1988

ANNUAL PROGRESS REPORT

State: Utah

Project Title: Survival of Trout Strains as Affected by Limnological Parameters

Project No: F-47-R Segment No: 3

Study No: 1

Study Title: Predation Losses, Habitat Needs and Out-Migration of Juvenile Rainbow Trout

Study Period: January 1, 1988 through December 31, 1988

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Study Period: January 1, 1988 through December 31, 1988

Segment Objective A: To measure the loss of juvenile trout to fish and bird predators.

Summary of Progress: Causey Reservoir contains a population of large brown and cutthroat trout which preyed on stocked juvenile trout for at least two months after stocking. Results from Causey Reservoir were similar to East Canyon Reservoir, brown trout had high levels of piscivority, cutthroat trout had moderate levels, and rainbow trout had low levels. Brook trout and small cutthroat trout (< 300 mm S.L.) preyed on juvenile trout, but only for the first week after stocking. No significant differences were detected in survival between two size groups of juvenile trout. A separate report is enclosed (Appendix I). Studies in Minersville Reservoir indicated that rainbow and cutthroat trout predation had minimal influence upon fingerling trout survival. The greatest impact upon both fingerling and adult trout survival in Minersville Reservoir was avian predation (see Appendix IV).

Segment Objective B: To determine the spatial overlap of predators (adult trout and birds) with juvenile trout.

Summary of Progress: The distribution of bird predators closely matched that of the juvenile trout stocked in Minersville Reservoir. The juvenile fish remained in the lower end of the reservoir near where they were stocked, and birds concentrated in this area to feed. The distribution of adult trout and the fingerlings also broadly overlapped, as large numbers of adult fish were captured in the lower end of the reservoir (Appendix IV).

Segment Objective C: To determine the importance of habitat (cover) in protecting juvenile trout from fish predation.

Summary of Progress: In East Canyon Reservoir juvenile trout selected structurally complex habitats throughout the day. In Causey Reservoir trout moved offshore during early morning and did not return to the littoral zone until after dusk. Low levels of food and low predation risk from birds are suggested as reasons why trout moved offshore. Preliminary results of zooplankton, indicates food levels are generally lower in Causey Reservoir than in East Canyon Reservoir. Also, there are lower numbers of diurnal avian predators in Causey Reservoir. In a pond experiment with brown trout as predators, survival rates of juvenile trout were 34% lower in areas with cover than in areas without cover. Further studies are needed to understand factors that regulate habitat use of juvenile rainbow trout. A separate report is enclosed (Appendix II).

Segment Objective D: Determine the importance of outmigration as a loss factor for juvenile trout in reservoirs.

Summary of Progress: A fish trap positioned below Minersville Reservoir indicated that few fingerling rainbow trout emigrated from the reservoir during the spring and summer months (Appendix IV).

Segment Objective E: To measure the dispersal rates of juvenile trout following their introduction into a reservoir.

Summary of Progress: The dispersal rates of fingerling trout after planting in Minersville Reservoir were monitored at approximately weekly intervals for two months. Dispersal into the lower section of the reservoir was rapid, but fish failed to move into the mid and upper sections of the system (see Appendix IV). Dispersal rates of catchable rainbow trout were measured in Causey Reservoir. These fish dispersed evenly throughout the entire reservoir within three days (Appendix I).

Segment Objective F: To measure basic limnological parameters in the study areas.

Summary of Progress: Secchi disc readings, dissolved oxygen and temperature profiles were measured on ten dates in Causey Reservoir. Chlorophyll a was sampled on one date, July 21, 1988. Results are given in Appendix III.

Segment Objective G: Integration of previous year's studies.

Summary of Progress: The relationship between fish predator size and size of their prey from East Canyon Reservoir, Causey R. and Bear Lake was summarized (Appendix I). Analysis of data on zooplankton abundance, feeding of juvenile rainbow trout, the trout's use of cover, and predation rates on the juveniles has led to a conceptual model of how these factors interact. This model suggests that in low-food environments juvenile trout will have to forage for long periods and expose themselves to predation by fish and birds for extended periods of time. In contrast, juvenile fish stocked in productive systems with abundant food can forage for short periods after which they can utilize cover to avoid predators. This hypothesis will be tested in the coming year (See appendix II).

APPENDIX I

EFFECTS OF FISH PREDATION ON THE SURVIVAL OF RAINBOW TROUT FINGERLINGS IN CAUSEY RESERVOIR, UTAH

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INTRODUCTION

Prior work at East Canyon Reservoir, Utah indicated that adult trout are important predators of stocked juvenile rainbow trout. Brown trout, in particular, were exclusively piscivorous when they exceeded 185 mm standard length. Fish became increasingly important in the diet of cutthroat trout greater than 330 mm. The purpose of this study was to further document the effect of adult trout on survival of juvenile rainbow trout in mid-elevation reservoirs. Causey Reservoir was chosen because it was thought to contain large brown and cutthroat trout and had not been intensively studied during the last eight years.

