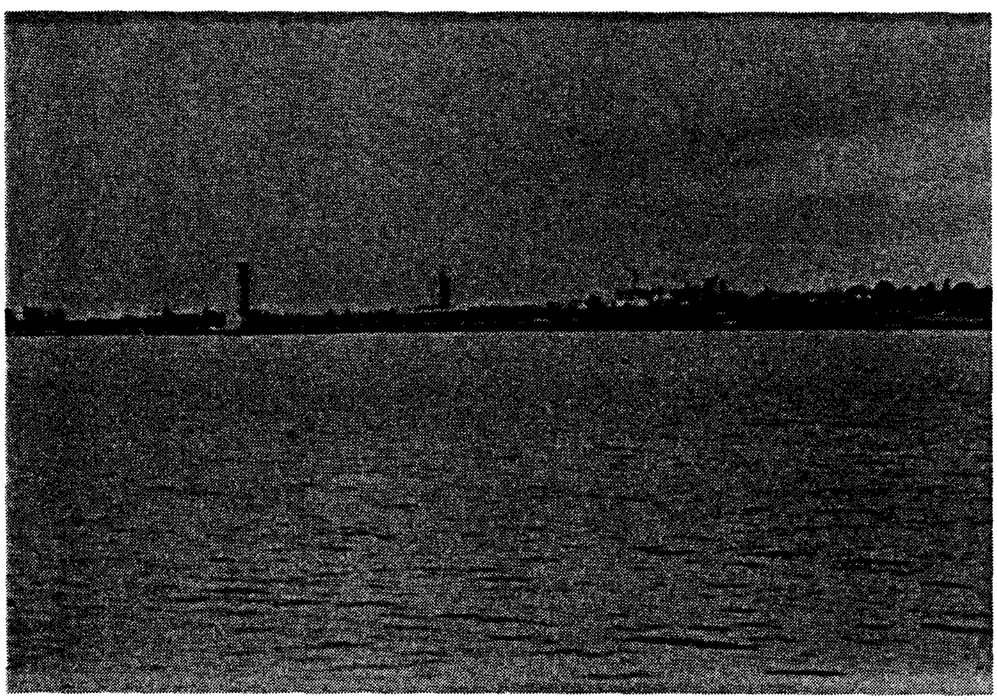
Volume 077
Article 08

FISHERY RESEARCH

FEDERAL AID IN
FISH RESTORATION

LAKE AND RESERVOIR INVESTIGATIONS

American Falls Reservoir Studies
Project No. F-71-R-11
Study No.
Job Nos. 1 and 2
For Period: March 1, 1988 to February 28, 1989



By

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June 1989

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JOB PERFORMANCE REPORT

State of: Idaho

Name: LAKE AND RESERVOIR INVESTIGATIONS

Project No.: F-71-R-11

Study No.: III

Title: American Falls Reservoir Studies

Job Nos.: 1 and 2

Period Covered: March 1, 1988 to February 28, 1989

ABSTRACT

We conducted a study on American Falls Reservoir to describe trout habitat as dissolved oxygen and temperature, trout habitat loss, and reservoir operating conditions effects. We also tried to assess the effects of trout habitat loss on fishing success. Water levels were much lower in 1988 than normal, which probably effect study results.

We defined Usable Trout Habitat (UTH) as temperature < 19°C and dissolved oxygen (D.O.) ≥ 5.0 mg/l, and Maximum Trout Habitat (MTH) as temperature ≤ 21°C and D.O. ≥ 3.0 mg/l. From June through early August, UTH was less than 84 km^3 (4% of full pool). MTH in most cases was 19% to 41% of full pool. Although total habitat declined with drawdown, the proportion of pool volume as trout habitat increased from mid- to late summer. The, increase was due to wind mixing and a higher influence of inflow oxygen with smaller pool volume.

Mean surface water temperatures were around 22°C for most of the sampling period, with little stratification. Anoxic conditions did not occur in the reservoir because mixing was high. Temperature limited habitat volume in 1988.

An emigration of hatchery rainbow trout *Oncorhynchus mykiss* from the reservoir was shown by decreased reservoir catch rates which were correlated to river catch rates. Declining habitat volume during late June and early -July may have initiated the emigration. In late July and August, 60% of the trout caught from the river had injuries which may have been turbine marks.

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INTRODUCTION

History of Reservoir

American Falls Reservoir is located in Bingham and Power counties on the Snake River in southeastern Idaho and is the largest irrigation storage reservoir in Idaho. The Dam was completed in 1927. Deteriorating concrete in the dam resulted in storage restrictions during the period 1976-1979. In 1979 a new dam was completed, and the original level to active storage (1,327 m above mean sea level) was restored. The new dam and power plant allowed an increased volume of water to pass through the turbines with a consequent increase in electrical production.

The reservoir covers 22,663 ha and contains 2,097 km^3 of water at full capacity. The reservoir is primarily used for irrigation storage. The U.S. Bureau of Reclamation owns and manages the dam and reservoir. Refill typically begins in October and continues through winter and early spring. Final fill is during the spring runoff. Irrigation starts in June, and drawdown starts as demands exceed inflow.

The annual water level fluctuations and poor water quality place stress on game fish populations. To better manage the fisheries, we need to know more about the effects of reservoir operations on game fish populations.

Water Quality

Bushnell (1969) reported an abundant supply of both nitrogen and phosphorous. The blue-green algae Aphanizomenon flos-aquae was the most abundant algae present. Bushnell also reported a significant oxygen deficit. Rose and Minshall (1972) assessed the effects of selected nutrients on algal growth in the reservoir and reported an overall increase in planktonic organisms in the reservoir from May 26 to August 12, 1971.

Dissolved oxygen and temperature problems have been recognized in the reservoir. Poor water quality seems to result in a substantial annual trout emigration. Summer fish kills, probably a result of dissolved oxygen depletion, occurred in the reservoir in 1967 and 1972. Only one winterkill is known to have occurred. It was localized near the mouth of the Aberdeen Drain in 1971. Since then no known winterkills have occurred.

Pesticides may be a problem in American Falls. Johnson et al(1977) found high organochlorine residues in Utah suckers Catostomus ardens. Mercury and cadium concentrations in the Utah suckers, black crappie Pomoxis nigromaculatus, and rainbow trout Oncorhynchus mykiss exceeded U.S. Food and Drug Administration standards at the time. The reservoir appears to serve as a large settling pond for pollutants from its upstream tributaries.

Fish Population and Fishery

American Falls Reservoir is productive and contains large numbers of nongame fish. Species such as the Utah chub Gila atraria, carp Cyprinus carpio, and Utah sucker are abundant. Warmwater species present include yellow perch Perca flavescens, black crappie, largemouth bass Micropterus solimodies, and brown bullhead Ictulorus nebulosus.

Populations of perch in the reservoir vary from year to year. Although few fish are taken in the reservoir, obvious year-to-year fluctuations occur in the river catch immediately downstream. Cause of the fluctuations is unknown.

Most game fish caught by anglers fishing the reservoir are hatchery-released rainbow trout. These fish are liberated at 200-250 mm in length usually in mid-April. From 75,000 to 100,000 fish are released annually (3.8/hectare). Release sites are at Seagull Bay and the Aberdeen Sportsmen's Park. Locations were selected away from the dam so that fish would become at least partially acclimatized to the reservoir conditions before any opportunity for emigration.

Growth of the planted trout is rapid. Fish often reach 400 g within three months. Most fish enter the creel two months after release. Return rates of released trout are high in some years and low in others. We believe that variation in water quality and habitat within the reservoir could influence the fishery. Do trout emigrate from the reservoir because of an environmental squeeze between high temperature and low oxygen?

Reservoir operations could effect trout habitat. As the reservoir is drawn down, should we expect trout habitat to improve or deteriorate? If the present operating conditions deleteriously effect trout habitat, can they be modified?

Two completed creel censuses estimated 25,000 to 30,000 angler days and 15,000 to 25,000 rainbow trout caught on the reservoir (Heimer 1984). About 40% of the fish released in the reservoir were taken by anglers. However two-thirds of the catch occurred in the reservoir and one-third in the river downstream.

Downstream movement of trout may be influenced by reservoir habitat conditions. We hypothesize that with good habitat conditions, a higher percentage of trout stay in the reservoir than with poor conditions. This should result in better catch rates. Trout passing downstream through the dam would be subjected to turbine losses, resulting in a net loss of fish to the reservoir even though they may contribute to the river fishery.

