DISTRIBUTION AND RELATIVE ABUNDANCE OF FISH IN RUTH RESERVOIR, CALIFORNIA, IN RELATION TO ENVIRONMENTAL VARIABLES[1]

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Abstract.— The fish population of Ruth Reservoir, California, was sampled every two weeks with variable mesh gill nets from May 1974 through May 1975. Fish were captured in the following order of numerical abundance: Humboldt sucker (*Catostomus humboldtianus*), golden shiner (*Notemigonus crysoleucus*), brown bullhead (*Ictalurus nebulosus*), white catfish (*I. catus*), rainbow trout (*Salmo gairdneri*), and largemouth bass (*Micropterus salmoides*). The three most abundant species made up about 95 percent of total numbers and weight. All species exhibited a similar cyclic temporal availability pattern: catch rates increased to a maximum during summer and fall and decreased during winter and spring. Environmental variables with the most pronounced relationships to fish catches were temperature (direct) and turbidity (inverse).

Information on Ruth Reservoir fish ecology collected prior to this study was limited; data consisted of stocking records, yearly creel survey data on opening weekends of the fishing season, five gill net sets during November 1968, and the results of a reward tagging program for salmonids during May 1972 (Ruth Reservoir file, California Department of Fish and Game, Eureka). Management measures have consisted primarily of stocking hatchery-reared salmonids. Unauthorized introductions of exotic species into the reservoir have also been made.

Alterations to the dam have been proposed that would affect the physical and chemical characteristics of the lake and thus the aquatic organisms, specifically the fish populations. The present dam may be modified or replaced by a larger structure to meet future water needs (U.S. Army Corps of Engineers 1973). Air-induced circulation and a multilevel discharge structure have been proposed to reduce downstream turbidity (Winzler and Kelly 1975).

The objectives of this study were to determine the relative abundance and distribution of fish in Ruth Reservoir and determine their relation to environmental variables.

Study Area

Ruth Reservoir is impounded behind R. W. Matthews Dam, near the headwaters of the Mad River in Trinity County, California (Fig. 1). This water supply reservoir, about 127 km by river from the Pacific Ocean, provides municipal and industrial water for the Humboldt Bay Area. The dam was completed in 1961 and is operated by Humboldt Bay Municipal Water District (HBMWD). The reservoir has a maximum surface area of 445.2 ha, a maximum storage capacity of 63.9 million cubic meters, a mean depth of 14.4 m at maximum pool, and a minimum discharge of 142 liters per second.

Annual water level fluctuations have ranged from 9.8 to 15.5 m, with a mean fluctuation of 12.6 m (HBMWD, unpublished data). The water level is usually lowest in November and highest in January. The highest recorded water level, 5.8 m above spillway elevation, was on 22 December 1964, and the lowest, 13.7 m below spillway elevation, on 29 November 1967. Water level fluctuated 14.4 m during the study.

The reservoir is 11.3 km long at full pool and has a mean width of 0.6 km (Winzler and

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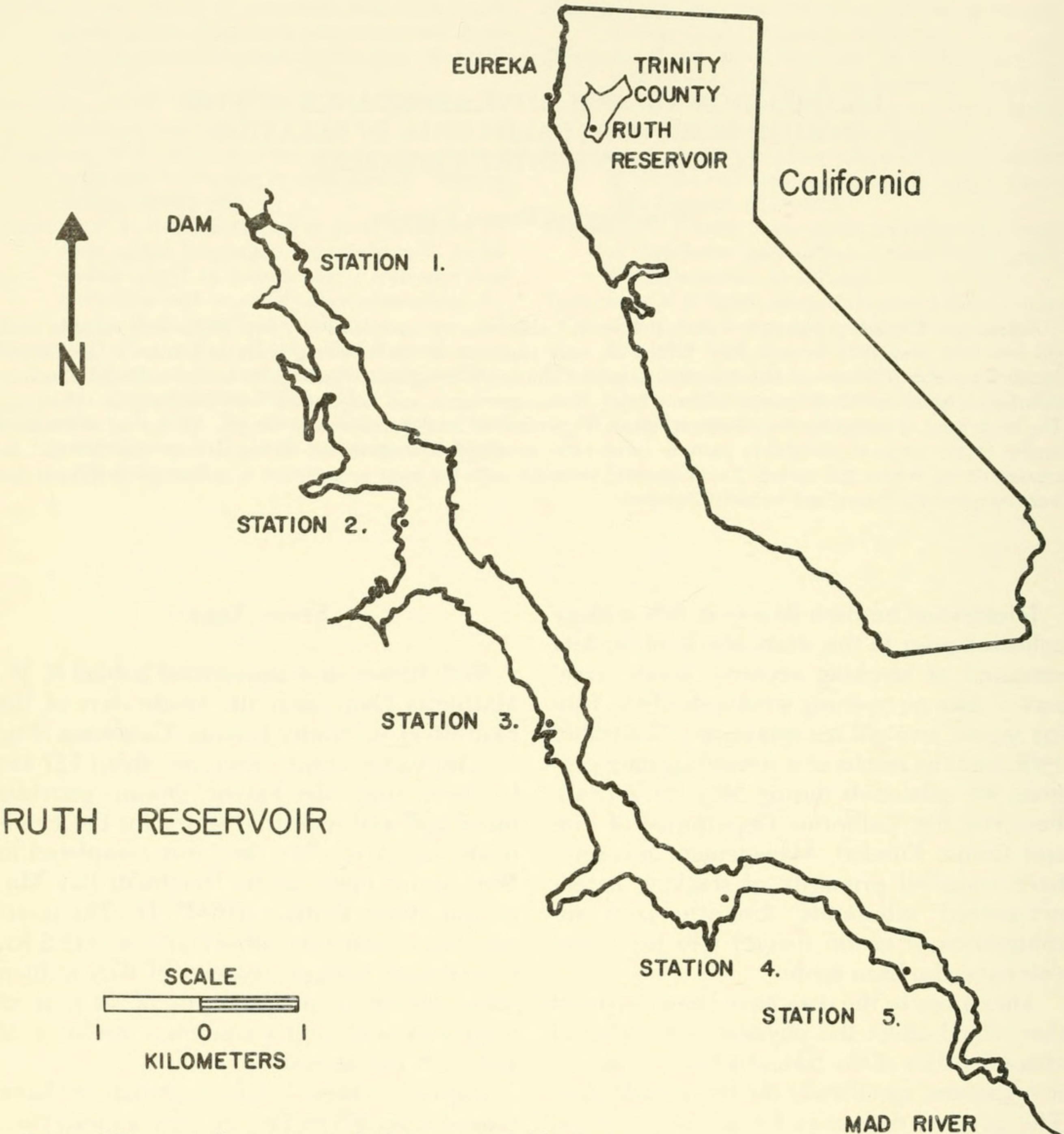