STUDY SITE

Causey Reservoir (CR) is a 58 hectare impoundment on the South Fork of the Ogden River. The reservoir has a mean depth of 20 m and a shoreline distance of 11.8 km. CR is fed by three streams that provide spawning habitat for salmonids. Four species of salmonids inhabit the reservoir; cutthroat trout (Oncorhynchus clarki), rainbow trout (O. mykiss), brown trout (Salmo trutta), and brook trout (Salvelinus fontinalis). Stocking of fish by Utah Division of Wildlife Resources has been variable. Different sizes of rainbow, cutthroat, and brook trout are often stocked each year. The brown trout population is maintained solely through natural reproduction. The only other fish species in CR is mottled sculpin (Cottus bairdi).

METHODS

On June 6, 1988, two groups of juvenile rainbow trout of the tensleep strain were stocked in Causey Reservoir near Camp Kiesel on the north arm of the reservoir. Two size groups were stocked, 22,260 trout with a mean weight of 8.2 g (55/lb) from Loa State Fish Hatchery, and 30,010 trout weighing 3.2 g (141/lb) from Kamas State Fish Hatchery. The group of large juveniles were marked with a red florescent dye while the group of small trout was marked with a yellow dye.

After stocking, adult trout in the reservoir were sampled periodically with overnight sets of sinking gill nets. Placement of nets was determined through stratified random sampling techniques to insure nets were placed throughout the reservoir. A topographic map of the reservoir was divided into four zones with a total of 34 approximately equal sections. Sections were revised slightly after the water level had dropped in late July. Gill nets were anchored on the shore and then set at an angle from shore (ranged from perpendicular to approx. 30°). Gill nets consisted of five panels of various mesh sizes (either ½", ³/₄", 1", 1¼", and 1½", or ½", 1", 1½", 2", and 2½" square mesh). The one-half inch mesh size was not fished to prevent capture of juvenile fish and subsequent net feeding by fish predators. Smaller mesh sizes, ³/₄" and 1", were not fished after the first two weeks because small rainbow and cutthroat were no longer feeding on juvenile trout. Fish were removed from gill nets and placed on ice to prevent further digestion of stomach contents. Within four hours, fish standard lengths were taken and stomachs examined.

Stomach contents were visually estimated to determined relative volume of major food items. Ingested fish were identified and their standard lengths (S.L.) measured. Remains of fish that were unable to be identified in the field were preserved in ethanol and analyzed in the lab. Diagnostic bones were then used to identify and estimate original length (Hansel et al. 1988). Unidentified trout found in the stomachs were assumed to be rainbow trout because: 1) later gill net samples of juvenile trout in the reservoir indicated 94% were rainbow trout, and 2) for their first month, stocked rainbow trout are probably more vulnerable to predation than other trout adapted to conditions in the reservoir.

We estimated the population size of adult trout with a mark-recapture method using hatchery catchable trout as the marked fish. On June 7, 1988, 2,000 catchable trout (mean weight 168 g, 2.7 fish/pound) were stocked. Gill net catches indicated that dispersal of catchable trout throughout Causey Reservoir took one day. The proportions of marked and unmarked fish were estimated with gill nets on three dates (one, two, and seven days after stocking). Four standard nets were used on each date. Gill nets were randomly placed within each of the four reservoir zones. Nets were fished overnight and removed the following morning. Stocked trout were distinguished from other rainbow trout by erosion of fins and coloration. Population estimates of each species were made with Bailey estimation procedures (Cushing 1981).

An estimate of the losses of juvenile rainbow trout to piscine predation was made using the following model:

$$\text{Total Mortality} = \text{Predator Abundance} \times \underline{\text{juvenile trout}}\ \text{stomach} \div \text{digestion interval (days)} \times \text{predation interval (days)}$$

A digestion interval of 1.4 days (Molnar et al. 1966) was used, as laboratory digestion experiments with brown and rainbow trout have not yet been completed. Predation interval was divided into two time periods: 1) the first week after stocking when juvenile trout were very vulnerable, and 2) 7 days - 90 days. After this period juvenile fish were large and were not preyed upon by most piscine predators.

Juvenile trout were sampled on November 11, 1988 to determine the relative survival rates of the two size groups that were stocked in June. Six gill nets (½", $^3/_4$", 1", and 1¼" panels) were placed randomly around the reservoir. Fish were examined for florescent dye markings, weighed and measured. Differences in survival were analyzed with a chi-square goodness of fit test (Zar 1974).