A number of physical factors may influence trout habitat in the reservoir. These include inflow, outflow, and reservoir surface elevation (volume). Water year and drawdown may influence flushing rate and physical habitat availability and may indirectly. influence temperature regime, stratification, primary production, and oxygen deficits. We may expect water year and operations to influence habitat, fishing success, and survival or emigration of fish. A better understanding of these relationships would allow us to either encourage better operations or select management alternatives better suited to the habitat limitations in the reservoir.

OBJECTIVES

Virtually no habitat work in relation to trout populations has been done at American Falls Reservoir. Information on reservoir habitat conditions and their effects on trout populations is needed to understand influences on the fishery and methods to improve it. The goals of the first year of the study are to describe reservoir trout habitat, the physical parameters that influence it, and the relationship between habitat and fishing success. The objectives for 1988 were:

1. Describe seasonal trends in trout habitat based on dissolved oxygen and temperature.
2. Determine if trout habitat loss is influenced by reservoir operating conditions.
3. Describe the effects of trout habitat loss on fishing success.

RECOMMENDATIONS

1. Environmental conditions for domestic rainbow trout are marginal. We doubt operations can be influenced enough to substantially improve habitat availability. Other strains that tolerate temperatures up to 22°C could perform better than our current hatchery stock. We recommend stocking 25,000 domestic Kamloops, 25,000 Lahontan cutthroat, 25,000 Henrys Lake cutthroat and 25,000 rainbow cutthroat hybrids to compare to the existing program. Fall stocking of fingerling should be evaluated also. We should also evaluate redband as they become available in the hatchery system..
2. 1988 was a record low water year. 1989 is anticipated to be a near normal water year, and we should continue collection of temperature and oxygen data to determine the relative influences of water year and drawdown on habitat availability.

TECHNIQUES

Seasonal Trout Habitat

We calculated trout habitat in American Falls Reservoir after Van Velson (1986). We calculated volumes of two different trout habitats to better define reservoir trout conditions. We defined Usable Trout Habitat (UTH) as water temperature ≤ 19°C and dissolved oxygen ≥ 5.0 mg/l. We defined Maximum Trout Habitat (MTH) as water temperature ≤ 21° and dissolved oxygen ≥ 3.0 mg/1.

Our trout habitat boundaries were identified from dissolved oxygen and temperature data collected at the sampling stations on regularly scheduled sampling days. The upper habitat boundary was located at the depth where water temperature or dissolved oxygen limits were first recorded and the lower boundary where the limits were last recorded. We calculated UTH and MTH as a proportion of both full pool and present pool elevations (volumes).

Oxygen-temperature profiles were collected at one meter intervals from the water surface to the bottom. A YSI Model 54A dissolved oxygen/temperature meter was used for sampling. The sampling program was started on June 24, 1988 and continued until September 27, 1988. Biweekly sampling was done in June, early July, and September; weekly sampling was done in late July and August. Dissolved oxygen and temperature sampling was done at eight stations selected to represent the reservoir (Figure 1). By late summer, sampling at the three upper stations had to be terminated because of low water levels.

To confirm sampling times and to assess diel oxygen changes in the reservoir, we sampled Station 1 (near the dam) every four hours for a 24-hour period on July 1, 1988. On four occasions in August, we sampled Stations 1, 2, and 3 between 2000 and 2100 on the evening before our scheduled sampling day. On all scheduled sampling days, we sampled the stations in ascending order, then returned to Station 1 and sampled again. This second sampling was often three to four hours later than the first sampling time. This sampling confirmed that during the period from sunrise to a few hours after little change in reservoir oxygen occurred.

Information on reservoir elevations and storage levels was obtained from an area capacity table for the reservoir (U.S. Bureau of Reclamation, 1979).

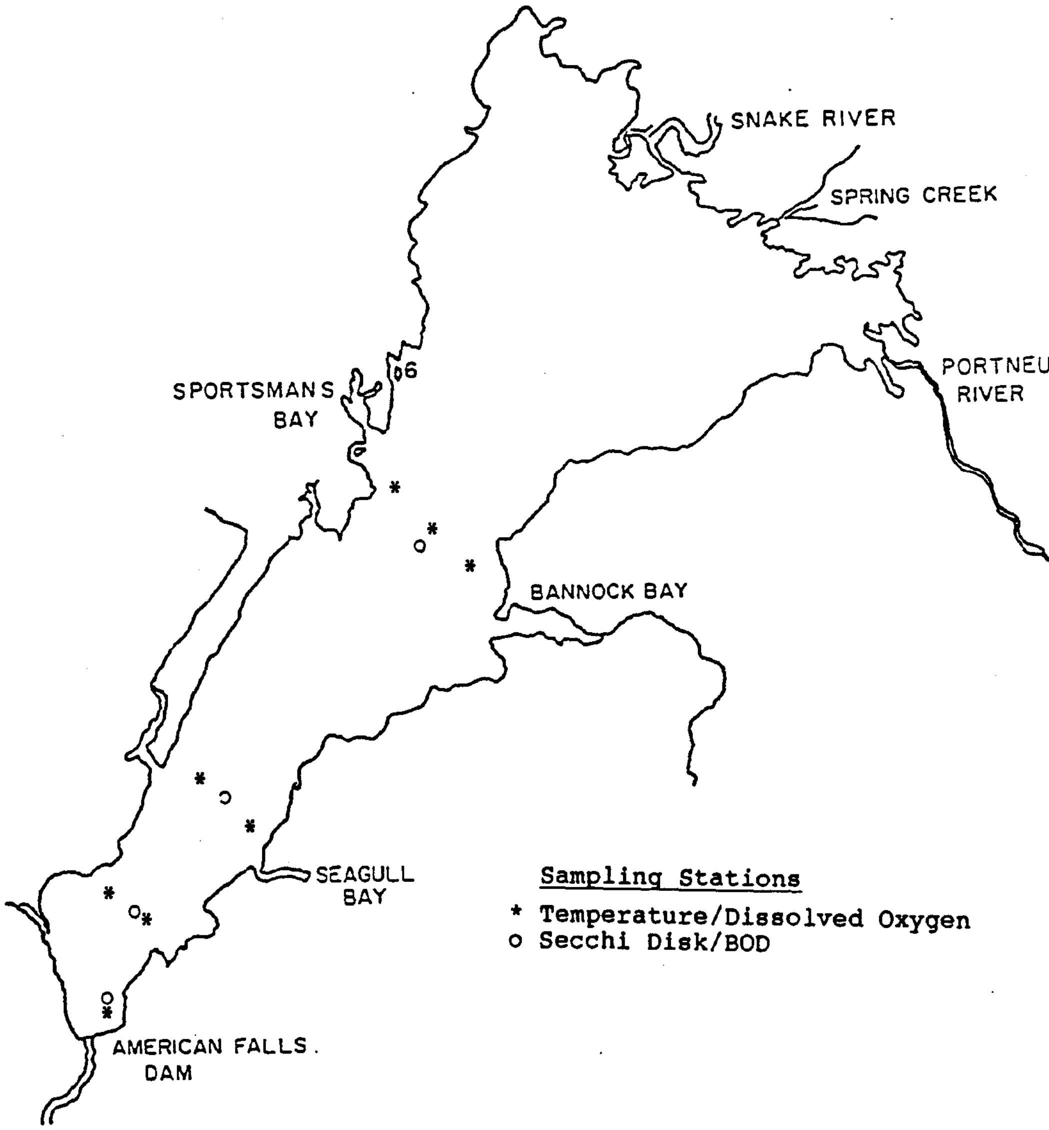

Figure 1. American Falls Reservoir sampling stations, 1988.

Influence of Reservoir Operations and Flows

Historic Approach

For the period May through October, dissolved oxygen readings are collected at each of three generators located within the American Falls Power Plant. Temperature readings of water passing the generators are also collected. Both temperature and oxygen readings are taken at ten-minute intervals. This information collected since 1983 was obtained from Idaho Power Company.

Means of penstock oxygen data were correlated with reservoir data. We reasoned that if we found a strong correlation, the historic penstock oxygen data could be used as an index of historic oxygen conditions in the reservoir. The index could then be correlated with historic flows, drawdown regimes, and storage volumes to look for any relationship between reservoir operation and oxygen conditions.

Oxygen Model

We are attempting to develop a simple model to describe oxygen consumption in American Falls Reservoir under different pool elevations and flow conditions. The model will be similar to one developed by Reininger et al. (1983) for winterkill projections at Cascade Reservoir. We partitioned the oxygen consumption into water column demand, sediment demand, and outflow. Total water column consumption and sediment consumption varied as a function of pool volume when calculated on an areal basis.