Fig. 1. Gill net sampling stations in Ruth Reservoir, California.

Kelly 1975). Several small tributaries flow into the reservoir, but the major inflow is from the Mad River, which has a watershed of 30,822 ha above the dam (Iwatsubo et al. 1972). The dominant geological feature of the watershed is the Franciscan Formation. Heavy precipitation, steep slopes, and unstable geology have resulted in high erosion in this area (Young 1971). The primary influx of sediment corresponds to major precipitation from November through April. During the rainy season, large amounts of fine suspended sediment are distributed throughout the mixed reservoir; surface turbidity diminishes by late spring as the suspended particles settle and thermal stratification confines suspended sediments to the bottom zone, thus developing a turbid density current (Winzler and Kelly 1975). Persistent turbidity occurs in the reservoir and downstream from the reservoir's bottom discharge.

Surface water temperatures range from 0 to 26.7 C; the minimum generally occurs in December or January, and the maximum in July or August. Bottom temperatures range from less than 4 to as high as 17 C. The reservoir has characteristic spring and fall overturns of a dimictic lake. Dissolved oxygen

(DO) ranges from saturation to seasonal anaerobic bottom deficits (California Department of Water Resources, Red Bluff, 1969).

METHODS

Sampling was conducted at two-week intervals from May 1974 to May 1975; 26 samples—7 each in summer and fall and 6 each in winter and spring—were analyzed by season. The seasons were defined as follows: summer, 1 June to 31 August; fall, 1 September to 1 December; winter, 2 December to 2 March; and spring, 3 March to 31 May. Five gill net sampling stations were established from the dam to reservoir headwaters (Fig. 1).

Fish populations were sampled with bottom set, variable mesh gill nets 1.83 × 54.86 m comprising six 9.14-m panels of the following mesh sizes (bar measure): 1.27, 1.91, 2.54, 3.18, 3.81, and 6.35 cm. All mesh sizes were made of number 104 multifilament white nylon except the 6.35-cm mesh, which was number 139.

The nets were set in the late evening and fished overnight for 12 to 16 hours. Fish catch was adjusted to a standard 12-hour set. The net was anchored in approximately 2 m of water at the inshore end and set perpendicular to shore. The end of the net placed closest to shore was randomized. Each gill net panel was marked with a painted vertical stripe to give two replicates for each set. Fish catch from the right and left halves of each mesh size was recorded separately and randomly assigned to one of two derived replicates. The data could thus be treated as replicate 27.43 m variable mesh nets in each location at each time, enabling the use of a nested analysis of variance design.

Limnological data were obtained during each sampling period at each station. Temperature, turbidity, conductivity, and DO were measured at limnetic stations corresponding to the gill net stations. Water samples were taken with a 2-l water bottle, 1 m below the surface, at middepth, and 1 m above the bottom. Immediately upon bringing the sample to the surface we measured temperature with a mercury bulb thermometer, or the thermistor of the DO meter. A bathythermograph was used to measure depth-temperature profiles. Turbidity, Jackson Turbidity Units (JTU), was measured with a Hach Model 1860 Turbidimeter. A Beckman Solu Bridge was used to measure electroconductivity, recorded as micro mhos per centimeter (μmho/cm) at 25 C. Dissolved oxygen determinations were made with a Hach Model CA-10 DO kit (June through October) and a Delta Scientific Model 85 DO Meter (November through May). Surface and discharge temperature, reservoir surface elevation, inflow, and discharge data were obtained from HBMWD records.

To detect significant differences in horizontal and seasonal fish distribution, and interaction between reservoir area and season, we analyzed the catch-per-unit-of-effort data by using a two-way nested analysis of variance design computer program. Fish relative abundance was analyzed by sampling station and season. One-way analysis of variance (Sokal and Rohlf 1969) was used to analyze seasonal differences in mean fish catch at Station 5. This station was dewatered by seasonal low water and was not included in the overall analysis. Fish catch data were transformed:

$(\log_{10}(Y+1))$ where Y = fish catch.