RESULTS

Size Composition of Fish and Diet Analyses

Gill net catches were dominated by small cutthroat trout, but sufficient numbers of large cutthroat and brown trout were also caught. No dominant age group existed for brown trout but there were two distinct year-classes of cutthroat trout, probably belonging to 1+ and 2+ age groups (Fig 1). There was only one year class of rainbow trout captured with the exception of a single individual measuring 410 mm S.L. Six brook trout were collected and all were less than 250 mm S.L.

Diet analysis indicated that both cutthroat and brown trout become more piscivorous as they increase in size. Both juvenile trout and sculpin were important prey fish. Brown trout less than 250 mm ate insects but our sample size for this size group was small (n = 4), precluding a definite description of their diet. In brown trout > 300 mm S.L. fish became the dominant item in the diet (Fig. 2). Catchable-size trout occurred in the diet of large brown trout (> 430 mm S.L.). Brown trout between 300-400 mm ate large numbers of sculpins, while larger fish ate primarily juvenile rainbow trout.

Cutthroat trout utilized zooplankton extensively until they were > 300 mm S.L., and then fish became increasingly important in their diet (Fig. 2). Aquatic and terrestrial insects were used by all sizes of cutthroat trout. Insects, zooplankton, snails, and vegetation were all important prey items for rainbow trout (Fig. 2). No fish were found in their diet.

Fish predation on juvenile rainbow trout was primarily by cutthroat and brown trout greater than 300 mm S.L. (Tables 1, 2;, Fig. 3). The average number of trout ingested by large brown trout was high (0.76 trout/stomach) but we sampled few brown trout after June (Fig. 3). Large cutthroat trout averaged 0.36 trout/stomach. Small cutthroat and brook trout also preyed on juvenile trout but only during the first week after stocking (Table 2).

As the size of the brown and cutthroat trout in Causey Reservoir and other systems increased, the maximum length of fish they consumed also increased (Figs. 4, 5). The maximum size of prey consumed by both species of predators followed similar relationships with size. Although large trout consumed larger prey, a considerable portion of their diet still consisted of small non-game fish such as sculpin, and in East Canyon Reservoir, redside shiners (Richardsonius balteatus).

Population Estimates and Mortality of Juvenile Trout

Forty-one catchable rainbow trout were recaptured from three days of gill netting. Population estimates of the highly piscivorous brown trout and cutthroat trout greater than 300 mm S.L. were both 432 individuals (Table 3). Cutthroat trout < 300 mm dominated the trout community with 10,423 individuals.

We estimate that 28,000 juvenile rainbow trout, or 53% of those stocked, were ingested by piscine predators in Causey Reservoir from June-September (Table 4). Brown and cutthroat trout accounted for 77% and 23% of the piscine predation, respectively.

Relative Survival Rates

A total of 154 marked juvenile rainbow trout were sampled in November, of which 99 were from the small size class and 55 from the large size class. Large fish represented 43% of the trout stocked, but only 36% of those recaptured. Survival, however, was not significantly different (X^2 = 2.97; P = .085) between the two size groups.

DISCUSSION

The degree of piscivory shown by the trout in Causey Reservoir varied between species and with the size of the predator. Brown and cutthroat trout became extensively piscivorous at respective standard lengths of 250 and 325 mm (ca. 285 and 375 mm total length, respectively). Brown trout between 300 and 450 mm S.L. also ate over twice the number of fish than did cutthroat trout in this size class (cf. Tables 1, 2). The adult rainbow trout captured in the reservoir were not piscivorous, but only one individual larger than 300 mm S.L. was captured and it was empty. Consequently, it is clear that brown trout are the most piscivorous species in the reservoir, but the relative differences between rainbow and cutthroat trout in this system cannot be determined.

Sculpin were the dominant forage fish eaten by intermediate-sized brown and cutthroat trout, but when these predators reached sizes of 300-350 mm, they switched to prey on juvenile rainbow trout (Fig. 2). This same switch-over from sculpin to salmonids has been observed in piscivorous cutthroat trout in Bear Lake, Utah-Idaho, but the reason(s) for the change is not obvious (L. Jacobson and W. Wurtsbaugh, Utah State University, unpublished data). One hypothesis to explain the change is that the predators are not fast enough swimmers until they reach a critical size to catch the mobil salmonids. This hypothesis is currently being tested at our university by C. Luecke.

