201 Garden Road, Monterey, California 93940. Present address: Marine Culture Laboratory, California Department of Fish and Game, Granite Canyon, Coast Route, Monterey, California 93940. This study was performed as part of Dingell-Johnson project F-25-R (Central California Marine Sportfish Survey), supported by Federal Aid in Fish Restoration funds. Accepted for publication October 1979.

KARYOTYPE OF THE SACRAMENTO PERCH, *ARCHOPLITES INTERRUPTUS*

INTRODUCTION

The family Centrarchidae contains 30 species of sunfishes and basses, grouped into nine genera. Karyotypic information is presently available for 23 centrarchid species representing eight genera (Chiarelli and Capanna 1973; Gold, Karel, and Strand 1979). The genus yet to be examined, *Archoplites,* contains a single species, the Sacramento perch, *A. interruptus.* This species was once common in Clear Lake (Lake County), and in the Pajaro-Salinas and the Sacramento-San Joaquin drainage systems, but habitat destruction and egg predation and competition by introduced fishes have made it rare in its original range. It has, however, been introduced into several lakes in California outside the original range, and into other states (Moyle 1976). The Sacramento perch is the only extant centrarchid native to waters west of the Rocky Mountains. Avise, Straney, and Smith (1977) pointed out that since centrarchids are lowland forms, *Archoplites* has likely been isolated from the other centrarchids since the time of formation of the Rockies in the Miocene or early Pliocene. This study was undertaken to determine if the Sacramento perch has diverged karyotypically from the other centrarchids.

METHODS AND MATERIALS

Five Sacramento perch collected in California were processed for chromosomal analysis, one from Upper Ruth Lake, Merced County, and four from Lake Greenhaven, Sacramento County. Chromosome preparations were made using either the leucocyte culture method of Thorgaard (1976) or the solid tissue method of Kligerman and Bloom (1977). Both pokeweed and phytohemagglutinin were used as mitogens in leucocyte cultures, but only phytohemagglutinin gave satisfactory results. Only well spread cells, in which chromosomes could be counted unambiguously, were scored.

RESULTS AND DISCUSSION

Acceptable chromosome spreads were obtained from three fish. The modal chromosome number for all three fish was 48 (Table 1). Of the 85 cells scored, 61 (72%) were modal, 17 (20%) were hypomodal, and 7 (8%) were hypermodal. The high percentage of hypomodal counts was due primarily to chromosome loss in the poor quality spreads of fish #4. The modal karyotype (Figure 1) is characterized by a single pair of subtelocentric chromosomes (the first pair shown) and 23 pairs of acrocentric chromosomes. Using the criterion that only metacentric and submetacentric chromosomes be counted as biarmed, the chromosome arm number of the fish sampled was 48. No sexual dimorphism in karyotype was seen; none has been reported in centrarchids.

Two basic centrarchid karyotypes have been reported. Most species have 48 chromosomes with 48 arms, a karyotype found in many diverse groups of fish (Ohno 1974). The orange-spotted sunfish, *Lepomis humilis,* and all black bass *(Micropterus)* species examined, however, differ from the common karyotype by a single centric fusion, and have 46 chromosomes with 48 arms (Roberts 1964; Post 1965; Thompson, Hubbs, and Edwards 1978). The green sunfish, *Lepomis cyanellus,* is polymorphic for the two karyotypes (Roberts 1964; Beçak,

TABLE 1. Chromosome Counts of Cells of Three Sacramento Perch. Numbers in Parentheses Indicate How Many of the Counts were Obtained by Doubling Bivalent Counts in Meiosis I Prophase Spreads.

			Counts						
Fish #	*Sex*	*Tissues sampled*	*≤44*	*45*	*46*	*47*	*48*	*49*	*50*
1	F	Leucocytes	1	2	1	1	22	1	
3	M	Testes		1		2	11(9)	1	2(2)
4	M	Kidney, gill, testes	2	2	3(1)	2	28(11)	1	2(2)
	Total		3	5	4	5	61	3	4

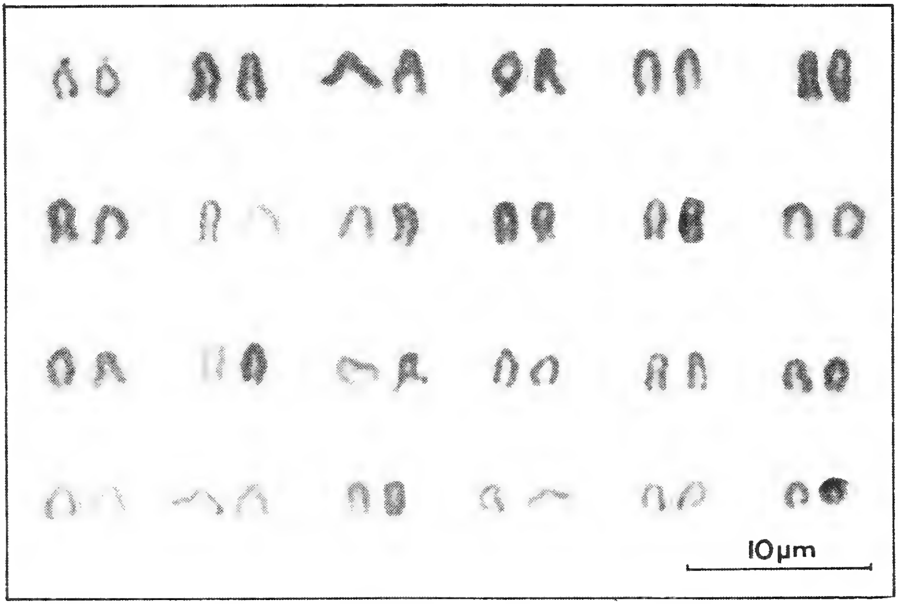

FIGURE 1. Metaphase chromosomes of a female Sacramento perch, *Archoplites interruptus:* 2n =48, 48 arms.

