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POPULATION STRUCTURE CHANGES AND YIELDS OF FISHES DURING THE INITIAL EIGHT YEARS OF IMPOUNDMENT OF A WARMWATER RESERVOIR[1]

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Data from creel census and netting programs were used to study changes in the relative abundance, age, and species composition of fish during the first 8 years of impoundment of Merle Collins Reservoir, Yuba County, California. The effects of the changes on fish yields are discussed.

High survival of the first (1964) year class of largemouth bass (*Micropterus salmoides*) produced a large population of slow growing bass that dominated the fishery through 1967. These fish limited survival and recruitment of all centrarchids in 1965 and 1966 and depressed initial yields.

Largemouth bass and green sunfish (*Lepomis cyanellus*) declined numerically after 1968. Bluegill (*L. macrochirus*) and redear sunfish (*L. microlophus*) increased dramatically. Catfish remained stable and were probably underexploited. Salmonids, introduced in late 1966, increased total pressure and effort and raised annual yields.

Age composition of centrarchids changed from adult fish and fish of the initial year class to a structure in which several year classes and all sizes were represented by the end of the 8-year study.

Anticipated changes in species composition failed to develop as numbers of nongame species remained extremely low throughout the study.

High initial yields customarily associated with new impoundments were not obtained. Yields ranged from 2.3 to 10.7 lb/acre.

INTRODUCTION

Warmwater impoundments in California and elsewhere are often characterized by high initial fish yields followed by abrupt declines (Abell and Fisher 1953; Kimsey 1958). This problem is particularly acute in large California reservoirs north of the Tehachapi Mountains, which traditionally offer angling of only mediocre quality. These waters often provide long term annual game fish yields of 3 to 8 lb/surface acre (von Geldern 1972), as compared to the national average of 22.6 lb/surface acre (Jenkins 1968). The need to improve angling in these impoundments is very great and an increased understanding of the mechanisms responsible for fishery declines is required before corrective management programs can be developed.

Completion of Merle Collins Reservoir in 1964 provided an opportunity to study various aspects of the initial aging process of a fluctuating warmwater impoundment. The research program was designed to test the hypothesis of Ellis (1937) that declines in yields of fish are the result of decreasing reservoir fertility (Chamberlain 1972) as well as the theory of Bennett (1947), which attributes declining production

[1] Accepted for publication June 1973. This study was performed as part of Dingell-Johnson Project California F-18-R, "Experimental Reservoir Management" supported by Federal Aid to Fish Restoration funds.

largely to changes in the structure of fish populations. This report summarizes the results of studies designed to test Bennett's theory and considers (i) changes in relative abundance, age, and species composition in fish populations as determined by netting and creel census, and (ii) the impact of these changes on reservoir game fish yield.

DESCRIPTION OF THE STUDY AREA

Merle Collins Reservoir is approximately 25 miles northeast of Marysville, California, in Yuba County, elevation 1,200 ft. The reservoir was formed in 1964 by the impoundment of French Dry Creek, a tributary of the Yuba River. Reservoir waters are used primarily for irrigation of pasture and crops. Annual fluctuations range from 30 to 60 ft. The reservoir covers 1,000 acres when full, has a capacity of 57,000 acre-ft, and a maximum depth of 155 ft. Surface water temperatures reached the mid-40's in winter and approached 90 F in summer. Stratification usually occurred by the end of May and destratification by mid-October. Dissolved oxygen levels ranged from near saturation at the surface to less than 1.0 ppm at the bottom. Large volumes of water suitable for salmonids are available throughout the year. Total alkalinities ranged from 24 to 52 ppm. The pH varied between 6.2 and 8.6.

Merle Collins Reservoir was chosen because its physical and chemical characteristics and basin morphometry typify the many warmwater reservoirs being built throughout the State. Its smaller size and single access made it easy to census and study. Management implications derived from results obtained here could then be more broadly applied to the larger waters.

HISTORY OF THE FISHERY

French Dry Creek was treated with rotenone prior to impoundment to reduce the numbers of undesirable nongame species. Several thousand fish were killed, predominantly Sacramento squawfish (*Ptychocheilus grandis*), as well as some bluegill, green sunfish, and black and brown bullheads (*Ictalurus melas* and *I. nebulosus*). The creek was treated from Lake Mildred, an 80-acre reservoir (now known as Royal Pines Lake) located 2 miles upstream from Merle Collins Reservoir. Lake Mildred is a private lake with a population of warm- and coldwater species, and is occasionally planted with rainbow trout (*Salmo gairdneri*). It was not chemically treated during the treatment of French Dry Creek. In the summer of 1966, mud gates in the dam at Lake Mildred burst, releasing all the water and unknown numbers of various species of fish into French Dry Creek and Merle Collins Reservoir.

Following the chemical treatment, the Department of Fish and Game stocked the reservoir with large- and smallmouth bass (*M. dolomieui*), Sacramento perch (*Archoplites interruptus*), and channel catfish (*Ictalurus punctatus*). Sizes ranged from fry to adults (Table 1). Threadfin shad (*Dorosoma petenense*) were stocked to provide forage for the game fish, in addition to the sunfish surviving the chemical treatment. Shad failed to become established from the initial introduction, but were reintroduced and became established in 1967. Initial introduction of rainbow and brown trout (*Salmo trutta*) occurred in late 1966 and introductions have continued annually thereafter.

TABLE 1—Fish Initially Stocked in Merle Collins Reservoir *

Species	Numbers	Remarks
Largemouth bass	356	225 fish were 3/lb; the remainder 1 to 4 lb.
Smallmouth bass	5,338	5,000 fish were 250/oz; the remainder 3/lb to 1/lb.
Sacramento perch	2,765	2,600 were 12/oz or smaller; the remainder ranged from 0.5 to 1/lb.
Channel catfish	20,000	All fish 25/oz.
Threadfin shad	17,400	2,000 shad 20/oz introduced in 1964; the remainder introduced in May and June 1967.

* All species except shad introduced in March and April 1964. Shad were introduced in July 1964.

The irrigation district controlling the reservoir opened it to fishing from June through October in 1965. Fishing was permitted from mid-March through September in 1966. The reservoir opened in March 1967 and has remained open the year around from that time.

Common and scientific names of fishes known to be present in the drainage are listed in Table 2.

TABLE 2—Common and Scientific * Names of the Fishes Known to be Present in Merle Collins Reservoir and Drainage

Clupeidae		
Threadfin shad	*Dorosoma petenense*	+†
Salmonidae		
Silver salmon	*Oncorhynchus kisutch*	+
Brown trout	*Salmo trutta*	+0
Rainbow trout	*Salmo gairdneri*	+0
Eastern brook trout	*Salvelinus fontinalis*	+
Catostomidae		
Sacramento sucker	*Catostomus occidentalis*	0
Cyprinidae		
Carp	*Cyprinus carpio*	0
Goldfish	*Carassius auratus*	0
Golden shiner	*Notemigonus crysoleucas*	0
Hardhead	*Mylopharodon conocephalus*	0
Hitch	*Lavinia exilicauda*	0
California roach	*Hesperoleucus symmetricus*	0
Fathead minnow	*Pimephales promelas*	0
Sacramento squawfish	*Ptychocheilus grandis*	0
Ictaluridae		
Channel catfish	*Ictalurus punctatus*	+
White catfish	*Ictalurus catus*	0
Brown bullhead	*Ictalurus nebulosus*	0
Black bullhead	*Ictalurus melas*	0
Centrarchidae		
Largemouth bass	*Micropterus salmoides*	+0
Smallmouth bass	*Micropterus dolomieui*	+0
Green sunfish	*Lepomis cyanellus*	0
Redear sunfish	*Lepomis microlophus*	0
Bluegill	*Lepomis macrochirus*	0
Sacramento perch	*Archoplites interruptus*	+
White crappie	*Pomoxis annularis*	0
Black crappie	*Pomoxis nigromaculatus*	0
Cottidae		
Sculpin	*Cottus* sp.	0

* Common and scientific names follow Special Publication No. 6 of the American Fisheries Society.
† 0 = present in drainage prior to impoundment
+ = introduced

METHODS

General

Changes in the relative abundance, age, and species composition were based primarily on a creel census and a standardized netting program. Observations during electrofishing operations conducted by other project personnel during the same period provided ancillary information, particularly on the presence and abundance of young-of-the-year fish.

The creel census, modified from Best and Boles (1956), involved angler interviews on all weekend days, national holidays, and 2 rotating weekdays each week. All anglers were interviewed each census day and a large proportion of all fish were weighed and measured. Camping was first permitted in 1969. Fish caught and cleaned by campers could not always be identified to species and in such instances were recorded as ''unidentified''.

Creel census data were expanded to give estimated total catch by multiplying the observed monthly weekday catch of each species by the ratio of the total number of weekdays in a month to the total weekdays censused and adding the observed catches for weekends and holidays. Monthly estimates were then summed to obtain annual estimates. Estimated total pounds of fish caught annually were calculated by multiplying the estimated monthly catch of a species by the average monthly weight of that species and summing monthly estimates.

The netting program was conducted from 1965 through 1968. Nets were fished three times a year to sample seasonal variations in the catch. Because most warmwater species are relatively inactive when the water is cold and therefore less vulnerable to passive gear, nets were set only after surface temperatures approached 60 F in the spring. Summer sampling began after the reservoir had permanently stratified and fall netting began when temperatures had again approached 60 F. Since seasonal variations were minor, data were combined annually and standardized by catch/net day for each species.

Netting stations were established in deepwater areas, in coves off rocky points, and in areas with and without submerged brush, in order to sample a wide variety of habitat types. Fyke nets, described by Pelgen and McCammon (1955), Oneida traps, and floating and diving gill and trammel nets of a variety of mesh sizes were fished in different locations in the spring and summer of 1965. Ten permanent stations were established in the fall of 1965. No nets were fished in the spring of 1967 because of manpower limitations.

Netting results accurately reflected changes in abundance for most species, with the exception of young-of-the-year during spring operations. Threadfin shad less than 3 inches were never taken. Large- and small-mouth bass are not effectively sampled with nets and other methods were used to describe changes in their abundance.

During netting periods, the nets were lifted daily. Length and weight was recorded for each fish and a scale sample or dorsal spine was taken for age determinations.

Relative Abundance

Catch/hour and estimated total catch from the creel census provided the basis for determining changes in the relative abundances of game species. Annual changes in catch/net day and total net catch provided an additional index to the abundance of game fish as well as information on the abundance of nongame species rarely seen in the census.

Catch/hour values were determined for each species by categorizing anglers according to fishing method. Data collected from boat anglers fishing during March, April, May, or June and using lures, minnows, or a combination of these two methods were used to calculate catch/hour values for bass. The sunfish fishery was described using data from anglers fishing from either a boat or from the shore from June through October and using worms for bait. Catch/hour values for crappie were calculated from data taken from boat and shore fishermen fishing with minnows during April, May, or June. Catch/hour values were based only on data which fitted the various categories. Values for sunfish were not calculated in 1969 because fishing methods were not sufficiently categorized and data from other years were not comparable. For large- and smallmouth bass in 1965 data from June were used because the reservoir was not open to fishing before June. Fishing effort and catches of catfish and bullheads were low at Merle Collins Reservoir and anglers could not be categorized by fishing method. Description of anglers by fishing method follow von Geldern (1972), with minor modifications.

Age Composition

Changes in age composition were based on scale or dorsal spine samples taken during the netting program for all species except large- and smallmouth bass. These two species were not often taken with the netting gear. Therefore, age determinations were based primarily on scales taken during the census and length frequencies from the anglers' catches.

Species Composition

Census and netting data and observations during electrofishing operations were used to describe changes in species composition.

Yields

Annual yields (lb/acre) were calculated using both the maximum surface acreage and the mean annual acreage. Values were derived by dividing the estimated total annual weight of all species by the maximum acreage or by the mean annual acreage to get the respective values. The latter calculation probably reflects yields more accurately because of the fluctuating nature of the reservoir. However, because most fishery workers report yields using maximum surface acreage, this value is also presented.

RESULTS

This section provides a general discussion of changes in the relative abundance and age of the major fish species during each year of the study. Quantitative information is provided in Tables 3–5 and Appendixes 1–10. Changes in the relative abundance of less abundant fish species and information on yields and changes in species composition follow the general discussion.

1965

The reservoir was first opened to fishing in June. Largemouth bass dominated the catch. Adult largemouth bass planted in 1964 spawned that year and their young had an extremely high survival. By 1965, there was a dense population of small bass. Over 72% of the bass seen in the census were less than 8 inches FL. Adults stocked in 1964 and adults surviving the chemical treatment accounted for only a minor portion of the catch. The 4,388 bass taken during the short 1965 season accounted for 75% of the total estimated catch.

Anglers apparently rejected these small bass. They caught and released numerous small bass and kept only the larger fish. The catch/hour (0.24) for proficient bass anglers accounts for only fish actually seen in the census and did not reflect accurately their actual abundance.

TABLE 3—**Summary of Creel Census Data at Merle Collins Reservoir, Showing Estimated Total Anglers and Hours, Estimated Total Catch, and Estimated Catch by Species**

	Year							
	1965	1966	1967	1968	1969	1970	1971	1972
Total anglers	3,410	5,118	8,194	10,118	11,756	11,170	15,393	12,484
Total hours	13,007	17,376	27,801	35,930	48,222	52,860	76,251	64,467
Largemouth bass	4,388	7,062	7,682	3,582	2,300	1,937	2,788	1,203
Smallmouth bass	248	916	503	309	970	656	1,049	580
Green sunfish	1,054	1,355	1,603	420	380	229	139	200
Bluegill	33	363	507	754	3,347	2,714	2,263	886
Redear sunfish	0	7	22	184	1,136	1,057	1,303	1,874
Black crappie	4	9	16	17	40	418	2,296	398
Channel catfish	0	6	16	5	9	23	47	224
White catfish	10	105	111	42	89	326	186	240
Black bullhead	46	160	217	264	73	234	79	55
Brown bullhead	56	56	60	89	30	30	10	0
Brown trout	0	8	290	194	592	220	528	288
Rainbow trout	0	23	2,681	3,565	5,646	3,327	3,344	2,634
Eastern brook trout	0	0	0	0	0	186	0	0
Silver salmon	0	0	0	0	0	53	119	435
All others*	9	8	13	17	†995	34	‡3,192	‡2,286
Totals	5,848	10,078	13,721	9,442	15,607	11,444	17,343	11,303

* Includes unidentified sunfish, Sacramento perch, and rough fish species.
† Many fish, caught and cleaned by campers, could not be identified to species and were placed in this category.
‡ Includes catchable rainbow trout.

During the first year, anglers caught only an estimated 248 smallmouth bass and averaged only 0.01 fish/hour. The fish were small, averaging only 7.0 inches FL. Undoubtedly, most of the bass caught in 1965 were from the 1964 introduction.

Initial sunfish populations resulted from fish remaining after the chemical treatment of French Dry Creek.

Green sunfish were easily the most abundant sunfish during the initial year of the study, as evidenced by both census and netting data. Sunfish accounted for 18.7% of the total estimated catch in 1965; green sunfish accounted for almost 97% of this total and bluegill and black crappie the remainder. Anglers took an estimated 1,054 green sunfish in 1965; proficient anglers took them at a rate of 0.08 fish/hour.

Netting data confirmed the abundance of green sunfish and the low numbers of other sunfish. Neither anglers nor nets took redear in 1965.

1966

The 1964 year class of largemouth continued to dominate the fishery in 1966. Anglers took 7,062 bass during the 6½-month season. Catch/hour increased slightly to 0.27, although the majority of bass remained small. Many of the stocked bass had been caught by the end of 1965; length frequencies showed that 98% of the bass taken by anglers in 1966 were still less than 8.0 inches FL.

Angling, netting, and electrofishing in both 1965 and 1966 revealed no young-of-the-year largemouth either year, but age determinations from scales taken in subsequent years indicated that limited reproduction had occurred each year. Neither year class contributed significantly to the fishery during the study.

The smallmouth bass population followed a pattern similar to that of the largemouth. Anglers took 916 smallmouth and their catch/hour rose slightly to 0.04. Length frequencies showed an increase in mean fork length to 8.4 inches in 1966. The unimodal distribution indicated a single year class moving through the fishery and confirmed that most smallmouth bass came from the stocked fingerlings.

Anglers' catches and net catches of sunfish increased for all species. Green sunfish continued to be the most abundant sunfish; however, bluegills showed a 10-fold increase in the census. Census and netting data recorded redear for the first time. Increased catch/hour values for green sunfish and bluegill reflected increased abundance and not the longer fishing season and increased pressure recorded in the second year of the study. Increased total net catches and catch/net day values for all sunfish species except bluegill also demonstrated their increased abundance.

Age composition of the green sunfish and bluegill populations changed as fish from the 1964 year class entered the catch. The large population of largemouth spawned in 1964 had suppressed reproductive success of all sunfish species in 1965 and 1966 and most fish recorded were either older adults or fish from the 1964 year class.

Additions of various numbers and species of fish from Lake Mildred when the flood gates burst in the summer of 1966 undoubtedly had some effect on relative abundances and age compositions of the various populations but it was impossible to quantify these changes.

1967

The reservoir opened in March and remained open all year. Estimated numbers of anglers, angler hours, and total harvest increased substantially over each of the previous 2 years.

The largemouth bass catch reached its maximum in 1967; all anglers caught 7,682 bass and catch/hour increased to 0.36 for proficient bass anglers, the highest recorded during the study. Although the 1964 year class began to decline in abundance, it still provided the major portion of the largemouth catch.

The proportion of largemouth in the bass catch declined from 70% of the estimated total catch of all species in 1966 to 56% of the catch in 1967, although both the total catch and catch rate of bass increased over 1966. Further increases in bluegill and green sunfish catches accounted for part of the decrease. A catch of almost 3,000 trout, stocked for the first time in 1967, also contributed to the decline.

The age composition of the bass population continued to change as the abundance of the 1964 year class declined and a definite year class was produced in 1967.

Anglers' catches of smallmouth bass declined in 1967 and catch/hour dropped slightly. Length frequencies of angler-caught fish continued to shift to the larger sizes, indicating the continued growth of the fish stocked in 1964. The absence of fish less than 8.0 inches confirmed the poor recruitment from the 1965 and 1966 year classes. A definite year class of smallmouth was produced in 1967.

The catch of sunfish continued to increase. Catch/hour values remained constant for bluegill, indicating little change in population size, but dropped slightly for green sunfish. Manpower limitations in 1967 limited netting operations to the summer and fall. Declines in the total net catches of sunfish and catch/net day values for all sunfish except bluegill reflected the failure to conduct netting operations in the spring. Catches of bluegill in the nets almost doubled and the catch/net day increased from 1.6 the previous year to 4.1 in 1967, despite the curtailed netting operations.

1968

The total number of anglers visiting Merle Collins Reservoir increased by almost 2,000 and total hours fished increased by over 8,000 in 1968. However, the total catch dropped by nearly a third, as largemouth bass and green sunfish catches declined sharply.

Although the catch of largemouth decreased by 3,100 fish, the catch/hour for proficient anglers remained almost as high as in the previous year, indicating more of a decrease in effort than a decline in abundance.

Age composition continued to change, with good representation in the smaller size classes and a fair number of larger fish being taken.

Smallmouth numbers continued to decline, as did catch/hour. In 1968, fewer large fish were caught, which indicated a decline in the abundance of the 1964 year class. The smaller sizes, represented by fish in the 5- to 7-inch groups, were probably fish from the 1967 year class.

Green sunfish dropped abruptly in abundance. Anglers took only 420 after a high of 1,603 the previous year. Netting results also confirmed the decline of green sunfish. Total net catch dropped to 35 in 1968 and catch/net day went from 8.5 in 1967 to 2.9 in 1968. A continued downward trend in catch/hour also reflected the decrease in abundance.

Bluegill and redear sunfish populations continued to increase steadily. Anglers took increased numbers, with a higher catch rate. Annual catches also increased and catch/net day values rose sharply in 1968. Statistics for black crappie changed little over those of the preceding year.

Stocking of rainbow and brown trout continued in 1968 and fishing effort for these species accounted for most of the increase in observed fishing pressure. The combined annual catch of both species approached 3,800 fish for the year. Increased effort directed at salmonids probably accounted for the decline in the total catch of other species.

1969

Use and effort increased for the fifth consecutive year. The total catch approached 16,000 fish, as trout, bluegill, and redear catches all increased dramatically while largemouth and green sunfish landings continued to decline. The catch/hour for bass fishermen dropped sharply, to 0.14 fish/hour and all anglers caught only 2,300 fish. Smallmouth abundance showed a reversal of its downward trend, with the catch tripling and catch/hour increasing slightly.

Length frequencies for all species of centrarchids showed a wide distribution of sizes, indicating the presence of several year classes. Shoreline observations during the spring and electrofishing operations confirmed the presence of definite year classes of both bass and all the sunfish. Definite year classes were produced thereafter.

Overnight camping was permitted at the lake in 1969 and thereafter. Netting operations were not conducted the last 4 years of the study.

1970

Angler use declined slightly from 1969 but effort increased moderately. Total annual catch dropped to 11,444 fish, as catches of all major species declined from the values recorded in 1969. Black crappie were the only exception. Anglers caught 418 crappie, an increase of almost 400 from the previous year as a strong year class produced in 1969 entered the catch. Catches of rainbow and brown trout also declined and Eastern brook trout and silver salmon, planted in 1970, contributed very little.

Catch/hour dropped for all centrarchids except bluegill, for which they rose dramatically from 0.07 to 0.21 fish/hour.

Length frequency data again showed a wide distribution of length classes for all species, indicating the presence of a number of year classes.

1971

Angler use, effort, and total harvest increased dramatically in 1971. Over 15,000 anglers spent more than 76,000 hr catching over 17,000 fish.

Catches of large- and smallmouth bass rose over those recorded the previous 2 years. Increased catch/hour values for anglers proficient in catching both species showed that there was a slight increase in abundance and that the increased catches were not due to increased pressure alone.

Catches of bluegill and redear sunfish remained approximately at the high levels recorded in 1970. Green sunfish abundance reached an all time low but the black crappie catch increased from 418 fish in 1970 to 2,296 in 1971 as the 1969 year class fully entered the fishery and the 1970 year class began to contribute.

Rainbow and brown trout continued to be stocked in the spring. At the same time, small numbers of Eastern brook trout and silver salmon were introduced. Additional plants of catchable-sized rainbows were made during early and late winter. Increased effort during these winter months, coupled with excellent sunfish angling (catch/hour ranged from 0.09 for redear to 0.43 for black crappie) accounted for much of the large increase in use and effort recorded.

Fifteen hundred catchable-sized channel catfish were stocked in late August as part of a companion study to determine harvest, survival, and mortality rates. All fish were marked or tagged and few were recovered by anglers in 1971.

1972

During the final year of the study, the total numbers of anglers visiting the lake and hours they fished dropped. Annual harvest and catch/hour of all major species, except redear, dropped. Catches of black crappie, after slowly increasing during the early years and being abundant the previous year, dropped sharply. Catches of bluegill, having maintained a high level over the previous 3 years, dropped almost as sharply as those of crappie. Sharp fluctuations in populations of crappie are not unexpected, but I am at a loss to explain the rapid drop in abundance of bluegill.

Total catches of both largemouth and smallmouth dropped. Smallmouth numbers fluctuated throughout the study; however, the decrease in the catch of largemouth, particularly in the smaller size classes, occurred because of a 12-inch size limit imposed on March 1, 1972. Previously there had been no size restriction on largemouth, but a tagging study conducted concurrently with this study showed possible overexploitation (Rawstron and Hashagen 1972). Therefore, a size restriction was instituted. A sharp drop in catch/hour (from 0.20 in 1971 to 0.10 in 1972) confirmed the decline in abundance.

Length frequencies for all species remained essentially the same as in the previous few years. Most size classes were well represented and there was a noticeable shift in numbers to larger size classes of black crappie and large- and smallmouth bass as a year class moved through the fishery.

Trout and catfish plants continued at approximately the same levels as in 1971. Total catches of trout dropped. Stocked channel catfish began to appear in the catch and silver salmon catches rose to over 400 fish.

Other Sunfish Species

White crappie were abundant in Lake Mildred and the entire population entered the reservoir through French Dry Creek when the mud gates burst in 1966. Many were seen dead and dying for several days in the upper reaches of the reservoir. Anglers caught no white crappie and none were seen during netting or electrofishing operations. This species apparently failed to establish itself in Merle Collins Reservoir.

Sacramento perch, stocked in 1964, also failed to become established. Anglers caught an occasional adult, as did the nets. Observations and field operations found no evidence of successful reproduction.

Catfish

Catfish, as a group, were one of the most abundant fish in the reservoir. Few anglers fished specifically for catfish and census results did not accurately reflect their abundance. During the study, angler catches represented a low of 1.3% of the estimated catch in 1969 to a high of only 5.4% the following year. Netting, however, showed that catfish comprised over 73% of the catch of game fish in 1965. In spite of increases in other game fish populations and the introduction of salmonids, the four catfish species still accounted for 46.4% of the game fish catch in the nets.

Black bullheads were the most abundant of the four species netted each year except 1967, when nets took more white catfish and brown bullheads. White catfish were more abundant than brown bullheads, while numbers of channel catfish remained low in all years. Netting indicated a decline in the percentage catch of black bullheads and a corresponding increase in the percentage of white catfish taken. Census results confirmed this trend, particularly near the end of the study. In numbers, white catfish jumped from 10.5% of the catfish catch in 1968 to 57.8% in 1971, while black bullheads dropped from 66.0% to 24.5% during the same period. Numbers of brown bullheads in the catch fluctuated throughout the study but remained at relatively low levels. Channel catfish never accounted for more than 6.6% of the net catch of catfish or 4.5% of the anglers' catch of the four species until supplementary plants were made in 1971 and 1972.

Attempts to calculate ages of catfish were unsuccessful. Dorsal spines were taken from all species during netting operations, decalcified, sectioned, and stained following procedures described by Perry (1967). Interpretation of annuli could not be agreed upon by two readers or even repeat readings by one person. Length frequencies of fish caught in the nets gave a confusing picture of the age composition of the catfish. Distributions of lengths were unimodal each year for all species except channel catfish, indicating only one year class. However, a few small fish of each species taken each year by the nets indicated that reproduction had occurred and the wide range of lengths in the distribution indicated that more than one year class was present.

Channel catfish recorded in the census before 1971 and taken in nets resulted from introductions made in 1964. The small numbers taken made an accurate description of this population difficult. Average weights of net-caught fish increased each year, and growth was relatively rapid. Anglers caught several large fish, up to 16 lb, in 1969 and 1970.

Salmonids

Nets fished in the summer and fall of 1966 caught fair numbers of trout, released into Merle Collins Reservoir when the mud gates in the dam at Lake Mildred burst. The fish were in excellent condition and growing on a diet of predominantly plankton and terrestrial insects.

An experimental plant of rainbow and brown trout, averaging 6.1/lb was made in mid-December 1966, and the fish grew rapidly. Natural spawning is limited to a short section of French Dry Creek, so annual stocking of 7 to 10 trout/acre has been continued each spring. Brown trout have averaged 3 to 5 fish/lb since the 1966 introduction, rainbows 1 to 2 fish/lb.

Trout rapidly became the most popular fish and their introduction resulted in substantial increases in the total numbers of anglers and hours fished. In 1966, an estimated 5,118 anglers fished 17,376 hr and 0.2% of their catch was trout. The following year 8,194 anglers fished an estimated 27,801 hr and trout accounted for almost 30% of their estimated catch. The percentage of trout in the catch increased each year except 1970. Additional plants of catchable-sized rainbow trout during winter months further increased the percentage of trout in the catch.

Silver salmon and Eastern brook trout were stocked in 1970 and 1971. Only silver salmon were stocked in 1972.

Evaluation of the trout stocking program and the contributions of all salmonids will be discussed in other papers.

Threadfin Shad

Introduction of 2,000 threadfin shad in 1964 proved unsuccessful and additional plants, totalling 15,400 shad, were made in early 1967 to strengthen the forage base. Beginning in 1967, young-of-the-year shad provided an additional source of forage for largemouth bass, trout, and other species large enough to utilize them.

Although netting operations were selective for adult shad, net catches reflected the failure of the first plant and the success of the second plant. Net catches in 1965 and 1966 totaled only six adult shad. In 1967, netting only in the summer and fall, 19 shad were caught. By the end of 1968 shad were very abundant; nets caught over 650 adults during that year.

Rough Fish

Populations of hitch, squawfish, fathead minnows, and golden shiners were present in the lake in very low numbers. Net catches of these species were low. Anglers caught only an occasional squawfish or golden shiner. No carp, Sacramento suckers, goldfish, California roach, or hardhead, all species known to be present in the drainage (Table 2), appeared in the nets or angler catches.