TABLE 1. Gill net catches at five sampling stations in Ruth Reservoir from May 1974 through May 1975.

Species		Relative abundance			Relative biomass (weight, g)		
Common name	Scientific name	Catch/h	Number	Percent of total	Mean	Total	Percent of total
Humboldt sucker	*Catostomus humboldtianus*	1.06	1,854	42.5	452.0	838,008	76.3
Golden shiner	*Notemigonus crysoleucus*	0.82	1,432	32.8	53.8	77,042	7.0
Brown bullhead	*Ictalurus nebulosus*	0.51	888	20.3	149.9	133,111	12.1
White catfish	*I. catus*	0.08	141	3.2	262.5	37,013	3.4
Rainbow trout	*Salmo gairdneri*	0.02	28	0.6	258.0	7,224	0.7
Largemouth bass	*Micropterus salmoides*	0.01	23	0.5	276.0	6,348	0.6
Total		2.49	4,366	100	–	1,098,746	100

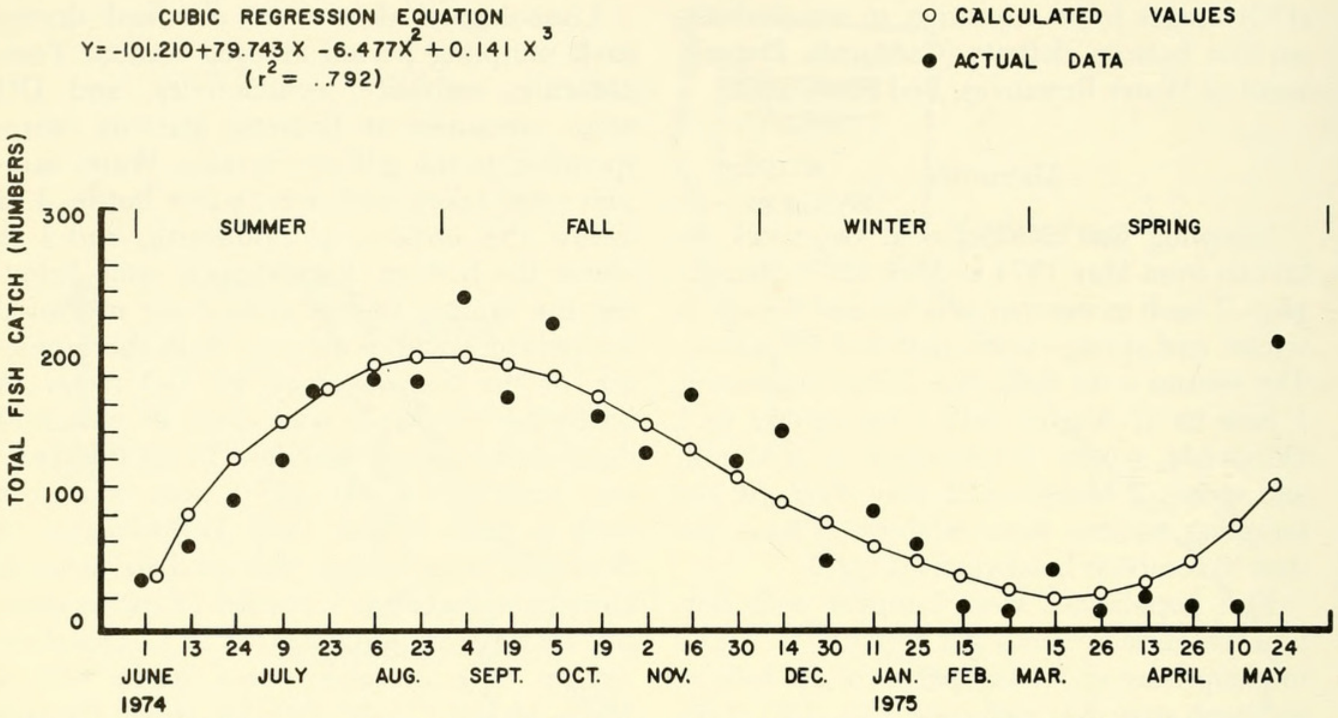

Fig. 2. Relationship between time and total fish catch in Ruth Reservoir, June 1974 through May 1975.

Correlation analysis was used to determine relationships between environmental factors and fish catch (by species and station). Product-moment correlation coefficients (r) between environmental parameters and fish catch were determined and tested for significance. We included variables with meaningful biological relationships that were significantly correlated with fish catch in multiple linear correlation analyses using the method of least squares (Cooley and Lohnes 1971).

Results

Species Composition and Relative Abundance

Humboldt sucker, *Catostomus humboldtianus,* the most abundant of the six fish species in the net catches, accounted for over 42 percent of the numbers of fish and over 76 percent of the weight (Table 1). Numerically, golden shiner, *Notemigonus crysoleucus,* was second in abundance and brown bullhead, *Ictalurus nebulosus,* third. Over 1.5 times as many shiners were captured as bullheads; however, the biomass of brown bullheads was over 1.7 times greater than that of golden shiners. White catfish, *Ictalurus catus,* made up slightly over 3 percent in terms of numbers and weight. Largemouth bass, *Micropterus salmoides,* and rainbow trout, *Salmo gairdneri,* accounted for less than 1 percent of the catch.