We calculated water column demand over four different time periods in late August and September. This was done by determining the difference in dissolved oxygen in water samples incubated in the dark at temperatures near those in the reservoir. The procedure was identical to that used to estimate BOD (Standard Methods, 1985) with the exception that our incubation temperatures were not standard. The estimated mean daily decrease in oxygen in the water column was multiplied by the mean depth to estimate water column demand on an areal basis.

We sampled oxygen in the Portneuf River and Snake River during the period June 25-August 19, 1988. We sampled the Portneuf River at the Siphon Road Bridge and the Snake River at Tilden Bridge and McTucker Landing. We calculated the oxygen volume of the inflow by multiplying the mean inflow (m^3/sec) and the mean dissolved oxygen. This figure was then multiplied by 86,400 to convert the oxygen volume from seconds to g/m^3/day. We divided by the area of the reservoir to estimate inflow on an areal basis.

Flow and dissolved oxygen in springs on the Fort Hall Indian Reservation were estimated from Bushnell (1969). Flows in 1.969 were used instead of those reported for other years, as conditions seemed more compatible to those in 1988.

We calculated the oxygen volume of the outflow by multiplying the mean outflow (m^3/sec) and the mean dissolved oxygen of the outflow for that day (obtained from Idaho Power Company). This figure was then multiplied by 86,400 to convert the oxygen volume to g/m^3/day. We divided by the area of the reservoir to put it on an areal basis.

We calculated oxygen deficits using the volume of the water column. This was multiplied by mean dissolved oxygen to arrive at metric tons of total oxygen. The oxygen decrease over a given number of days was divided by the surface area to obtain the oxygen deficit (Witzel and Likens, 1979).

We anticipate comparisons of oxygen and temperature conditions in different years. If flow or drawdown dramatically influence temperature and oxygen in the reservoir, we should see differences in those conditions in different years.

Habitat Loss and Fishing Success

To assess angler and catch at the river and reservoir, we collected creel data from mid-June through mid-October. We checked catch at the reservoir on Saturdays from 1100 to 1700. We parked where the access road to the boat dock near the dam intersects Highway 39 and interviewed anglers while they were stopped at the stop sign. We checked river catches every other Saturday from 1100 to 1700 at the access site immediately downstream from the dam. At both locations anglers were checked after they had completed fishing.

We correlated river and reservoir catch rates to determine the relationships between the two. We also correlated catch rates from both locations with UTH and MTH. We used line plots of all data to look for trends in habitat availability and fishing success.

FINDINGS

Seasonal Trout Habitat

Both 1987 and 1988 were considered drought years. Consequently, carryover water at the end of the 1988 irrigation season was extremely low (Figure 2). Obviously, the maximum possible trout habitat available in 1988 was strongly influenced by pool drawdown.

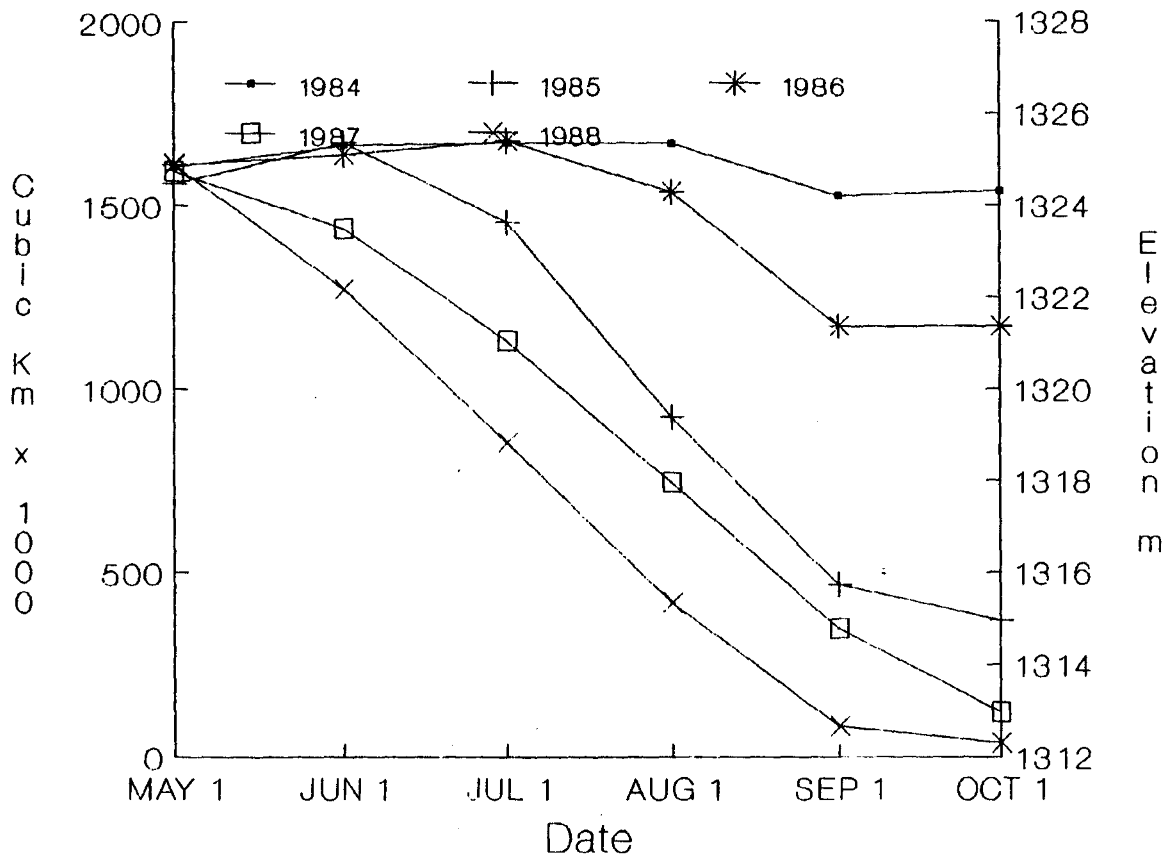

Figure 2. Storage volume at American Falls Reservoir, May 1-October 1, 1984-1988.

Reservoir dissolved oxygen concentrations were relatively stable through time (Figure 3). We found the lowest dissolved oxygen concentrations in July. Mean surface temperatures at the reservoir were approximately 22°C for most of the sampling period (Figure 4).

Dissolved oxygen readings taken every four hours over a twenty-four hour period peaked in late afternoon and early evening. We found a similar pattern for temperatures (Figure 5).

Secchi transparency was highest near the dam rather than in the upstream areas of the reservoir (Figure 6). Transparencies in the reservoir decreased through the season (Figure 7). During the period secchi disk measurements were taken, we observed no algae, indicating that sediment turbidity was the main cause of the low readings.

UTH as a percentage of full pool was less than 10% throughout the sampling period. UTH as a percentage of the available pool increased from August 11 to August 18 and stayed high through the remainder of the sampling period (Figure 8). Temperature was typically the most important influence of UTH during the period June 24-August 11. Temperatures were often greater than 19°C even though dissolved oxygen concentrations were generally greater than 5.0 mg/l.

MTH as a percentage of present pool levels was relatively high throughout the entire sampling period (Figure 9). As a percentage of full pool, MTH was less than 10% in late August and early September. As UTH is a subset of MTH, the same limiting factor (i.e. temperature) was typically most important. Temperatures in the latter stages of the sampling period were often in excess of 21°C, though dissolved oxygen concentrations rarely dropped below 3.0 mg/l.

Influence of Reservoir Operations

Historic Approach

A correlation exists between penstock mean dissolved oxygen concentration and reservoir mean dissolved oxygen concentration for the same day ($r = 0.68$ $P < 0.05$). Thus one could predict the overall reservoir oxygen conditions for a given day using penstock oxygen means and the equation $X = 3.858 + 0.394Y$ where Y = the penstock mean dissolved oxygen and X = mean reservoir dissolved oxygen. We were unable to predict environmental conditions in the reservoir (UTH or MTH) using penstock oxygen means.

Oxygen Model

The mean water column demand for oxygen over four different time periods varied from 0.87 mg/l/day to 0.55 mg/l/day. Overall water column demand was 0.69 mg/l/day.