The large brown and cutthroat trout in Causey Reservoir are capable of catching not only stocked fingerling trout, but catchable-sized ones as well. One 425 mm brown trout had eaten a 195 mm S.L. (ca. 8.5 inches total length) cutthroat. The regressions between predator size and maximum prey size in cutthroat trout and brown trout are quite similar (cf. Figs. 4, 5), and both suggest that trout over 600 mm can eat salmonids near 265 mm in length. Our sample size of very large predators is small, however, so it is difficult to determine the exact upper boundary on prey size. Nevertheless, these data indicate that many of the 1+ rainbow trout in Causey Reservoir (Fig. 1) are vulnerable to the largest predators. Although our sample was small (n=3), brown trout larger than 400 mm appeared to feed selectively on the yearling trout. In June, after the fingerlings were planted, the larger browns still fed on the 1+ trout, even though the fingerlings were much more abundant.

Fingerling rainbow trout were most vulnerable to predation during the first few days after they were stocked (Fig. 3.) when even small cutthroat and brook trout were able to prey on them (Table 4). The exact reason(s) the fingerlings are more vulnerable to predation during this period is unknown, but Sigismondi and Weber (1988) recently demonstrated that handling stress can severely decrease salmonid reaction time to stimuli for at least 24 hours. The stress associated with hauling and stocking may therefore increase the vulnerability of juvenile trout to predation.

The loss of fingerling trout is not, however, greatly affected by the initially high rates of piscivory, but rather by the prolonged, steady loss of fish to large predators. Even though predation rates on juvenile trout fell to less than $1.0 \cdot \text{predator}^{-1} \cdot \text{day}^{-1}$ after the first week they were in the reservoir, we estimate that 88% of the predatory losses occurred during the subsequent 90 days (Table 4). The prolonged impact of predators has also been demonstrated in simulation models of piscivores preying on Great Lakes fishes. For example, Stewart et al. (1983) demonstrate that a 3 kg lake trout (S. namaycush) will eat about 8 kg of $\text{fish} \cdot \text{yr}^{-1}$, or the equivalent of 800, 10 g fingerling trout. An equal-sized brown trout could probably eat even higher numbers because they prefer higher temperatures than lake trout and consequently have higher metabolic rates.

We estimate that piscivores consumed over 50% of the 52,000 fingerling trout stocked in Causey Reservoir (Table 4), but this calculation is imprecise due to high variability in several parameters of the predation model. First, our estimate of the number of predators in the reservoir is weak because only 18 fish larger than 300 mm were recaptured during the mark-recapture experiment. Additionally, confidence limits on the estimate are not available because the statistical properties of the "stock-recapture" technique we employed have not been evaluated. There may also be some bias in our estimate, as we only recaptured fish with gill nets set near the shore. Modde and Hepworth (unpublished data) have shown in a southern-Utah reservoir that newly stocked catchable rainbow trout utilize this habitat more than do adult cutthroat trout. If trout in Causey Reservoir behaved similarly, we may have underestimated the total number of predators and the importance of piscivory as a mortality factor for the fingerling trout.

A second source of variability in the model was our estimate of the number of fingerling trout consumed each day by the predators (Fig. 3). This was, in part, a problem of small number of adult trout that we could capture, and also due to an apparent high natural variability in feeding by the piscivores.

Large trout in Causey Reservoir most frequently had empty guts, but at other times they had ingested several fish. In a similar reservoir (East Canyon Reservoir) we have encountered brown trout with up to 50 fingerling trout in the guts. This apparent pattern of fasting and gorging aggravates a precise determination of predation rates when sample sizes are low.

Although these sources of variance preclude a precise estimate of the amount of piscivory in Causey Reservoir, our work there and elsewhere indicates that predation is a significant source of mortality for fingerling trout stocked in reservoirs. Piscivory has also been demonstrated to be a major mortality factor for other juvenile fish. Migrating salmonids in the Columbia River system are severely depleted by predation from squawfish (R. Beamesderfer, Oregon Dept. of Fish and Wildlife, personal communication), and juvenile muskellunge, Esox masquinongy, stocked in lakes are decimated by largemouth bass and other predators (Wahl and Stein 1984).

The importance of piscivory as a loss factor for salmonids has also been indicated in "experiments" where predacious brown trout or squawfish have been removed from lakes (Ricker 1952, Wales and Borgeson 1961). Survival rates near 100% have been found for trout fingerlings stocked into barren lakes (Eschmeyer 1938), also indicating the potential importance of fish predators for reducing fish survival.

The primary management implication of this study is that moderate to large populations of "trophy" trout in a reservoir or lake are incompatible with high survival rates of stocked fingerling trout. When predators are present managers must resort to stocking larger trout that are presumably less vulnerable. The relationship between predator size and maximum size of prey consumed demonstrates, however, that even catchable-size trout can be consumed by brown and cutthroat trout greater than 400 mm S.L. (Figs. 4, 5). Besides stocking larger trout, we perceive three other possible management options to minimize the loss of juvenile fish when a high-yield trout fishery is desired.