Humboldt suckers and rainbow trout were the only fish captured in Ruth Reservoir that were established in the upper Mad River drainage prior to impoundment. The reservoir has been stocked yearly with rainbow trout from various hatcheries. The coho salmon, *Oncorhynchus kisutch,* was introduced in 1972, and the Japanese ayu, *Plecoglossus altivelis,* in 1964–1965. Neither of these two species was taken in the net catches.

Distribution

A total of 4366 fish were caught in 1756 gill net hours. Total catch was highest during late summer and early fall, greatly decreased during winter and early spring, and remained low until late spring (Fig. 2). All species showed a cyclic seasonal trend (Fig. 3). The increased catch of golden shiners in the spring sample was most evident, and accounted for 52 percent of the total spring catch.

Total catch was consistently higher at the upper end of the reservoir (Stations 4 and 5) during all seasons, accounting for 55 to 86 percent of the catch (Table 2). Catches were most evenly distributed during fall, when

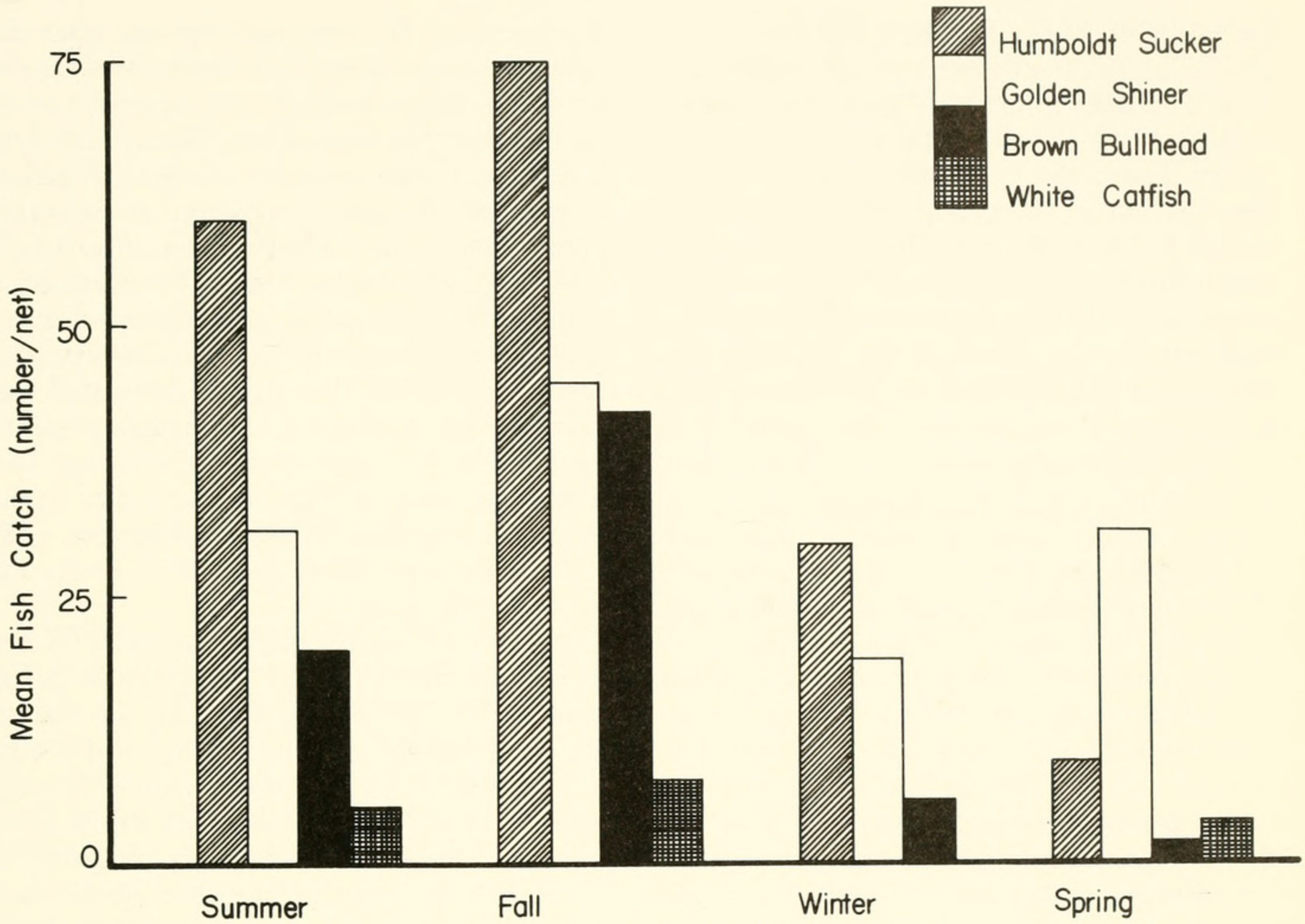

Fig. 3. Mean fish catch by species and season in Ruth Reservoir, 1974–1975.

about 45 percent of the fish were taken at the lower three stations. Catches of Humboldt suckers, golden shiners, and brown bullheads illustrate this trend of higher abundance at upper reservoir stations. Catches of white catfish were more evenly distributed throughout the reservoir; but were slightly higher in the middle and lower than in the upper reservoir areas.