Beçak, and Ohno 1966). Fontana, Chiarelli, and Rossi (1970) reported a karyotype of 46 chromosomes with 56 arms for the pumpkinseed sunfish, *Lepomis gibbosus,* a species previously reported to exhibit the common karyotype (Roberts 1964). The Sacramento perch, with 48 single-armed chromosomes, is a chromosomally typical centrarchid.

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BOOK REVIEWS

Marine Life

By David and Jennifer George; Published in the USA by Wiley-Interscience, a Division of John Wiley and Sons, Inc., New York; 1979; 288 pp; $39.95.

One of the most valuable contributions of this richly illustrated encyclopedia of marine invertebrates is that it contains the most recent survey of their classification by taxonomists. Since it was written and researched by two biologists from Great Britain, the classification scheme probably represents more of a European view than a North American view. For example, the marine members of Phylum ARTHROPODA, crustaceans, etc., have been separated out and divided into three new phyla: Crustacea, Chelicerata (horseshoe crabs, sea spiders) and Uniramia (no truly marine representatives). Twenty-seven phyla are covered, the description includes a schematic breakdown of each phylum into classes, superorders, orders, suborders, and infraorders. The narrative contains a brief description of the life history of the animals within each group and representative species are discussed in terms of general description of the animal, habitat and known geographic range, maximum size, and, in some cases, additional life history data is given. The selection of the 1,300 illustrated species is biased toward the Atlantic-Mediterranean-Caribbean area and the Indo-Pacific area.

A cursory sample of Phyla PORIFERA, CNIDARIA, and CRUSTACEA yielded 53%, 44%, and 50% of the species, respectively, from the Atlantic area and 29%, 41%, and 17% of the species, respectively, from the Indo-Pacific area. Northeastern Pacific species are poorly represented. Thus, the authors' statement in the Introduction . . . "text and colour photographs of the living marine animals in their natural environment, which should enable readers to *identify* and classify the marine invertebrates that they see" . . . would certainly not hold true for the Pacific coast area.

Another small problem arises for the information given for the illustrated species—it appears that some of this information may be misleading. For example, the range of the common California subtidal snail, *Calliostoma ligatum's* is given as occurring in the northeast Atlantic; their occurrence in the northeast Pacific is not mentioned.

The photos are very good, ranging from fair to excellent, and add greatly to the overall presentation. I recommend this book to those marine biologists interested in the most recent marine invertebrate classification. Amateur naturalists and divers will find the book helpful in classifying at least some of the invertebrates they may observe.—*Daniel W. Gotshall*

Big Game of North America—Ecology and Management

Edited by John L. Schmidt and Douglas L. Gilbert for Wildlife Management Institute; Stackpole Books, Harrisburg, PA. 1978; 490 pp; illustrated; $17.95.

Big Game of North America is an easy to read collection of 27 chapters and 2 appendices dealing with the animals, their management in the past, present, and future. The first chapter presents the general evaluation and taxonomic key to North America big game. The next 15 chapters are devoted to individual species or species groups, including exotics. Each of these chapters has a more or less standard format that includes: taxonomy, population dynamics, ecology, management, and future considerations for a species or group. The remaining chapters present management considerations, including behavior, modeling, carrying capacity, predator control, and sociological considerations in management and in the future.

All chapters are not equally well done, but as a text for students of big game management or as a reference for managers will be a valuable asset. I enjoyed the book and, as California's Big Game Coordinator, have encouraged its use by our big game biologists.—*Brian Hunter*

Tuna and Billfish—Fish Without a Country

By James Joseph, Witec Klawe, and Pat Murphy; paintings by George Mattson. Inter-American Tropical Tuna Commission, P.O. Box 1529, La Jolla, CA; 1979; VII + 46 pp; illustrated; $7.95.

Tuna, billfish, and their close relatives are among the most fascinating and sought after creatures inhabiting the world's oceans, but well grounded, popular accounts of their life have been rare. This book admirably fills that gap, presenting, in 18 pages, a capsule of information on the birth, growth, adaptation, migration, fishery, and conservation of the tunas and billfish. Most of the remainder of the book is devoted to 12 of George Mattson's superb watercolors of tuna and billfish, alone worth the purchase price, and five maps detailing present knowledge of the distribution, migration, and spawning areas of albacore, bluefin tuna, skipjack tuna, yellowfin tuna, and striped marlin. A summary of International Game Fish Association world record catches of tuna, billfish, and related species completes the book.—*Robson A. Collins*

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