Yields

Creel census results for the 5 months the lake was open to fishing in 1965 indicated that Merle Collins Reservoir did not have the high initial yield customarily found in new waters. Using expanded creel census data and the maximum surface acreage, the 1965 yield was 1.6 lb/acre. Values for 1966 through 1972 ranged from a low of 2.3 lb/acre in 1966 to a high of 10.7 lb/acre in 1971 (Table 4).

TABLE 4—Yield Values, Merle Collins Reservoir 1965–1972

			Yield values (lb/acre)					
			Estimated total weight/maximum surface acreage			Estimated total weight/average surface acreage		
Year	Estimated total weight (lb)	Average surface acreage*	All fish except trout	Trout	All fish	All fish except trout	Trout	All fish
1965	1,551	855†	1.6	---	1.6	1.8	---	1.8
1966	2,300	755	2.3	---	2.3	3.0	---	3.0
1967	5,629	890	3.9	1.7	5.6	4.4	1.9	6.3
1968	4,340	855	2.7	1.6	4.3	3.2	1.9	5.1
1969	7,980	860	4.5	3.5	8.0	5.2	4.1	9.3
1970	6,675	885	4.4	2.3	6.7	5.0	2.5	7.5
1971	10,747	910	5.7	5.0	10.7	6.3	5.5	11.8
1972	7,669	830	3.9	3.8	7.7	4.7	4.5	9.2

* Maximum surface acreage = 1,000 acres.
† Data not available. Value is average elevation 1966–1972.

More meaningful yield values were obtained by using average, instead of maximum, surface acreage. This calculation raised all yield estimates slightly to a high of 11.8 lb/acre in 1971.

The harvest of introduced trout significantly increased yield values from 1967 through 1972. Using average surface acreage values, trout accounted for 1.9, 1.8, 4.1, 2.6, 5.5 and 4.5 lb/acre from 1967 through 1972, respectively.

DISCUSSION

Relative Abundance

Dominance of a fishery by one species or by one year class has previously been reported in the literature. Thompson (1941) reported that one year class of black crappie dominated the fishery at Lake Senachwine in Illinois for 4 years, controlling the survival of both its own young and the young of most other species. The initial year class of largemouth bass, supplemented with 85,000 stocked fingerlings, dominated the fishery for 3 years at newly impounded Clearwater Reservoir, Missouri (Patriarche and Campbell 1957).

The initial year class of largemouth at Merle Collins Reservoir was extremely abundant. The mean number of young-of-the-year bass (86/0.1-mile section) in 1965 was far greater than that reported by von Geldern (1971) for Lake Nacimiento, San Luis Obispo County. Results for 1965 through 1968 at this older lake showed mean numbers of 35.0, 4.6, 48.1, and 1.2 young-of-the-year largemouth/0.1-mile section.

The 3-year dominance by this year class can be attributed to any or all of the following: (i) the failure of the initial stocking of threadfin shad to become established as a source of forage, (ii) lack of natural predators to reduce the numbers of this year class, and (iii) little or no competition from young of other species. Relatively low angling pressure for the first 3 years and angler release of the small, slow growing bass reduced the harvest and compounded the problem.

I cannot explain the decline in bass abundance after 1968, but several possible causes should be considered. Bennett (1971) indicates predation by a large population of bluegill on largemouth eggs and embryos will quickly reduce the bass population. The decline of bass in this study corresponded with dramatic increases in numbers of bluegill, redear, and black crappie. Weidlein (1971) and von Geldern (1972) have noted declines in largemouth catches concurrent with increases in smallmouth catches in other California waters. At Merle Collins Reservoir, numbers of smallmouth fluctuated moderately and, although numbers remained relatively low, their abundance in the total catch ranged between 5.1 and 6.2% in the last 4 years of the study, higher than all of the previous 4 years except 1967 (9.1%). McConnell and Gerdes (1964) indicated possible competition for food between adult threadfin shad and young-of-the-year bass. Von Geldern (1971) reported an inverse relationship between numbers of adult threadfin and young-of-the-year bass at Lake Nacimiento. The decline in bass at Merle Collins Reservoir corresponded with the reintroduction of threadfin shad and resultant establishment of an abundant population. Rawstron and Hashagen (1972) report the harvest and mortality of tagged largemouth at Merle Collins Reservoir and include a discussion of possible overexploitation of the largemouth population. Fluctuations of water levels during the spawning season were minor during this study and may be disregarded as a cause for the declining bass population.

The increase in smallmouth abundance concurrent with a decline in largemouth numbers at Merle Collins Reservoir was discussed briefly above. The same situation occurred at Shasta Lake, Shasta County, where the fishery was initially supported by largemouth (Weidlein 1971). Folsom Lake, Placer-El Dorado-Sacramento counties, was heavily stocked with largemouth following impoundment in 1955. No smallmouth were stocked, but they were present in the drainage. A 1962 creel census showed the bass catch to be evenly divided between the two species (von Geldern 1972). However, at Clearwater Lake in Missouri, smallmouth failed to become abundant in the first 7 years of impoundment, although they were the predominant predator before impoundment (Patriarche and Campbell 1957). Although smallmouth numbers have fluctuated during this study, no distinct trend is apparent.

The greatest changes in relative abundance were seen in the sunfish population. Bluegill increased dramatically during the first 7 years and accounted for almost 24% of the total catch in 1970. Abell and Fisher (1953) reported that over 50% of the the total catch during 7 of the first 8 years at Millerton Lake, Fresno-Madera counties, consisted of bluegill. Of the two species, bluegill have consistently been the most abundant sport species in Indiana waters (Gerking 1952).

The subordinate role of redear when both bluegill and redear are present was also noted by Gerking (1952) and is apparent during the present study.

Green sunfish survival was suppressed by the large population of largemouth until 1967. This, coupled with rising populations of bluegill and redear, which were undoubtedly competing with the green sunfish, contributed to the sharp decline noted during the final 5 years of the study.

Other fishery workers have reported similar declines in green sunfish populations. Catches were high during the first 2 years of fishing at Sutherland Reservoir, San Diego County, but declined rapidly after that, probably due to competition with largemouth (La Faunce, Kimsey, and Chadwick 1964). Data from Millerton Lake showed that green sunfish catches were insignificant after the first year of fishing, although they accounted for over 90% of the stocked fish (Abell and Fisher 1953).

Black crappie increased steadily during the study, with a 40-fold increase in 1970, and another sharp increase to 2,263 fish in 1971, followed by an abrupt decline in 1972. Crappie populations characteristically increase slowly and then decrease abruptly.

The failure of Sacramento perch to become established is probably due to competition with other centrarchids. Good populations were found in Clear Lake, Lake County, when trout comprised the only other species present. Numbers declined rapidly following the introduction of exotic centrarchids (Murphy 1948). Other attempts to stock this species in California waters have been largely discontinued because of poor results (Tharratt and McKechnie 1966).

Catch/net day values indicate that catfish populations remained relatively stable the first 3 years after impoundment before declining in 1968. Accurate analysis of catfish abundance is not possible for the last

4 years of the study because census data do not reflect actual abundance. Low angler effort and the low annual landings indicate that all four catfish species were underexploited. Few anglers fished specifically for catfish, although those who did were usually successful. Few anglers fished after 9 p.m., even though the irrigation district allowed night fishing the last 3 years of the study. Other California studies have shown high survival rates and low fishing and natural mortalities, indicative of underharvesting, for white catfish and brown bullhead (McCammon and Seeley 1961; Rawstron 1967).

The reason for the failure of the first introduction of threadfin shad is not clearly understood. Shad are customarily introduced into waters with existing fish populations and usually very few adults are required to establish a population. At Merle Collins Reservoir, stocked largemouth had already spawned when shad were introduced in July 1964. Any shad fry produced in 1964 probably did not survive predation by fish of the 1964 year class or stocked adults. Adult shad suffer high mortalities when water temperatures fall below 45 F and few overwinter to spawn a second time (Parsons and Kimsey 1954; Kimsey 1958). Net catches confirmed that low numbers of shad overwintered in 1965 and 1966 and numbers surviving were probably too low to provide adequate recruitment to maintain the population. By 1967, the 1964 year class of largemouth was reduced while sunfish had spawned to provide additional forage. These factors, coupled with the large numbers of shad stocked, assured the success of the second introduction. By late 1968 shad were very abundant and were utilized by most game fish large enough to prey on them.

Age Composition

The initial age structure of most centrarchid populations consisted predominantly of stocked adult fish (with some additions from fish surviving the chemical treatment), and fish spawned during the 1964 spawning season, supplemented by stocked fry. This situation changed little during 1965 and 1966 due to the large year class of bass. Occasional small fish taken in the nets indicated that reproduction occurred in 1965 and 1966 for all species and scale samples from both the netting and census showed that limited recruitment had occurred. In 1967 and in each of the remaining years of the study, year classes of all centrarchids were produced and the age structures of the various populations were represented by all year classes.

The catfish populations did not follow the same pattern. Attempts to age catfish by means of dorsal spines were unsuccessful, as mentioned, and a possible explanation is offered here. Before the construction of the dam, French Dry Creek had a large population of stunted black bullheads and probably brown bullheads and white catfish, since they were also present in the drainage. When these fish, of similar sizes but different year classes, were placed in a new environment where forage was plentiful, growth resumed. When this population of fish was combined with fish produced after impoundment and fish added to the reservoir from Lake Mildred, all with variations in initial growth rates, a confusing picture of the age structure existed. Three distinct populations of each species could produce the confusing unimodal structure of the length frequencies for white catfish and black and brown bullheads and explain the wide range in sizes.

Channel catfish were not present in the drainage before impoundment. Limited recruitment occurred, but the small numbers taken in the nets and by anglers make an accurate analysis of changes in the age structure impossible.

Species Composition

It was anticipated that rough fish populations would increase and, through competition, eventually lower the yield of game fish. However, rough fish populations failed to increase rapidly, as is usually the case in a new reservoir. Several possible causes account for this: (i) the chemical treatment of the drainage, while not completely successful, did decrease numbers of rough fish; (ii) the large population of largemouth undoubtedly suppressed survival and recruitment of rough fish until 1967, delaying the characteristic rapid population increase; and (iii) suckers, hardhead, squawfish, and some populations of hitch are known to spawn in streams and suitable spawning habitat in French Dry Creek is limited.

Other changes in the initial species composition resulted from intentional introductions; i.e., Eastern brook, rainbow and brown trout, and silver salmon. Future papers will discuss their introduction, harvest, and survival.

YIELDS

High initial yields characteristic of newly impounded waters failed to develop at Merle Collins Reservoir and I have attributed this failure to the abundant 1964 year class of slow growing largemouth, lack of forage, low angling pressure, and lack of angler acceptance of small bass. Bennett (1971) states that in artificial ponds and lakes in which natural predators are limited, low fishing and natural mortalities may cause severe competition among the fish and result in poor growth.

Yields at Merle Collins Reservoir increased slightly in 1966 and 1967, as the numbers of anglers and the length of the fishing season increased both years. The introduction of trout each year beginning in late 1966 increased the yield each of the last 6 years.

Excluding the contributions of trout and using the maximum surface acreage, annual yields never rose above 5.7 lb/acre, and were comparable to yields from larger, older reservoirs. Folsom Lake had a yield of 4.2 lb/acre in 1962. Clear Lake yields increased from 4.2 lb/acre in 1947 to 21 lb/acre the following year. Yields fluctuated between 2.6 and 7.5 lb/acre at Millerton Lake over a 4-year period (Table 5). Kathrein (1953) reported yields of 6.8, 10.4, 31.3, and 15.2 lb/acre during the first 4 years of fishing at Clearwater Lake, a 1,650-acre Missouri impoundment. Although fishing was permitted only part of each of the first 2 years, he believed that high initial yields had not been realized in any of the first 4 years.

The harvest of trout increased yields appreciably. Increases ranged from a low of 1.6 lb/acre in 1968 to a high of 5.0 lb/acre in 1971, but the increase was not the natural increase anticipated from a new water.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Chamberlain (1972) describes research activities at Merle Collins Reservoir designed to determine whether declines in yields of fish are a result of decreasing reservoir fertility. He found that fertility (primary productivity) did not decline during the first 4 years of impound-

TABLE 5—Yields from Selected Warmwater Reservoirs *

Water	Maximum surface acreage	Year	Yield (lb/acre)	Source	Remarks
Merle Collins Reservoir, California	1,000	1965	1.6	Present study	Lake open June through October
		1966	2.3		Lake open mid-March through September
		1967	5.6		Lake open March through December
		1968	4.3		Lake open all year
		1969	8.0		Lake open all year
		1970	6.7		Lake open all year
		1971	10.7		Lake open all year
		1972	7.7		Lake open all year
Folsom Lake, California	10,000	1962	4.8	C. E. von Geldern 1972	
Millerton Lake, California	4,500	1949	2.6	Abell and Fisher 1953	60 census days
		1950	6.7		93 census days
		1951	7.5		76 census days
		1952	5.1		59 census days
Clear Lake, California	40,000	1947	4.4	Murphy 1951	Intensive sampling of 3 boat rental docks, and shore catches
		1948	21.0		Postal card survey
Clearwater Lake, Missouri	1,650	1949	6.8	Kathrein 1953	Lake closed part of year
		1950	10.4		Lake closed part of year
		1951	31.3		Lake open all year
		1952	15.2		Lake open all year

* Yields based on maximum surface acreage.

ment. He noted increases in primary productivity in 1966, which he associated with an influx of nutrients when the mud gates in Lake Mildred burst, and in 1967 and 1968, which he correlates with the establishment of the planktivorous shad.

Bennett's theory that the cause of decreasing production is due to changes in the structure of fish populations could neither be proved nor disproved, since initial high yields were not achieved. The study did clearly show the effects of the dominance of a fishery by one year class, and the effects of this dominance on the yield. Yield values for the first 8 years of impoundment are also given. Fisheries literature has few quantitative reports of yields in new waters.

Possibly higher initial yields could have been achieved if introductions of largemouth had been limited to fry or smaller numbers of mature adults. An introduction of fry would have permitted some control of the initial year class of largemouth, reduced predation on the other centrarchids, and possibly allowed threadfin shad to become established. Growth of all species undoubtedly would have increased, larger bass would have been more acceptable to the anglers, and increased catches of larger fish would have attracted more anglers. Year-round angling in 1965, 1966, and 1967 would have increased yields during those years.

Merle Collins Reservoir has the potential for much higher yields. The introduction of limnetic predators to utilize the abundant threadfin population has resulted in increased yields. Possible additional limnetic species such as striped bass (*Roccus saxatilis*) or white bass (*Roccus chrysops*) could be introduced to further increase production.

The large populations of underexploited catfishes offer the most immediate potential for increased yields. If anglers could be shown how to catch catfish successfully and angling effort for these species was increased, substantially increased yields could result.

Populations of bluegill and redear appear to be increasing and should increase yields. Spotted bass (*Micropterus punctulatus*), introduced in small numbers in late 1970, should add another littoral predator intermediate between the smallmouth and largemouth, if the introduction is successful.

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APPENDIX 1—**Largemouth Bass Catch Statistics and Length Frequencies**

	1965	1966	1967	1968	1969	1970	1971	1972
Catch/angler hour	*0.24	0.27	0.36	0.33	0.14	0.13	0.20	0.10
Estimated annual catch	4,388	7,062	7,682	3,582	2,300	1,937	2,788	1,203
Catch/net day	3.1	1.3	1.3	1.7				
Total net catch	25	16	10	20				

* June data only.

Fork length (inches)	Year*							
	1965	1966	1967	1968	1969	1970	1971	1972
4.0- 4.9	0	0	0	0	0	0	0	0
5.0- 5.9	182	45	2	10	1	3	0	0
6.0- 6.9	583	2,780	93	25	7	13	11	0
7.0- 7.9	202	1,882	828	27	13	46	16	2
8.0- 8.9	90	158	568	66	110	36	48	7
9.0- 9.9	104	30	449	293	435	57	83	21
10.0-10.9	91	14	148	270	348	130	209	38
11.0-11.9	53	8	34	61	87	135	184	48
12.0-12.9	22	11	7	30	156	270	106	168
13.0-13.9	6	30	5	10	162	150	223	129
14.0-14.9	10	23	12	5	55	49	178	61
15.0-15+	0	27	54	17	35	59	120	136

* Creel census data only.

APPENDIX 2—**Smallmouth Bass Catch Statistics and Length Frequencies**

	1965	1966	1967	1968	1969	1970	1971	1972
Catch/angler hour	*0.01	0.04	0.03	0.01	0.03	0.02	0.05	0.03
Estimated annual catch	248	916	503	309	970	656	1,049	580
Catch/net day	0.0	0.8	0.1	0.2				
Total net catch	0	9	1	2				

* June data only.

Fork length (inches)	*Year							
	1965	1966	1967	1968	1969	1970	1971	1972
4.0- 4.9	0	0	0	0	0	0	0	0
5.0- 5.9	14	1	1	5	2	2	0	1
6.0- 6.9	33	43	2	15	5	6	1	1
7.0- 7.9	41	77	5	3	22	9	26	0
8.0- 8.9	13	263	15	3	83	16	103	21
9.0- 9.9	1	69	82	11	90	25	120	53
10.0-10.9	0	32	66	8	199	45	133	40
11.0-11.9	0	3	23	7	57	26	52	53
12.0-12.9	0	1	12	17	14	72	19	94
13.0-13.9	4	0	4	15	6	74	44	57
14.0-14.9	0	1	0	3	11	14	40	15
15.0-15+	0	2	1	1	11	14	12	31

* Creel census data only.

APPENDIX 3—**Green Sunfish Catch Statistics and Length Frequencies**

	1965	1966	1967	1968	1969	1970	1971	1972
Catch/angler hour	0.08	0.15	0.12	0.09	---	0.02	0.02	0.02
Estimated annual catch	1,054	1,355	1,603	420	380	229	139	200
Catch/net day	8.4	9.1	8.5	2.9				
Total net catch	67	109	68	35				

	Year*							
Fork length (inches)	1965	1966	1967	1968	1969	1970	1971	1972
4.0– 4.9	4	130	100	12	62	15	16	8
5.0– 5.9	65	399	161	14	91	21	22	20
6.0– 6.9	146	336	131	16	42	27	17	26
7.0– 7.9	68	112	30	2	2	7	6	10
8.0– 8.9	3	2	3	0	0	3	1	4
9.0– 9.9	0	0	1	0	0	0	0	2

* Creel census data only.

APPENDIX 4—**Bluegill Catch Statistics and Length Frequencies**

	1965	1966	1967	1968	1969	1970	1971	1972
Catch/angler hour	0.00	0.04	0.04	0.18	---	0.21	0.40	0.05
Estimated annual catch	33	363	507	754	3,347	2,714	2,263	886
Catch/net day	2.3	1.6	4.1	10.4				
Total net catch	18	19	33	125				

	Year*							
Fork length (inches)	1965	1966	1967	1968	1969	1970	1971	1972
4.0– 4.9	1	31	39	18	347	99	104	7
5.0– 5.9	0	69	37	37	705	206	249	69
6.0– 6.9	5	103	26	18	365	198	166	89
7.0– 7.9	3	24	61	17	124	75	93	42
8.0– 8.9	1	6	33	19	24	16	15	8
9.0– 9.9	0	0	3	7	8	5	3	0
10.0–10.9	0	0	0	2	1	0	1	0
11.0–11.9	0	0	0	0	1	0	0	0

* Creel census data only.

APPENDIX 5—**Redear Sunfish Catch Statistics and Length Frequencies**

	1965	1966	1967	1968	1969	1970	1971	1972
Catch/angler hour	0.00	0.00	0.00	0.04	---	0.05	0.09	0.14
Estimated annual catch	0	7	22	184	1,136	1,057	1,303	1,874
Catch/net day	0.0	2.6	1.9	6.9				
Total net catch	0	31	15	55				

	Year*							
Fork length (inches)	1965	1966	1967	1968	1969	1970	1971	1972
4.0– 4.9	0	0	0	0	10	10	3	0
5.0– 5.9	0	1	0	1	64	34	51	73
6.0– 6.9	0	2	1	9	189	48	118	133
7.0– 7.9	0	1	1	7	216	140	135	173
8.0– 8.9	0	2	2	0	96	137	169	146
9.0– 9.9	0	1	7	1	21	20	25	20
10.0–10.9	0	0	4	5	10	3	3	2
11.0–11.9	0	0	0	0	0	0	1	0

* Creel census data only.

APPENDIX 6—**Black Crappie Catch Statistics and Length Frequencies**

	1965	1966	1967	1968	1969	1970	1971	1972
Catch/angler hour	0.00	0.00	0.00	0.00	---	0.07	0.43	0.08
Estimated annual catch	4	9	16	17	40	418	2,296	398
Catch/net day	0.0	0.2	0.1	0.3				
Total net catch	0	2	1	4				

	Year*							
Fork length (inches)	1965	1966	1967	1968	1969	1970	1971	1972
5.0– 5.9	0	0	0	1	0	0	1	0
6.0– 6.9	0	0	0	0	0	24	28	2
7.0– 7.9	0	0	0	0	1	43	313	17
8.0– 8.9	0	0	0	0	2	20	241	14
9.0– 9.9	0	3	0	3	8	22	176	20
10.0–10.9	0	0	4	2	9	32	111	87
11.0–11.9	0	0	2	0	0	21	7	52
12.0–12.9	0	0	3	0	0	4	5	13
13.0–13.9	0	0	2	0	1	0	2	1

* Creel census data only.

APPENDIX 7—**White Catfish Catch Statistics and Length Frequencies**

	1965	1966	1967	1968	1969	1970	1971	1972
Catch/angler hour	---	---	---	---	---	---	---	---
Estimated annual catch	10	105	111	42	89	326	186	240
Catch/net day	2.4	7.4	14.6	1.3				
Total net catch	19	89	117	103				

Fork length (inches)	Year*			
	1965	1966	1967	1968
6.0– 6.9	0	4	8	2
7.0– 7.9	6	10	9	7
8.0– 8.9	6	22	18	13
9.0– 9.9	12	15	29	0
10.0–10.9	9	17	23	20
11.0–11.9	2	14	13	9
12.0–12.9	5	8	7	12
13.0–13.9	3	10	2	7
14.0–14.9	0	7	4	1
15.0–15+	0	7	1	2

* Netting data only.

APPENDIX 8—**Brown Bullhead Catch Statistics and Length Frequencies**

	1965	1966	1967	1968	1969	1970	1971	1972
Catch/angler hour	---	---	---	---	---	---	---	---
Estimated annual catch	56	56	60	89	30	30	10	0
Catch/net day	8.3	4.3	12.4	3.3				
Total net catch	66	51	99	39				

Fork length (inches)	Year*			
	1965	1966	1967	1968
6.0– 6.9	0	1	0	0
7.0– 7.9	3	0	0	0
8.0– 8.9	7	3	1	1
9.0– 9.9	9	7	1	0
10.0–10.9	11	16	6	5
11.0–11.9	13	24	29	12
12.0–12.9	4	10	26	20
13.0–13.9	0	1	0	8

* Netting data only.

APPENDIX 9—**Black Bullhead Catch Statistics and Length Frequencies**

	1965	1966	1967	1968	1969	1970	1971	1972
Catch/angler hour	---	---	---	---	---	---	---	---
Estimated annual catch	46	160	217	264	73	234	79	55
Catch/net day	29.4	24.0	10.1	10.3				
Total net catch	235	288	81	123				

Fork length (inches)	Year*			
	1965	1966	1967	1968
6.0– 6.9	6	0	0	0
7.0– 7.9	11	2	1	2
8.0– 8.9	22	4	0	0
9.0– 9.9	19	22	5	4
10.0–10.9	26	45	14	4
11.0–11.9	18	86	49	57
12.0–12.9	14	23	35	75
13.0–13.9	2	0	0	3
14.0–14.9	0	0	0	1

* Netting data only.

APPENDIX 10—**Channel Catfish Catch Statistics and Length Frequencies**

	1965	1966	1967	1968	1969	1970	1971	1972
Catch/angler hour	---	---	---	---	---	---	---	---
Estimated annual catch	0	6	16	5	9	23	47	224
Catch/net day	1.3	2.5	2.1	0.3				
Total net catch	10	30	17	3				

Fork length (inches)	Year*			
	1965	1966	1967	1968
6.0– 6.9	1	4	0	0
7.0– 7.9	4	1	0	0
8.0– 8.9	3	9	0	0
9.0– 9.9	1	5	1	1
10.0–10.9	0	2	0	0
11.0–11.9	0	0	1	0
12.0–12.9	0	1	3	0
13.0–13.9	0	1	1	0
14.0–14.9	0	3	4	1
15.0–15+	0	1	8	2

* Netting data only.

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HARVEST, MORTALITY, AND COST OF THREE DOMESTIC STRAINS OF TAGGED RAINBOW TROUT STOCKED IN LARGE CALIFORNIA IMPOUNDMENTS[1]

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Rainbow trout of three strains were tagged and planted in four California impoundments: Lake Berryessa, Merle Collins Reservoir, Pine Flat Lake, and Lake Isabella. Coleman Kamloops consistently outperformed the Shasta and Whitney strains. They had similar mean annual exploitation rates, the highest survival rates, highest ratio of weight returned to weight planted, and lowest cost/lb to the angler's creel compared to the other strains. Their superior performance is attributed to their limnetic distribution and their decreased vulnerability to shore anglers shortly after planting. Where emigration into downstream areas occurred Whitney rainbows emigrated at the highest rate, followed in order by the Coleman Kamloops and Shasta strains. No difference in growth rate occurred among the three strains.

INTRODUCTION

California has many large reservoirs at low elevations with a history of poor limnetic fish yields. These lakes typically have limnological conditions suitable for salmonids, abundant threadfin shad (*Dorosoma petenense*) populations for forage, and few predatory limnetic competitors. Some support low populations of wild rainbow trout (*Salmo gairdneri*) which show an excellent growth rate, frequently an inch per month or greater. Generally natural recruitment is not sufficient to produce a satisfactory salmonid fishery.

Increased "catchable" trout (fish $\gtrsim$ 7.5 inches) production, resulting from a hatchery expansion permitted the California Department of Fish and Game to begin a greatly increased stocking of rainbow trout into some of these reservoirs to increase overall fish yields and improve angling quality. However, a pilot study in 1968 at Lake Berryessa had shown substantial differences in survival and cost to the angler's creel between the Coleman Kamloops strain and the Mt. Whitney strain (Rawstron 1972). Since California's hatchery system has developed a number of strains of rainbow trout to make "catchables" available all year for its "put-and-take" fisheries and to provide for a diversity of management options, differences among these strains had to be tested to find the most economical fish to stock. Furthermore, the possibility that "hybrids" between strains might produce an even better fish for this program needed examination. Therefore, I began this study in 1969 with the objective to find an existing strain, or to develop through hybridization a new strain of rainbow trout which would:

[1] Accepted for publication April 1973. This work was performed as part of Dingell-Johnson Project California F-18-R, "Experimental Reservoir Management", supported by Federal Aid to Fish Restoration funds.

1) Reach a size large enough to stock (4/lb about May, after approximately 1 year in a hatchery).
2) Have high survival for relatively long periods after stocking.
3) Have high total harvest rates (50% or higher).
4) Be late maturing and long lived with a resultant buildup of older age classes in the reservoir which would provide substantial numbers of trophy trout 5 lb or larger.
5) Have low initial harvest rates.
6) Be genetically stable.
7) Be economically feasible to plant (low cost/lb to the angler's creel).

This report compares exploitation, survival, growth rates, and cost to the angler's creel of the parent strains of planted trout for the first 2 years of a 4-year program. Because of difficulties in consistently obtaining hybrids and because of a total loss of all trout from a heavy copepod infestation at San Joaquin Hatchery which postponed one experiment, tests of interracial hybrids were too few to be meaningful in 1969 and 1970. Information on these will be presented in a final report.

DESCRIPTION OF STUDY WATERS

Four study waters were chosen: Lake Berryessa, Napa County; Isabella Lake, Kern County; Pine Flat Lake, Fresno County; and Merle Collins Reservoir, Yuba County. All are close to population centers, support high angling pressure, are limnologically suitable for salmonids, and have abundant threadfin shad populations. The littorally oriented black basses (*Micropterus salmoides, M. dolomieui*) and bluegill (*Lepomis macrochirus*) dominate the fisheries, although in some years crappie (*Pomoxis nigromaculatus, P. annularis*) are important as limnetic predators during summer. In addition, they all contain similar species of ictalurids and cyprinids. Merle Collins Reservoir, a 1,000-acre impoundment, has been previously described by Rawstron (1971). Rawstron and Hashagen (1972) and Hashagen (1973) provided other details of this fishery. Rawstron (1972) described Lake Berryessa, a 20,000-acre reservoir and certain aspects of that fishery. Pine Flat, a 6,000-acre reservoir, has been described by Goodson (1965). Lake Isabella is a 12,000-acre reservoir, located on the Kern River and is used primarily for irrigation and domestic water. When rainfall is low in the drainage, this lake becomes marginal trout habitat due to high surface temperatures and low dissolved oxygen in the hypolimnion. Most years, however, it can support trout and was chosen to serve the large population of southern California. Midsummer limnological conditions of all test lakes except Merle Collins Reservoir have been described (Rawstron 1964). Chamberlain (1972) presented extensive limnological information on this lake.