Humboldt suckers were generally more abundant in catches than other species during all seasons. However, during summer and fall catches of brown bullhead were highest. Golden shiner catches were relatively high during summer at Station 5 and during spring at Stations 2 and 4. White catfish were the second or third most abundant species in the catch at the lower end of the reservoir (Stations 1 and 2) during all seasons except winter, when only one was captured in the entire lake.

Temporal and spatial fish distribution patterns were summarized by analysis of variance. Mean catches of Humboldt suckers, golden shiners, brown bullheads, and total species were significantly different ($P<0.01$) with respect to season and station. The mean catch of white catfish differed significantly by season ($P<0.001$) but not by station. A significant interaction for catches of brown bullhead by season and station ($P<0.01$) indicated that seasonal distribution was not consistent on a spatial basis. There was a large difference in seasonal mean catches of bullhead in the upper end of the reservoir, but catches in the lower end were consistently low and not greatly different. There was no significant interaction for Humboldt sucker, golden shiner, white catfish, and total catch. Thus, mean seasonal catch for these species was independent of lake area effects and, conversely, differences in area fish catch were significant, regardless of season.

There was a significant difference in replicates within season and station for all species ($P<0.005$). Seasons were not biologically discrete units of time, i.e., temporal trends of fish catch existed within seasons.

At station 5 total species mean catch was significantly higher for the summer-fall than for winter-spring ($P<0.001$, Table 3). There was a significant difference in mean catch of brown bullhead ($P<0.001$) and golden shiner ($P<0.05$) between the two time periods. Catches of both species were higher during summer and fall than during winter and spring. There was no significant difference in the catches of Humboldt sucker and white catfish between the two time periods. Temporal catch trends within the time periods are indicated by the significant differences in replicates for all species except the white catfish, which was scarce in catches during both periods.

Environmental Variables

Fish catch and limnological data were tabulated by sample period, station, and depth (Vigg 1979). Seasonal variations of environmental parameters were pronounced (Table 4). Temperature was highest during August (maximum 27.0 C), and lowest in late December (1.0 C). The surface DO concentration was never below 8.0 mg/l. Bottom DO deficits occurred during August and September. During early August, when maximum annual water temperatures occurred in the upper end of the reservoir, bottom DO decreased there to 2 mg/l. Bottom DO was depleted in midreservoir in late August and in the lower end in September (Fig. 4). This DO depletion trend probably indicated either movement of the low-oxygen water mass down reservoir or differential in-place bottom DO depletion, or both. Destratification and mixing in the upper end of the reservoir in late August resulted in high DO concentrations (10 mg/l) throughout the water column. Destratification and reoxygenation of the midreservoir area took place during late September, and by October the entire reservoir was well mixed. Dissolved oxygen concentrations were near saturation levels for the rest of the year.

Definite seasonal variation in turbidity occurred. Surface turbidity was highest (maximum of 79 JTU during February at Station 4) during the winter and spring, when high rainfall, runoff, and erosion resulted in large amounts of suspended sediments in the lake. Inorganic suspended sediments persisted in the bottom zone of the lake throughout summer. Turbidity was lowest during fall, when

TABLE 2. Percentage fish catch (adjusted to 12-h set) by station and season in Ruth Reservoir, June 1974 through May 1975.

Season, and samples per station	Station	Species: Humboldt sucker	Golden shiner	Brown bullhead	White catfish	Rainbow trout	Largemouth bass	Total
Summer								
7	1	17	7	< 1	11	38	0	10
7	2	8	7	1	23	0	0	6
7	3	13	6	< 1	23	13	18	8
7	4	32	26	32	26	25	18	30
7	5	31	54	66	17	25	64	47
Fall*								
7	1	21	8	6	41	11	25	15
7	2	19	2	10	33	11	25	13
7	3	19	31	3	7	33	0	18
7	4	41	60	81	19	45	50	55
Winter*								
6	1	25	9	18	100	0	0	19
6	2	3	0	3	0	0	0	2
6	3	15	4	6	0	0	100	10
6	4	57	98	74	0	100	0	70
Spring								
6	1	1	0	0	13	0	0	1
6	2	4	7	5	26	0	0	7
6	3	11	0	5	26	0	0	6
6	4	22	77	39	30	0	0	52
6	5	62	16	52	4	0	0	34

*Catches at Station 5 were excluded because this lake area was dry in fall and winter.

all suspended sediments had been flushed from the reservoir. Turbidity was highest at the bottom and lowest at the surface during all seasons. Lake area effects also introduced considerable variation in turbidity—i.e., spatial trends in turbidity occurred as storm runoff moved through the reservoir.

Conductivity varied with time and with vertical and horizontal lake area. However, variation was not great, the values ranging only from 80 to 200 μmho/cm (mean, about 125 μmho/cm).

Simple and Multiple Linear Correlations

Correlations between fish catch and concurrent measurements of environmental variables at specified stations indicated that temperature and turbidity had major effects on fish catches (Table 5). Consistent significant direct temperature and inverse turbidity relationships with the catches of Humboldt sucker, brown bullhead, white catfish, and total species occurred.