First, populations of predators can be reduced by poisoning or fishing. Wales and Borgeson (1961), for example, increased survival of fingerling brook trout from 2% to 35% by poisoning the piscivorous brown and lake trout in a mountain lake. Increased survival of juvenile trout following rotenone-restoration projects in Utah and elsewhere may similarly be due to the removal of predators. Reduced competition between trout and non-game fish may also enhance survival by allowing the trout to grow faster and thus reducing the length of time that they are vulnerable to predators (Johannes and Larkin 1961). Although chemical removal may be the most effective way to remove predators, relaxed angling regulations on spawning populations of piscivorous fish might also be an efficient way to reduce their abundance.

A second management option is to introduce alternative forage fish to buffer the impact of piscine predators on stocked trout. In Causey Reservoir, for example, naturally occurring sculpin are preyed upon extensively by intermediate-sized predators, and in East Canyon Reservoir redside shiners are utilized considerably by the brown trout there (Wurtsbaugh and Modde 1988). In both systems, however, large trout appear to prefer the stocked trout over the alternative forage fish, so that "buffering" with these species will seldom be entirely effective. Additionally, forage fish may compete with juvenile trout for zooplankton and other invertebrates, thus reducing the growth of the trout and again making them vulnerable to predation for longer periods than if the forage fish were not there (Johannes and Larkin 1961, Li et al. 1976). Competition with forage fish might be a particularly important consideration in oligotrophic systems where invertebrate prey is scarce. Forage species might also allow brown and cutthroat trout to grow to greater sizes, thereby increasing predation rates on stocked fingerlings. Consequently, the successful use of forage species to buffer predation is problematical.

Finally, managers may improve survival of fingerling trout by insuring that adequate cover is available for the stocked fish. Our work at Causey (Tabor and Wurtsbaugh 1989) and particularly East Canyon Reservoir (Wurtsbaugh and Modde 1988) has demonstrated that fingerling rainbow trout use shoreline cover such as boulders and inundated vegetation. In a pond experiment Tabor and Wurtsbaugh (1989) demonstrated that cover reduced predation rates of brown trout on fingerling rainbows by about 25%. Potential management options to increase cover include: (1) leaving some trees and brush in reservoirs when new reservoirs are created, (2) adding artificial cover near the shoreline of lakes and reservoirs, and (3) stocking fish when reservoirs are full and vegetation and boulders at this high-water level are inundated.

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Table 1. Abundance of fishes in the stomachs of brown trout in Causey Reservoir, 1988.
RBT = rainbow trout; UTRT = unidentified trout; SCLP = sculpin; UFIS = unidentified fish

				PREY SPECIES					
Month	No. of Days	Size Class	N	RBT	UTRT	SCLP	UFIS	Total	Fish/Pred
June (week 1)	3	<150	1	0	0	0	0	0	0
		150-249	1	0	0	0	0	0	0
		250-299	1	0	0	0	0	0	0
		300-450	8	8	2	4	2	16	2.000
		>450	2	0	0	0	1	1	0.500
June (week 2-4)	3	<150	1	0	0	0	0	0	0
		150-249	1	0	0	0	0	0	0
		250-299	0	0	0	0	0	0	0
		300-450	13	4	5	6	0	15	1.154
		>450	8	3	3	0	3	9	1.125
July	3	<150	1	0	0	0	0	0	0
		150-249	0	-	-	-	-	-	-
		250-299	1	0	0	0	0	0	0
		300-450	0	-	-	-	-	-	-
		>450	2	0	0	0	1	1	0.500
August	1	<150	0	-	-	-	-	-	-
		150-249	0	-	-	-	-	-	-
		250-299	1	0	0	2	0	2	2.000
		300-450	0	-	-	-	-	-	-
		>450	0	-	-	-	-	-	-
Total	10	<150	2	0	0	0	0	0	0
		150-249	2	0	0	0	0	0	0
		250-299	3	0	0	2	0	2	0.667
		300-450	21	12	7	10	2	31	1.476
		>450	12	3	3	0	5	11	0.917

Table 2. Abundance of fishes in the stomachs of cutthroat and brook trout in Causey Reservoir. 1988.
RBT = rainbow trout: UTRT = unidentified trout: SCLP = sculpin: UFIS = unidentified fish