METHODS AND MATERIALS

Three strains of rainbow trout were chosen for the first series of experiments. Strains tested were the two previously used at Lake Berryessa and Shasta strain. Rawstron (1972) briefly described the history of Coleman Kamloops while Cordone and Nicola (1970) gave extensive descriptions of the Shasta and Whitney strains.

In the three larger lakes, approximately 400 of each strain planted were tagged with Swedish trailer tags (modified Carlin tags). This tag was considered the best tag to use since it had shown a low shedding rate, long retentivity, low tagging mortality, and a small effect on growth (Nicola and Cordone 1969). These authors gave excellent descriptions of this tag and its application. Rawstron (1972) also used this tag in the pilot study at Lake Berryessa. Tags were serially numbered and had a legend offering $5 for their return.

At Merle Collins Reservoir 100 of each strain bore similar tags, but offered no reward for their return. Tags were recovered during a 4 days/week completed effort creel survey which included all weekends and National holidays and two rotating weekdays per week. All fish of each strain were further identified with a specific fin clip to determine differences in growth rates and the proportion of tagged and untagged trout by strain in the creel. Harvest rates, as determined from both tags and marks, differed by only 2%, so only tag returns were used to determine mortality estimates at Merle Collins Reservoir.

While it was assumed that growth of the various strains would be similar within lakes, this was tested further by clipping fins from all fish for each lake. Growth difference between strains was then determined from weekend creel censuses in October at Lake Berryessa and Pine Flat Lake. The creel census was usually conducted until at least 30 fish of each strain were weighed and measured. Mean monthly weights from the creel survey at Merle Collins, in which all fish were weighed and measured were generally substituted from the same year to compute cost/lb to the angler's creel for the various lakes.

The pilot experiment at Lake Berryessa in 1968 showed that the major reason for the success of Coleman Kamloops resulted from higher returns after October 1, when fish had increased their planted weight by 400 to 700% (Rawstron 1972). These fish had left the littoral zone where they became less vulnerable or available to shore anglers. Therefore, in this study, monthly tag returns were catalogued to determine the percentages of the total catch returned by month. When anglers did not initially provide the date of their catch, they were immediately contacted for this information.

Survival and weighted mean annual exploitation rates (Ricker 1958) were determined by considering tags returned from 0 to 365 days after the median date of planting as first year returns. Second year returns were those tags from fish recaptured between 366 and 730 days, etc. These estimates assumed that all tags from the three larger lakes were returned for the $5 reward.

Ideally, all fish should have been stocked on the same day, but practically and logistically this was impossible. Therefore, the planting date used for purposes of mortality and survival estimates was the median date between starting and finishing. In addition, since the fish were separated by strain in the hatchery ponds, loading operations were rendered more difficult. However, an attempt was made to stock an equal number of each strain each planting day. This routine was generally followed. Since the total elapsed time from start to finish was usually less than 10 days, only slight errors could occur in survival and mortality estimates.

The public was made aware of the program through talks with local sportsmen's and commercial groups, as well as releases to local newspapers and television and radio stations. Posters, which described the program and informed anglers where to return tags, were prominently displayed at each lake and at all the resorts, marinas, and local businesses at each lake. Franked envelopes were also placed at these businesses.

All fish for the program were "pond run" fish with no active attempt to select for faster growing or more aggressive fish. Since, however, they usually came from normal production for the "catchable" trout program, they were frequently graded and thinned to provide space for oncoming fish. To reduce variability between hatcheries, all fish were originally scheduled to be reared at Darrah Springs Hatchery (Shasta County), but interference with normal hatchery procedures and production necessitated rearing the fish in hatcheries closer to the study lakes. Thus, in 1969 rainbow trout for Merle Collins and Lake Berryessa were reared at Darrah Springs Hatchery, while trout for Isabella and Pine Flat Lakes were reared at San Joaquin (Fresno County) and American River Hatcheries (Sacramento County), respectively. In 1970 American River Hatchery reared trout for Merle Collins Reservoir and Lake Berryessa and Pine Flat Lake. Fish planted in Lake Isabella in 1970 were reared at Kern River Hatchery (Kern County). No evaluation of the effects of rearing fish in different hatcheries was made.

Unpublished data from both Pine Flat Lake in 1963 and Merle Collins Reservoir in 1968 indicated that most wild rainbow trout between 8 and 10 inches FL had begun to utilize threadfin shad as food. These trout had substantially higher condition factors than smaller trout, whose stomachs generally contained small amounts of zooplankton and debris. Therefore, in order to insure early utilization of shad, fish approximately 8 to 10 inches were planted (Figure 1). May was selected as the planting date. This month coincided with the appearance of larval shad (Kjelson 1972) which provided a ready supply of food and stimulated early growth of trout. In addition, rising water temperatures forced trout away from shore into cooler, deeper waters, thus reducing early fishing mortality from efficient shore anglers. However, interference with normal hatchery procedures frequently necessitated planting earlier during the first 2 years of the study.

RESULTS

Lake Berryessa—1969

Mortality and Survival

Anglers returned 170 tags (42.6%) from Shasta rainbow, 138 (34.7%) Whitney, and 170 (43.0%) Coleman Kamloops through December 31, 1972. Mean annual exploitation rates ranged from 0.314 for Whitney rainbow to 0.396 for Shasta strain (Table 1). Estimated annual survival rate of Coleman Kamloops trout (0.156) was greater than twice that for Shasta (0.076), while their natural (0.472) rate was the lowest. Of the total returns for all years anglers returned tags from 109 Coleman Kamloops (64.1%) before October 1 of the year of planting, while they harvested 130 (76.5%) of the Shasta (Table 2, Figure 2). At least one tagged fish of each strain was caught in the fall of the third year after stocking.

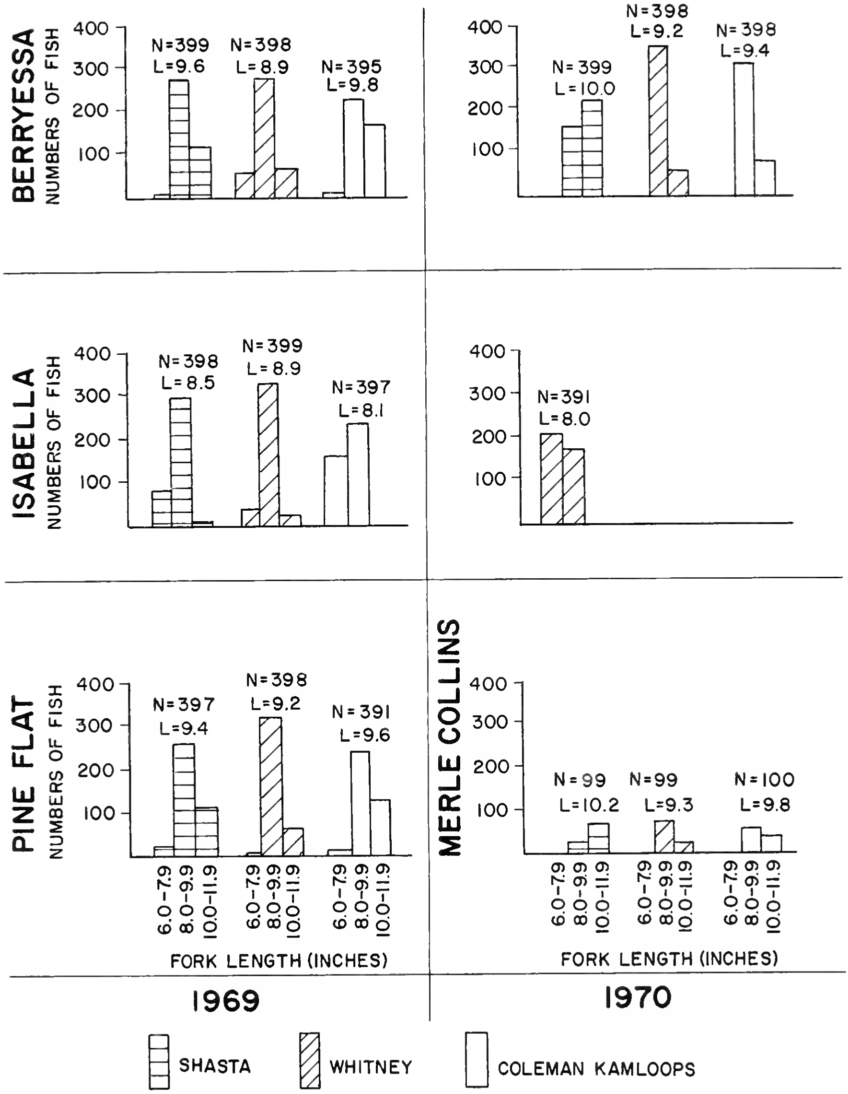

FIGURE 1. Length frequencies of the strains of rainbow trout planted in Lake Berryessa and Lake Isabella in 1969 and 1970, Merle Collins Reservoir in 1970, and Pine Flat Lake in 1969.

Growth, Weight Returns, and Cost

The October 1969 creel survey revealed that all strains had achieved similar growth since planting with no significant differences ($\alpha = 0.05$). Shasta strain rainbow averaged 0.99 (C.I. = 0.91 to 1.07 lb), while Coleman Kamloops were 0.95 (C.I. = 0.87 to 1.02 lb). Whitney strain had an intermediate mean weight of 0.97 (C.I. = 0.90 to 1.04 lb). These observed weights and those obtained in the October 1970 creel survey were comparable to those observed in the creel survey at Merle Collins (Figure 3). Therefore, mean monthly weights from Merle Collins Reservoir were assigned to Lake Berryessa trout to determine the weight returned per pound of trout planted. These weights were then multiplied by the monthly returns to obtain the total weight of tagged trout returned.

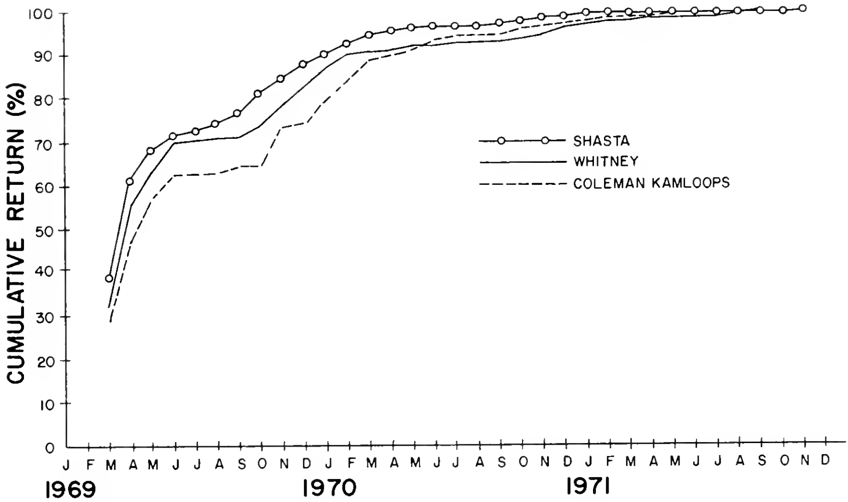

FIGURE 2. Cumulative percentages of tag returns by month for three strains of tagged rainbow trout planted in Lake Berryessa in 1969.

TABLE 1—Tag Returns, Mortality and Survival Rates, and Cost/Lb to the Angler's Creel of Tagged Rainbow Trout Planted in Lake Berryessa in 1969 and 1970

Strain	Total returns	Number tagged	Percent total harvest	Annual rates: Fishing mortality (u)	Annual rates: Survival (s)	Annual rates: Natural mortality (v)	Percent total returns before Oct. 1	Percent Wt. returned / Wt. planted	Cost/lb* to angler's creel
1969									
RTS†	170	399	42.6	0.396	0.076	0.528	76.5	82.2	$0.99
RTW	138	398	34.7	0.314	0.104	0.582	71.0	80.0	$1.03
RTK-C	170	395	43.0	0.372	0.156	0.472	64.1	95.0	$0.86
Total	478	1,192							
1970									
RTS	117	399	29.3	0.279	0.051	0.670	66.7	53.3	$1.28
RTW	141	398	35.4	0.316	0.122	0.562	36.9	118.7	$0.58
RTK-C	130	398	32.7	0.261	0.254	0.485	27.7	128.8	$0.53
Total	388	1,195							

* Based on cost/lb of $0.814 (Schafer 1970) and $.683 (Bruley 1971) to produce in the hatchery in 1969 and 1970, respectively.
† RTS = Shasta strain
RTW = Whitney strain
RTK-C = Coleman Kamloops

TABLE 2—**Tag Returns by Strain, Month, and Year for Three Strains of Rainbow Trout Planted in Lake Berryessa in 1969**

Period	Number returned								
	Shasta			Whitney			Coleman Kamloops		
	Year 1 1969-70	Year 2 1970-71	Year 3 1971-72	Year 1 1969-70	Year 2 1970-71	Year 3 1971-72	Year 1 1969-70	Year 2 1970-71	Year 3 1971-72
March 1*	66	4	0	44	1	0	48	7	1
April	38	1	0	32	0	1	30	2	0
May	12	2	0	11	2	0	18	2	1
June	5	0	0	9	0	0	10	4	0
July	3	0	0	1	1	0	1	1	0
August	2	0	0	1	0	1	0	0	0
September	4	1	0	0	0	1	2	0	1
October	8	1	0	3	1	0	0	3	0
November	6	2	1	7	1	0	16	1	0
December	5	0	0	6	3	0	2	2	0
January	4	1	0	6	1	0	9	0	0
February	4	0	0	4	1	0	8	1	0
Total	157	12	1	124	11	3	144	23	3

* Median planting date.

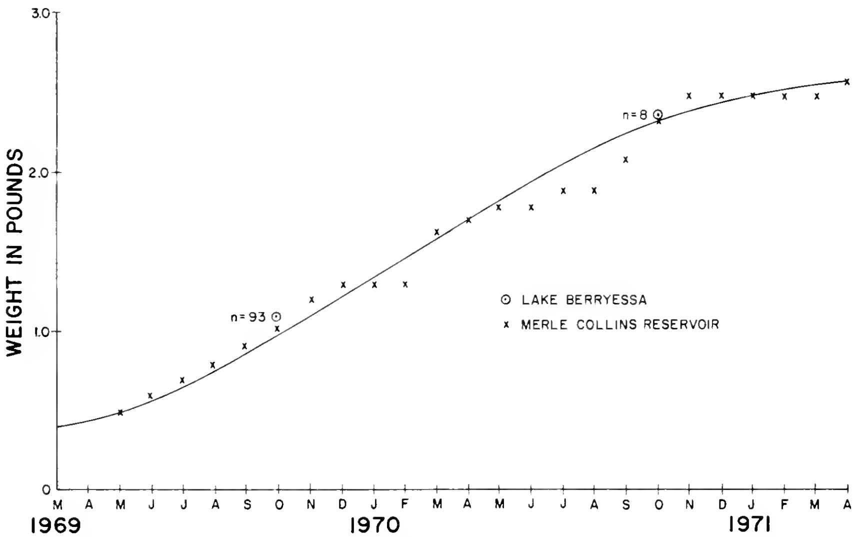

FIGURE 3. Mean monthly growth of all strains combined from 1969 creel surveys at Merle Collins Reservoir and Lake Berryessa.

Shasta, Whitney, and Coleman Kamloops returned 82.2%, 80.0%, and 95.0% of the total weight planted, respectively (Table 1). Based on $.814/lb to produce and plant these trout (Schafer 1970), the cost/lb to the angler's creel was $.99, $1.03 and $.86 for these strains, respectively.

Lake Berryessa—1970

Mortality and Survival

Anglers harvested 117 (29.3%) Shasta rainbows, 141 Whitney (35.4%), and 130 (32.7%) Coleman Kamloops from April 1, 1970 to December 31, 1972. Whitney rainbows had the highest mean annual exploitation rate of 0.316, followed by the Shasta at 0.279 and Coleman Kamloops with 0.261 (Table 1). The survival rate of 0.254 for Coleman Kamloops was approximately five times that for Shasta (0.051) and twice that for Whitney (0.122) trout. As in 1969, natural mortality was substantially lower for Coleman Kamloops than the other strains. The monthly returns were substantially lower for Coleman Kamloops during the April-through-September period following stocking, while Shasta strain rainbow again had the highest initial return of 78 (66.7%) (Table 3, Figure 4). Whitney strain again was intermediate.

TABLE 3—Tag Returns by Strain, Month, and Year for Three Strains of Rainbow Trout Planted in Lake Berryessa in 1970

	Number returned								
	Shasta			Whitney			Coleman Kamloops		
Period	Year 1 1970–71	Year 2 1971–72	Year 3 1972–73	Year 1 1970–71	Year 2 1971–72	Year 3 1972–73	Year 1 1970–71	Year 2 1971–72	Year 3 1972–73
April 1	41	2	0	19	1	1	16	2	0
May	25	1	0	13	1	1	11	4	0
June	5	0	0	14	2	0	3	2	0
July	4	1	0	3	1	0	3	3	0
August	2	0	0	3	0	0	1	1	0
September	1	0	0	0	0	0	2	0	0
October	6	0	0	11	0	0	9	4	0
November	9	2	0	16	2	0	21	6	0
December	9	0	0	10	4	0	12	2	0
January	6	0	--	11	2	--	9	4	--
February	3	0	--	12	2	--	8	2	--
March	0	0	--	12	0	--	2	3	--
Total	111	6	0	124	15	2	97	33	0

Growth, Weight Returns, and Cost

Again the Merle Collins creel survey showed all strains of trout grew at essentially the same rate and achieved weights comparable to those recorded in 1970. Mean size of all strains combined in mid-October 1970 at Lake Berryessa was 1.07 lb with a confidence limit of 0.96 to 1.18 lb ($\alpha = 0.05$). By October 1971, trout at Lake Berryessa planted in April 1970 had a mean weight of 2.44 lb (Figure 5). These weights again were essentially the same as those recorded in the creel survey at Merle Collins, so the mean monthly weight from this lake was assigned to determine the weight returns. Total weight of each strain planted was 159 lb, 134 lb, and 132 lb for Shasta, Whitney and Coleman Kamloops, respectively. Anglers returned 84.7 lb, 159.0 lb and 170.0 lb for the strains listed above. Shasta rainbow were returned at 53.3% by weight, while Whitney and Coleman Kamloops had 118.7%

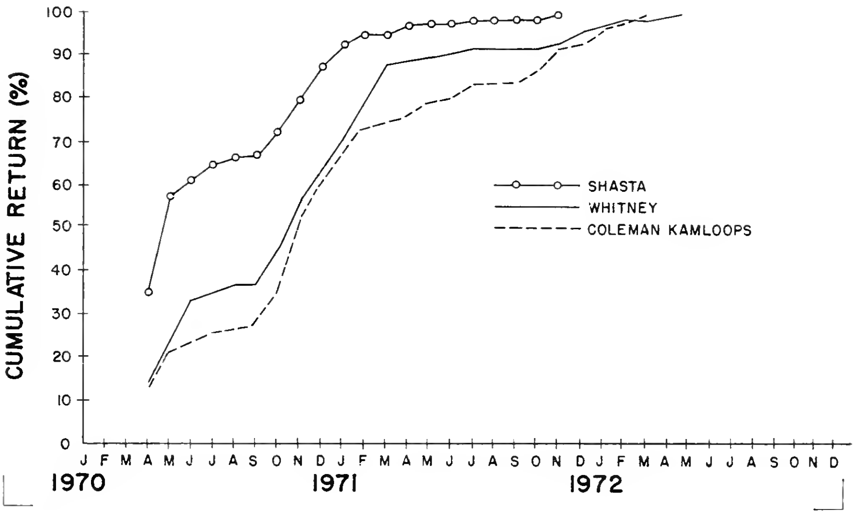

FIGURE 4. Cumulative percentages of tag returns by month for three strains of tagged rainbow trout planted in Lake Berryessa in 1970.

and 128.8%, respectively. Hatchery costs of planting and producing these trout amounted to $.683/lb (Bruley 1971). Costs/lb to the angler's creel were: Shasta, $1.28; Whitney, $.58; and Coleman Kamloops, $.53.

Merle Collins—1970

Mortality and Survival

Mean annual estimated mortality due to angling ranged from 0.400 to 0.444 for the three strains (Table 4). Survival rate ranged from

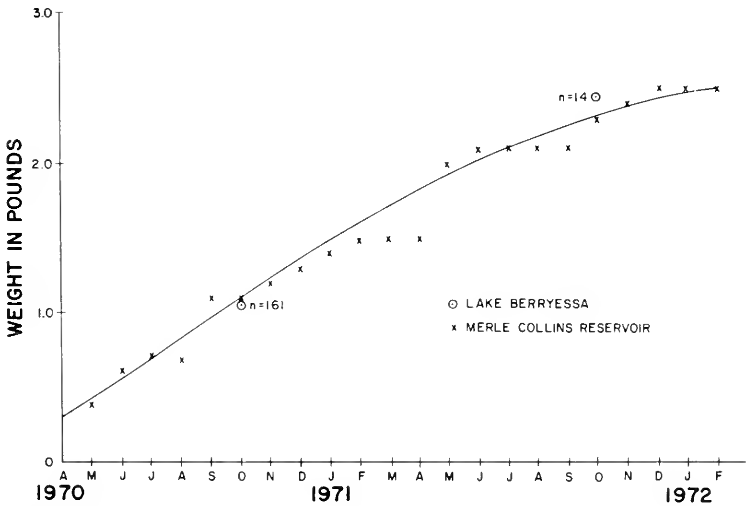

FIGURE 5. Mean monthly growth of all strains combined from 1970 creel surveys at Merle Collins Reservoir and Lake Berryessa.

0.000 for Shasta to 0.050 for Coleman Kamloops. Total annual mortality was nearly complete, ranging from 0.950 for Coleman Kamloops to 1.000 for Shasta rainbow. Annual natural mortalities were similar, averaging 0.556 for all strains.

Because only nonreward tags were used and 3 weekdays per week were not censused, the mortality rates were consistently underestimated. In addition, no corrections were made for nonresponse for anglers who did not return nonreward tags caught on noncensus days. The creel survey, however, showed that anglers caught marked fish of the same strains at a rate only 2% more than the tagged fish. Survival as determined from marked fish was also low and did not differ substantially from that for tagged fish.

Shasta strain rainbow again had the highest early harvest rate with 37 (84.1%) of their total returns (44) coming before October, while Coleman Kamloops had the lowest return of 22 (52.4%) (Table 5, Figure 6). All three strains suffered the heaviest angling mortality during the week following their introduction.

Growth, Weight Returns, and Cost

The creel census showed insignificant growth differences between the three strains. The points plotted in Figure 5 and the monthly returns in Table 5 were used to calculate the percentage of weight returned to weight planted and the cost. Tagged Shasta rainbows weighed a total of 43.6 lb; Whitney, 32.5 lb; and Coleman Kamloops, 38.1 lb when planted. Anglers caught 54.2% of the Shasta strain by weight, while the Coleman Kamloops and the Whitney strains returned 104.2% and 96.3%, respectively (Table 4). The cost/lb to the angler's creel was $1.26 for the former, while the latter two were $.66 and $.71, respectively.

TABLE 4—Tag Returns, Mortality and Survival Rates, and Cost/Lb to the Angler's Creel of Tagged Rainbow Trout Planted in Merle Collins Reservoir in 1970

Strain	Total returns	Number tagged	Percent total harvest	Annual rates: Fishing mortality (u)	Annual rates: Survival (s)	Annual rates: Natural mortality (v)	Percent total returns before Oct. 1	Percent Wt. returned / Wt. planted	Cost/lb* to angler's creel
1970									
RTS†	44	99	44.4	0.444	0.000	0.556	84.1	54.2	$1.26
RTW	41	99	41.4	0.414	0.024	0.562	61.9	96.3	$0.71
RTK-C	40	100	40.0	0.400	0.050	0.550	52.4	104.2	$0.66
Total	125	298							

* Based on a cost/lb. of $.683 to produce in the hatchery (Bruley 1971).
† RTS = Shasta strain
RTW = Whitney strain
RTK-C = Coleman Kamloops

TABLE 5—**Tag Returns by Strain, Month, and Year for Three Strains of Rainbow Trout Planted in Merle Collins Reservoir in 1970**

Period	Number returned					
	Shasta		Whitney		Coleman Kamloops	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
May 24, 1970*	35	0	23	0	19	0
June	1	0	1	0	1	0
July	0	0	0	0	0	0
August	0	0	0	0	0	1
September	1	0	2	0	2	0
October	7	0	6	1	11	0
November	0	0	3	0	3	1
December	0	0	1	0	0	0
January	0	0	0	0	0	0
February	0	0	2	0	2	0
March	0	0	2	0	1	0
April	0	0	1	0	1	0
Total	44	0	41	1	40	2

* Median planting date.

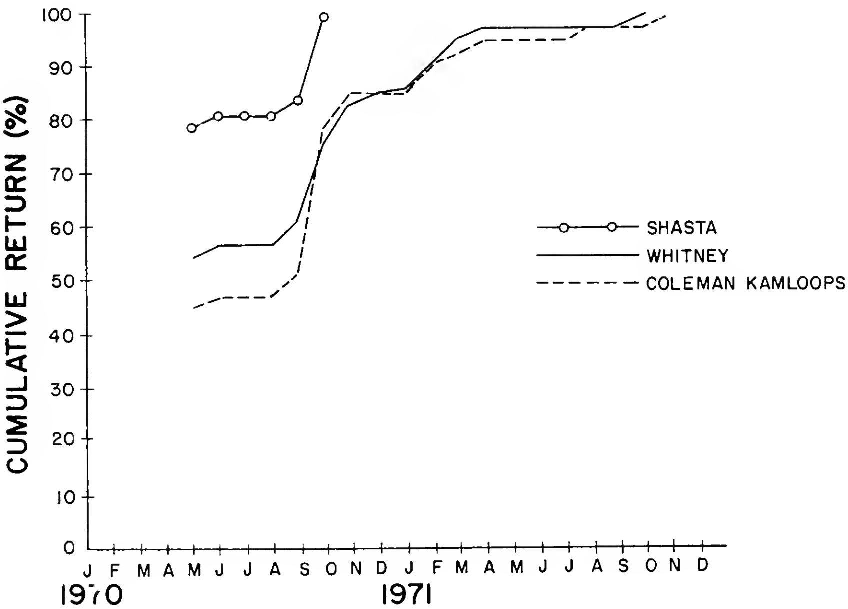

FIGURE 6. Cumulative percentages of tag returns by month for three strains of tagged rainbow trout planted in Merle Collins Reservoir in 1970.

Pine Flat Lake—1969

Mortality and Survival

The water year of 1969 produced 191% more rainfall than average in the Kings River drainage (U.S. Army Corps of Engineers precipitation records). Consequently, the surface elevation of Pine Flat Lake remained nearly constant throughout the spring runoff period and spilled. Large volumes of water were released to maintain flood control above the dam. Many planted trout emigrated into the river and irrigation canals below. All anglers who did not indicate where they caught their fish were immediately contacted for this information. Much emigration occurred in late May through August (Table 6). It is assumed that fish harvested below the dam grew at a lesser rate and were probably more vulnerable to the anglers. Therefore, returns from the river have been eliminated from estimates of mortality and cost. Whitney strain had the highest percentage of the total returns (26.0%) from the river, while the Shasta strain had the lowest (15.4%) from the river. Coleman Kamloops were intermediate at 22.1%.

Anglers harvested a total of 143 (36.0%) tagged Shasta rainbow, 134 (33.7%) Whitney and 134 (34.3%) of the Coleman Kamloops from the lake (Table 7). Shasta strain showed the highest mean exploitation rate (0.357), but did not differ significantly from the 0.327 for Whitney or Coleman Kamloops strains. Coleman Kamloops again had the highest survival rate (0.061).

Shasta strain again was the most vulnerable in the earlier months after planting (Table 6). No tags were returned from this strain in the second year and only one from the lake was returned in the third year. Anglers returned approximately 94% of all tags from the lake from this strain prior to October 1, 1969 (Figure 7). Whitney and

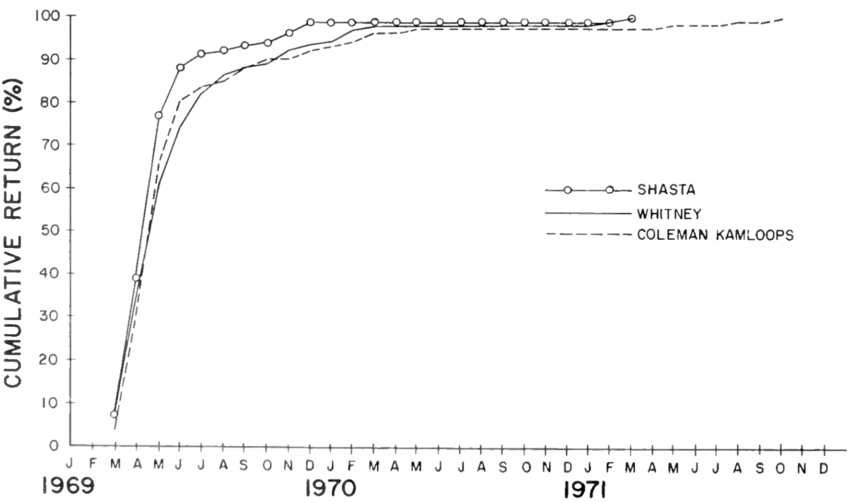

FIGURE 7. Cumulative percentages of tag returns by month for three strains of tagged rainbow trout planted in Pine Flat Lake in 1969.