Although a significant inverse relationship existed between fish catches and DO, there was no discernible biological basis for a cause-effect relationship of this type; i.e., increased DO concentrations would not be expected to cause a decrease in fish catches. The range of DO saturation variation was not great, and DO concentrations measured at the water depths of net sets were not limiting to fish. Since there was generally a high correlation ($r \geq 0.90$) between temperature and DO concentration, it is reasonable to assume that the fish-DO correlation is a result of the indirect temperature effect. Conductivity and fish catches were not consistently related.

Environmental variables with biologically explainable effects on fish catch were included in multiple linear correlations with fish catch (Table 6). Significant ($P<0.01$) multiple linear correlations existed between total and individual species catch and the turbidity-temperature environmental system. Surface turbidity and bottom temperature accounted for 80.5 percent of the variation in total fish catch. Time of year, depth of sampling station, and Mad River inflow explained very little additional variation in total fish catch. This pattern was consistent for all major fish species. Turbidity and temperature accounted for 72.2, 53.5, and 58.8 percent of the catch variation for Humboldt suckers, brown bullheads, and white catfish, respectively. A significant ($P<0.05$) relationship also existed between the turbidity-temperature system and the catch of golden shiners. However, the proportion of catch variation explained by temperature and turbidity—about 30 percent—was substantially less for the golden shiner than for the other species. In all tests, inclusion of additional environmental variables did not account for a statistically significant proportion of independent variation. The catches of largemouth bass and rainbow trout were so small that correlation analyses would not be meaningful.

DISCUSSION

The fish population dynamics of the reservoir have not been continuously monitored since the dam was completed in 1961. However, current evidence does suggest that establishment of nonnative species in the late 1960s was associated with a decline in the rainbow trout population. Introductions of the golden shiner, brown bullhead, white catfish, and largemouth bass were unauthorized. Golden shiners were first observed during

TABLE 3. Gill net catches (adjusted to 12-h set) at Station 5 during summer-fall (s-f) and winter-spring (w-s) in Ruth Reservoir June 1974 through May 1975.

Species, and seasonal period	Number of sets	Catch Total	Catch Mean
Humboldt sucker			
s-f	10	223	22.3
w-s	9	171	19.0
Golden shiner			
s-f	10	429	42.9
w-s	9	45	5.0
Brown bullhead			
s-f	10	305	30.5
w-s	9	12	1.3
White catfish			
s-f	10	9	0.9
w-s	9	1	0.1
Total			
s-f	10	978	97.8
w-s	9	233	25.9

summer and fall 1968 (La Faunce 1968), and brown bullhead and white catfish during fall 1968. Largemouth bass are believed to have been introduced later—possibly in 1970. Changes in relative abundance of adult fish of different species are apparent from comparisons of gill net samples taken in 1968 with those taken during the present study. Rainbow trout composed 31 percent of the catch in 1968, but less than 1 percent in 1974–1975. The relatively high trout catch in 1968 probably represents a population that remained from the stocking of hatchery-reared fish in the previous May and the resident river population entrapped by the dam. Corresponding to the dramatic difference in trout catches were the substantial differences in catches of golden shiners (from 15 to 33 percent), brown bullheads (from 0 to 20 percent), and white catfish (from a trace to 3 percent). Humboldt suckers made up 54 percent of the catch in 1968 and 43 percent in 1974–1975. The largemouth bass maintains a naturally reproducing population and supports a sizable fishery in the reservoir. It was probably more abundant in 1974–1975 than the gill net samples indicated (<1 percent) because centrarchids are typically difficult to capture in nets. Crayfish, which were very abundant in the 1968 sample, were present only in trace amounts in 1974–1975.

Western suckers and golden shiners are two of the most successful competitors of rainbow trout in terms of reduced trout production in California reservoirs (Inland Fisheries Branch 1971). Humboldt sucker and golden shiner composed over 75 percent of the sample in numbers and 83 percent in weight during 1974–1975. Thus, the 1974–1975 species composition and relative abundance of nongame fish in Ruth Reservoir could have been a factor detrimental to the reservoir trout population. Erman (1973) reported that populations of (*Catostomus tahoensis*) and (*C. platyrhynchus*) in Sagehen Creek increased from 17.8 percent (1952–1961) before impoundment to 41.3 percent in Stampede Reservoir and 79.2 percent upstream (1970–1972) after impoundment. This illustrates that this stream-reservoir system favored sucker populations.

Since Humboldt suckers spawn in the Mad River during the same (spring) season as rainbow trout, it is likely that the young of the two species compete for space and food. At present, the natural reproduction of trout in the Mad River above Ruth Reservoir appears negligible.

The rainbow trout fishery of the reservoir has been maintained by stocking fingerling (1962–1968) and catchable-size fish (1969–1975). Since these hatchery-raised trout compete unsuccessfully with other reservoir species, the recent strategy of stocking catchable trout during times of heavy angler effort (i.e., before the opening weekend of the fishing season and before holidays) on a put-and-take basis is logical. However, if trout of a more predaceous strain were planted at a larger size, they would be able to forage on golden shiners.