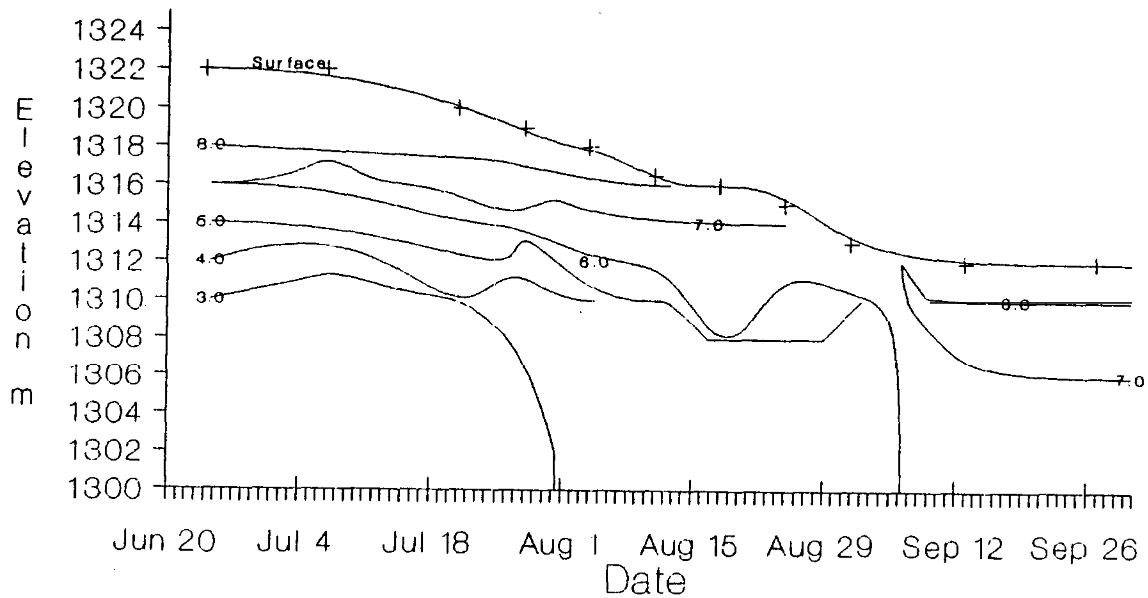

Figure 3. Mean dissolved oxygen concentration (mg/l) at American Falls Reservoir, June 24-September 27, 1988.

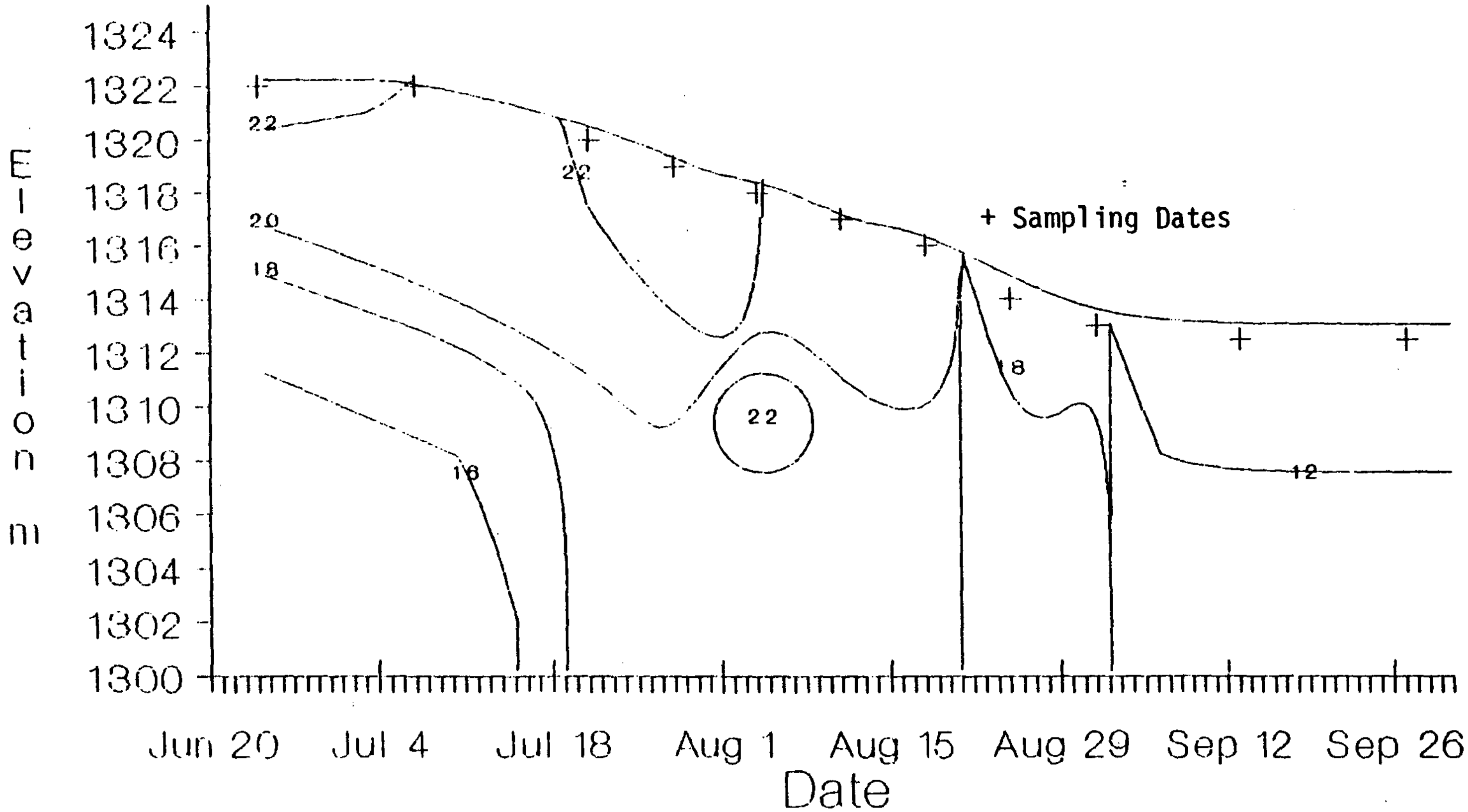

Figure 4. Mean water temperature (^{o}C) at American Falls Reservoir during the period June 24-September 27, 1988.

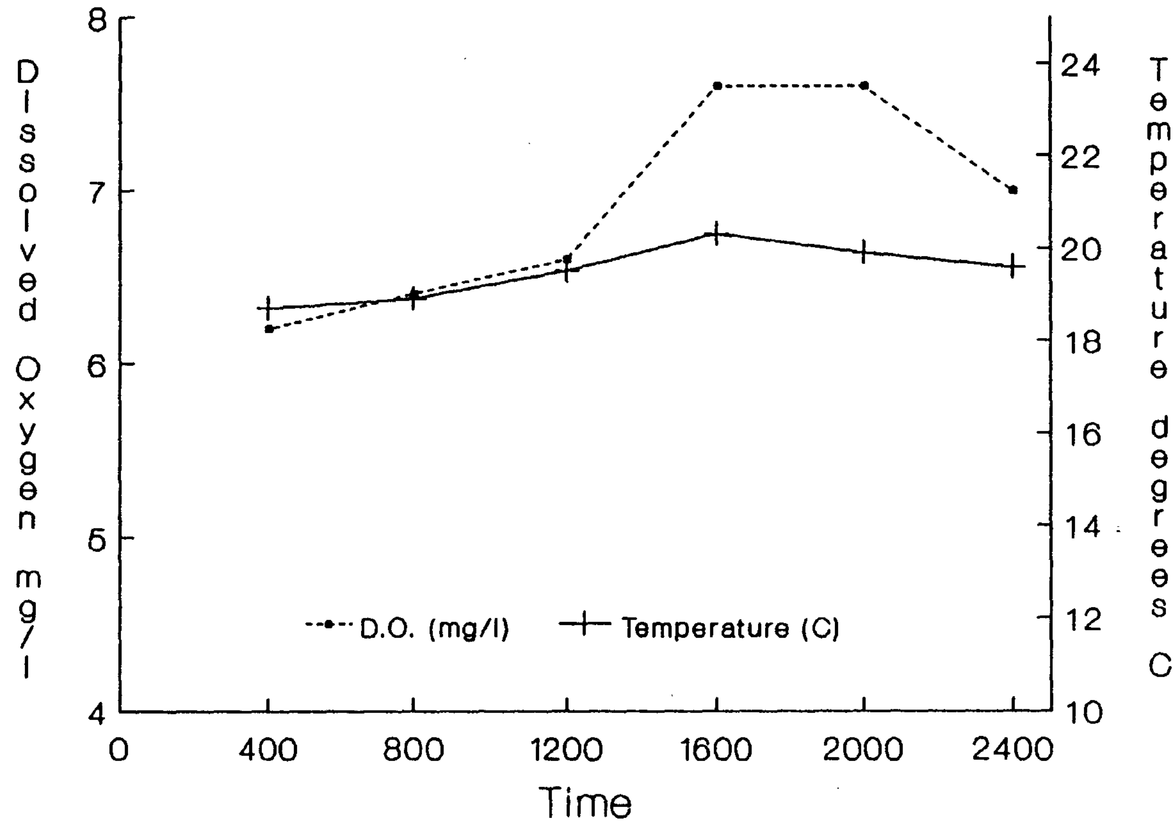

Figure 5. Mean dissolved oxygen (mg/l) and temperature (°C) over a 24-hour period on July 1, 1988 at Station 1 on American Falls Reservoir.