Month	No. of Days	Size Class	N	PREY SPECIES RBT	UTRT	SCLP	UFIS	Total	Fish/Pred
A) CUTTHROAT TROUT									
June (week 1)	3	<150	3	0	0	0	0	0	0
		150-249	192	8	4	1	1	14	0.073
		250-299	16	5	1	2	2	10	0.625
		300-450	14	15	6	1	0	22	1.571
June (week 2-4)	3	<150	2	0	0	0	0	0	0
		150-249	46	0	0	0	0	0	0
		250-299	27	0	0	4	0	4	0.148
		300-450	21	0	3	7	1	11	0.524
July	3	<150	0	-	-	-	-	-	-
		150-249	21	0	0	1	0	1	0.048
		250-299	14	0	0	2	0	2	0.143
		300-450	42	0	4	12	1	17	0.405
August	1	<150	0	-	-	-	-	-	-
		150-249	3	0	0	0	0	0	0
		250-299	1	0	0	0	0	0	0
		300-450	7	2	0	2	1	5	0.714
Total	10	<150	5	0	0	0	0	0	0
		150-249	262	8	4	2	1	15	0.057
		250-299	58	5	1	8	2	16	0.276
		300-450	84	17	13	22	3	55	0.655
B) BROOK TROUT									
June (week 1)	3	150-249	4	1	1	0	0	2	0.5
June (week 2-4)	3	150-249	2	0	0	0	0	0	0
TOTAL	10	150-249	6	1	1	0	0	2	0.333

Table 3. Population estimates of cutthroat, rainbow, brown, and brook trout using stocked catchable rainbow trout as marked fish, Causey Reservoir, June 1988.

Trout Species	Number in Sample	Percent	Population Estimate
Cutthroat			
< 300 mm	219	81.7	10,423
> 300 mm	9	3.4	431
Rainbow	25	9.3	1,190
Brown			
< 300 mm	3	1.1	143
> 300 mm	9	3.4	431
Brook	3	1.1	143

Table 4. Mortality estimates of juvenile rainbow trout by piscine predators. During the first week predators were only sampled in the zone where fish were stocked and thus predator population estimates were reduced. Causey Reservoir, June-September 1988.

Predator	Abundance	# trout / stomach	digestion interval (days)	predation interval (days)	Mortality
Week 1					
Cutthroat					
< 300 mm	3,066	0.0975	1.4	7	1,495
> 300 mm	127	1.5000	1.4	7	953
Brown					
> 300 mm	127	1.2140	1.4	7	771
Brook					
< 250 mm	42	0.5	1.4	7	105
Remaining 90 Days					
Cutthroat					
< 300 mm	10423	0	-	-	0
> 300 mm	431	0.1470	1.4	90	4,073
Brown					
> 300 mm	431	0.7453	1.4	90	20,650
Brook					
< 250 mm	143	0	-	-	0
					28,047