TABLE 6—Tag Returns by Strain, Month, and Year for Three Strains of Rainbow Trout Planted in Pine Flat Lake in 1969 *

Period	Number returned								
	Shasta			Whitney			Coleman Kamloops		
	Year 1 1969–70	Year 2 1970–71	Year 3 1971–72	Year 1 1969–70	Year 2 1970–71	Year 3 1971–72	Year 1 1969–70	Year 2 1970–71	Year 3 1971–72
March 1†	11 (11)	(0)	1 (1)	11 (1)	2 (2)	1 (1)	5 (5)	3 (3)	(0)
April	45 (45)	(0)	(0)	37 (37)	0 (1)	(0)	37 (37)	(0)	(0)
May	55 (57)	(0)	(0)	34 (37)	(0)	(0)	46 (46)	2 (2)	1 (1)
June	16 (28)	(0)	(0)	18 (36)	0 (1)	(0)	20 (38)	(0)	(0)
July	4 (8)	(0)	(0)	10 (30)	(0)	0 (2)	4 (17)	(0)	(0)
August	1 (4)	(0)	(0)	6 (11)	0 (1)	0 (1)	2 (6)	(0)	1 (1)
September	2 (4)	(0)	(0)	2 (4)	0 (1)	(0)	4 (6)	(0)	(0)
October	1 (2)	(0)	0 (1)	2 (4)	(0)	(0)	3 (4)	(0)	1 (1)
November	3 (4)	(0)	(0)	4 (4)	(0)	(0)	(0)	(0)	(0)
December	4 (4)	(0)	(0)	1 (1)	(0)	(0)	3 (3)	(0)	(0)
January	(0)	(0)	(0)	1 (1)	(0)	(0)	1 (1)	(0)	(0)
February	(0)	(0)	(0)	4 (4)	1 (1)	(0)	1 (1)	(0)	(0)
Total	142 (167)	(0)	1 (2)	130 (170)	3 (7)	1 (4)	126 (164)	5 (5)	3 (3)

* Numbers in parentheses include returns from Kings River below Pine Flat Lake.
† Median planting date.

TABLE 7—**Tag Returns, Mortality and Survival Rates, and Cost/Lb to the Angler's Creel of Tagged Rainbow Trout Planted in Pine Flat Lake in 1969 and 1970**

Strain	Total returns*	Number tagged	Percent total harvest	Annual rates: Fishing mortality (u)	Annual rates: Survival (s)	Annual rates: Natural mortality (v)	Percent total returns before Oct. 1	Percent Wt. returned / Wt. planted	Cost/lb† to angler's creel
1969									
RTS‡	143 (26)	397	36.0	0.357	0.007	---	93.7	54.2	$1.49
RTW	134 (47)	398	33.7	0.327	0.030	---	88.1	65.9	$1.18
RTK-C	134 (38)	391	34.3	0.327	0.061	---	88.1	65.1	$1.19
Total	411 111	1,186							
1970									
RTS	198	398	49.8	0.482	0.030	0.488	89.9	90.4	$0.91

* Figures in parentheses represent tags returned from fish caught in Kings River and irrigation canals below Pine Flat Lake.
† Based on cost/lb of $0.814 (Schafer 1970).
‡ RTS = Shasta strain
RTW = Whitney strain
RTK-C = Coleman Kamloops

Coleman Kamloops had identical percentages (88.1%) during this same period.

Growth, Weight Returns, and Cost

The October creel survey produced little information on growth. Only 38 fish of all strains were seen due to low angling pressure. Those fish weighed, however, were similar to those at Merle Collins and Lake Berryessa. Moreover, weights reported by anglers closely paralleled similar data from Merle Collins Reservoir and Lake Berryessa in 1969. Therefore, the same weights were used to calculate weight returns and cost (Figure 3). The weight planted of each strain amounted to 150 lb. Shasta rainbows returned only 54.2% by weight of the tagged trout, while Whitney and Coleman Kamloops strains were nearly identical, 65.9% and 65.1%, respectively. Cost/lb to the angler's creel was $1.49 for Shasta, $1.18 for Whitney and $1.19 for Coleman Kamloops.

Pine Flat Lake—1970

Mortality and Survival

Only Shasta strain rainbow were available for planting in 1970 due to the total destruction of all fish at San Joaquin Hatchery mentioned in the introduction. Anglers harvested 198 of the 398 tagged fish for a total harvest of 49.8% (Table 7). Mean annual exploitation and survival rates were 0.482 and 0.030, respectively. Anglers returned 6 tags in the second year. Natural mortality again exceeded fishing mortality and, when combined, yielded a total annual mortality rate of 0.970.

Anglers harvested 89.9% of the total tagged from May through September 1970. Most of these were harvested during the 2 months after planting (Figure 8).

Growth, Weight Returns, and Cost

Planted trout had a mean weight of 1.21 lb (C.I. = 1.10 to 1.32 lb, $\alpha = 0.05$) in October 1970. Anglers reported fish averaging 3 lb in June 1971. One specimen seen in the October 1971 census weighed 5.02 lb. It seems apparent that fish from this group grew more rapidly than those at Lake Berryessa and Merle Collins during 1970 and 1971. Therefore, the weights assigned arbitrarily were: May to June 30, 1970, 0.35 lb; July 1 to Sept. 30, 0.75 lb; Oct. 1 to Dec. 31, 1.25 lb; Jan. 1, 1971 to March 31, 2.00 lb; April 1 to June 30, 2.75 lb; July 1 to September 30, 3.75 lb; October 1 to December 31, 4.50 lb. Tagged trout weighed 124.2 lb when planted. Anglers caught 112.2 lb, accounting for 90.4% of the planted weight. Using hatchery costs of \$.814/lb, these fish cost \$.91/lb to the angler's creel.

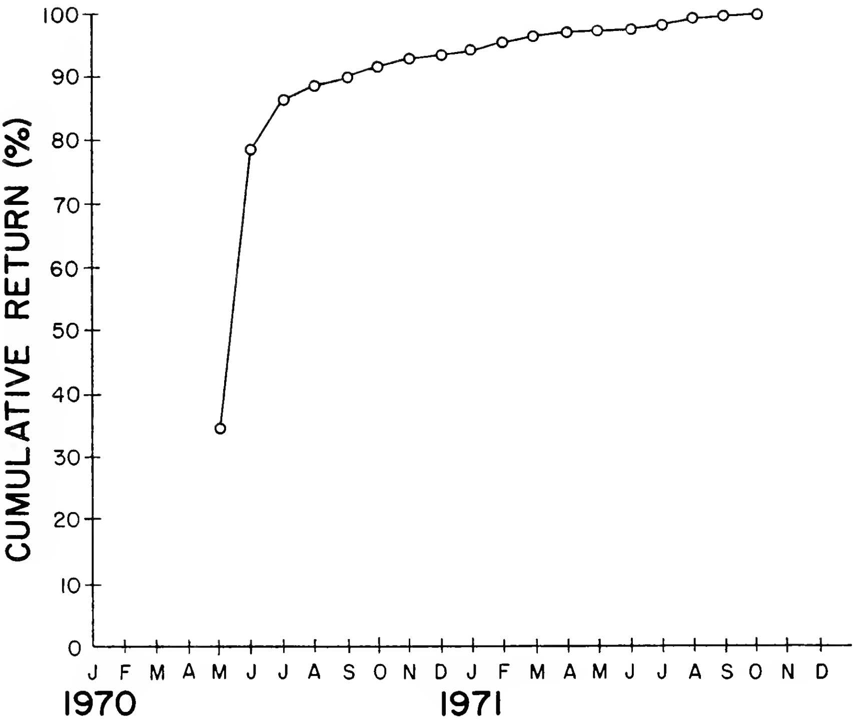

FIGURE 8. Cumulative percentages of tag returns by month for tagged Shasta strain rainbow trout planted in Pine Flat Lake in 1970.

Lake Isabella—1969

The heavy runoff in 1969 noted for Pine Flat Lake similarly affected the experiment at Lake Isabella. Emigration also occurred at this lake and, as at Pine Flat Lake, a higher fraction (0.451) of Whitney tag returns came from anglers fishing downstream areas than both of the other two strains. This value was nearly twice that of Coleman Kamloops (0.238) and three times that of Shasta strain (0.156) (Table 8).

Considering only returns from the lake, anglers harvested 35.4%, 19.8% and 23.4% of the Shasta, Whitney, and Coleman Kamloops strains, respectively, in the first year (Table 9). More than 90% of the total harvest of all three strains occurred during the first 3 months after planting (Table 8, Figure 9) during which time no growth was assumed to occur. Little information was obtained, but reports from wardens and other field personnel in the area indicated that growth of the few fish which did survive far surpassed that noted for the other study lakes. Therefore, cost/lb of all strains was extremely high, and exceeded that for a typical "catchable" program where at least 50% are caught by anglers. Because of the high early harvest and lack of accurate growth data, I did not determine the cost to the angler's creel.

TABLE 8—Tag Returns by Strain, Month, and Year for Three Strains of Rainbow Trout Planted in Lake Isabella in 1969 *

Period	Number returned					
	Shasta		Whitney		Coleman Kamloops	
	Year 1 1969–70	Year 1 1970–71	Year 1 1969–70	Year 2 1970–71	Year 1 1969–70	Year 2 1970–71
April 2†	79 (81)	(0)	21 (22)	(0)	55 (55)	(0)
May	39 (58)	(0)	34 (78)	0 (1)	24 (37)	1 (1)
June	11 (13)	(0)	8 (17)	(0)	7 (19)	(0)
July	3 (6)	(0)	2 (5)	(0)	2 (4)	(0)
August	1 (1)	(0)	3 (6)	(0)	(0)	(0)
September	3 (3)	(0)	3 (6)	(0)	1 (2)	(0)
October	(0)	(0)	(0)	(0)	2 (2)	(0)
November	2 (2)	(0)	5 (5)	(0)	1 (2)	(0)
December	(0)	(0)	1 (1)	(0)	(0)	(0)
January	(0)	(0)	(0)	(0)	(0)	(0)
February	1 (1)	(0)	1 (1)	(0)	(0)	(0)
March	2 (2)	(0)	1 (2)	(0)	(0)	(0)
Total	141 (167)	(0)	79 (143)	0 (1)	92 (121)	1 (1)

* Numbers in parentheses include tagged trout taken in Kern River below Lake Isabella.
† Median planting date.

Lake Isabella—1970

Only Whitney strain was planted this year due to the loss of all fish at San Joaquin Hatchery which was scheduled to produce fish for Lake Isabella. Due to slow growth the fish did not achieve the desired size in the Kern River Hatchery until late June. When planted in July, water temperatures were 69 F. Anglers harvested only 22.5% of the 391 tagged fish. Of the 88 tags returned, all but one were returned during July and August. In addition, 55 (63.6%) of the tags recovered came from trout caught in the Kern River above Lake Isabella where they had apparently migrated in search of cooler water. This river is heavily planted and receives intensive angling effort. That such a small fraction of the tagged fish were caught can probably be attributed to an outbreak of furunculosis in the hatchery diagnosed less than 1 week after these fish were stocked. This disease was undoubtedly

TABLE 9—Tag Returns, Mortality and Survival Rates, and Cost/Lb to the Angler's Creel of Tagged Rainbow Trout Planted in Lake Isabella in 1969

Strain	Total* returns	Number tagged	Percent total harvest	Annual rates: Fishing mortality (u)	Annual rates: Survival (s)	Annual rates: Natural mortality (v)	Percent total returns before Oct. 1
1969							
RTS†	141 (26)	398	35.4	0.354	0.00	---	96.4
RTW	79 (65)	399	19.8	0.198	0.00	---	89.9
RTK-C	93 (29)	397	23.4	0.232	0.01	---	95.5
Total	313 (120)	1,194					

* Figures in parentheses represent tags returned from fish caught in Kern River and irrigation canals below Lake Isabella.
† RTS = Shasta strain
RTW = Whitney strain
RTK-C = Coleman Kamloops

present during tagging operations and placed undue stress on tagged fish. Thus, a differential mortality between tagged and untagged fish probably occurred, making mortality and survival estimates unreliable. Their smaller mean size and radically different length frequeney (Figure 1) may also have been a factor in reduced harvests (Weidlein 1971).

DISCUSSION

This study confirmed previous findings that Coleman Kamloops rainbow trout proved superior when compared to the Whitney strain of domestic trout (Rawstron 1972). In the present study they were definitely superior not only to the Whitney but also the Shasta strain. In every test, they showed the highest survival rate while their annual

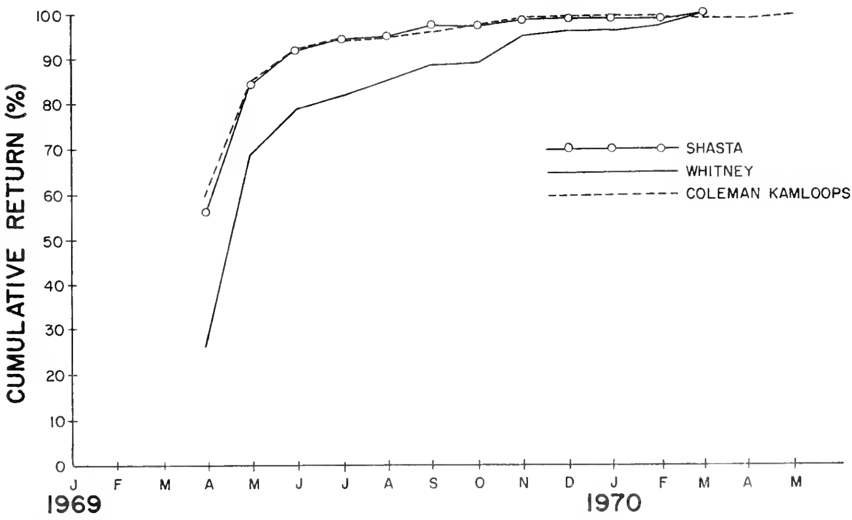

FIGURE 9. Cumulative percentages of tag returns by month for three strains of tagged rainbow trout planted in Lake Isabella in 1969.

exploitation rate did not differ substantially from the other strains. Their high annual survival rate, coupled with their low harvestability for 4 or 5 months after stocking combined to produce consistently the most economical fishery which, barring unusual climatic conditions, returned a higher ratio of weight returned to weight planted than the other two strains.

The major reason for their superiority to the other strains tested is their ability to evade the angler shortly after planting and throughout their first summer in the lake. I do not believe that these trout have an inherently lesser vulnerability to angling than the other strains since neither the annual expectation of death due to fishing nor the total proportion eventually harvested differed dramatically from the other strains in any test water in any given year. My 1968 study offered evidence that their superior performance stemmed from a behavioral trait since they were caught less frequently by shore anglers. Evidence offered then has been expanded and confirmed from incomplete and unpublished creel survey data from 1971 and 1972 at Merle Collins Reservoir. Here, shore anglers have consistently caught less than 40% of Coleman Kamloops annually while capturing nearly 70% of the Shasta strain and 55% of the Whitney strain. The Coleman Kamloops apparently leave the planting site and quickly disperse into the limnetic zone where they are less available to highly efficient shore anglers in the spring and where they probably become scattered over the deeper area of the lake near the dam and less vulnerable to boat anglers.

Weidlein (1971) has demonstrated that Coleman Kamloops migrated more rapidly to the area of the dam at Shasta Lake. These same three strains were planted from January through May 1968 at Antlers on the upper Sacramento River about 20 miles by the shortest straight line distance from the dam. Annual shore fishing effort in the area of the dam was high and, in addition, from March 1, 1968 to May 19, 1968, a highly efficient night fishery became established. Fishing from lighted docks, anglers exploited only Coleman Kamloops. None of the other groups were caught at night near the dam, although some apparently were taken in the daytime. Moreover, for all plants combined the period through September yielded more than 50% of the planted Kamloops in the area of the dam while the other strains were taken mainly from the Sacramento River arm.

Coleman Kamloops tended to become oriented to the surface sooner in the fall and thus more vulnerable to the angler near the dam at Lake Berryessa. During the October 1970 creel survey at the resort nearest the dam, boat fishermen landed 93 marked Coleman Kamloops and only 30 each of the other two strains. Many other marked Coleman strain were not counted or measured because statistically valid data on this strain had been obtained. While sample size is small, tag returns from all three strains for the whole lake were not as disparate (Table 3). During October, schools of rainbow trout were seen attacking schools of threadfin shad at the surface in the lower end of the lake near the dam. Anglers fished near these schools. Presumably, the majority of the schooled trout were Coleman Kamloops since they completely dominated the catch. Eventually this feeding activity extended all over the lake with no apparent concentration of trout by strain. These observations do not preclude the possibility that the other planted strains were not also present in large numbers. They could have been occupying deeper zones and, if so, were still less vulnerable to the angler.

No strain tested showed the desired late maturity and consequent development of older age classes. This was not surprising since all domestic strains of rainbow trout in California's hatchery system have been selected for sexual maturity as 2-year-olds. Thus, those used in this study became sexually mature during the spring of the year following stocking. Many were undoubtedly lost due to the rigors of spawning; others were known to become trapped in the upper reaches of vernal streams which they had ascended. Since annual natural mortality rate was consistently higher than that for angling, spawning mortality could be a factor. This study did not ascertain any of the causes of natural mortality nor their magnitude, but I believe that a combination of mortality due to tagging, spawning mortality, and hooking mortality combined to reduce survival to older age classes.

These views are supported by preliminary results from the second half of this study and the results of a companion study on the efficiency of various tags which reveal that a reduced bag limit of three fish has maintained total harvest rates between 30–40% while the ratio of weight returned to weight planted is greater than 1.25 for all strains tested at Lake Berryessa and Merle Collins Reservoir. Furthermore, the trailer tag appears to cause an accelerating rate of tag loss and mortality (Rawstron 1973). This loss of trailer tags or mortality of trout peaks after 6 to 12 months in the reservoir. While these two factors may have contributed to high estimates of natural mortality, the intensive creel survey at Merle Collins Reservoir also showed poor survival and virtually no buildup of older age classes among untagged fish. The oldest specimen seen by members of the investigating team has been a Whitney strain rainbow planted in 1969 at Lake Berryessa which had been at liberty for 40 months. It weighed 4 lb 15 oz in January 1972. One tag was returned from a Shasta strain rainbow trout in September 1972 after approximately 42 months in Lake Berryessa.

MANAGEMENT IMPLICATIONS

California has many other large reservoirs with abundant shad populations and limnological conditions suitable for trout. The past practice of not stocking catchable trout in large impoundments was partially based on the inability to produce enough trout for these reservoirs and still satisfy other demands for catchable trout. Since the California Fish and Game Commission policy states that a 50% return by number must be realized to maintain a catchable trout fishery, the minimum cost/lb to the angler's creel of this type of fishery ranges from the prevailing annual rate to produce them in the hatchery to twice that rate. In most cases, reservoir stocking in May with Coleman Kamloops catchable trout will produce an economical quality fishery and provide an opportunity for the average angler to catch a trout 1 lb or larger.

This type of fishery also provides angling opportunities during the fall and winter periods when warmwater fish are less active and other trout fisheries are closed or inaccessible. Estimates of angling use at Lake Berryessa have shown a hundredfold increase during the fall, winter, and early spring with only a moderate increase in summer (Gilbert Yates, Napa County Park District, pers. comm.). At Merle Collins the creel survey has shown that angling use has doubled since the introduction of trout in 1968. Then, anglers expended an estimated 36,000 hr annually. In 1971 this figure had increased to 76,000. This increase is primarily attributed to trout fishing generated through this experiment. These fall fisheries at Lake Berryessa and Merle Collins have become extremely popular with residents of the San Francisco Bay area and the Sacramento area. Unfortunately, the southern lakes failed to attract as many anglers during this period. This was due to heavy angling pressure during the spring and summer which left few fish available in the fall, as well as the climatic conditions and disease problems already discussed.

One of the overall objectives of California's long-range reservoir investigations has been to increase the yield to anglers of our large impoundments by 5 lb/acre. Characteristically, these reservoirs have shown low yields ranging from 5 to 10 lb/acre. These introductions of rainbow trout were part of this overall attempt to improve limnetic yields. The 1970 Lake Berryessa study showed that if all fish planted had been Coleman Kamloops, then anglers would have harvested nearly 55,000 lb of additional trout, an amount equivalent to 2.75 lb/acre. This figure must be accepted cautiously and is not offered as a panacea for all similar reservoirs. Other conditions which the fishery manager must consider may prevail.

For example, the tendency of Whitney strain to emigrate downstream during high water and the Shasta's early vulnerability limits their usefulness in many large impoundments. However, in lakes where frequent spilling is normal or can be anticipated, a dramatically reduced bag limit may permit the use of Shasta strain rainbows if Coleman Kamloops are not available. However, if an efficient downstream fishery can be maintained, such as in the Kings River below Pine Flat Dam, then the Whitney strain becomes less of a risk in the lake since the responsible fishery manager is concerned not only with the lake above but also with the river below. Generally, these fisheries which are maintained by stocking rainbow trout produce virtually no carryover. Emigration of trout from the lake does provide a substantial number of larger fish to Kings River anglers. If Coleman Kamloops occupy only the area near the dam and food is not limiting, then a combination of Shasta and Coleman Kamloops may serve to obtain maximum yields. Each reservoir must be evaluated independently and a management plan developed for each, but the Coleman Kamloops appears to be the most ideally suited of the three strains tested for most large, deep reservoirs in California with threadfin shad and suitable limnological conditions. Further study of the distribution of various strains throughout a reservoir, the impact of stocking fish which mature at 3 years and evaluation of other promising domestic strains, species and interracial rainbow hybrids are future subjects for continued research to improve the yield of California's reservoirs and improve the quality of angling for California's fishermen.

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COMPARISONS OF DISK DANGLER, TRAILER, AND INTERNAL ANCHOR TAGS ON THREE SPECIES OF SALMONIDS[1]

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Total harvest, annual exploitation, and survival rates of rainbow trout, coho salmon, and brown trout, bearing internal anchor tags with tube (Floy FD-67) and wire frame tags, were compared in several California reservoirs. Angler returns of internal anchor tags yielded estimates of mortality and survival similar to those determined from disk dangler and trailer tags. Because it can be more rapidly applied and is available commercially, the anchor tag was therefore deemed superior. Its major disadvantage was a relatively high initial shedding rate, but this was accounted for in some experiments by retaining tagged fish in the hatchery for 1 to 4 weeks.

INTRODUCTION

A suitable tag was required to obtain estimates of total harvest and annual exploitation and survival rates of various salmonids from large scale stockings in large reservoirs. These fish, when planted at 8 to 10 inches and approximately 1 year old, were expected to grow rapidly to large size, incur low natural mortality, and have high survival to older age classes. The tag had to be easily and rapidly applied, have a low shedding rate, have an insignificant effect on mortality and growth, and had to be retained by the fish for at least 2 years after planting. Estimates developed had to be both accurate and precise since they were to be used in a companion study to determine the most economical strain of rainbow trout *(Salmo gairdneri)* (Rawstron 1973), brown trout *(Salmo trutta)*, and coho salmon *(Oncorhynchus kisutch)* to plant in these reservoirs.

A literature review and personal communications led me to test the following tags: (i) the trailer tag used on Atlantic salmon *(Salmo salar)* smolts (Carlin 1955, Saunders 1968) and rainbow trout (Nicola and Cordone 1969); (ii) the modified Atkins tag or disk dangler tag widely used in California on a variety of fish (Rawstron 1967, Chadwick 1968, Nicola and Cordone 1969); (iii) the internal anchor tag (Floy FD-67) with vinyl tube (Dell 1968); and (iv) the Floy "flag" tag with the same internal anchor design as in (iii) (Thorson 1967, Allen Essbach, Arizona Game and Fish Department, pers. comm.).

California fisheries workers have employed disk dangler tags extensively on salmonids where little growth and rapid harvest are expected. The additional link of the trailer provides potential for increased growth. Both tags were retained for 2 years under hatchery conditions, with little effect on growth (Nicola and Cordone 1969). These same

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authors chose the trailer tag to evaluate a stocking of various strains and sizes of rainbow trout in Lake Tahoe in 1964 (California Department of Fish and Game, unpublished data). While anglers harvested these trout heavily during the first year, surviving fish were caught for 4 years. At Shasta Lake, good results have also been obtained from trailer tags placed on rainbow trout (Weidlein 1971). Therefore, I accepted this tag as the standard.

This study compared the accuracy and precision of estimated total harvest and annual mortality and survival rates produced from these four tag types on rainbow trout, brown trout, and coho salmon. Six separate experiments were carried out at Lake Berryessa, Napa County, and Merle Collins Reservoir, Yuba County, from 1968 to 1971.

METHODS AND MATERIALS

Tags and Tagging Technique

The trailer and disk dangler tags both have a triangular wire frame of soft stainless steel wire (0.012 inch diameter) placed through the musculature under the longest ray of the dorsal fin, one third the distance from the dorsal fin to the lateral line. They differ in that the trailer or modified Carlin tag has a link which connects the wire frame to the pennant, allowing for considerable growth without obscuring the pennant. In addition, the link of the trailer allows the tag to stream behind when the fish is swimming and to hang down at rest, while the disk dangler tag remains fixed against the fish's body when swimming or at rest. Pennants were made of laminated green vinyl, 0.25 inch wide, 0.825 inch long, and 0.050 inch thick. The tags used in my study were made to the exact specifications of Nicola and Cordone (1969) and applied similarly. The other two tags had internal anchors. The "T-shaped" nylon anchor was inserted with a tagging "gun" under the dorsal fin on the left side of the fish at a 45° angle trailing posteriorly. Gun and tags are available from Floy Tag and Manufacturing, 4616 Union Bay Place N. E., Seattle, Washington 98105. The needle penetrated the fish to a depth great enough to allow the "T" bar to become secured behind one or more of the interneural bones. In this position, tags were less likely to be lost or pulled out. The internal anchor tag with tube had a 2½-inch length of yellow vinyl tubing (0.020 inch outside diameter) cemented to the shaft of the nylon monofilament anchor. "Flag" tags were made completely of nylon with a rectangular pennant 0.158 inch wide, 0.393 inch long, and 0.040 inch thick. The longest axis of the pennant was perpendicular to the nylon shaft. Thorson (1967), Dell (1968) and Keller (1971) described these tags and their application more completely. All fish tagged were first anesthetized in MS-222 (tricaine methane sulfonate). Fork lengths (inches) and weights (lb) were recorded for all tagged fish.

Mortality Estimates

Harvest and survival rates from tagged fish at Merle Collins Reservoir were estimated from tags recovered in a creel survey. All anglers were interviewed at the single access point after they had completed fishing. This census has been conducted since 1965 on all weekends and national holidays, as well as two rotating weekdays each week. No attempt was made to expand the data for the missing days. Therefore, exploitation rates were underestimated consistently while survival rates were assumed to be unaffected. Survival and exploitation rates were estimated using Ricker's (1958) formulas 4.2 and 4.4. First year recoveries were those seen in the catch between 0 and 365 days after the date of planting. Second year returns were those from 366 to 730 days after planting.

In the first experiment at Merle Collins Reservoir neither of the internal anchor tags had legends. The wire frame tags, however, had the following legend: "Return tag to: Dept. F & G, Sacramento". All experiments thereafter used tags bearing similar legends.

At Lake Berryessa these rates were estimated similarly but relied only on the return of tags whose legends also offered a $5 reward. All tags were assumed to be returned for the reward and the estimated rates were probably close to the true rates.

Mortality and survival estimates of rainbow and brown trout were based only on tags received for 2 years after planting, except in 1971. However, tags were received after the fish had been at liberty longer than 2 years and these are mentioned in the results. Returns for coho salmon, which typically spawn and die in their third year of life, were considered complete after the second December in the lake. Therefore, 1971 estimates of coho mortality are complete. Estimates of mean annual exploitation of rainbow and brown trout are probably close to the true rate, since most tags were returned in the first year. Survival estimates of rainbow and brown trout were underestimated for experiments conducted in 1971.

The proportion of total disk dangler and internal anchor tags returned was each divided by the proportion of trailer tags returned to compare the relative returns of the former tags with the standard.