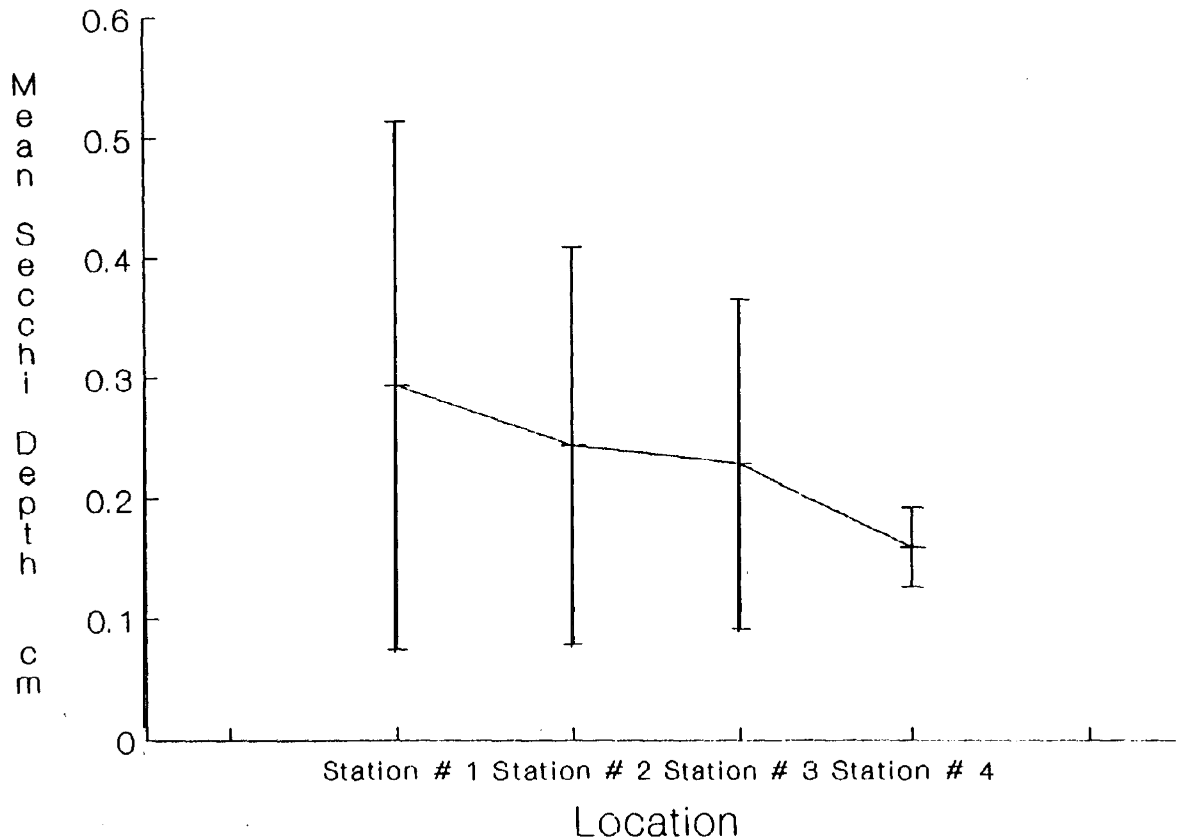

Figure 6. Mean secchi transparency ± standard deviations at 4 sampling stations (1: near dam; 2: American Falls Marina; 3: Seagull Bay; 4: upper reservoir) for the period August 4-September 27, 1988 at American Falls Reservoir.

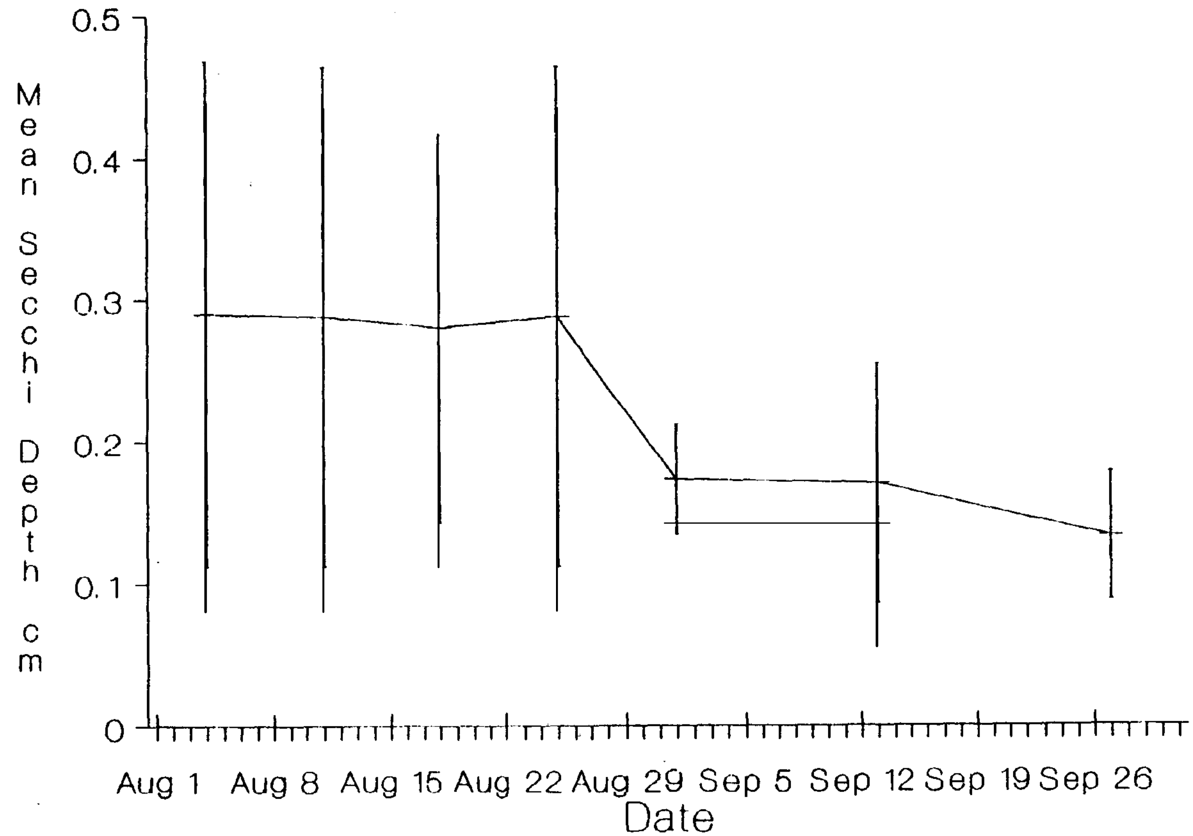

Figure 7. Mean secchi transparency $\pm$ standard deviation for 7 sampling dates at American Falls Reservoir, 1988.