Both temporal availability and spatial distribution of the fish in Ruth Reservoir were associated with environmental properties that varied on a seasonal basis. A cyclic trend of high catches during the warm summer and fall, and low catches during the cold and rainy winter and spring was apparent for all species. The environmental-fish relationships quantified during this study were simple; i.e., temperature was directly related, and turbidity inversely, to fish catches. Both temper-

Table 4. Mean seasonal environmental measurements at 1m below the surfaces (S), mid-depth (M), and 1m above the bottom (B) at Stations 1–4 in Ruth Reservoir, June 1974 through May 1975.

	Temperature (C)			Turbidity (JTU)			Conductivity (μmho/cm at 25 C)			Dissolved oxygen (mg/l)		
Season	S	M	B	S	M	B	S	M	B	S	M	B
Summer	22.2	18.3	14.8.	14.8	21.9	41.8	101.9	99.7	97.3	10.0	9.0	8.0
Fall	16.5	16.1	15.6	5.7	6.0	8.2	146.8	145.2	142.2	9.5	8.9	7.9
Winter	4.6	4.4	4.6	30.5	34.1	39.9	133.4	131.3	126.4	13.1	13.0	12.8
Spring	8.6	7.8	7.2	27.6	29.4	34.5	165.4	108.0	115.8	12.2	12.1	12.0
Annual mean	13.0	11.7	10.6	19.7	22.9	31.1	136.9	121.1	120.4	11.2	10.8	10.2

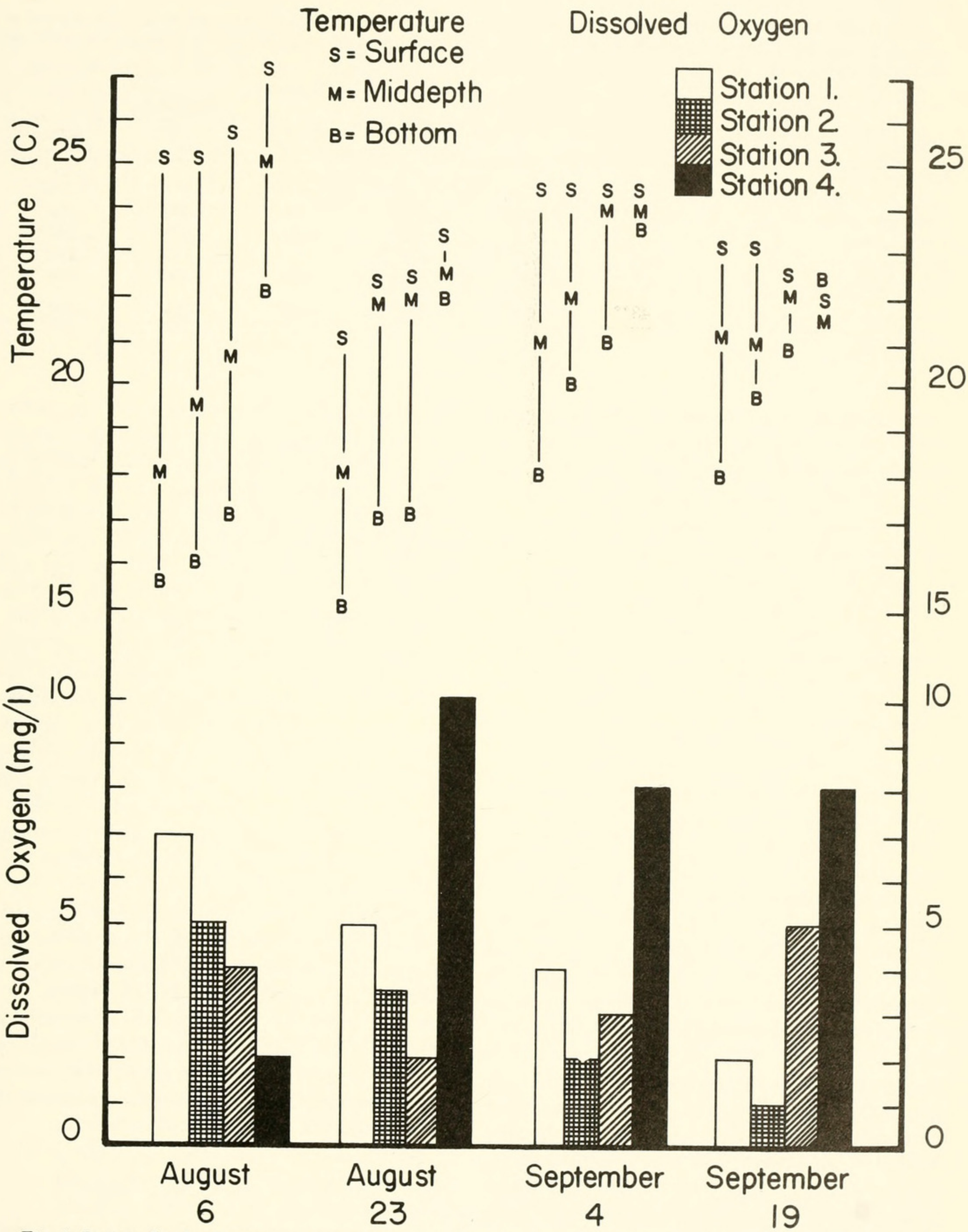

Fig. 4. Bottom-dissolved oxygen concentration and vertical temperature profile by station in Ruth Reservoir, August and September 1974.

ature and turbidity have known biological relationships affecting the survival, physiology, and behavior of fish.