RESULTS AND DISCUSSION

Experiment #1—Merle Collins, 1968

Trailer, disk dangler, internal anchor with tube, and "flag" tags were used on rainbow trout (Table 1). As a control, 4,800 fish were not tagged. The experiment lasted only from December 27, 1967 through May 1968. Large numbers of trout emigrated from the lake during a prolonged spilling period and too few fish were seen after May to make meaningful estimates of survival or mean annual exploitation rates. Planted fish had a mean length of 8.1 inches and averaged 0.16 lb.

TABLE 1—**Returns of Tagged and Untagged Rainbow Trout, Merle Collins Reservoir, December 1967 Through May 1968. Experiment 1**

Tag type	Number planted	Observed returns	Exploitation rate	Expected returns	Chi square	95% significance
None	4,800	547	0.114	---	---	
Trailer	976	120	0.123	111.3	0.40	No
Disk dangler	991	119	0.120	112.9	0.32	No
Internal anchor with tube	980	91	0.093	111.7	3.83	No
"Flag"	1,000	40	0.040	114.0	57.35	Yes

Anglers caught a total of 547 (0.114) of the 4,800 untagged fish. This harvest compares favorably with that of the trailer (0.123), disk dangler (0.120), and internal anchor tag with tube (0.093). The "flag" tag had a significantly lower return rate (0.040) than either the control or the other tag types (Table 1). However, the lower harvest rates of the tags with internal anchor design indicated either a higher shedding rate or post tagging mortality. Since all fish landed during the census were examined by trained observers, nonrecognition of tags was not a significant factor. Census clerks noted that during February and March, 1968, 63 fish in the catch appeared to have definite single holes or scars at the point where internal anchor tags had been affixed. Anglers also reported finding three "flag" tags on the shore after water levels had receded. These observations provided support that tag shedding was more serious than post tagging mortality. Because of their poor performance, "flag" tags were not used in subsequent experiments.

Because of the heavy emigration noted earlier, too few fish were returned in the second year to make meaningful estimates of survival rate. However, of the five tags returned later, two were anchor tags with tube, one a trailer and the other a disk dangler. One anchor with tube tag was returned in the third year.

Experiment #2—Lake Berryessa, 1968

A total of 816 tagged rainbow trout was planted on March 20, 1968. Approximately half bore trailer tags and the remainder had tube type internal anchor tags (Table 2). The mean lengths and weights of planted trout bearing each tag type were 8.6 inches and 0.24 lb, respectively.

Anglers returned a total of 70 trailer tags and 51 anchor tags for mean annual exploitation rates of 0.139 and 0.105, respectively. Survival, however, was essentially the same for fish bearing each type of tag. Since survival rates were the same, an early loss of tube tags was again indicated. Further evidence to support this comes from the analysis of catches by month (Table 3). When compared for the first 3 months, returns of anchor tags were approximately 60% of those recorded for trailer tags, but were virtually equal thereafter. While this could be due to lowered vulnerability of trout bearing anchor tags shortly after planting, I believe that these data, coupled with the similar survival rates, more strongly supports the conclusion of a rapid early shedding rate. All tagged fish were stocked 2 to 4 days after tagging. Originally, 425 of each tag type were used, but tag shedding in the hatchery accounted for 25 (5.9%) of internal anchor tags, while mortality of trout with trailer tags amounted to 9 (2.1%). Therefore, a continued shedding of anchor tags after stocking was indicated.

Anglers caught three trout bearing trailer and three with internal anchor tags in their third year at large. In addition, one trout carrying a trailer tag remained at liberty more than 3 years before capture.

Experiment #3—Merle Collins, 1969

Trailer and disk dangler tags, 389 and 395, respectively, were placed on rainbow trout planted on March 14, 1969 (Table 2). Each tagged group had a mean length and weight of 8.8 inches and 0.37 lb, respectively.

TABLE 2—**Tag Returns, Mortality and Survival Rates, and Index of Total Returns. Experiments 2–6**

Tag type	Number tagged	Number returned		Percent total harvest	Mean annual exploi-tation	Survival	Index
		Year 1	Year 2				
Experiment 2—Lake Berryessa, 1968 RAINBOW TROUT							
Trailer	416	58	12	16.8	0.139	0.207	
Anchor	400	42	9	12.8	0.105	0.214	0.76
Total	816	100	21				
Mean				14.8	0.123	0.210	
Experiment 3—Merle Collins Reservoir, 1969 RAINBOW TROUT							
Trailer	389	173	7	46.3	0.445	0.041	
Disk dangler	395	183	8	48.4	0.463	0.044	1.04
Total	784	356	15				
Mean				47.3	0.454	0.042	
Experiment 4—Merle Collins Reservoir, 1970 RAINBOW TROUT							
Trailer	699	246	13	37.1	0.352	0.053	
Disk dangler	697	270	6	39.6	0.388	0.022	1.05
Anchor	671	233	7	35.8	0.347	0.030	0.97
Total	2,067	749	26				
Mean				37.5	0.362	0.035	
COHO SALMON							
Trailer	95	5	0	5.3	0.053	0.000	†
Disk dangler	95	8	0	8.4	0.084	0.000	†
Anchor	95	12	0	12.6	0.126	0.000	†
Total	285	25	0				
Mean				8.8	0.088	0.000	
Experiment 5—Merle Collins Reservoir, 1971 RAINBOW TROUT							
Trailer	986	249	7	26.0	0.252	0.028	
Anchor	720	197	4	27.9	0.274	0.020	1.03
Total	1,706	446	11				
Mean				26.8	0.261	0.025	
COHO SALMON							
Trailer	248	62	17	31.9	0.250	0.274	
Anchor	241	52	20	29.9	0.216	0.385	0.93
Total	489	114	37				
Mean				30.9	0.233	0.325	

TABLE 2—**Tag Returns, Mortality and Survival Rates, and Index of Total Returns. Experiments 2–6—Continued**

Tag type	Number tagged	Number returned		Percent total harvest	Mean annual exploi- tation	Survival	Index
		Year 1	Year 2				
BROWN TROUT							
Trailer	249	53	8	24.5	0.213	0.151	
Anchor	179	36	10	25.7	0.201	0.278	
Total	428	89	18				
Mean				25.0	0.208	0.202	1.05
Experiment 6—Lake Berryessa, 1971 RAINBOW TROUT							
Trailer	990	225	65	29.3	0.227	0.289	
Anchor	472	100	25	26.5	0.212	0.250	0.84
Total	1,462	325	90				
Mean				28.4	0.222	0.277	
COHO SALMON							
Trailer	499	166	22	37.7	0.333	0.133	
Anchor	237	82	17	41.8	0.346	0.207	1.11
Total	736	248	39				
Mean				39.0	0.337	0.157	
BROWN TROUT							
Trailer	398	58	7	16.3	0.146	0.121	
Anchor	233	33	5	16.3	0.142	0.152	1.0
Total	631	91	12				
Mean				16.3	0.144	0.132	

† Sample too small.

Anglers harvested a total of 180 and 191 rainbow trout bearing trailer and disk dangler tags, respectively, over the first 2 years. This amounted to observed total harvests of 46.3 and 48.4%. Mean annual exploitation and survival rates were 0.445 and 0.041 for fish with trailer tags and 0.463 and 0.044 for those carrying disk dangler tags. Monthly tag returns showed an almost identical pattern with no difference in early or late returns (Table 4). Disk dangler tags returned at 1.04 of trailer tags. Census clerks recorded one trailer tag in May 1971 from a trout at liberty for 26 months.

Experiment #4—Merle Collins, 1970

Rainbow trout and coho salmon were used in this experiment. Rainbow bore 699 trailer, 697 disk dangler and 671 internal anchor tube tags (Table 2). Coho salmon had 95 each of the same tags.

TABLE 3. **Monthly Returns of Tagged Rainbow Trout from Lake Berryessa March 20, 1968 Through March 19, 1970. Experiment 2**

Month	1968–69		1969–70	
	Trailer	Anchor	Trailer	Anchor
March 20*	5	7	2	2
April	22	10	2	2
May	6	3	3	1
June	4	2	0	0
July	1	2	1	0
August	0	0	1	0
September	1	1	0	0
October	2	3	0	0
November	4	4	2	4
December	5	3	1	0
January	3	4	0	0
February	3	2	0	0
March 19	2	1	0	0
	58	42	12	9

* Median planting date.

Both species were planted on May 4. The former averaged 8.9 inches and weighed 0.27 lb, while the latter had a mean fork length of 6.1 inches and weighed 0.10 lb.

Rainbow Trout

Anglers exploited 39.6% of rainbow trout carrying disk dangler tags over the 2 years, while they harvested 37.1% of the fish with trailer and 35.8% of those with internal anchor tags (Table 2). Mean annual exploitation rates were also similar: 0.352, trailer; 0.388, disk dangler; 0.347, internal anchor. Survival of trout was low, ranging from 0.022 for those with disk dangler to 0.053 for those with trailer tags.

TABLE 4—**Monthly Returns of Tagged Rainbow Trout from Merle Collins Reservoir, March 24, 1969–March 23, 1971. Experiment 3**

Month	1969–70		1970–71	
	Trailer	Disk dangler	Trailer	Disk dangler
March 24	15	28	0	1
April	105	98	1	5
May	17	20	2	0
June	5	2	1	0
July	0	1	0	0
August	0	3	0	0
September	2	6	0	0
October	9	8	1	0
November	9	9	0	1
December	5	5	0	0
January	0	0	0	1
February	4	2	2	0
March 23	2	1	0	0
	173	183	7	8

Return by month showed similar returns for all tag types (Table 5). Contrary to the first experiment, anglers recovered all anchor tags at a higher rate (0.97) compared with trailers, while disk danglers were recovered at 1.05 that of the standard. All tagged fish were held 3 to 4 weeks in the hatchery before planting.

Hatchery workers recovered 29 (6.0%) of the total numbers of internal anchor tags attached originally from pond bottoms and screens, while less than 1% of each of the other two tags were recovered. This provided further evidence that internal anchor tags with tube were shed shortly after tagging and that the effects of shedding might be accounted for by holding fish several weeks before planting.

Census takers observed no tags from this experiment after May 1972.

Coho Salmon

Creel census clerks recovered only 5 trailer (5.3%), 8 disk dangler (8.4%) and 12 internal anchor tags (12.6%) from the catch during the first year (Table 2). The census takers recorded none in the second or third years; thus, tagged coho did not survive to the second year. Natural mortality was extremely high, averaging 0.912 for all tags combined. These fish had the lowest mean fork length of any group planted in previous experiments and apparently suffered substantial post tagging mortality from all tag types. This form of mortality probably accounted for the high calculated natural mortality, since the creel survey showed exploitation and survival rates of 0.331 and 0.041, respectively, for untagged salmon.

TABLE 5—Monthly Returns of Tagged Rainbow Trout and Coho Salmon from Merle Collins Reservoir, May 4, 1970–May 3, 1972. Experiment 4

Month	1970–71						1971–72		
	Rainbow trout			Coho salmon			Rainbow trout		
	Trailer	Disk dangler	Anchor	Trailer	Disk dangler	Anchor	Trailer	Disk dangler	Anchor
May 4	177	173	147	4	3	6	5	1	4
June	3	8	8	0	0	0	0	0	1
July	1	0	0	0	0	0	1	0	1
August	1	0	1	0	0	0	1	0	0
September	6	12	8	0	1	1	0	1	0
October	35	46	36	0	0	1	1	0	1
November	9	12	11	0	0	1	1	1	0
December	1	0	1	0	0	0	0	0	0
January	1	3	4	0	2	0	1	2	0
February	6	5	4	0	0	2	1	0	0
March	4	4	9	1	1	0	0	0	0
April	2	7	4	0	1	0	1	0	0
May 1-3	0	0	0	0	0	1	1	1	0
Total	246	270	233	5	8	12	13	6	7

Experiment #5—Merle Collins, 1971

Rainbow trout, brown trout, and coho salmon were tagged with internal anchor with tube and trailer tags. Planted rainbow trout bore 986 trailer and 720 internal anchor tags. Brown trout had 249 and 179 trailer and anchor tags, respectively. Similarly, coho salmon had 248 and 241 tags (Table 2).

Brown and rainbow trout were planted on May 14. Rainbow trout had a mean length of 8.7 inches and a mean weight of 0.32 lb. Brown trout averaged 8.3 inches in length and had a mean weight of 0.23 lb. Coho salmon were planted on May 26 and were 8.2 inches long and weighed 0.21 lb.

Rainbow Trout

The total harvest of rainbow trout tagged with trailer and internal anchor tags amounted to 26.0% and 27.9%, respectively (Table 2). Mean annual exploitation rates were essentially the same for fish with each tag type, 0.252 and 0.274. Survival rates through December 31, 1972 only, were also similar, 0.028 and 0.020. While both the total percentage harvested and the survival rate were underestimated, they should not increase dramatically.

Early loss of anchor tags after stocking apparently did not occur (Table 6). Tags returned during the first 2 months were in approximate proportion to the number tagged (0.13) for both tags, while overall, anchor tags were recovered at 1.03 of trailer tags. All anchor tags were placed on the trout 7 to 10 days before the trailer tags. The fish were then held in the hatchery where tags, recovered from screens, pond bottoms, and dead fish were recorded. Hatchery workers found 77 internal anchor tags (9.7%) of the 797 originally affixed. Of these, 75 had fallen from the fish's side and two fish had died. Seven (0.7%) of the trailer tags were recovered from dead fish.

Coho Salmon

Fishermen recovered a total of 79 of 248 trailer tags (31.9%) and 72 of 241 internal anchor tags (29.9%) (Table 2). Annual rate of fishing for salmon with trailer tags was slightly higher (0.250) than for those with tube tags (0.216), but fish with anchor tags survived at a higher rate (0.385) than those with trailer tags (0.274). Monthly returns were essentially the same, although returns of anchor tags for earlier months lagged slightly behind those for trailer tags (Table 6). The index of total returns was 0.93 anchor tag for each trailer tag. All fish were tagged the day before planting. Nine anchor tags and two trailer tags were recovered in the hatchery.

Brown Trout

Brown trout tagged with the anchor tag had a higher total percentage return (25.7%) than those with the trailer tag (24.5%) (Table 2). Mean annual harvest rates were nearly the same, 0.201 and 0.213, respectively. Survival rate for brown trout with internal anchor tags amounted to 0.278, while trout with trailer tags had a rate of 0.151.

These trout were tagged 4 to 7 days before stocking and held in the hatchery. Only one trailer tag (0.4%) was recovered from a dead fish, while 21 anchor tags (10.5%) were found on screens and the pond bottom. Monthly returns showed once more that both tags were recovered in the first 2 months in approximate proportion (0.14) to the number tagged (Table 6). Total tag returns showed a ratio of 1.05 internal anchor tags to trailer tags.

TABLE 6—**Monthly Returns of Tagged Rainbow Trout, Coho Salmon, and Brown Trout from Merle Collins Reservoir, May 5, 1971–December 31, 1972 Experiment 5**

Month	1971-72						1972-73					
	Rainbow trout		Coho salmon		Brown trout		Rainbow trout		Coho salmon		Brown trout	
	Trailer	Anchor	Trailer	Anchor	Trailer	Anchor	Trailer	Anchor	Trailer	Anchor	Trailer	Anchor
May 5	112	71	3	1	31	24	0	1	8	6	3	3
June	16	26	6	6	2	2	2	1	8	10	3	5
July	4	5	2	0	1	1	1	1	1	3	2	1
August	3	3	2	1	0	0	0	0	0	0	0	0
September	2	3	1	1	0	0	0	0	0	0	0	1
October	63	69	7	6	3	4	0	0	0	1	0	0
November	16	8	2	0	1	0	4	1	0	0	0	0
December	4	1	5	3	1	0	0	0	0	0	0	0
January	10	6	4	4	0	2	--	--	--	--	--	--
February	8	1	5	4	1	0	--	--	--	--	--	--
March	3	2	10	14	4	1	--	--	--	--	--	--
April	8	2	15	10	9	2	--	--	--	--	--	--
May 1–4	0	0	0	2	0	0	--	--	--	--	--	--
Total	249	197	62	52	53	36	7	4	17	20	8	10

Experiment #6—Lake Berryessa, 1971

Rainbow trout, brown trout, and coho salmon were stocked. Nine hundred and ninety trailer tags and 472 internal anchor tags with tube were placed on rainbow trout; 398 and 233, respectively, on brown trout; and 499 and 237, respectively, on coho salmon (Table 2).

Rainbow and brown trout were planted on May 14, while the coho were planted on May 26.

Rainbow Trout

From the total of 990 rainbow trout bearing trailer tags, anglers returned 290 (29.3%) (Table 2). Rainbow tagged with internal anchor tags had a total recovery rate of 26.5%. Annual mortality due to fishing was 0.227 for fish bearing trailer tags and 0.212 for those with tube tags. Survival rates were higher for trout bearing trailer tags (0.289) than for those with internal anchor tags (0.250).

Monthly returns from anchor tags were considerably lower than expected for the first 2 months after planting and were not returned in proportion to the numbers tagged (Table 7). The proportion of the total anchor tags recovered compared to the proportion of trailer tags returned amounted to only 0.84. Fish were tagged with anchor tags the day before planting, but six tags were recovered from the pond bottom or screens. During the week of actual tagging operations, 10 fish with trailer tags died.

Coho Salmon

Anglers harvested a higher percentage (41.8%) of coho with internal anchor tags than those with trailer tags (37.7%) (Table 2). Mean exploitation rates were similar (0.346 to 0.333), but survival rates favored coho tagged with anchor tags (0.207). Trailer tags, returned over the 2 years, yielded a survival estimate of 0.133.

Once again, returns of anchor tags during the first few months after tagging lagged behind the expected return based on trailer tags, but eventually anchor tags were returned at a higher rate (Table 7). For the duration of the study anglers returned a higher fraction (1.11) of the internal anchor tags in comparison with the standard tags. Tagged salmon were held 10 to 14 days before planting. Of the 500 trailer and 250 anchor tags originally placed on salmon, one trailer tag (0.2%) and 13 (5.2%) internal anchor tags were recovered in the hatchery.

Brown Trout

Anglers harvested an identical percentage (16.3%) of the tagged brown trout during this experiment and mean annual exploitation rates were approximately equal (Table 2). Survival rate of brown trout tagged with anchor tags (0.152) was higher than that of trailer tags (0.121).

Interestingly, these fish were the only ones from which early recovery of internal anchor tags was higher than that of trailer tags (Table 7). In later months, the proportion of anchor to trailer tags returned was more consistent with the proportion of each tag issued. I have no explanation for this phenomenon since, like the rainbow, these trout were tagged only 1 to 2 days before their release into Lake Berryessa. Tag losses in the hatchery amounted to 2 trailer (0. 5%) and 17 (6.8%) internal anchor tags.

TABLE 7—**Monthly Tag Returns of Tagged Rainbow Trout, Coho Salmon, and Brown Trout at Lake Berryessa, May 14, 1971–December 31, 1972. Experiment 6**

Month	1971-72						1972-73					
	Rainbow trout		Coho salmon		Brown trout		Rainbow trout		Coho salmon		Brown trout	
	Trailer	Anchor	Trailer	Anchor	Trailer	Anchor	Trailer	Anchor	Trailer	Anchor	Trailer	Anchor
May 14-30	25	8	7	0	5	7	0	5	3	2	1	1
June	15	5	6	3	2	5	2	1	6	1	1	1
July	8	9	10	1	1	1	1	3	3	5	2	2
August	14	5	16	6	3	3	7	0	2	2	0	0
September	15	3	14	6	5	1	8	0	2	1	0	0
October	34	16	9	6	2	0	7	7	3	2	1	0
November	18	18	22	18	5	1	32	7	2	2	1	0
December	39	15	19	8	1	1	8	2	1	2	1	1
January	34	11	18	6	6	2	--	--	--	--	--	--
February	7	5	17	7	9	2	--	--	--	--	--	--
March	9	1	21	10	13	7	--	--	--	--	--	--
April	4	3	6	3	5	2	--	--	--	--	--	--
May 1-13	3	1	1	8	1	1	--	--	--	--	--	--
Total	225	100	166	82	58	33	65	25	22	17	7	5

General

By combining all experiments except the first short-term study, anglers returned 27.3% of all anchor tags placed on rainbow trout and 28.3% of all trailer tags. Anchor tags returned at a rate of 0.97 that of trailer tags. Similarly, fishermen harvested trout with disk danglers at 1.06 that of trailer tags. Coho and brown trout bearing anchor tags showed comparative return rates of 0.99 and 1.05, respectively. Too few disk danglers were placed on these species for meaningful comparisons. With all species combined, the internal anchor with tube was returned at 0.98 of trailer tags.

CONCLUSIONS

The precision of estimated mortality and survival rates of tagged salmonids planted when 8 to 10 inches long was excellent. All tag types yielded similar estimates. Moreover, accuracy was good, since the creel survey at Merle Collins showed that harvest estimates generated by untagged, fin clipped fish were only 2% higher (Rawstron 1973). Speed of application makes the internal anchor tag more efficient. Under ideal conditions a skilled tagger can place 400 to 500 wire frame tags on trout per man day, while anchor tags can easily be applied at a rate of 300/hour.

Moreover, an additional savings can be realized, since wire frame tags require considerable time for assembly, while internal anchor tags are commercially available. Presently, one man can assemble approximately 150 to 300 trailer tags/day. This, in addition to the cost of component parts, makes wire frame tags as expensive as internal anchor tags.

The major drawback of the internal anchor tag is a rapid early shedding of tags, presumably insecurely placed. Keller (1971) indicated that his initial failure to secure tags behind the interneural bones stemmed from placing the tags too low on the back. In a following experiment he placed the tags higher on the back and reduced tag loss from 58% to 2% over a 2-month period. The placement he used in his later experiment is the same as used in my experiments. Double tagging of adult salmon at sea with both anchor and spaghetti tags showed that anchor tags were lost at a substantially higher rate than spaghetti on both coho and king salmon *(Oncorhynchus tshawytscha)* (Butler and Loeffel 1972). In this experiment, however, these authors did not attempt to lock the tags behind the basal bones of the dorsal fin, but simply placed them into the dorsal musculature.

Shedding also appears to be related to the ability of the tagger to determine whether the "T bar" is securely locked behind the interneurals, or simply in the dorsal musculature. This comes with experience. The ability to insert the needle, rotate the hand, and squeeze the "trigger" properly so that the "T bar" opens up in the flesh far enough axially to engage the proper bones requires substantial practice. This experience factor has been noted by the manufacturer, who follows closely research using his tags (Paul Lyon, Floy Tag and Manufacturing Co., pers. comm.) and by Carline and Brynildson (1972), who attributed the lower shedding rate in their second experiment with brook trout *(Salvelinus fontinalis)* to added experience in technique.

Other factors, which have contributed to early shedding in the hatcheries, are the frequent breaking of half of the nylon "T bar", insecure gluing of the vinyl tubing to the nylon monofilament anchor, and other malfunctions of the "gun" or tag cartridges. One practice which I used to reduce the shedding resulting from all but the last factor was to tug firmly on the vinyl tubing after tag insertion. If the tag is improperly secured, generally, it will slip out. Another tag can then be inserted into the same fish following the original path of insertion.

During these studies, the vinyl tube was inserted part way into the fish. However, recent attempts to do this with the FD-67 tag have resulted in about a 90% breakage of the tag where the vinyl and monofilament are glued. This failure was also noted in California's ocean salmon tagging program (Patrick O'Brien, California Dep. of Fish and Game, pers. comm.). The manufacturer now makes this tag with a longer distance between the cross bar of the "T" and the point of attachment to the vinyl tube. Since the outside diameter of the tube is essentially equal to the outside diameter of the entry made by the "needle" of the tagging gun, intuitively the area around the wound should heal faster, thus aiding retention, than if the monofilament only were entirely within the fish. What effect the manufacturer's different FD-67 tag has on the estimates examined in this study should be tested.

To reduce the effects of shedding in studies in which mortality rates are the prime objectives, fish should be held in the hatchery as long as possible after tagging. Careful inventory of lost tags should then be kept, in order to know the actual number of tagged fish planted.

As a check on the effect of these three tags on growth, weights of tagged rainbow trout bearing the trailer, disk dangler, and internal anchor tags were compared for the months of October and November 1970 after 6 months at liberty with untagged trout seen in the creel survey at Merle Collins Reservoir. Twenty rainbow with trailer tags weighed an average of 1.17 lb (C.I. = 0.93 to 1.41 lb) ($\alpha = 0.05$) compared to the mean weight of 1.15 lb (C.I. = 0.99 to 1.31 lb) for 176 unmarked fish. Similarly, 27 trout with disk dangler tags averaged 1.18 lb (C.I. = 0.92 to 1.44 lb), and 25 internal anchor tagged fish weighed 1.12 lb (C.I. = 0.87 to 1.37 lb). Small differences in growth may occur, but they are not significant. Similarly, tag type caused no obvious differences in growth rate of brown trout or coho salmon. The continued use of the extra link of the trailer is unjustified since growth, exploitation, and survival rates of salmonids were essentially the same for both wire frame tags.

These findings contradict those reported for Atlantic salmon smolts, in which trailer tags retarded growth severely (Saunders and Allen 1967). While little is known about the effect of disk dangler tags on growth of salmonids under field conditions, Nicola and Cordone (1969) found no evidence that either type of wire frame tag retarded growth severely under hatchery conditions. Brook trout bearing Floy FD-67 tags showed a significantly reduced growth from October 1967 to January 1968, but by June 1968 differences were not significant (Carline and Brynildson 1972). However, their 1969 study showed slight but significant differences between the weight of tagged and untagged brook trout by June 1970.

All the tags have a common drawback of creating a wound(s). The wire frame tags sometimes produce a wound on each side of the back at the point of attachment, but more frequently a crater shaped wound appears on the side opposite the knot. The majority of the trout and salmon, however, do not have serious wounds by the October following planting and in most cases the knot has been healed over completely. The internal anchor tag has only a wound on one side and is invariably not serious after 6 months if the tag is still in its proper attitude. Occasionally, however, fish which are losing their tags are seen. These fish show a serious ulcer where one prong of the anchor has nearly worked out. This condition probably occurs on fish which were tagged too low (Keller 1971). Severe ulcers were noted for 6 of 10 brook trout observed in June 1969, but only 2 of 20 in 1970 (Carline and Brynildson 1972).

The internal anchor tag, therefore, was the best tag for tagging salmonids of this size under the conditions of my experiments. This tag, when compared with wire frame tags now used most commonly in California, yielded comparable estimates of total harvest, annual mortality, and survival as well as growth rates, and was more economical to use. If shedding can be overcome or accounted for, this tag should replace these wire frame tags for use in salmonid exploitation rate studies, even for short term studies. It should also prove practical for use on other species, especially those which require rapid tagging and minimum handling and when shedding rate can be measured.

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ON THE ANALYSIS OF ANGLER CATCH RATE DATA FROM WARMWATER RESERVOIRS[1]

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A method for estimating angling quality on large warmwater impoundments with multiple access points is described. The plan features a roving census clerk who contacts anglers while they are actively fishing. Consideration is given to the selection of a catch rate estimator and a procedure for calculating the associated variance is described. Computer output utilizing data descriptive of the bluegill segment of the Lake Nacimiento, California, fishery is used to illustrate this census procedure.

INTRODUCTION

During the past several decades, California's development has featured the construction of a great many warmwater impoundments which offer difficult and unique assessment problems. These waters are very often large with multiple access points and multiple species fisheries. Many of them are open to night angling. As a group, they provide only mediocre fishing (Abell and Fisher 1953, Kimsey 1958) and management efforts to improve angling quality have greatly increased in recent years. In order to achieve a measure of the success or failure of new management programs, it became necessary to develop creel census procedures for efficiently estimating angling quality on these impoundments.

The first major question to be resolved was whether a census should be designed to obtain a measure of total use and catch or to obtain a measure of catch rate which can be related to population abundance. Murphy (1966) has observed that catch rate (most often expressed as catch per angler hour) is a better measure of lightly exploited fish populations than total catch and fish tagging studies on this type of impoundment indicate generally low angler harvest rates (Fisher 1953, Rawstron 1967). Based on these observations, we chose to emphasize the refinement of catch rate estimates at the expense of precise estimates of total use and catch. This decision was reinforced by the observation of Robson (1960, 1961) that unbiased estimates of total use and catch can be developed only by contacting anglers at the end of their fishing day. A sampling procedure which features census clerks located at landings (a general requirement for completed effort checks) on large waters with multiple access points inevitably results in an inefficient use of manpower and must be rejected for practical considerations alone (Di Costanzo 1956). The alternative method, a roving census whereby the census clerk moves through the fishery by boat and contacts active anglers was then selected for estimating catch rate on this

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type of impoundment. This efficient data collection process (Grosslein 1962, von Geldern 1972) carries with it the general assumption that catch rates obtained in this manner will produce indices of angling quality which can, within limits, be related to game fish population abundance.