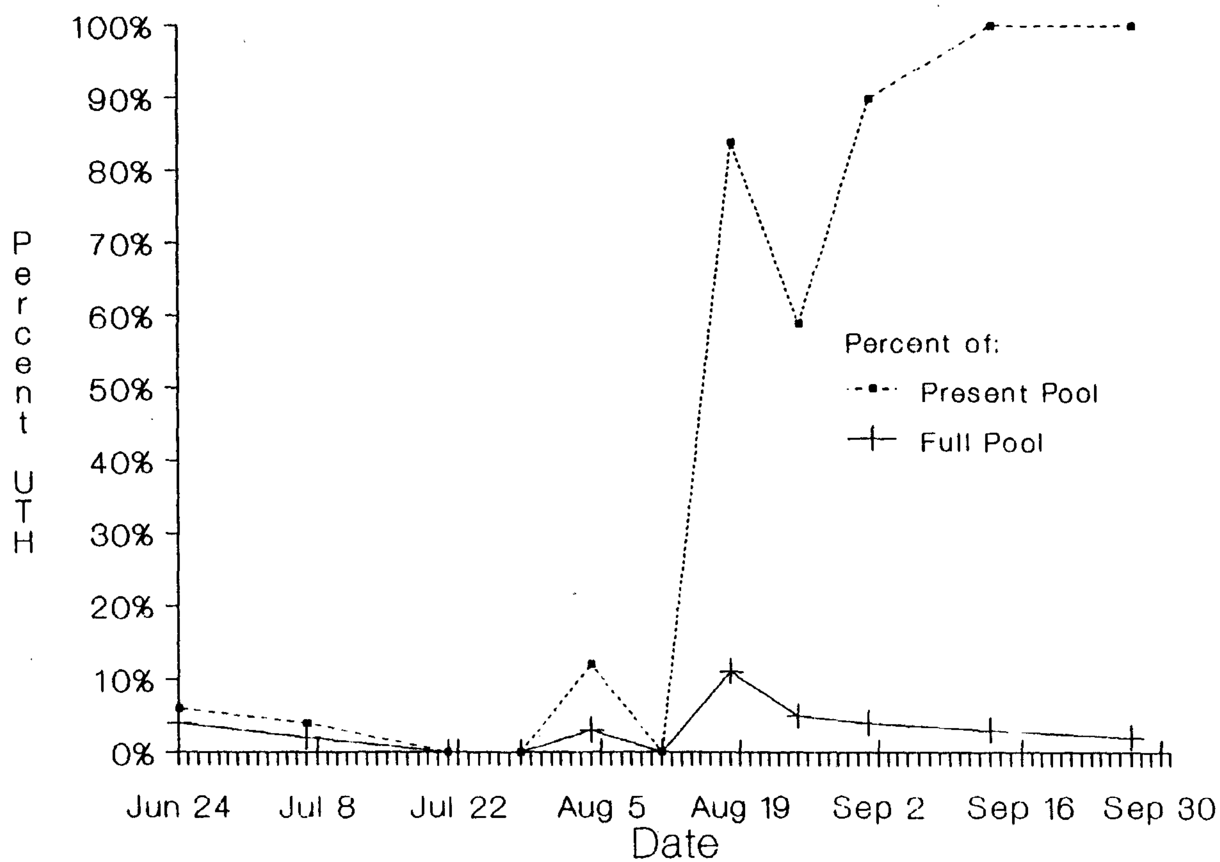

Figure 8. Percent Usable Trout Habitat (UTH) in American Falls Reservoir for the period June 24-September 27, 1988. Habitat was defined as dissolved oxygen greater than, or equal to, 5.0 mg/l and temperature less than, or equal to, 19°C.

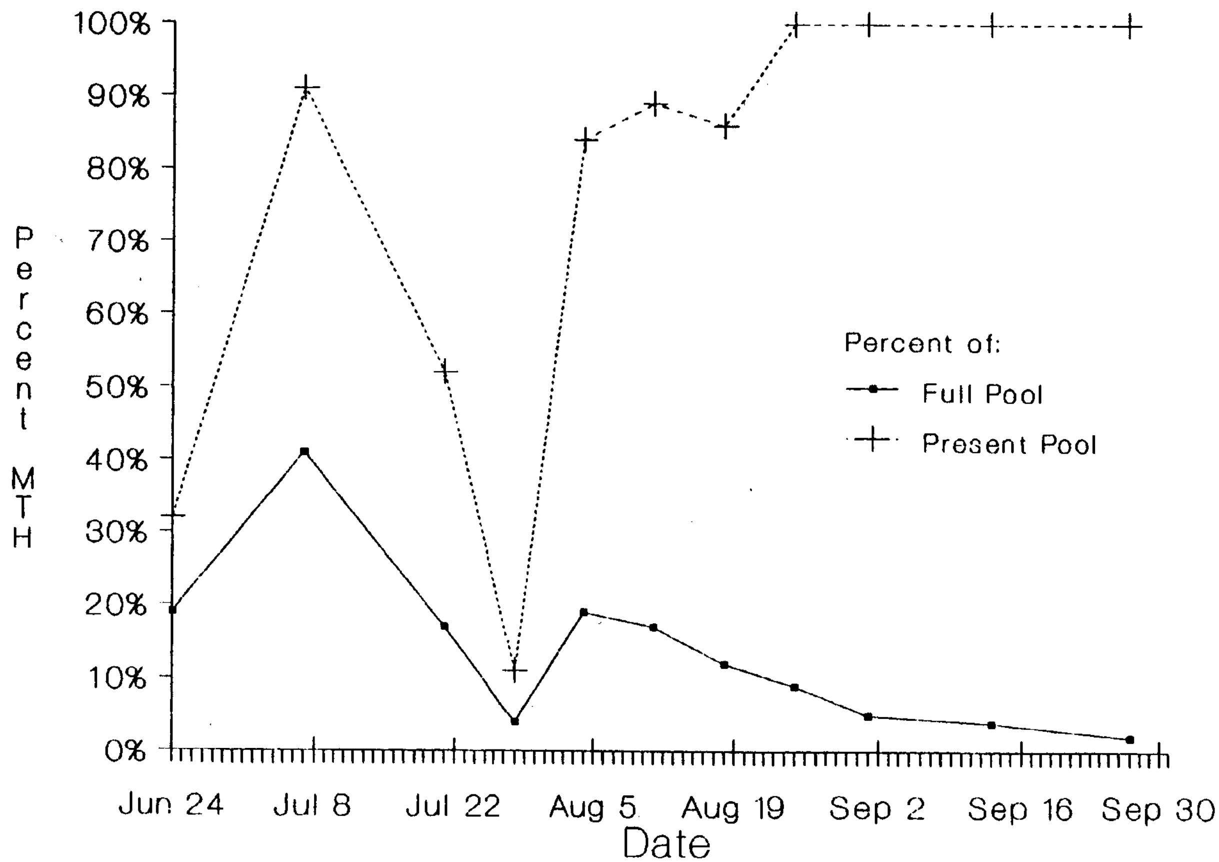

Figure 9. Percent Maximum Trout Habitat (MTH) in American Falls Reservoir for the period June 24-September 27, 1988. Habitat was defined as dissolved oxygen greater than, or equal to, 3.0 mg/l and temperature less than, or equal to, 21°C.

Estimated oxygen input into the reservoir varied from 0.05 $g/m^2/day$ on June 24, 1988 at surface elevation 1323 m to 0.35 $g/m^2/day$ on September 27, 1988 at surface elevation 1311 m.

Estimated oxygen output from the reservoir was much higher than oxygen input due to irrigation demands. It ranged from 0.22 $g/m^2/day$ on June 24, 1988 at surface elevation 1323 m to 1.44 $g/m^2/day$ on September 27, 1988 at surface elevation 1311 m.

Oxygen deficits were higher than 5.0 g $O^2/m^2/day$ on several occasions (Table 1). In some cases oxygen deficits were negative, indicating an oxygen gain within the strata over time.

The oxygen volume in the reservoir declined through the season. The decline was explained in large part by declining pool volume ($r = 0.97$ $P < 0.05$) (Figure 10). Oxygen volume did show some variation, which could be explained as oxygen consumption within the reservoir. Due to the record low water conditions that occurred in 1988, we feel additional data should be incorporated in our model to adequately test it.

Habitat Loss and Fishing Success

Highest reservoir catch rates occurred in June and the lowest in late August and September (Figure 11). Reservoir catch rates varied considerably during the census but generally declined through the season until October. Overall reservoir anglers averaged 0.15 trout per hour and 0.65 trout per angler (Table 2).

The relationship which explains the most variation in catch rate was pool volume and monthly catch rates for June - October, 1988 ($r = .92$, $p < .01$). There was a significant correlation between UTH volume and reservoir catch per angler ($r = 0.79$, $P < 0.05$). We also found a significant correlation between MTH volume reservoir catch per angler ($r = 0.62$, $P < 0.05$).

Catch rate in the Snake River during the census period was highest in July and lowest -in September and early October (Figure 12). Declining catch rate in the reservoir proceeded the July peak in the river catch rate. We found no significant correlation between catch rate from the reservoir and catch rate from the river ($r = 0.08$, $p > 0.05$) for the June through October period of 1988. However, if June catch rates are dropped because UTH is at high point (Figure 8), then a significant relationship between reservoir catch rate and river catch rate exists for July through October ($r = .85$, $p > .05$).