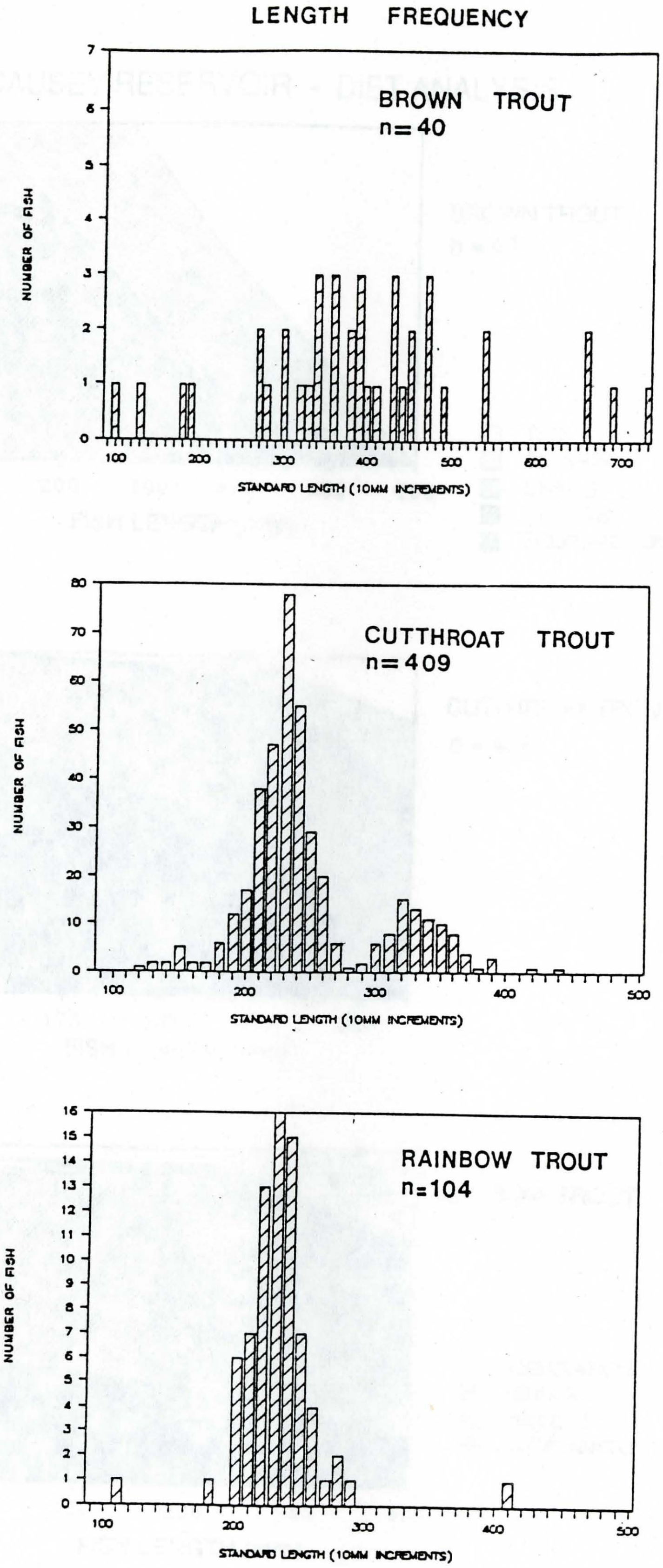

Figure 1. Length-frequencies of three species of trout found in Causey Reservoir. Fish were sampled on ten dates during June-August, 1988. Rainbow trout length frequency data does not include juvenile and catchable trout stocked during 1988. Standard length can be converted to total length by multiplying by 1.15 (Carlander 1967).

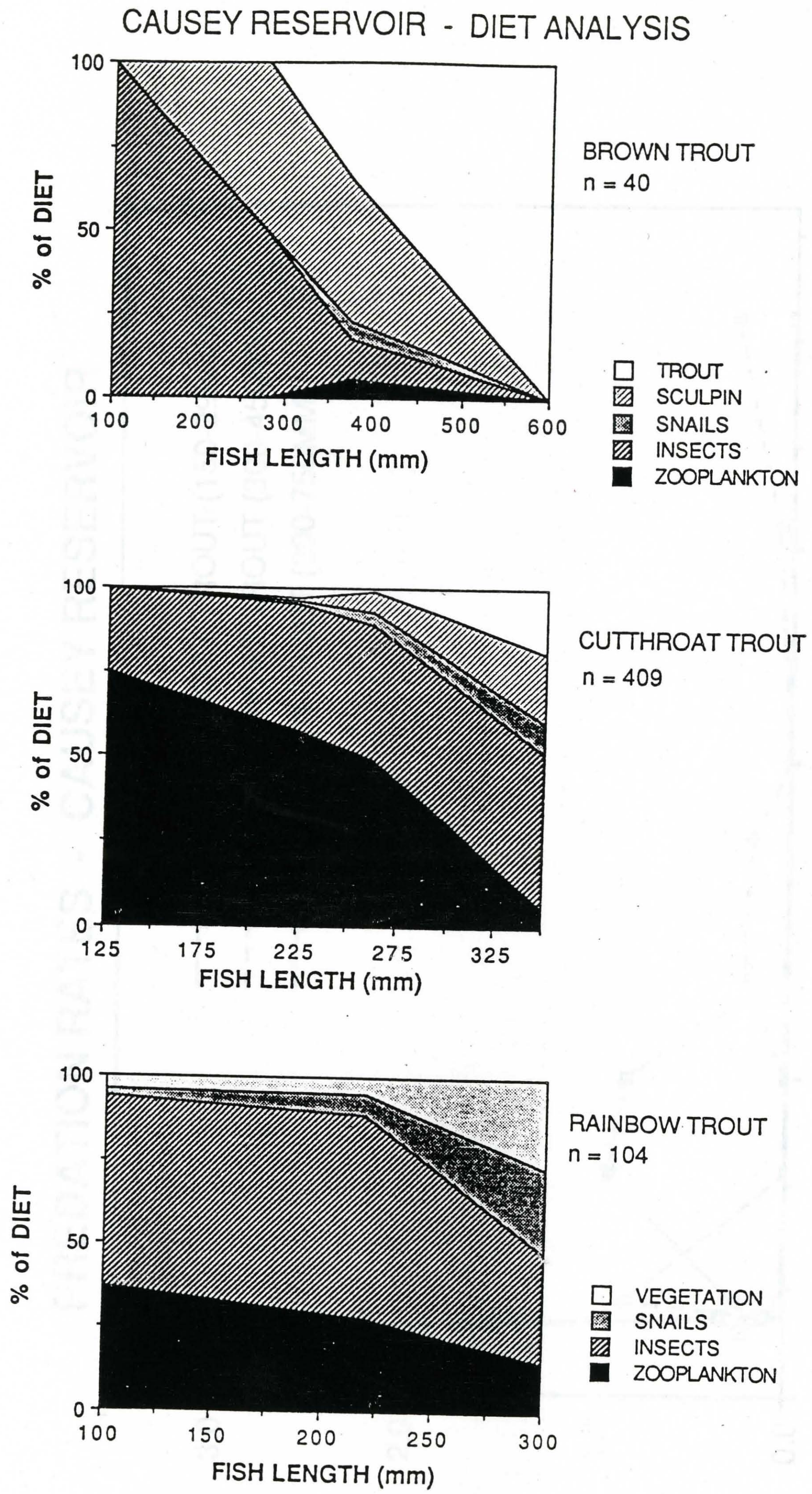

Figure 2. Diet analysis of brown, cutthroat, and rainbow trout from Causey Reservoir, June-August, 1988. Stomach samples were visually estimated to determine relative volume of major food items. Note that larger brown trout were captured than were cutthroat or rainbow trout.