The mean summer temperature in Ruth Reservoir (22.2 C) approximates the preferred temperature of the two most abundant fish species—Humboldt sucker and golden shiner (Reutter and Herdendorf 1974). The maximum surface temperature of Ruth Reservoir (27 C) exceeds the upper lethal threshold

TABLE 5. Significant correlation coefficients between fish catch and selected environmental variables measured at surface (S), mid-depth (M), and Bottom (B) at Stations 1-4 in Ruth Reservoir from June 1974 through May 1975 (26 observations per station, n = 104).

Species	Temperature S	Temperature M	Temperature B	Turbidity S	Turbidity M	Turbidity B
Rainbow trout						
Largemouth bass	.213*	.272**	.311**	-.214*	-.271**	-.202*
Humboldt sucker	.381**	.436**	.477**	-.383**	-.400**	-.369**
Golden shiner		.214*	.276**	-.201*	-.233*	-.269**
Brown bullhead	.269**	.347**	.417**		-.215*	-.243*
White catfish	.411**	.460**	.482**	-.323**	-.360**	-.289**
Total catch	.343**	.431**	.519**	-.350**	-.391**	-.421**

*P<0.05
**P<0.01

of rainbow trout (National Academy of Sciences 1972); thus, the summer temperature regime restricts the spatial distribution of the trout. All other species, however, are capable of inhabiting the productive littoral and surface waters during the entire growing season. In fact, higher temperatures than those in Ruth Reservoir would favor largemouth bass and catfish, since their temperature for optimum growth exceeds 27 C (Strawn 1961, Andrews and Stickney 1972, Kilambi et al. 1970, Crawshaw 1975).

The linear area sampling design provided a description of the fish species habitat preference in relation to seasonal environmental dynamics. The relatively shallow upper end provides most of Ruth Reservoir's littoral area, and the river-reservoir interface. It represents an important habitat for the adult fish population, and probably serves as a spawning and nursery area. Humboldt sucker and golden shiner primarily inhabited this region, regardless of season. Brown bullhead likewise preferred this habitat during all seasons; however, the relative proportion of this species in the upper end of the reservoir increased during the summer. The relation between higher catches and the warm upper reservoir area indicates an interaction with temperature, since the upper end was the first to warm during spring and remained the warmest area of the lake throughout summer.

Turbidity and the associated high inflow-outflow were inversely related to fish catch; the behavior and distribution of all fish species were negatively influenced by turbid water. Turbidity, inflow, outflow, flushing rate, and water level are all closely interrelated in Ruth Reservoir. Water level fluctuations affect the reproductive success of reservoir-spawning fish such as largemouth bass, white catfish, brown bullhead, and golden shiners in terms of spawning habitat, nursery habitat, and food availability. Drawdowns resulting in elimination of the shoals during the spawning season can cause direct mortality to eggs and larvae. Since larvae and juvenile fish feed on zooplankton, an abundant population of zooplankton is necessary at the time fish eggs hatch. Lider (1977) documented the depleting effect of the flushing rate on zooplankton populations in Ruth Reservoir; appreciable populations did not develop during spring until surface spilling ended. Young fish can also be lost in the discharge of a reservoir. Walberg (1971) reported that the timing and rate of flushing affects the year-class survival of reservoir fish.

In addition to biological parameters, inflow and outflow play a major role in the development of water quality patterns within a reservoir (Wunderlich 1971). Therefore, factors that alter the flow regime—downstream water needs, modification of the dam, or modification of the outlet structure, would affect the biotic and abiotic ecosystem of Ruth Reservoir.

Summary and Conclusions

The fish population of Ruth Reservoir was dominated by Humboldt sucker, golden shiner, and brown bullhead. White catfish formed an appreciable proportion of the population. Although largemouth bass were not heavily represented in the catch, their population is naturally maintained and their actual abundance is probably substantial. The species

Table 5 continued.

Conductivity			Dissolved oxgyen			Sampling period	Sampling station
S	M	B	S	M	B		
			−.283°°	−.247°		−.195°	
.213°	.214°		−.393°°	−.469°°	−.376°°	−.406°°	.307°°
			−.256°°	−.198°			.365°°
			−.261°°	−.195°	−.230°		.320°°
			−.496°°	−.453°°	−.415°°	−.248°	
.210°	.231°	.203°	−.436°°	−.398°°	−.320°°	−.223°	.443°°

composition and relative abundance of the Ruth Reservoir fish population is not conducive to salmonid production. The rainbow trout population is negligible and maintained by put-and-take stocking. Catch of all fish species was positively correlated with temperature and negatively correlated with turbidity and inflow-outflow. Management practices affecting these environmental parameters would thus effect the fish population of Ruth Reservoir.

We believe the following measures would be beneficial in the management of the Ruth Reservoir fishery:

1. Promote the Ictalurid fishery, including night fishing.
2. Continue stocking catchable-size rainbow trout during times of high angler effort. Study the feasibility of stocking more predacious salmonids (e.g., steelhead, *Salmo gairdneri*, or brown trout, *Salmo trutta*) at a larger size.
3. Study the detailed ecology of the largemouth bass population.
4. Study the spawning potential for salmonids in the upper Mad River.
5. Undertake watershed management in the upper Mad River to alleviate soil erosion and the associated turbidity problems.

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