During the river creel census, we checked 134 hatchery-released rainbow trout, 3 rainbow trout of unknown origin, 6 brown trout, 31 yellow perch, and 2 black crappie. The mean total length of the 83 hatchery rainbows caught in July was 335 mm. The mean of 17 rainbows caught in August was 346 mm. On July 30, August 6, and August 20, we

Table 1. Calculated oxygen deficits (g $0_2/m^2$/day) below the specified elevations in American Falls Reservoir, 1988.

Date	Elevation (m)						
	1323	1321	1319	1317	1315	1313	1311
6-24/7-7	1.872	1.751	2.085	0.995	-0.543	-0.089	1.563
7-7/7-21	-0.289	0.093	0.604	1.071	3.751	2.448	-
7-21/7-28	2.577	1.741	0.265	2.875	0.813	-	-
7-28/8-4	1.122	1.206	1.068	4.502	5.364	-	-
8-04/8-11	1.263	1.619	5.153	1.164	-	-	-
8-11/8-18	0.924	0.552	3.596	5.379	-	-	-
8-18/8-25	0.394	-4.331	1.447	-	-	-	-
8-25/9-01	5.649	4.387	4.597	-	-	-	
9-01/9-13	-0.922	-0.890	-	-	-	-	-
9-13/9-27	2.252	3.494	-	-	-	-	-

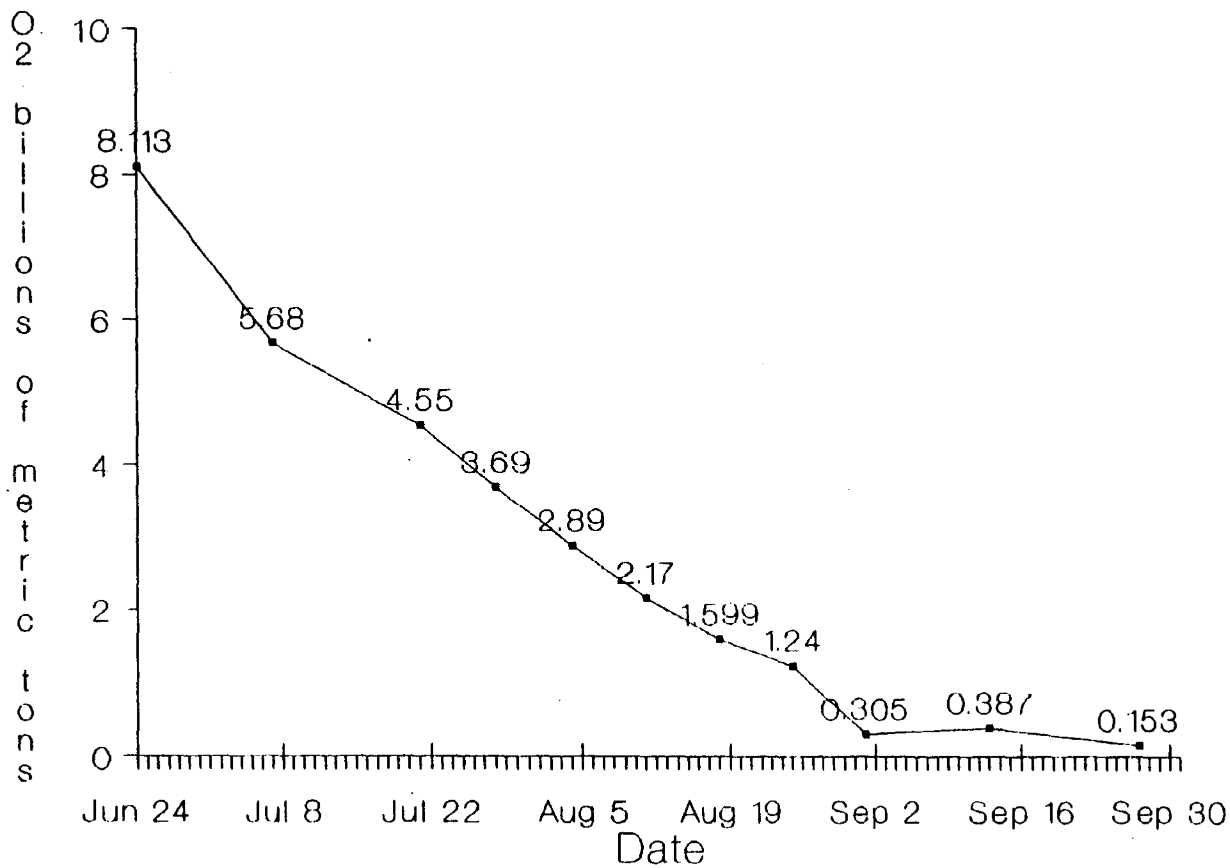

Figure 10. Mean oxygen volume (metric tons x10^4) in American Falls Reservoir, 1988.

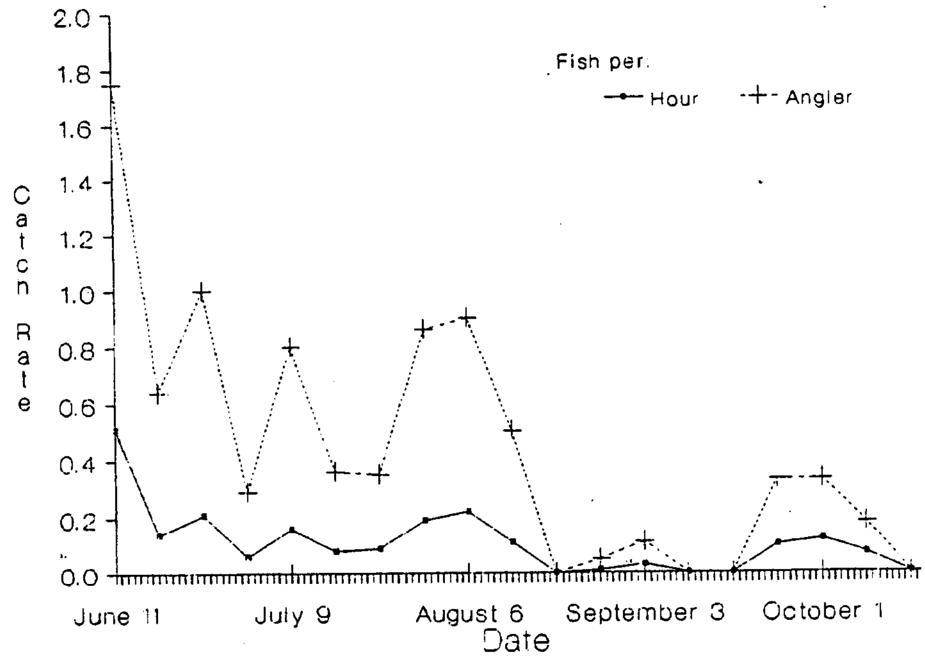

Figure 11. Catch rates of hatchery rainbow trout anglers fishing American Falls Reservoir in 1988.

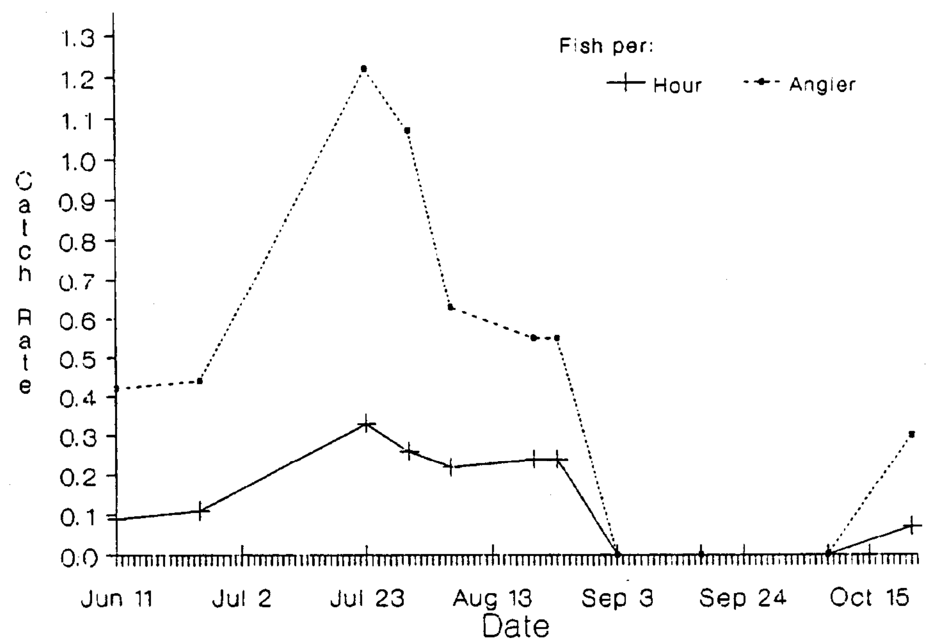

Figure 12. Catch rates of hatchery rainbow trout by anglers fishing the Snake River downstream from the American Falls Dam in 1988.