This report examines the general nature of catch rate estimates derived from incompleted angler effort checks and considers (i) the basic roving creel census as used on some California impountments, (ii) the selection of an estimator for catch rate, (iii) a procedure for calculating the variance of catch rate estimates, (iv) a computer program for producing catch rate estimates and their associated variances, and (v) an example of catch rate analysis from Lake Nacimiento, California.

THE ROVING CREEL CENSUS

The conceptual basic feature of the roving creel census on a given day is that the census clerk move through the entire fishery at a fixed rate of travel and interview all anglers encountered to determine catch and time fished. Ideally, the starting point and direction of travel should be chosen at random and the trip should include the entire fishing day (Robson 1961). For practical reasons, however, this idealized concept of the roving census can only be very roughly approximated in the field. Census clerks, for example, cannot reasonably be expected to work for more than about 8 hr per day. In a continuous fishery with respect to time (the case when an impoundment is always open to angling), the implementation of the idealized concept would require a manpower expenditure of not less than 3 man days during any 24-hr. period. During nighttime periods and early morning hours very limited numbers of anglers will normally be contacted and, in the interest of economy, we chose to sacrifice whatever small gains in precision might be achieved by night censusing. As an alternative, we select as our sample unit a single 8-hr midday period which effectively covers the time span when angler use is high and assume that a properly measured catch rate during these hours will produce data relating to the general abundance of game fish populations.

Similarly, the requirement that travel direction be random cannot always be achieved. Boat traffic on some California impoundments is required by law to move in a counterclockwise direction which effectively restricts the travel route options of the census clerks. We also do not make an attempt to generate random starting points along the travel route, because this procedure inevitably results in time spent traveling to and from boat docks at the beginning and end of nearly all census days. A systematic approach whereby the travel route begins at opposite ends of the impoundment (one end being the dock) on alternate days was adopted. This procedure eliminates the need to travel before or after the census on 50% of the sample days.

In an attempt to standardize travel rates of census clerks, we normally divide impoundments into sections (lengths of shoreline) which are censused in accordance with a pre-arranged time schedule. While this procedure sometimes creates waiting periods between sections or necessitates leaving an area before all anglers are checked, the speed of travel through the fishery becomes more uniform and the between day catch rate data more comparable.

A more extreme departure from the idealized concept centers on our selection of sample days. We have found that most warmwater impoundments receive much higher pressure on weekends than weekdays (Abell and Fisher 1953, von Geldern 1972) and have chosen to census on weekends only when relatively large numbers of anglers can be easily contacted. The implications of these various departures from the idealized concept of the roving census advanced by Robson (1961) will be examined in a later section. For the present, we will briefly describe the census procedures used at Lake Nacimiento, since data collected at this impoundment will be used to illustrate our procedures for catch rate analysis.

Lake Nacimiento is a 5,300-acre impoundment located in San Luis Obispo County which contains a warmwater fishery dominated by largemouth bass (*Micropterus salmoides*), black crappie (*Pomoxis nigromaculatus*), and bluegill (*Lepomis macrochirus*). For census purposes the reservoir is divided into four sections which are censused in reverse order on alternate Saturdays and Sundays. The entire fishery is traversed on each sample day by one or two census clerks in a single 16-ft aluminum boat powered with an 18 or 20 hp outboard motor. Census activity covers the period 9 a.m. to 5 p.m. PST and 2 hr are allotted to each section. When contact with an angler or party of anglers is made the following information is obtained: (i) whether boat or shore angler(s); (ii) number of anglers in the party; (iii) elapsed party fishing time to the nearest ½ hr; (iv) angling method(s); and (v) party catch by number and species. A systematic sample of lengths of fish caught to the nearest inch (FL) and the number of shore anglers and fishing boats not censused in each section are also regularly recorded. Each party interview is conducted as if the party is a single angler. No effort is made to separate catches by individual members of a party. Similarly, if a party of two consists of one person who used lures exclusively and another who fished only with worms the angling method recorded for the party is as if both anglers had used both methods.

Reasonable efforts are made to obtain accurate information from each party of anglers interviewed. To determine party fishing time, anglers are asked when they started fishing. They are then asked if they fished continually between starting time and interview time. This procedure is also adopted to determine if the angling method being used at interview time has been used throughout the party's fishing day. If an interview is considered unsatisfactory (uncooperative anglers, catch not with the party, etc.) the party is recorded as "not censused". Parties of anglers contacted a second time on the same day are also not censused because of the general inability of census clerks to separate catches made before and after the first interview.

CHOICE OF ESTIMATOR

We have previously noted that our estimate of catch rate ($\hat{r}$) is intended to function as an index of fishing quality which is, in a broad sense, related to the biological health or fish population abundance of the various segments of a lake or reservoir fishery. In that context, we observe that the catch rate of all anglers combined may produce a poor measure of angling quality for individual species (or groups of closely allied species) in a multiple species fishery. This phenomenon is well documented (Grosslein 1957, Neuhold and Lu 1957, Lambou and Stern 1959, von Geldern 1972, and others) and is related to the fact that anglers exercise considerable control over the species composition of their catch by their choice of angling methods and fishing sites. For this reason, catch rate estimates for individual species are derived only from anglers using relatively efficient angling methods for that species.

A distinction exists between the suitability of catch rate parameters designed to function as part of a total catch estimator and those designed to measure fishing quality. Take, for example, a series of angler party interviews (segregated by angling method) over n sample days from which catch by species (c_{ij} = catch of the j^{th} party on the i^{th} day), angler hours fished (h_{ij} = angler hours fished by the j^{th} party on the i^{th} day), and catch per angler hour ($r_{ij} = c_{ij}/h_{ij}$) are determined. For simplicity, assume randomness with regard to the selection of sample days and angler parties. Assume further that the number of angler parties contacted on a given day (m_i) is variable because of variations in angling pressure between days. Given these conditions, we will now examine the suitability of various estimators for measuring angling quality.

One measure of angling quality (R) is simply the sum over n days of the total observed catch divided by the total observed angler hours fished. This relationship may be referred to as a ratio total and is expressed by

$$R = \sum_{i}^{n} \sum_{j}^{m_i} c_{ij} \Big/ \sum_{i}^{n} \sum_{j}^{m_i} h_{ij}. \qquad (1)$$

Examination of this parameter reveals that the value of R is a weighted average and that the weights correspond to both trip lengths and variations in daily pressure. We further note that the ratio total estimator will generate a value for $\hat{r}$ which is not the true average $\hat{r}$ over n days if fishing pressure and angling quality are correlated. A variety of arguments can be presented which would tend to make suspect any assumption that fishing pressure and angling quality are independent variables and, for that reason, the use of the ratio total estimator does not appear justified. In cases where total catch estimates are desired, however, the ratio total estimator is intuitively attractive since precision between effort and catch rate is a vital prerequisite of such estimates.

A second estimator of $\hat{r}$, the mean ratio total, may be expressed as

$$\overline{R} = \frac{1}{n} \sum_{i}^{n} \left[\sum_{j}^{m_i} c_{ij} \Big/ \sum_{j}^{m_i} h_{ij} \right]. \qquad (2)$$

This estimator appears more desirable than the ratio total because the difficulties associated with positive or negative correlations of pressure and angler success between days are eliminated. The generation of $R_j = \sum_{j} c_{ij} / \sum_{j} h_{ij}$ is weighted, however, by time fished prior to time of interview. For this reason, we find it necessary to examine the potential impact of the weighting process of R_j on the estimate of $\hat{r}$.

It is clear that if the fishing process among parties segregated by angling method is Poisson (waiting time between catches are chance independent variables) the weighting process can have only trivial effects on the estimate of $\hat{r}$. It can be argued, however, that given the Poisson condition, a weighted catch rate for each day is desirable because increased emphasis is given ratios with large h_{ij} which are presumed less subject to sample error. In this context, the weighted catch rate, R_j, is probably a better estimate of what has happened to the body of anglers as a whole on a given day. These considerations, however, do not create sufficient reason to select R_j since it is intuitively obvious that an unweighted measure is a better estimate of angling quality obtained by the average party of anglers at time of interview. Moreover, it can be easily demonstrated that given a situation where anglers fishing for long periods have different success rates than anglers fishing for short periods (again assuming a Poisson process within long- and short-term fishermen) R_j will be biased because a higher fraction of long-term anglers will be contacted in a roving census (Di Costanzo 1956).

Severe deviations from the Poisson condition can assume forms whereby neither weighted or unweighted estimates of catch rate produce meaningful results in a roving census. For purposes of illustration, assume a fishery where the first portions of anglers' trips are variable periods of time spent locating a school of fish. Further assume similar catch rates among angler parties once a school is located, that time spent fishing a school is a constant between parties, and that the trip ends after contact with the first school of fish. Given this condition, it is clear that the weighted catch rate estimator could produce very serious underestimates of fishing quality because of the process referred to by Grosslein (1962) as "double weighting", i.e., angler parties which have difficulty locating a school of fish are censused in higher proportion than more successful anglers and their success ratios are given more emphasis in the computation of $\hat{r}$. The conclusion follows that the unweighted method would produce a more desired estimator for a fishery of this type. In situations where total trip lengths are fairly uniform between angler parties and the first part of the trip is a variable in time spent locating a school and the second part of the trip is a variable in time spent in contact with a school, R_j may be desirable because catch rate is correlated with time fished (Grosslein 1962).

Such gross departures from the Poisson condition are not a likely characteristic of warmwater reservoir fisheries similar to Lake Nacimiento. Largemouth bass and bluegill are not commonly considered schooling species. Black crappie are most often sought by anglers during spring spawning periods when they are found in aggregations near shore and it appears most likely that several such aggregations are encountered in the course of a normal day's fishing.

While arguments can be presented favoring both weighted and unweighted daily catch rates, we favor the unweighted value because: (i) there is little evidence that catch rate is a function of time fished (Di Costanzo 1956, Schmulbach 1959); (ii) the unweighted measure relates directly to the average party of anglers contacted while the weighted measure does not; (iii) sources of potential bias which may affect the absolute value of an unweighted catch rate are of little concern because catch rate is not normally used to generate an estimate of total catch; (iv) it is intuitively obvious (to us) that the greatest deviation from the Poisson condition is apt to occur when anglers change fishing methods; (v) because sample errors are more easily determined (Tait 1953); and (vi) because we believe that the roving creel census can be conducted in such a way that each party of anglers interviewed has an equal opportunity of measuring available fishing quality. Given this choice, our estimator for average $\hat{r}$ over n days becomes

$$\hat{r} = \frac{1}{n} \sum_{i}^{n} \frac{1}{m_i} \sum_{j}^{m_i} c_{ij}/h^{ij}. \qquad (3)$$

This parameter is simply an unweighted estimate of catch rate in which the primary sample unit is the day and the sample elements within days are a variable m_i parties ($M_i = \infty$). Each day receives equal weight in the computation of the mean because we assume between day variation to be due to variation in the catchability of fish populations. We also assume that each party has an equal chance of measuring fish abundance regardless of how long they fish. This latter assumption is clearly true if fishing is Poisson and is probably approximately true given certain departures from the Poisson condition. Even when dealing with schooling species, it must be true that waiting periods between encounters with schools are inversely correlated with the number of schools present and that catch rates obtained when schools are located must, within limits, be positively correlated with school density.

THE VARIANCE

We have previously noted that our census procedure is one in which a series of angler interviews m_i ($M_i = \infty$) are collected over a series of n days where N is finite. We further observe that N is the number of days in a time stratum (weekend days in one month at Lake Nacimiento) and that a series of time strata are normally used to construct estimates of fishing quality. This latter estimate over a series of time strata is defined simply as

$$\bar{r}_{st} = \sum^{K} N_k \hat{r}_k / \sum^{K} N_k \qquad (4)$$

where K constitutes the number of time strata (months) used to generate the estimate and where $\hat{r}_k$ is computed from equation (3).

Within a given time stratum, these sampling procedures are the equivalent of two stage sampling where the primary units (days) constitute a finite measure and where the secondary sample elements (party interviews) are equal ($M_i = \infty$) even though m_i is variable. In constructing a combined estimate, each stratum is given equal weight. The development of formulae for the calculation of estimated catch rate variances parallel Cochran (1963) with the following notation:

N = total days in stratum.

n = number of days sampled.

m_i = number of party interviews on day i.

$r_{ij} = c_{ij}/h_{ij}$ = catch per angler hour by party j on day i prior to time of interview.

$\bar{r}_i = \sum_j^{m_i} r_{ij}/m_i$ = estimate of party mean catch per hour on day i prior to time of interview.

$\hat{r}_k = \sum_i^{n} \bar{r}_i/n$ = estimate of party mean catch per hour for stratum k prior to time of interview.

$\bar{r}_{st}$ = estimate of average party mean catch per hour over all strata.

An estimate of within day variance is produced from

$$s_{2i}^2 = \sum_j^{m_i} (r_{ij} - \bar{r}_j)^2/m_i - 1$$

while the companion estimate of between day variance is defined as

$$s_i^2 = \sum_i^{n} (\bar{r}_j - \hat{r}_k)^2/n - 1.$$

With the addition of the appropriate finite correction factor for s_i^2, these parameters combine to form an estimate of variance for $\hat{r}_k$ which is

$$v(\hat{r}_k) = \frac{N - n}{(n)(N)} s_i^2 + \frac{1}{(n)(N)} \sum_i^{n} s_{2i}^2/m_i$$

with a standard error of

$$s(\hat{r}_k) = v(\hat{r}_k)^{1/2}.$$

Individual monthly variance estimates of $\hat{r}_k$ over time interval N_K further combine to produce an estimate of variance and standard error for $\bar{r}_{st}$ which are, respectively,

$$v(\bar{r}_{st}) = \left[\sum^{K} N_k^2 \, v(\hat{r}_k)/\sum^{K} N_k\right]^2$$

and

$$s(\bar{r}_{st}) = v(\bar{r}_{st})^{1/2}.$$

Assuming normal distribution of sample means, 95% ($\alpha = 0.05$) confidence intervals about $\bar{r}_{st}$ may be expressed as

$$\bar{r}_{st} \pm z_{1/2\alpha}^2 s(\bar{r}_{st})$$

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

THE COMPUTER PROGRAM

A generalized computer program (FORTRAN) is available which produces output tables for each species caught during a specified time interval. Separate tables can be generated for boat and shore anglers as well as for weekend days and weekdays if desired. Each table may contain from 1 to 10 angling methods. The tables list the following parameters for each species.

1) Lake name, dates, and species.
2) Angling method (from 1 to 10).
3) Total number of days in the stratum; N.
4) Number of days sampled; n.
5) Number of party interviews for the stratum; $\sum_{i}^{n} m_i$.
6) Mean number of party interviews for the stratum; $\sum_{i}^{n} m_i/n$.
7) Number of anglers interviewed for the stratum; $\sum_{i}^{n} \sum_{j}^{m_i} a_{ij}$.
8) Hours fished by party members prior to time of interview; $\sum_{i}^{n} \sum_{j}^{m_i} h_{ij}$.
9) Fish of selected species caught by party members prior to time of interview; $\sum_{i}^{n} \sum_{j}^{m_i} c_{ij}$.
10) Estimate of party mean catch per hour for the stratum; $\hat{r}_k$.
11) Sum of within day variances; $\sum_{i}^{n} s_{2i}^2/m_i$.
12) Sum of squares between days; $(n - 1)s_i^2$.
13) Standard deviation of party mean catch per hour for the stratum; $s(\hat{r}_k)$.

The program contains a variety of options designed to meet a wide range of problems. For example, while most studies classify the catch by species when data is collected, the program permits up to four additive groups to be formed with each additive group being constructed from a combination of two, three, or four recorded species. A new group may be formed by the adding or subtracting of other groups. The program, therefore, permits either positive or negative addition in forming these additive groups. Similarly, the user may decide which tables (species) he wishes to have printed. For each table, the user can also specify the angling methods used to construct catch rate estimates and angling methods can be combined for single species or combinations of species if desired. This program requires that $n >$ within a stratum and that $m_i >$ with respect to angling method on each sample day. A listing of the program and directions for its use is available from: California Department of Fish and Game, Inland Fisheries Branch, Resources Bldg., 1416—9th Street, Sacramento, CA 95814, U.S.A.

EXAMPLE PROBLEM

As an illustrative example of how this program is used, we chose to describe annual trends in angling quality for bluegill from 1965 through 1968 as determined by the boat segment of the Lake Nacimiento fishery. Our primary interest was to obtain yearly measures of angling quality which could be related to the biological health or general abundance of the bluegill population. In this context, it was necessary to select (i) the group of boat anglers (as differentiated by angling method) which best describe the bluegill fishery, and (ii) the time interval which would produce data most likely to relate directly to the general abundance of the bluegill population.

Early in the study, it became apparent that anglers using worms most accurately described the bluegill segment of the Lake Nacimiento fishery. Bluegill catch rates for this group of anglers were nearly always more than twice as large as opposing groups. Worm anglers annually comprised from 10 to 34% of boat anglers contacted, while their annual catch ranged from 45 to 71% of all bluegill seen. This group of anglers was also highly selective for bluegill which annually comprised from 65 to 92% of their total catch. For these reasons, we have no reservations concerning the selection of worm anglers as the group which most accurately reflects the quality of the boat segment of the bluegill fishery at Lake Nacimiento.

The time interval March through October was used to generate estimates of annual fishing quality. The November through February period was excluded because of low angler use and because catch rates were more related to variations in weather and reservoir turbidity than to the abundance of the bluegill population. Monthly estimates of bluegill angling quality from March through October for each year (1965 through 1968) were produced (Appendix I). These were then combined to construct annual indices of fishing quality.

Bluegill angling quality at Lake Nacimiento was 1.195, 1.008, 1.841, and 1.499 bluegill per angler hour from 1965 to 1968, respectively. Ninety-five percent confidence intervals expressed as ± the percent of annual indices of fishing quality ranged from a low of ±17.9% in 1965 to a high of ±25.4% in 1968 (Table 1). Based on these data, it appears reasonable to assume that a significant improvement in angling

TABLE 1—Annual Indices of Angling Quality and Associated Statistics for Bluegill at Lake Nacimiento, 1965–1968

Population parameters	Year 1965	1966	1967	1968
Total days in universe	70	70	70	70
Total days censused	67	62	56	52
Total anglers interviewed	1,150	884	693	536
Total parties interviewed	386	306	241	189
Total hours fished	3,788	2,825	1,918	1,532
Total bluegill caught	4,216	2,407	3,630	2,032
Index of angling quality	1.195	1.008	1.841	1.499
Variance of angling quality index	0.0119	0.0159	0.0497	0.0377
Standard deviation of angling quality index	0.1092	0.1259	0.2229	0.1940
95% confidence limits about angling quality index	0.981–1.409	0.761–1.255	1.404–2.278	1.119–1.880
95% confidence limits expressed as ±% of angling quality index	±17.9	±24.5	±23.8	±25.4

quality (population density) occurred between 1965–66 and 1967. We cannot, however, attach significance to the decline in angling quality recorded between 1967 and 1968.

DISCUSSION

We have attempted in this paper to develop a rationale for conducting creel censuses on large impoundments with multi-species fisheries. The methodology described is imperfect to the extent that complete objectivity is sacrificed in the interest of economy of operation. As noted in an earlier section, we employed a series of departures from the idealized concept of the roving census advanced by Robson (1961) which now require examination.

Of major consideration is our selection of an 8-hr midday interval as the primary sample unit. It can be reasonably argued that catch rate data collected during this time period may not be representative of the entire day's angling if fish vulnerability is significantly different at night or in the early morning or late evening. We fully recognize this possibility and defend our selection of an 8-hr midday sample unit primarily on the assumption that real changes in game fish abundance will manifest themselves by changes in fishing quality during this midday period. Since catch rate estimates derived in this manner are not normally used to generate an estimate of total catch, we do not feel compelled to speculate on how they might compare with values obtained from completed effort checks or those collected over a broader within day time base. We maintain only that catch rates obtained in the described manner will serve as useful indices of available angling quality which can be used to quantitatively detect fishery changes between years.

The same general arguments apply to our decision to restrict the universe to weekend days only. As noted earlier, fishing effort is greater on weekends which increases the efficiency of the data collection process. Moreover, there is every likelihood that different categories of anglers (tourists and locals) utilize the lake during the two time periods. For these reasons, we consider weekday strata as a separate and discrete universe which is perhaps more difficult to sample effectively because of low angling pressure. We acknowledge the need to census on weekdays if catch rate data are used to construct an estimate of total catch but cannot see how such sampling could improve the precision of catch rate estimators designed to function as indices of fishing quality.

Census problems associated with the systematic selection of starting points and the restriction of travel to a counter-clockwise direction appear trivial. Catch rates obtained in the four sections of Lake Nacimiento were roughly comparable in all years and no serious bias or errors from this source are suspected. Angler contacts are made on a systematic basis to the extent that they are censused as they are encountered along the travel route. The sampling level normally ranges from 70 to 100% of all anglers observed. We have no reason to suspect that this sampling procedure will produce variance estimates greatly different from those obtained by simple random sampling at comparable levels.

While the catch rate estimates derived from this sampling procedure are designed primarily to function as indices of available fishing quality, we also hope that, within limits, they can serve as indices which relate to the biological health or population abundance of the game fish species under consideration. How efficiently these indices reflect actual population abundance may, in part, be related to variations in the game fish food supply between years at individual impoundments. Considerable evidence is now available which indicates that catch rates and food abundance are inversely correlated for a variety of warmwater game fish species (Bennett 1954, Lux and Smith 1960, Forney 1961, and others) and, to that extent, the catch rate index may not function as desired. Variations in reservoir drawdowns between years and their subsequent effects on concentrations of game fish and forage organisms should also be considered prior to the application of the catch rate index as a population indicator.

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APPENDIX I—**Monthly indices of Angling Quality and Associated Statistics for Bluegill at Lake Nacimiento, 1965–1968**

	1965						1966					
Month	N	n	h*	c†	$\hat{r}$	$S(\hat{r})$	N	n	h	c	$\hat{r}$	$S(\hat{r})$
March	8	7	247	265	1.492	0.512	8	4	59	13	0.153	0.097
April	8	8	343	388	0.882	0.187	9	8	479	344	1.033	0.302
May	10	10	868	989	1.501	0.237	9	8	778	633	1.648	0.620
June	8	8	645	775	1.309	0.233	8	7	225	261	1.302	0.312
July	9	9	457	517	1.308	0.504	10	10	480	313	0.805	0.172
August	9	9	431	490	1.130	0.193	8	7	241	258	0.781	0.351
September	8	8	509	643	1.283	0.217	8	8	272	167	0.915	0.342
October	10	8	288	149	0.700	0.194	10	10	291	418	1.320	0.374

	1967						1968					
Month	N	n	h	c	$\hat{r}$	$S(\hat{r})$	N	n	h	c	$\hat{r}$	$S(\hat{r})$
March	8	5	103	19	0.529	0.220	10	8	165	210	1.079	0.209
April	10	5	32	3	0.043	‡0.000	8	7	178	355	1.552	0.483
May	8	7	305	317	0.716	0.178	8	6	301	414	1.064	0.270
June	8	8	282	560	2.163	0.576	10	4	106	187	2.653	1.108
July	10	10	466	1,308	2.743	0.381	8	5	139	324	1.768	0.493
August	8	6	285	630	3.994	1.645	9	6	175	138	1.161	0.397
September	9	7	188	207	2.236	0.492	9	9	387	299	0.870	0.130
October	9	8	257	586	2.410	0.348	8	7	81	105	1.783	0.356

* $h = \sum_{i}^{n} \sum_{j}^{m_i} h_{ij}$

† $c = \sum_{i}^{n} \sum_{j}^{m_i} c_{ij}$

‡ <0.0005

Calif. Fish and Game 59(4) : 293–298. 1973.

AGE AND LENGTH COMPOSITION OF NORTHERN ANCHOVIES, *ENGRAULIS MORDAX*, IN THE CALIFORNIA REDUCTION FISHERY FOR THE 1971–72 SEASON[1]

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A total of 53,426 tons of anchovies was landed for reduction during the 1971–72 season. Sampling revealed that the catch was dominated by age groups I and II in southern California and I, II, and III in central California.

INTRODUCTION

This is the fifth in a series of reports on age and length composition of northern anchovies landed for reduction in California. Data presented are the results of sampling anchovy reduction landings during the 1971–72 season (September 15, 1971, to May 15, 1972, in southern California, and August 1, 1971, to May 15, 1972 in central California). Methods of sampling, age determination, and estimating numbers and weights have remained unchanged since the 1968–69 season (Collins 1971).

The two fishing areas, central and southern California (Messersmith 1969), combined for a total catch of 53,426 tons with 98.2% landed in southern California and 1.8% in central California (Table 1).

Catch estimates for southern California were based on landings at San Pedro reduction plants which provided 73% (38,467 tons) of the southern California landings. Landings for reductions at Port Hueneme (13,342 tons) and San Pedro fresh fish markets (631 tons) were not sampled. A total of 195 samples was taken and 3,454 individual fish were processed in southern California.

Catch estimates for central California were based on landings at Moss Landing (Monterey Bay). Twenty-four samples were taken and 227 individual fish were processed.

[1] Accepted for publication December 1972.

TABLE 1—**Anchovy Landings by Port During 1971–72 Season**

Port	Tons	Percent
Southern California		
San Pedro	39,098	73.2
Port Hueneme	13,342	25.0
Central California		
Moss Landing	986	1.8
Total	53,426	100.0

LENGTH COMPOSITION

Southern California

Anchovies sampled from southern California ranged in size from 87 mm SL to 165 mm SL. Nearly 81% of the estimated 2.1 billion anchovies caught were between 105–134 mm SL (Table 2). This is comparable to the 1970–71 season when fish in these length groups comprised 77% of the catch (Spratt 1973). About 12.5% of the catch consisted of fish smaller than 105 mm SL.

Length-age data show the mean length of all year classes to be 3 to 10 mm SL smaller than in the 1970–71 season. This is unusual, but during the course of the season many anchovies were sampled whose otoliths showed a greater number of annuli than would be expected based on the length of the fish. These older but shorter fish accounted for the decreased mean lengths of year classes.

TABLE 2—Estimated Number of Anchovies by Length Group Landed at San Pedro During 1971–72 Season

Length group mm SL	Estimated number	Standard deviation	Percent of landings
85– 94	28,770,250	10,226,884	1.38
95–104	232,815,250	32,314,278	11.14
105–114	770,444,500	36,951,610	36.87
115–124	582,733,000	22,763,407	27.89
125–134	335,615,500	18,938,089	16.06
135–144	117,548,250	11,350,762	5.63
145–154	19,577,000	4,103,429	.94
155–164	1,295,500	1,396,947	.06
165–174	543,250	829,694	.03
Total	2,089,342,500	---	100.00

Central California

Anchovies sampled from central California ranged from 107 mm to 163 mm SL. Fish between 115–144 mm SL comprised 82% of the estimated 35 million anchovies landed (Table 3). While no samples were taken in central California during the 1970–71 season, data indicate 1969–70 season fish between 115–144 mm SL also provided 82% of the catch (Spratt 1972). A comparison of data from central and southern California shows that the mean length of a given age group is 6 to 11

TABLE 3—Estimated Number of Anchovies by Length Group Landed in Central California During 1971–72 Season

Length group mm SL	Estimated number	Standard deviation	Percent of landings
105–114	3,847,250	1,248,608	11.04
115–124	11,896,250	2,192,871	34.16
125–134	9,409,750	1,341,754	27.01
135–144	7,233,750	1,024,498	20.76
145–154	2,196,750	808,098	6.31
155–164	250,500	231,549	.72
Total	34,834,250	---	100.00

mm SL larger in central California. This difference in length at age agrees with data from previous seasons (Collins, 1969, 1971; Spratt, 1972, 1973).

AGE COMPOSITION

Otoliths were taken from samples for age determination. Age and year class were assigned using the method described by Collins and Spratt (1969).

Southern California

The 1971–72 season age composition was dominated by age group I fish (1970 year class) which comprised 51% by number and 46% by weight of the catch (Tables 4 and 5). This is the largest contribution a single year class has made to the catch in the history of the anchovy reduction fishery. This indicates that recruitment of anchovies into the fishery continues at a high level. Age groups I, II, and III provided 80% by number and 88% by weight of the catch. This is down slightly from the 1970–71 season when age groups I, II, and III contributed 92% of the catch in both number and weight.

Central California

The 1971–72 season catch in central California was comprised of three strong age groups. Age group I (1970 year class) provided 36% of the catch by number and 28% by weight while age group II (1969 year class) contributed 31% of the catch in both number and weight. Age group III (1968 year class) provided 22% of the catch by number and 28% by weight. Together the three year classes contributed 90% and 87% by number and weight respectively of the catch (Tables 6 and 7). No samples were taken in central California during the 1970–71 season, but during the 1969–70 season these three age groups provided 93% in both number and weight of the catch (Spratt, 1972).