Table 2. Monthly effort and catch rate of hatchery released rainbow trout by anglers fishing American Falls Reservoir, 1988. The mean fish per hour for the five different monthly periods (95% CI) was .11 ± .09. The mean fish per angler for the same periods was .46 + .43.

Month	Anglers Checked	Hours Fished	Fish Caught	Fish Per	
				Hour	Angler
June	227	999	228	.23	1.00
July	23	1,088	131	.12	.56
August	121	489	50	.10	.41
September	47	147	5	.03	.11
October	14	35	3	.09	.21
Total	642	2,758	417	.15	.65

Table 3. Monthly effort and catch rate of hatchery released rainbow trout by anglers fishing the Snake River downstream from the American Falls Dam, 1988. The mean fish per hour for the different monthly periods (95% CI) was .14 + .16.. The mean fish per angler for the same periods was .46 + .43.

Month	Anglers Checked	Hours Fished	Fish Caught	Fish Per Hour	Fish Per Angler
June	65	290	28	.10	.43
July	74	286	86	.30	1.16
August	28	74	17	.23	.61
September	20	52	0	.00	.00
October	19	63	3	.05	.16
Total	206	765	134	.18	.65

examined 50 rainbow trout caught in the river downstream from the dam for turbine marks. Of this total, 30 (60X) had visible turbine marks. Most were in the form of skin abrasions with a distinct curved mark along the side of the fish where the scales were gone.

DISCUSSION

Seasonal Trout Habitat

Unusually low pool elevation and volume occurred in the reservoir in 1988. Water elevations were lower than average due to the drought. Habitat conditions in 1988 may not be typical of normal water years.

We anticipated that habitat conditions would deteriorate throughout the summer. In 1988 that occurred but primarily as a result of declining pool volume. From June through early August, habitat conditions were poor, in all cases less than 12% of full pool. After mid-August, conditions within the existing pool actually improved. The absolute volume of UTH declined in late summer only because the pool volume dropped with continued drawdown. The improvement in water quality with decreasing surface levels was probably due to cooler air temperatures, wind action on the reservoir, decreasing depth (which increased mixing), and increasing influence of tributaries.

Since anoxic conditions did not occur during the 1988 sampling period, it would be reasonable to assume that primary production or mixing of the reservoir was high. Exposure of the reservoir to wind means that stratification usually will not occur for any extended period of time. Stratification may be more prevalent at higher pool elevations; but under 1988 conditions, we believe summerkill due to hypolimnetic anoxia will be rare.

In 1988, reservoir drawdown actually seemed to have a positive influence on dissolved oxygen. As the reservoir pool was lowered, the relative percentage of both UTH and MTH increased. However, this may not be the case during a normal water year when stratification could be more prominent.

Bushnell (1969) found the lowest concentrations of dissolved oxygen on July 22 in mid-reservoir areas between Seagull Bay/West Bay and Bannock Creek/Big Hole. He attributed an oxygen increase in August to a stormy period that lasted about two weeks. This storm dropped the weighted average temperature from 22.2°C to 17.0°C. During our study, reservoir temperatures remained fairly constant during the summer months.

Influence of Reservoir Operations

Sediment concentrations in the reservoir increased as the pool level decreased. This increase was reflected in secchi disk transparencies. A correlation of reservoir catch per angler and mean secchi disk transparencies was not significant ($r = 0.31$, $P > 0.05$). Sigler et al. (1984) reported decreased growth in water containing as little as 25 NTU turbidity. They assumed the reduced growth was related to the ability of the fish to feed. Although turbidity in the reservoir aggravated by drawdown might be expected to influence catch rate as well, this was not obvious in our data.

Secchi transparency was lower in the upper part of the reservoir, probably due to headcutting of previously deposited material. This material settled out as it progressed towards the dam. Horner and Rieman (1981) also reported lower secchi disk visibility near the upper end of Cascade Reservoir.

In normal water years, inflow rates would be higher and surface elevations higher than in 1988. Under these conditions, a strong stratification could develop. We do not know how stratification and oxygen conditions will change with higher summer volumes. To fully evaluate summerkill risks, it would be useful to describe oxygen and temperature during normal years. Snowpack information indicates that the 1989 water year will be in this category.

Summerkills can also result from algal bloom collapse and elimination of primary production. Papst et al. (1980) reported that periods of thermal instability following a bloom collapse is a requirement and that wind stress and night air temperatures are the principal factors determining stability. In this case, mixing of the water column can actually aggravate the risk of a kill. Oxygen consumption rates at the reservoir, however, are not adequate to produce the short-term anoxia associated with a bloom collapse. Much higher water column consumption rates would have to be present for this to occur. Barica (1978) discussed summer fish kills in eutrophic lakes in relation to collapses of the algae *A. flos-aquae* and concluded that the algal collapses coincided with a significant drop in air temperature.

We believe that algal bloom collapse and thermal instability are actually the most likely causes of the fish kills observed in the reservoir in the past. We do not know if necessary conditions are more likely in low water years, but conditions in 1988 should have been good for such an event if that were the case. Algal blooms are strongly influenced by other environmental conditions. Nutrient loading is obviously important. We suggest that increased nutrient loading to the reservoir may be a more important factor in future fish kills than reservoir operations or flows. Any increase in the nutrient loading could increase the likelihood of massive algal blooms and bloom collapse. Increased nutrient loading would also aggravate the existing oxygen deficit and related constraints on the trout habitat.

Habitat Loss and Fishing Success

Past observation of angling at the reservoir suggests that rainbow trout typically congregate in front of the dam in late July and August. During this period fishing success can be good. Tag return information from Heimer (1984) indicates a large number of trout move through the dam to the river downstream . River catch rates declined as the reservoir catch rates declined during this time period. We believe that increased river catch rates in July represent large numbers of fish leaving the reservoir.

An excessive turbine mortality during this time period could offset the benefit of reservoir growth. If passage mortality studies showed this, then a portion of the fish scheduled for release in the reservoir could be released in the river. Other options would be to rear the fish scheduled for release to the river to a large size before release.

We found significant correlations between pool volume, UTH volume and MTH volume to reservoir catch rate. If catch rate in the reservoir is controlled by emmigration resulting from UTH, then the release of strains or species of game fish more adaptable to the reservoir environmental conditions could increase catch rates.

Calculated oxygen deficits, the same as areal rates of hypolimnetic oxygen depletion (AHOD), were high. Trimbee and Prepas (1988) calculated oxygen deficits over four summers for a meromictic lake in Alberta, Canada, and reported variations between 0.22 and 0.52 g O_2/m^2/day. This was considerably lower than some for American Falls Reservoir which exceeded 5.0 g O_2/m^2/day.

SUMMARY

Usable Trout Habitat (UTH) volume was low throughout the summer of 1988. Very low habitat volume in 1988 was related primarily to high temperature not dissolved oxygen. The UTH of the existing pool actually improved in late summer. Available habitat was more limited by temperature than oxygen.

Drawdown did not appear to aggravate environmental conditions related to oxygen and temperature in the reservoir after the elevation dropped below 1315 m in late July, 1988. Reservoir conditions were poor and immigration of trout evident by July, which was at 50% reduction in storage volume. Pool volume greater than 30% of full could increase the strength of stratification in the reservoir. If that occurs, anoxic conditions could develop in the hypolimnion and create more oxygen limitations than observed in 1988. We do not know at what pool elevation is critical for this in normal years. We do not believe that maintaining high storage levels would substantially improve trout habitat or fishing success. The present strain of hatchery rainbow trout being released is not well adapted to reservoir environmental conditions. Strains of trout more suitable to high temperatures should be released to utilize more of the reservoir volume. Redband, Lahontan cutthroat, Henrys Lake cutthroat and rainbow cutthroat hybrids should be evaluated.

ACKNOWLEDGEMENTS

I would like to thank biological aides Doug Taki and Steve Howser who helped with the collection and analysis of data, respectively, and Bruce Rieman for editing and experimental design guidance.

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