SEX AND BIOMASS RATIO

Sampling data were used to estimate numbers and pounds landed by sex, and the corresponding sex and biomass ratios were calculated.

Southern California

Sample data show a female to male numerical ratio of 1.5:1 and a weight ratio of 1.6:1 (Table 8), and are comparable to 1970–71 season data which indicate a 1.6:1 and 1.7:1 numerical and biomass ratio respectively (Spratt 1973). Collins (1971) has shown that a wide degree of variance may be expected in sex and weight ratios from season to season due to the nature of our sampling plan.

Central California

Sampling data from central California indicate both a sex and weight ratio of nearly 1:1 (Table 8). This compares with a .63:1 and .70:1 sex and weight ratio calculated for the 1969–70 season (Spratt, 1972). Sex ratios calculated from central California reduction landings from the 1965–66 season through the 1968–69 season ranged from 1.2:1 to 1.4:1, and biomass ratios ranged from 1.3:1 to 1.5:1. There is no apparent reason for the decrease in female to male ratios during the past two seasons, but it may be related to decreased anchovy landings and the subsequent small number of samples.

TABLE 4—Estimated Number of Anchovies by Year Class Landed During 1971–72 Southern California Reduction Season

Year class (age)	1971 (0)	1970 (1)	1969 (2)	1968 (3)	1967 (4)	1966 (5)	Total
Number	235,575,500	1,065,174,750	559,188,500	175,711,500	49,762,250	3,929,500	2,089,342,500
Standard deviation	36,775,112	33,151,042	19,809,143	12,195,447	6,544,595	2,280,292	---
Percent	11.28	50.98	26.76	8.41	2.38	0.19	100.00

TABLE 5—Estimated Weight of Year Classes Landed for Reduction in Southern California During 1971–72 Season

Year class (age)	1971 (0)	1970 (1)	1969 (2)	1968 (3)	1967 (4)	1966 (5)	Total
Pounds	5,776,500	35,708,250	23,040,000	9,299,250	2,883,250	226,000	76,933,250
Standard deviation	694,662	1,023,289	865,555	652,476	378,518	136,452	---
Percent	7.51	46.41	29.95	12.09	3.75	0.29	100.00

TABLE 6—Estimated Number of Anchovies by Year Class Landed During 1971–72 Central California Reduction Season

Year class (age)	1971 (0)	1970 (1)	1969 (2)	1968 (3)	1967 (4)	1966 (5)	1965 (6)	1964 (7)	Total
Number	715,000	12,688,250	10,914,000	7,817,250	1,817,750	729,000	---	153,000	34,834,250
Standard deviation	527,177	2,152,391	1,926,713	1,335,452	852,665	488,294	---	153,141	---
Percent	2.05	36.43	31.33	22.41	5.22	2.09	---	0.44	100.00

TABLE 7—Estimated Weight of Year Classes Landed for Reduction in Central California During 1971–72 Season

Year class (age)	1971 (0)	1970 (1)	1969 (2)	1968 (3)	1967 (4)	1966 (5)	1965 (6)	1964 (7)	Total
Pounds	24,000	550,250	604,250	559,000	155,000	62,250	---	17,250	1,972,000
Standard deviation	17,532	94,576	97,197	95,228	72,968	42,392	---	17,283	---
Percent	1.22	27.90	30.64	28.35	7.86	3.16	---	0.87	100.00

TABLE 8—Sex and Biomass Ratio for 1971–72 Anchovy Reduction Season

	San Pedro	Central California
Sex ratio		
Males		
Number	766,590,000	17,438,000
Percent	36.69	50.06
Females		
Number	1,164,991,500	16,829,250
Percent	55.76	48.31
Unknown		
Number	157,761,000	567,000
Percent	7.55	1.63
Females:males	1.52:1	0.96:1
Biomass ratio (weight)		
Males		
Pounds	28,161,500	950,000
Percent	36.61	48.17
Females		
Pounds	45,109,750	998,250
Percent	58.63	50.62
Unknown		
Pounds	3,662,000	23,750
Percent	4.76	1.21
Females:males	1.60:1	1.05:1

ACKNOWLEDGMENTS

I wish to express my sincere thanks to all the people who participated in collecting and analyzing the data. Eugene Fleming, William Maxwell, and Dave Parker sampled landings at San Pedro, and James Hardwick sampled at Moss Landing. Special thanks is extended to the otolith reading team of Marian Haxby, Phil Lehtonen, Ralph Norberg, and John Sunada.

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Calif. Fish and Game 59(4) : 299–304. 1973.

AMBICOLORATION IN SOME CALIFORNIA FLATFISHES[1]

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Five partially or extremely ambicolorate California flatfishes; the bigmouth sole, *Hippoglossina stomata*; Dover sole, *Microstomus pacificus*; curlfin sole, *Pleuronichthys decurrens*; horneyhead turbot, *Pleuronichthys verticalis*; and California tonguefish, *Symphurus atricauda*, are described. Possible causal factors of ambicoloration are discussed but no definite conclusions are reached.

INTRODUCTION

I have recently examined several flatfishes which exhibit various degrees of ambicoloration, the occurrence of pigmentation and pattern on the normally uncolored blind side. This phenomenon is not particularly rare in flatfishes, but thus far it has been described in only 10 of 82 American species of flatfishes, mostly from the coast of the western Atlantic and the Gulf of Mexico (Dawson 1962 and Moe 1966). Herein are described new records of five species of ambicolorate flatfishes from three families of California heterosomates.

Ambicoloration can be extreme or partial depending on the area of anomalous pigmentation. Extreme ambicoloration includes flatfishes with total blind side pigmentation, and flatfishes where only the blind side of the head is unpigmented. Anomalous development of the anterior dorsal fin and irregular eye migration are usually associated with extreme ambicoloration. Partial ambicoloration includes flatfishes with blind side pigmentation that is less extensive than for extreme ambicoloration. Anomalous development of head structures is not generally found in partially ambicolored individuals.

The flatfishes were each examined for other possible anomalies including reversal, anomalous scalation, reversal of liver-intestine orientation (*situs inversus viscerum*), and abnormal fin ray counts. None of these anomalies was found in any of the flatfishes examined. None of the fishes examined had any injuries.

The fishes described here are deposited in the ichthyological collection of the Los Angeles County Museum of Natural History (LACM).

DESCRIPTIONS AND DISCUSSION

Bothidae

Bigmouth sole, *Hippoglossina stomata* Eigenmann and Eigenmann, 1890

On May 3, 1972, a 170 mm SL *Hippoglossina stomata* was collected by Mr. Dave Parker from a catch made by the *Frankie Boy II*. The specimen was taken incidentally by purse seine off Newport Beach, California, in waters no deeper than 40 m.

[1] Accepted for publication June 1973.

The blind side of this fish has three areas of pigmentation, which are similar in coloration to that of the ocular side (Figure 1). In addition, there are lighter pigmented areas adjacent to and anterior of the ambicolorate area on the peduncle, and another just dorsal to the blind side pectoral fin. The blind side caudal rays are pigmented, but this is apparently not an uncommon occurrence.

Meristic counts are within ranges given by Ginsburg (1952), and are: dorsal rays (d.r.), 64; anal rays (a.r.), 49; pectoral rays (P_1), 11; and pelvic rays (P_2), 6. The specimen is LACM 32239-1.

FIGURE 1. Blind side of bigmouth sole, *Hippoglossina stomata* showing partially pigmented areas.

Pleuronectidae

Dover sole, *Microstomus pacificus* (Lockington), 1878

A 135 mm SL *Microstomus pacificus* was collected by Mr. Doug Hotchkiss on January 13, 1972 from the Los Angeles County Sanitation District's research vessel *Sea-S-Dee*. The fish was trawled in the western part of Santa Monica Bay (approximate lat 33°49′N, long 118°26′W) in 82 m of water.

The blind side is partially ambicolored (Figure 2) and closely resembles the pigmentation on the eyed side. The area on and slightly posterior to the head is mottled with many chromatophores, as is often found in normal dover soles. Meristic counts fall in the ranges given by Norman (1934) and are: d.r., 103; a.r., 82; P_1, 10 on blind and 11 on eyed side; and P_2, 5. This specimen is LACM 32610-1.

Curlfin sole, *Pleuronichthys decurrens* Jordan and Gilbert, 1881

On December 20, 1971, a 136 mm SL *Pleuronichthys decurrens* was collected by Mr. Dee Chamberlain of the University of Southern California from the research vessel *Vantuna*. This fish was trawled in 15 m of water near Port Hueneme (approximately lat 34°07′N, long 119° 10′W).

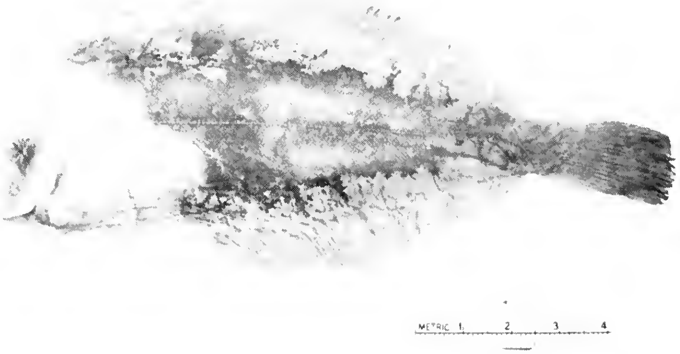

FIGURE 2. Blind side of partially ambicolored dover sole, *Microstomus pacificus*.

This fish is almost totally ambicolored (Figure 3) with only the blind side of the head being unpigmented. As is often the case in extreme ambicoloration, hooking of the dorsal fin over the migrating (left) eye has occurred. The first 9 or so dorsal rays have been eliminated, an anomaly probably unique to the genus *Pleuronichthys* where the origin of the dorsal fin is on the blind side. The migrating eye does not seem to have been displaced as is often the case when structural head anomalies appear.

Fitch (1963) found 21 ambicolored of 899 *P. decurrens* examined, but did not describe these specimens. He also found that ambicoloration

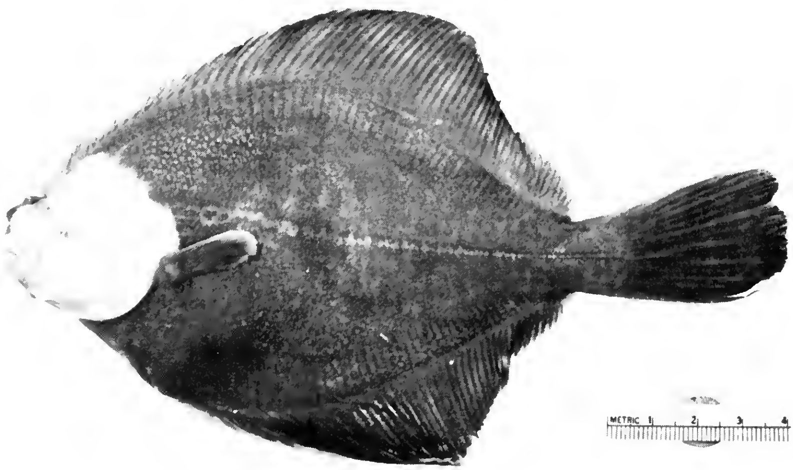

FIGURE 3. Blind side of an almost totally ambicolored curlfin sole, *Pleuronichthys decurrens*.

was more frequently seen in *P. decurrens* than in the other species of *Pleuronichthys*.

Positive separation of *P. decurrens* from other closely related species was made using vertebral counts taken from x-rays of the specimen. There are 14 precaudal and 25 caudal vertebra, including the hypural plate. Other meristic counts fall within ranges given by Fitch (1963) and are: d.r., 70 (about 9 anterior rays are deleted); a.r., 52; P_1, 13 on eyed and 12 on blind side; and P_2, 6. There are no indications of skeletal or external injury. This fish is LACM 32606-1.

Horneyhead turbot, *Pleuronichthys verticalis* Jordan and Gilbert, 1881

On March 16, 1972 I collected a female horneyhead turbot 178 mm SL aboard the California Department of Fish and Game research vessel *Kelp Bass* in Monterey Bay near Seaside (approximate Lat. 36°37′N, long 121°52′W). The fish was taken by bottom trawl in 21 m of water over a sand bottom.

The blind side of the head (Figure 4) is pigmented similarly to the eyed side, except for an unpigmented area anteriad of the operculum. Meristic counts fall into the ranges listed by Fitch (1963) and are: d.r., 66; a.r., 44; P_1, 10 on ocular and 8 on blind side; and P_2, 6. This fish is LACM 32763-1.

FIGURE 4. Blind side of horneyhead turbot, *Pleuronichthys verticalis* showing ambicolorate area on head.

Cynoglossidae

California tonguefish, *Symphurus atricauda* (Jordan and Gilbert), 1880

On May 21, 1971, an immature 65 mm SL *Symphurus atricauda* was collected by Mr. Larry Allen of Cerritos College while aboard the research vessel *Vantuna*. The specimen was taken by otter trawl 1.9 to 2.8 km off the Long Beach Harbor breakwater in about 21 m of water.

The fish is partially ambicolored, only the blind side of the head and dorsal anterior areas being unpigmented (Figure 5). The blind side pigmentation and pattern are identical to that of the normally colored ocular side. There are about 100 dorsal rays, 84 anal rays, no pectoral fins, and the single left pelvic fin has 4 rays.

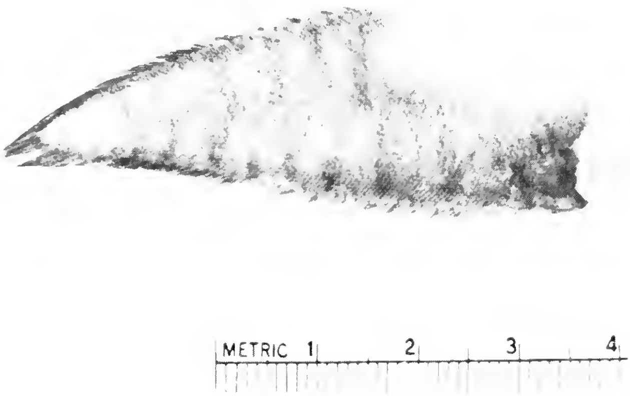

FIGURE 5. Blind side of a partially ambicolored California tonguefish, *Symphurus atricauda*.

Reports for anomalous cynoglossids are rare. Only two previous records of ambicolorate tonguesoles are known, *S. plagiusa* (Dawson, 1962) and *S. diomedianus* (Moe, 1968).

This fish is the first record of any anomaly in *S. atricauda*. It is LACM 32238-1.

Many theories have been suggested as to the cause of ambicoloration. Norman (1934) stated his belief in the idea that most flatfish anomalies were simply variations toward the more primitive (less specialized) condition of bilateral symmetry. If this were the case, higher anomaly rates would be found in the more primitive flatfishes, a condition that was found in a study of two species of flatfishes (Haaker and Lane 1973). This trend is generally seen in the heterosomates by the rarity of anomalies in the more specialized families including soleids and cynoglossids.

Shelbourne (1965) reported high numbers of abnormally pigmented plaice, *Pleuronectes platessa*, resulting from laboratory rearing experiments. Houde (1971) also found abnormal development in his laboratory reared *Achirus lineatus*, including anomalous eye migration, hooked dorsal fins, ambicoloration and albinism. Both of these experiments indicate that environmental factors may have an effect on the occurrence of flatfish abnormalities. The low frequency of occurrence of ambicoloration in flatfish populations argues against environmental factors as being the major factor contributing to these anomalies. However, it should be noted that data on how various anomalies affect larval and juvenile survival is non-existent. An interaction between environmental and genetic factors may be the controlling elements of the various flatfish anomalies including ambicoloration.

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STATUS OF THE FISHER IN NORTHERN CALIFORNIA, OREGON AND WASHINGTON[1]

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Recent records and observations for fishers are given for three Pacific states. For California only the northwest part of the state is included. It appears that fishers are increasing in Humboldt and Trinity counties, California along the Trinity and Klamath rivers.

INTRODUCTION

Grinnell, Dixon and Linsdale (1937) showed two indigenous areas in California for the fisher (*Martes pennanti*); from the Oregon line in the northwestern part of California south to Lake and Marin counties and east only as far as Mount Shasta; south from Lassen National Park to north central Kern County in the Sierras.

Apparently fisher became very scarce during the 1920's and 1930's and remained at a low population level until the noticeable increase that occurred in the 1960's and 1970's in Humboldt, Trinity, and Del Norte counties (Figure 1). Possibly the increase in porcupines throughout these counties furnished a food supply that allowed fisher populations to increase (Yocom 1971).

Ingles (1965) stated that fisher could be seen in the Sierra-Nevada region between Yosemite and Sequoia national parks and in the Trinity Mountains of California.

Yocom started to search for records of fisher in northwestern California in the early 1950's. Rumors that these animals had been seen in the Willow Creek area were the only information obtained until the late 1950's and early 1960's.

OBSERVATIONS AND RECORDS

California

William Hawes reported one taken on Horse Linto Creek by Dr. Lathan Williams, Willow Creek, in the winter of 1961, when he was trapping for bears. Hawes also mentioned other fishers captured by bear trappers in that area within the last few years. In March, 1959, in the Willow Creek-Hawkins Bar area, Mr. Raymond Perry felled a snag which contained the nest of a fisher at the top. The stunned animal, 10 inches long, with still unopened eyes revived and was nursed to health on a bottle of milk and pablum by Mrs. Perry. In April, 1961, the fisher was given to the Eureka Zoo.

Robert Talmadge wrote that one was caught in a trap in the late fall of 1962 or 1963 in Salyer Heights, 3 miles northeast of Salyer, Trinity County. Many of the sightings by the United States Forest Service

[1] Accepted for publication June 1973.

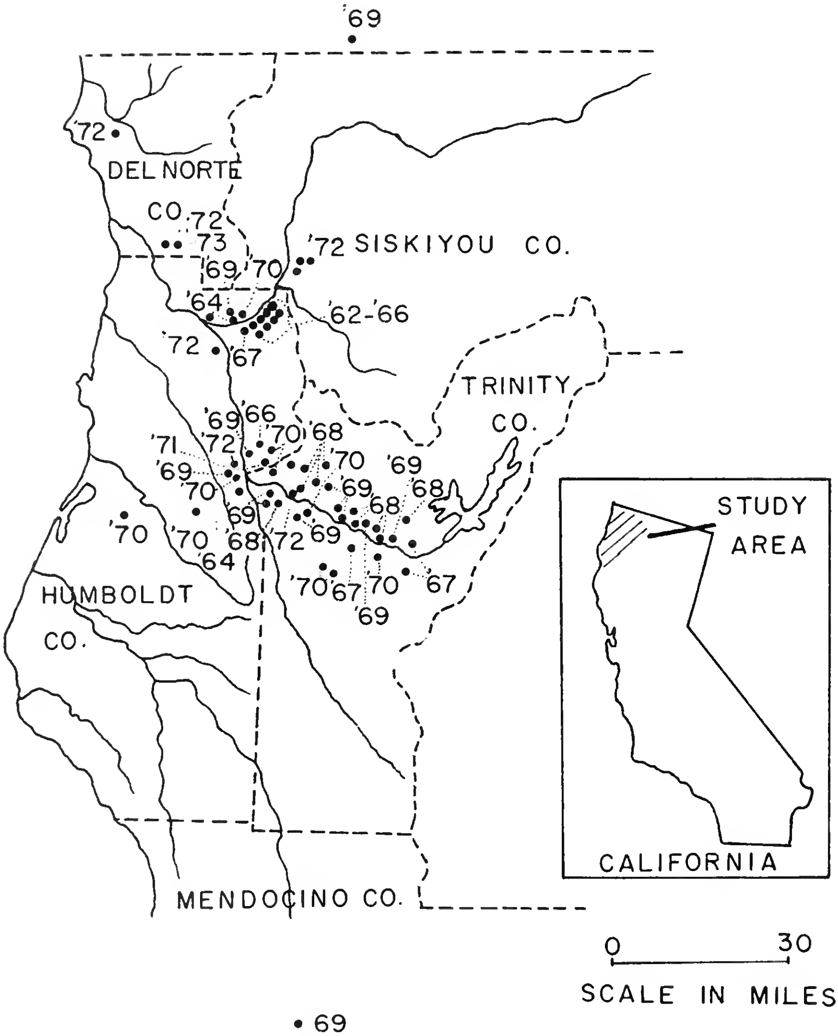

FIGURE 1. Northwestern California locations where fishers have been seen. Rivers from north to the south are: Smith, Klamath and Trinity, Redwood Creek, Mad, Eel and Van Duzen, and Mattole.

(U.S.F.S.) personnel along the Trinity River were furnished by Donald K. Blake, a former student in Game Management from California State University, Humboldt. McCollum obtained records from bear hunters, and D. P. Garber, U.S.F.S. biologist, helped obtain records of fishers seen from the Six Rivers, Klamath, and Shasta-Trinity national forests (Figure 1).

According to houndsmen, the fisher leaves a strong scent that most, but not all, hounds will follow. When pursued by dogs, fisher seldom run farther than ½ mile before taking refuge in a tree or other suitable place. Chases up to 3 hr were reported however, and one chase covered a distance of approximately 3 miles. No cases were reported where hounds were able to catch a fisher on the ground and harm it.

Several treed fisher reportedly perched in the very tops of conifers. Generally fisher that were treed remained in a single tree until dogs and handlers left, but incidents were reported where fishers tried to escape by jumping into trees nearly. In one case, the fisher jumped out of a tree and escaped the pursuing hounds on the ground. The majority of observations of fisher occurred at night although daytime observations were not uncommon.

Several hunters who have been familiar with the Willow Creek area for a number of years feel that fisher are increasing there. It is also felt by some hunters that fisher predation upon small game populations including gray fox, *Urocyon cineroargenteus*, bobcats, *Lynx rufus*, and racoons, *Procyon lotor*, have led to reductions in these populations in that area.

While Mack Davis and Sherman Chisholm were driving on the Hawkins Bar Road near Waterman Ridge, probably in Humboldt County, they observed a fisher overtake and kill a gray fox. This incident happened during daylight hours in November 1971. There were about 6 inches of fresh snow on the ground. The fisher was observed chasing a gray fox down the road towards the vehicle. The fisher overtook the fox twice, but both times after a scuffle the fox escaped. The third time the fox was overtaken, the hunters were close enough to jump out of the vehicle and chase off the fisher. The fox was critically injured and soon died. The fox was large and apparently had been a healthy animal.

From our records, it appears that fisher are increasing in numbers in both Humboldt and Trinity counties along the Trinity and Klamath rivers. Mr. Jim Gordon, Wildlife Biologist for the Shasta-Trinity Nation Forest, reports that 51 fisher have been seen in that national forest from 1971 to 1973. Apparently, the fisher is increasing in that area. Fisher have not been recorded, except for the one record on the Fickle Hill-Kneeland Road, in redwood forest type. We have three records for Del Norte County, three for Siskiyou County, none from southern Humboldt County, and one from Mendocino County. Undoubtedly, fisher occur throughout the relatively inaccessible areas in the east side of Del Norte County, Siskiyou and Shasta counties, but are believed absent from northeastern California.

Oregon

From Oregon, we have 29 recent records of fisher: one from Jackson County, Oregon, about a mile north of the California State line in the Applegate drainage; 11 records from around the rim road at Crater Lake, Klamath County dated from 1955 to 1972 (Figure 2); one at Diamond Lake just north of Crater Lake National Park in Douglas County; eight have been seen during 1971 and 1972 in northern Winema National Forest, Klamath County, northeast of Crater Lake National Forest; one from Deschutes National Forest in upper Klamath County, August, 1972, and two from areas 16 and 23 miles west of Bend, Deschutes County, in the summer of 1972; one record from the coastal mountains in April, 1973, northeast of Reedsport (T 20S R

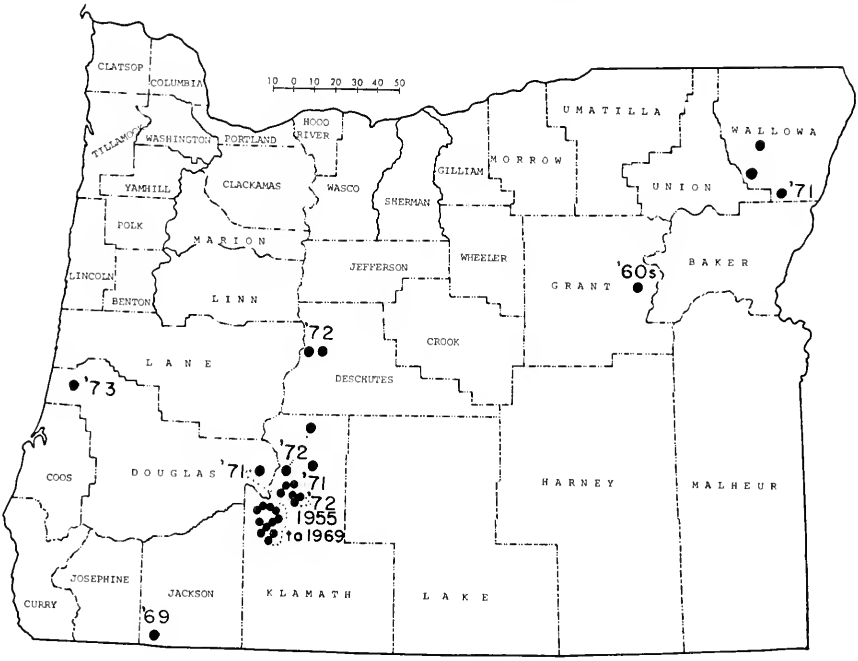

FIGURE 2. Oregon locations where fishers have been seen. Numbers by the dots indicate the year that the animal was seen.

11W) in the Siuslaw National Forest. We have no fisher records from Fremont National Forest and Malheur National Forest. There are three records only from the Wallowa-Whitman National Forest, Wallowa County. Two of these records from the Lostine River country are undated and based on tracks. One was seen in the summer of 1971 and was 17 miles southeast of Wallowa Lake. All records for Oregon were furnished by the United States National Forest Service and the United States National Park Service personnel.

Washington

Nine recent Washington records of fisher include two from Olympic National Park, T 25N R6W, on Hurricane Ridge, Clallum County, June, 1969, and one near Lake Quinault, Grays Harbor County, in the late 1960's. Five records are from Olympic National Forest area: two near Eldon, Mason County, T 24N R34W, April, 1972; one in T 21 N R4W, Mason County, February, 1973; one in T30N R11W, Sect. 3, Clallum County, October, 1971; one T25N R3W, Sect. 16, Jefferson County, September, 1971. J. B. Lauckhart in a paper for the Washington Chapter, The Wildlife Society, "Rare Mammals of Washington," referred to a trapped fisher in Lilliwaup Swamp area, Mason County, January 1969. A recent record from North Cascades National Park includes a fisher seen 8 to 10 miles northeast of Marblemount, T 36N R11E, Sect. 1, Skagit County, July, 1971. There are no records for the Wenatchee National Forest or the Colville National Forest. Tracks of a fisher, however, have been seen on Highes Ridge, 5,500′, Sect. 32, T65N R5W, March 4, 1972 by Dave Freddy, University of Idaho, just across the Washington-Idaho state line. One old record for a fisher with two kits is recorded for the Okanogan National Forest for the year 1955, T39N R21E, Sect. 34, Okanogan County.

Apparently, the fisher is rarely seen in Washington and appears to be absent from the southern half and the eastern half of the state (Figure 3). All records for fisher in Washington were furnished by the U. S. Forest Service and the National Park Service personnel, and Dave Freddy, University of Idaho.

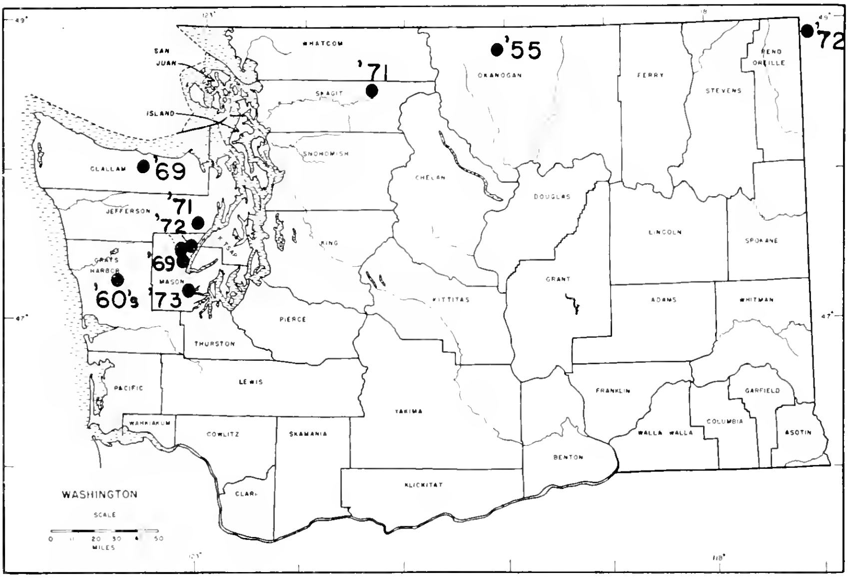

FIGURE 3. Washington locations where fishers have been seen. Numbers by the dots indicate the year that the animal was seen.

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NOTES

THE FIRST OCCURRENCE OF *KYPHOSUS ANALOGUS* IN CALIFORNIA

On September 5, 1972, a single specimen of *Kyphosus analogus* was taken off Encina Power Plant, located several miles south of Oceanside, California. The fish was taken in a gill net used to catch perch (Family Embiotocidae). Several fish of the genus *Scomberomorus* were also captured. Positive identification of these fish was impossible since gill raker counts were not made. Inspection of external characteristics indicate they were *S. sierra* and not *S. concolor*. In November, a second specimen of *K. analogus* was taken by the same method in an area not far from where the first was captured.

Kyphosus analogus is a tropical species usually found off Mexico or central America (Meek and Hildebrand, 1925). It occurs in the Gulf of California, the northernmost record being from a collection made at Topolobampo Bay Mexico (John Bleck, pers. comm.). In the Pacific Ocean, *K. analogus* is reported from the mouth of Magdalena Bay (Carl L. Hubbs, pers. comm.). The two records from Encina Power Plant represent a northern range extension of over 685 miles. Only one other member of the family Kyphosidae is present in California, it being the zebraperch (Miller and Lea 1972).

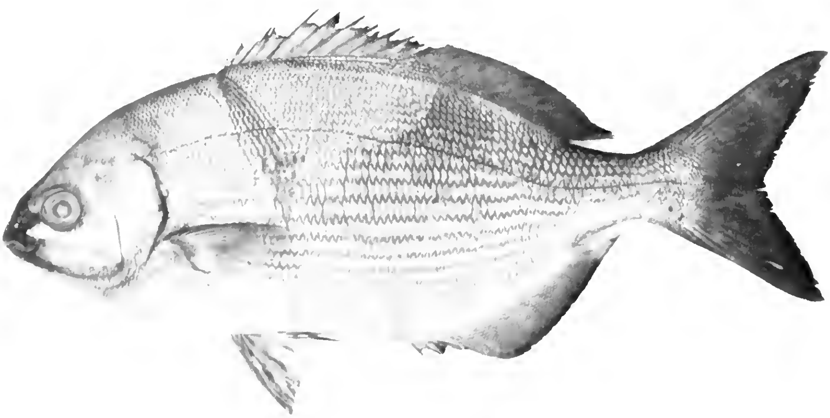

FIGURE 1. *Kyphosus analogus taken September 5, 1972. Photograph by Jack Schott, September 1972.*

How these two fish reached California is open to speculation. They could have arrived as juveniles, swimming under a kelp paddy or other flotsam that was swept up from Baja California. The young of this species are commonly found under flotsam off the coast of central America (Hunter and Mitchell 1966). The second possibility that exists is for adults to have migrated north during the period of warm water experienced last summer. Because of the large size of the fish (260 mm and 240 mm TL), if they arrived as juveniles, they must have been in the area for some time. It is interesting that the larger of the two fish is bigger than any referred to in the literature. This indicates that both are adults and either hypothesis is valid. Once in California, it is only natural to expect such tropical fish to occur around the warm water discharge of a power plant.

I would like to thank John E. Fitch for his identification of *K. analogus*. Dan West caught both specimens and Bill Miyagawa was inquisitive enough to save them for me. Carl L. Hubbs and John Bleck provided current information about the range of the fish.

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—*Stephen J. Crooke, Marine Resources Region, California Department of Fish and Game, Long Beach, Calif. 90802.* *Accepted June 1973.*

THE CENSUS OF NORTHERN ELEPHANT SEALS ON SAN MIGUEL ISLAND, 1965–1973

Some 75 to 80 years ago northern elephant seals *Mirounga angusstirostris* (Gill) were believed virtually extinct off the California and Mexican coasts, having become victims of seal hunters who took them for their valuable oil. They were hunted from as early as 1818, until they were no longer plentiful enough to make hunting them economically feasible. The reappearance of elephant seals on San Miguel in very small numbers has been known at least since 1938 (Bartholomew 1967). He also believes the present population, which is probably in the order of 20,000 animals on California and Mexican islands, is derived from only a few or possibly a single family group.

Beginning in 1965 an annual census of elephant seals has been conducted on San Miguel Island. Since the mid-1960's this Island has been by far the most important site for breeding and reproduction of this interesting marine mammal in California waters.

Prior to 1965 marine wardens of the Department on regular visits to the Island estimated that the peak population numbered about 800 animals. In 1965 their estimate was that this number had doubled. Because of this expanding population and the importance of San Miguel as the major rookery in California waters it became desirable that an annual census be initiated in addition to the irregular aerial pinniped censuses for the whole California coast (Carlisle 1971).

Most of the elephant seals haul out at Point Bennet, at the west end of the Island, where large expanses of sand, preferred by these pinnipeds, predominate. The census is accomplished by two biologists walking among or near all groups of animals, tallying as they go. On large, difficult to count groups, each man takes an independent count; the totals are compared and an average taken. Usually the two counts are very close.

It appears that the elephant seal population on the Island reaches a peak during the breeding season in January and February each year. After that the bulls begin to leave the Island for a period of pelagic life in offshore California and Mexican waters, followed later by most of the other animals. There have been reports of elephant seals seen in offshore waters of Oregon, Washington and southeast Alaska. In order to obtain as close to a maximum count as possible the census was moved up from April to February each year. The average annual counts taken in February and March is over 13% higher than the average for those years when the census was conducted in April.

The highest count of the period was made in 1967 when the total reached 3,700 and the low as made in 1970 with a count of 2,200, Table 1. It was quite evident during that census that many animals, especially bulls, had already left the Island. It may be assumed that all counts are minimal as it is unlikely that the absolute population peak is present on the days of the census. Also, with the densely packed herds, a behavioral trait common to elephant seals, it is virtually impossible to see and count every animal. Generally in the presence of man, careful to create a minimum of disturbance, these huge mammals, which can attain a maximum length of 22 ft and a weight of 5,000 lb, remain relatively docile despite their enormous size. This characteristic makes it possible to approach the herds closely and obtain a reliable count.

TABLE 1—San Miguel Island Elephant Seal Census

Year	Number of elephant seals	Month of census
1965	3,000	April
1966	3,000	April
1967	3,700	April
1968	---	----
1969	3,000	April
1970	2,200	April
1971	3,200	February
1972	3,500	February
1973	3,600	March

During the 1973 census the distribution of elephant seals was unusual in our experience. In previous years, most of the animals were concentrated at Point Bennet. This year, even at Point Bennet they were more widely dispersed, and hundreds of animals were hauled out about 2½ and 3 miles to the east at Judith Rock and Tyler Bight; a few were on the other, north side, of the Island at Simonton Cove. An aerial observation, made three weeks previous to our visit, had shown an estimated 500–600 elephant seals at the latter site. Only six were present there on March 21.

I have conducted all censuses since the inception of the counts in 1965. Harold Clemens of this Laboratory has aided in all but two of these years.

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—*Carlisle, John G. Jr., Marine Resources Region, California Department of Fish and Game.* *Accepted for publication June 1973.*

FIRST RECORD OF BRYDE'S WHALE (*BALAENOPTERA EDENI*) OFF CALIFORNIA

Four San Diego men (W. A. De Court, A. Santmyer, F. Morejohn, and C. R. Nicklin, Jr.), while on a spiny lobster fishing trip off La Jolla, California, on January 8, 1963, encountered a whale that they thought to be a fin whale (*Balaenoptera physalus*) about 1 km from shore (approximately lat 32°47′ N long 118°44′ W). They thought the whale was asleep. As they approached, the whale blew. Since it did not move away from them they suspected something amiss and cautiously pulled alongside in their 45-ft boat. Two of them put on their wet suits and submerged next to the whale to investigate and to take underwater photographs. They went down with snorkels leaving their air tanks aboard so as not to be bulky. On their second dive they noticed a ⅜-inch line caught on the flukes of the whale, the float line of a commercial gill net. The weight and drag of the net apparently held the whale fast. The men had opportunity to swim all around the whale and to climb on its exposed back. The whale periodically blew fine spray from its blowholes but barely moved about. It appeared to be exhausted. Several still photographs were taken as well as motion pictures, and many pencil sketches were made by F. Morejohn. The men were eventually able to free the whale from the float line. The whale remained quiet for several minutes after being freed. Enough time elapsed so that the men were able to swim back to the boat. In time the whale began to swim, but it did not depart immediately; it swam around the boat slowly and then left for the open ocean. The whale appeared to be about as long as their boat—13.7 m. The entire episode lasted about 3 hr.

An account of this incident, along with several photographs (captioned "finback whale"), was published by Nicklin (Skin Diver 12(11):12–15, 1963). Recently, Kodachrome slides of the whale were provided by Frank Morejohn (brother of the senior author). Several photographs (e.g. Figure 1) show the prominent longitudinal ridges, one on each side of the dorsal surface of the rostrum, that are diagnostic of Bryde's whale *Balaenoptera edeni* (see Omura, 1966). In a letter of April 14, 1965 to the junior author, Omura, referring to the published photographs, wrote ". . . the whale is without doubt a Bryde's whale".

Other characteristics visible in the photographs that aid in distinguishing *B. edeni* from the other four species of *Balaenoptera* (all of which occur regularly in southern California waters), are: (i) The ventral surface of the body is mostly dark, thus ruling out the fin whale; and (ii) The shape of the dorsal fin and its relative size is intermediate between that of a fin whale and that of a sei whale (*Balaenoptera borealis*). Unfortunately none of the photographs shows whether the ventral grooves extend posteriorly to the umbilicus, the only obvious external character (other than the rostral ridges) that distinguishes *B. edeni* from *B. borealis*. The blue whale (*B. musculus*) and the minke whale (*B. acutorostrata*) differ in other characters and require no comparison with our animal (see Daugherty 1972:20–23).

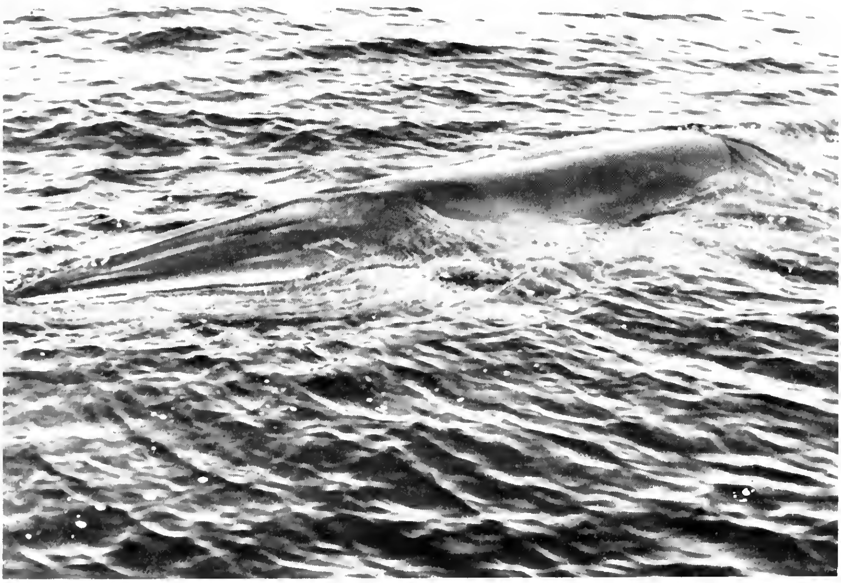

FIGURE 1. Bryde's whale (*Balaenaptera edeni*) off La Jolla, California. Note the lateral ridge on each side of the median ridge of the rostrum (photo by Frank Morejohn).

Bryde's whales are primarily inhabitants of coastal waters warmer than 20C. In the eastern Pacific, they are common year-round as far north as lat 26°12′N on the west coast of southern Baja California, but they have not previously been found north of that latitude. None was identified among the whales landed at the whaling stations at Richmond, California (lat 38° N) from 1956 through 1971. Two alleged to have been taken there during the 1966 season (Anon. 1967) were almost certainly misidentified. At sea, living Bryde's whales appear so similar to sei whales and immature fin whales that they can be identified with certainty only when seen at very close range.

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—*G. Victor Morejohn and Dale W. Rice, Moss Landing Marine Laboratories of the California State University and State Colleges, Moss Landing, California 95039; and National Marine Fisheries Service, Southwest Fisheries Center, La Jolla, California 92037.* *Accepted for publication April 1973.*

OBSERVATIONS ON THE SPAWNING OF THE MISSISSIPPI SILVERSIDES, *MENIDIA AUDENS*, HAY.

The Mississippi silversides, *Menidia audens* Hay, introduced into California in 1967 (Cook and Moore 1970) is part of the fish fauna in Lexington Reservoir, Santa Clara County. Originally introduced into Clear Lake, Lake County, for purposes of gnat reduction, planktonic algae reduction, and sport fish forage enhancement, the silversides became established rapidly (Cook 1968; Cook and Moore 1970). The Department of Fish and Game restricted further introductions of the silversides in 1971 because of concern for the high reproductive potential and possible damage of existing fisheries. They were first observed in Lexington Reservoir in 1969 as a result of an unauthorized introduction (Wallace Strohschein, Dep. Fish and Game, pers. comm.).

On May 11, 1973, during mid-morning, silversides were observed spawning in Lexington Reservoir, over a gentle slope in water 1 to 24 inches deep. Water temperature was 68 F. The slope was covered with rooted aquatic plants and some inundated terrestrial plants. The vegetation formed a mat 1 to 2 inches thick. A school of 25 to 150 individuals would approach parallel to the shoreline led by one or more females with visibly swollen abdomens. When sampled, one school contained 2 large females and 39 smaller males. When a school turned onto the slope, males began to swim vigorously around the female, nipping and prodding at her abdomen. Occasionally during this frenzied activity, a female would suddenly break free, closely accompanied by 3 to 5 males. She would dive, along with the males, into the rooted vegetation. There, both sexes began trembling violently. While lying on her side in close contact with the males, the female laid her eggs. Upon completion, she would rapidly swim away, still closely pursued by several males. The spawning group rejoined the larger school and left the shallow area. Examination of the vegetation showed each female deposited from 10 to 20 eggs. As each school passed, the females made a single spawning pass and were not observed to repeatedly broadcast eggs.

Mense (1967) found that the mean number of mature eggs per female was 984 with a standard deviation of 358.6 and a range from 384 to

1699. He also stated that all ripe females contained additional immature eggs, and no completely spent female was ever found. Saunders (1959), cited by Mense (1967), found that he could remove only between 10 to 200 eggs by stripping and that many immature eggs remained in the ovaries. From this he concluded that females may spawn more than once. Apparently as the eggs mature in the ovary the females spawn, which causes a prolonged spawning period.

Eggs were collected from the vegetation and placed in an aerated aquarium. Larval silversides were observed in the aquarium on the same day of egg collection; apparently spawning had occurred some time prior to the date of observation. Hubbs, Sharp, and Schneider (1971) report that at 68 F silverside eggs require 10 days to hatch. This would place the initial spawning date at about May 1, 1973. The eggs are attached to the vegetation with adhesive filaments. Rooted aquatic plants at a depth of 1 to 6 inches appear to be the preferred spawning substrate. A few eggs were collected from the inundated terrestrial vegetation to a depth of 3 ft, but were not numerous. Fish were seen spawning among these plants as well.

Silversides appeared to be attracted to this spawning area; numerous other schools utilized the area. Elsewhere along the lakeshore, eggs were collected only in similar shallow areas with gently sloping bottoms covered with vegetation.

The spawning or reproductive behavior of *M. audens* has not previously been reported in the literature. Observations from Lexington Reservoir indicate that spawning occurs from early May until mid-September. The silversides in Lake Texoma, Oklahoma, spawn from late March through early summer (Mense 1967). In Lake County spawning commenced about the same time as in Lake Texoma, but small fry were noted as late as mid-September (Cook and Moore 1970).

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—*Frank Fisher, Inland Fisheries Branch, California Department of Fish and Game, Menlo Park, California 94025.* *Accepted June 1973.*

CALIFORNIA CONDOR SURVEY, 1972

The eighth annual California condor (*Gymnogyps californianus*) survey was conducted on October 11 and 12, 1972. Twenty observation stations were manned by 50 observers. Survey methods and evaluation procedures were essentially the same as those for past surveys (Carrier, et al. 1972), except that deer carcasses were placed at three locations on the Tejon Ranch, Kern County and one location on the edge of the Sespe Condor Sanctuary, Ventura County in an effort to congregate condors. Counting started at noon each day and ran until dark. Daily survey results were transmitted to survey headquarters in Bakersfield, California. Observation stations on the Tejon Ranch, Kern County, were equipped with radios, so movement of birds congregated in the area could be closely monitored.

Weather on October 11 was partly overcast in the Tehachapi Mountain area, with high scattered clouds in the Sespe Condor Sanctuary area. Hi Mountain Lookout, San Luis Obispo County, was completely weathered in with some rain. Winds from the south to southeast were variable from 2 to 30 mph with gusts to 50 mph. Day temperatures were moderate, varying from 55 F at Tollgate Lookout, Tulare County, to 70 F at Green Cabins near the south boundary of the Sespe Condor Sanctuary, Ventura County. Weather on October 12 was partly overcast, temperatures varied from 40 F on Mt. Pinos, Ventura County, to 65 F at Green Cabins. Winds increased slightly. Hi Mountain Lookout continued to be weathered in.

Survey evaluations indicate a minimum of 36 individual condors were seen on October 11: two immature, 29 adults and five unclassified. On October 12 a minimum of 21 individual condors were seen: four immatures and 17 adults. Condors continued their behavior pattern to congregate in southeastern Kern and northeastern Ventura counties during the October survey. Recruitment of young birds to the population has apparently remained low. Of condors classified by age on October 11 and 12 only four immatures were reported. Other raptors reported during the survey are summarized in Table 1.

TABLE 1—Raptors Observed During the Annual Condor Survey, October 11–12, 1972

Species	Numbers	
	10/11/72	10/12/72
Turkey vulture (*Cathartes aura*)	345	31
Golden eagle (*Aquila chrysaetos*)	58	60
Bald eagle (*Haliaeetus leucocephalus*)	--	1
Sharp-shinned hawk (*Accipiter striatus*)	13	10
Cooper's hawk (*A. cooperi*)	14	7
Red-tailed hawk (*Buteo jamaicensis*)	68	62
Swainson's hawk (*B. swainsoni*)	2	--
Ferruginous hawk (*B. regalis*)	2	1
Sparrow hawk (*Falco sparverius*)	11	14
Prairie falcon (*F. mexicanus*)	--	3
Peregrine falcon (*F. peregrinus*)	1	--
Marsh hawk (*Circus cyaneus*)	4	3
Osprey (*Pandion haliaetus*)	--	1
Unidentified raptors	24	19
	542	212

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—*Robert D. Mallette, California Department of Fish and Game; Sanford R. Wilbur, U.S. Fish and Wildlife Service; W. Dean Carrier, U.S. Forest Service; and John C. Borneman, National Audubon Society.* *Accepted May 1973. A contribution from Federal Aid in Wildlife Restoration Project W-54-R "Special Wildlife Investigations." Prepared with approval of the Condor Technical Committee.*

BOOK REVIEWS

Saltwater Flies—Popular patterns and how to tie them

By Ken Bay and Hermann Kessler; J. B. Lippincott Company, Philadelphia and New York, 1972; 150 p., profusely illustrated with black and white and color photographs; $8.95

Ken Bay has written a reference of saltwater flies for the saltwater flyfishermen. This book fills a gap in a complete angling library on a subject which until now, has only been touched upon by other writers.

This book includes complete tying instructions and lifesize sequence photos for eight of the most popular saltwater patterns. Background information is included for these eight patterns along with instructions for an additional 50 popular patterns.

The author has included almost all the standard patterns for throughout the Eastern seaboard, Florida and the Pacific coast. Noticeably lacking however are popular and important patterns for Southern California bonito, yellowtail and albacore fishing. Also, streamer patterns for the Pacific Northwest saltwater salmon fishing are missing.

Other features of this book include a brief discussion of materials for flytying and basic saltwater fly fishing. Ken Bay's material section is adequate since he covers the most important parts in the basic eight discussion and tying instructions. The chapter titled "A word on Tackle" is completely out of place in this book and totally inadequate. A simple summary of what the experts use is of little value to a person just beginning saltwater flyfishing and the experts already know what to use. The purpose of this book is flytying and a tackle discussion should be left to more comprehensive volumes.

The California saltwater flyfishing angler will find numerous useful patterns and ideas for his own patterns in Ken Bay's book. This book should become the beginning of a standardization of fly patterns for saltwater flyfishing and a valuable guide for beginning and advanced tyers.—*Dennis Lee.*

Modern Saltwater Sport Fishing

By Frank Woolner; Crown Publishers Inc., New York, 1972; 319 pp., illus., $8.95

"Modern Saltwater Sport Fishing" has put saltwater angling from ultralight to big big game in one complete volume for the fishermans library.

This is one of the most comprehensive books yet written on this subject. The author is Editor-in-Chief of the magazine, *Salt Water Sportsman* and his experience with that publication has greatly added to the information presented in this book. The book covers all forms of saltwater angling including chapters on equipment, flyfishing, natural baits, the high surf, big game, beach buggies, and deep sea fishing.

With the old and new challenges of marine angling being discovered by more fishermen each day, a desire for accurate information is being generated. Frank Woolner's book supplies that information in a style which is technical and at the same time entertaining.

Woolner catches his share of gamefish in this book, as all angling writers usually do with regularity, but does not let the trophies and one that got away dominate his writing. For a beginner or expert, this book is one volume library on tackle, techniques and strategies. The excellent, up to date material provides a dependable reference for saltwater fishermen.—*Dennis Lee.*

Growth and Ecology of Fish Populations

By A. H. Weotherley; Academic Press, Inc., 111 Fifth Avenue, New York, 1972; 293 p., illustrated. $13.50.

This text is a well written and easily understood, an exegetical discussion on the interrelationship between an ecosystem and how environmental and ecological stresses affect fish growth. Dr. Weatherley's basic approach is that of the "open system" and how environmental and ecological stresses affect the growth of fish. By acquiring an adequate understanding of the interrelationship, he postulates various principles for controlling selected populations of fish within an ecosystem.

Subjects covering fish growth are: basic animal growth concepts; specific dynamics of fish growth; physiological growth processes in fish; effect of food, competition and the niche; maintenance of populations; predator-prey relationships among fish; production; trophic environments and fish growth; and an operational programme for the study of fish growth.

This book is an invaluable primer for any fishery biologist wishing to understand the dynamics and character of fish growth.—*Paul A. Zellmer.*

Nymphs and the Trout

By Frank Sawyer; Crown Publishers, Inc., 1973; 272 p. $5.95.

Frank Sawyer is recognized as one of the world's best nymph fishermen and his job of river keeper on a stretch of England's Avon river has given him a lifetime of observation of fish and insects and provided him with the opportunity to perfect nymph limitations and nymphing techniques.

The book has been available in England since 1958; this is a revised, updated version. It is a very pleasant book to read and it provides a great deal of information on nymphs and fish behavior, techniques for stream and lake nymphing, and hooking and casting. Instructions are given for tying Sawyer's basic, proven patterns, including his well-known Sawyer's (pheasant tail) Nymph. Throughout the book the author uses personal experiences to illustrate the various points he makes. He touches on grayling fishing, experiments with salmon, and fishing in Wales, Bavaria, and Sweden. Few anglers will have the opportunity to fish these far off places, but *Nymphs and the Trout* will provide any nymph fisherman with much valuable information and food for thought.—*K. A. Hashagen, Jr.*

Art Flick's Master Fly-Tying Guide

By Art Flick; Crown Publishers, Inc., N.Y., 1972; ix + 207 p. illustrated. $10.00.

A quote from Art Flick's introduction to his *Master Fly-Tying Guide* does a far better job of stating the purpose of his book than I could:

> "It is for the beginner—and the expert; the freshwater and saltwater fisherman; the tyer of eastern and western patterns; the bass bugger and the salmon fisherman; the traditionalist and the experimenter; the tyer of dry flies, wet flies, nymphs, midges, terrestrials, large flies, small flies—just about everything."

Nine of the best U. S. fly-tyers describe in detail the methods they use to tie their specialties. Each description is accompanied by excellent step-by-step, black-and-white photographs. Helen Shaw takes the reader through the construction of streamers, bucktails, and bass flies; Ted Niemeyer ties his nymphs and wet flies and Art Flick his beautiful dry fly patterns. Doug Swisher and Carl Richards, authors of *Selective Trout* show how to tie their effective No-Hackles and Paraduns patterns; Dave Whitlock demonstrates his western ties suitable for heavy water fishing—the sculpins, muddlers and hoppers; Ernie Schweibert handles salmon flies and Lefty Kreh concludes with his saltwater patterns.

Some of the patterns are extremely simple and can be tied quickly, even by an amateur tyer. Others are complex, requiring specially dyed materials and more advanced techniques. The techniques the experts use for any given procedure differ widely, proving that there is no *right* way.

In addition to the chapters already mentioned there is an additional chapter "New Tools and Materials" and also a list of reliable sources for quality fly-tying materials which are of interest to any tyer. There are also eight pages of beautiful color photographs of each of the patterns demonstrated.

I don't think the book is the one for the beginner; the basic steps are not pointed out clearly and the vocabulary might be confusing. Anyone past the beginner stage of tying should add this book to their library; the information and quality are well worth the $10.00 price tag.—*K. A. Hashagen, Jr.*

Through the Fish's Eye

By Mark Sosin and John Clark; Harper and Row, N.Y., 1973; 249 p. illustrated. $7.95.

Through the Fish's Eye is an ichthyology text for the fisherman, full of interesting facts and figures. The various chapters cover anatomy, movement, vision, hearing, taste, touch, temperature, feeding, coloration, and camouflage. Clark is an ichthyologist and Sosin a professional writer, lecturer, and fisherman of note. They have combined to produce an accurate, interesting account of gamefish behavior and how knowledge of this behavior will help the fisherman catch more fish. Excellent color photographs, drawings, and personal fishing experiences are scattered throughout the book to illustrate various points. The book will be of little value to the professional biologist but it does an excellent job of presenting technical information to the layman.—*K. A. Hashagen, Jr.*

Nymphs

By Ernest Schwiebert; Winchester Press, N.Y., 1973; 339 p. illustrated. $9.95.

Nymphs is another excellent book by Ernie Schwiebert, author of *Matching the Hatch* and *Remembrances of Rivers Past*. It is a book for the advanced angler/fly-tier, although there are many delightfully written anecdotes used for introductory material or examples which almost anyone interested in fishing would enjoy.

Basically, the book describes the nymphs of all the important insect types utilized by trout for food. Detailed, technical information on nymphal behavior, water preferences, and distribution across the U.S. is given. Over 300 nymphs are described and over 200 illustrated by the author. Explicit directions are given for tying imitations. Introductory chapters discuss the origins of nymph fishing, both abroad and in America, and tackle; fishing techniques for this specialized form of fly fishing are scattered throughout the text.

There is a vast amount of information in *Nymphs*, but be cautioned that portions of the vocabulary is that used by an entomologist. The major shortcoming of the book, in my opinion, is the lack of information on California species. Many of the species described are undoubtedly found in California, but it will be up to the California angler to collect and identify nymphs from his favorite streams before checking *Nymphs* for an effective imitation. As with Schwiebert's other books, this one is informative, well written and well worth the price.—*K. A. Hashagen, Jr.*

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AUTHOR

SCIENTIFIC NAMES

SUBJECT

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Notice is hereby given that the Fish and Game Commission shall meet on October 5, 1973 at 9:00 a.m. in Room 1138, New State Building, 107 South Broadway, Los Angeles, California, to receive recommendations from its own officers and employees, from the Department and other public agencies, from organizations of private citizens, and from any interested groups as to what, if any, regulations should be made relating to fish, amphibia, and reptiles, or any species or subspecies thereof.

Notice is hereby given that the Fish and Game Commission shall meet at 9:00 a.m. on November 8, 1973, in Room B-109, State Building, 1350 Front Street, San Diego, California, for public discusion of and presentation of objections to, the proposals presented to the Commission on October 5, 1973, and after considering such discussion and objections, the Commission, at this meeting, shall announce the regulations which it proposes to make relating to fish, amphibia and reptiles.

Notice is hereby given that the Fish and Game Commission shall meet on December 7, 1973 at 9:00 a.m. in the Main Auditorium, Resources Building, 1416 Ninth Street, Sacramento, California, to hear and consider any objections to its determinations or proposed orders in relation to fish, amphibia and reptiles or any species or subspecies thereof for the 1974 sport fishing season, such determinations and orders resulting from the hearings held on October 5, 1973 and November 8, 1973.

FISH AND GAME COMMISSION

Leslie F. Edgerton

Executive Secretary

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