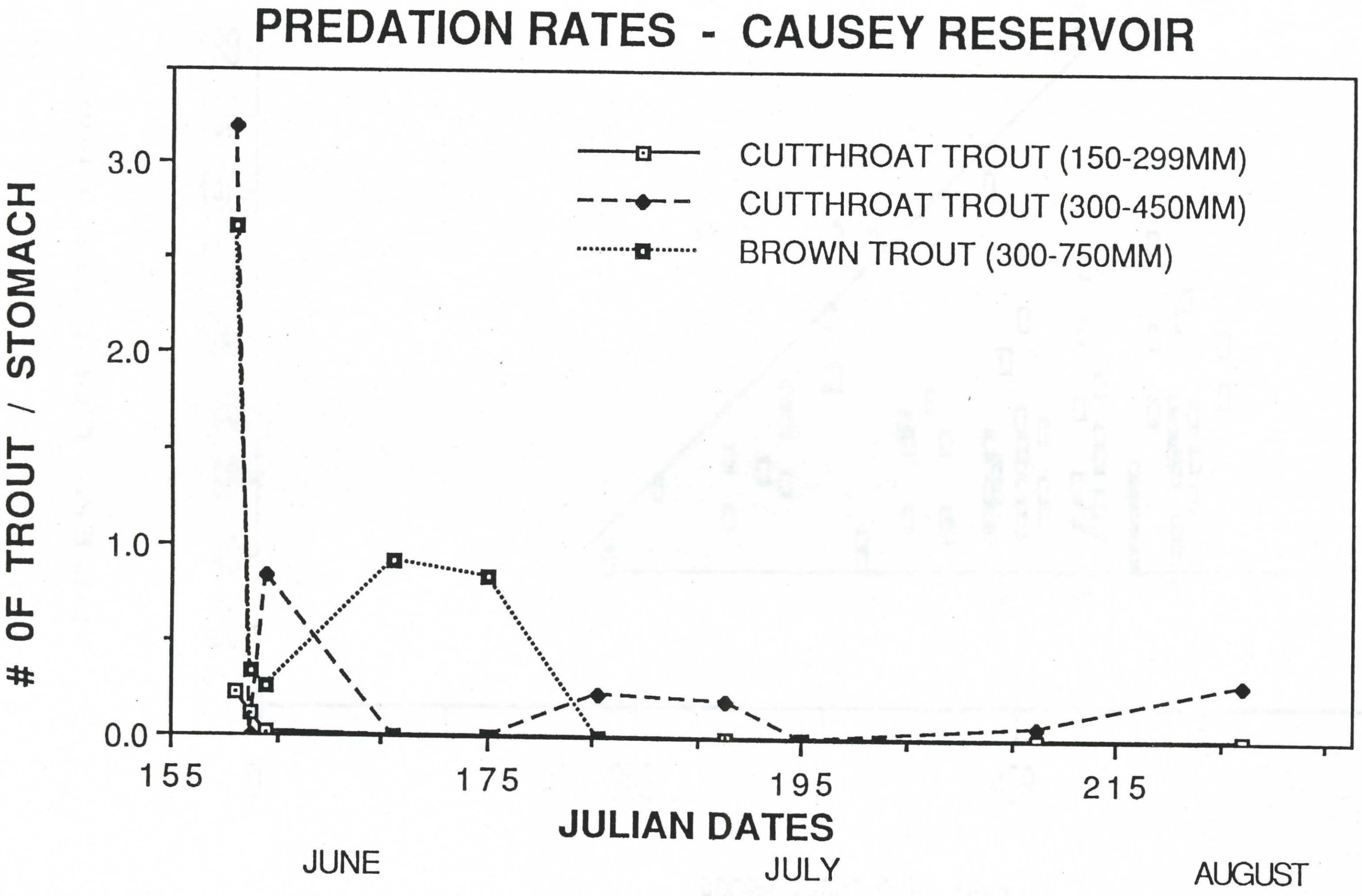

Figure 3. Mean number of trout in stomachs of adult brown and cutthroat trout in Causey Reservoir. First sampling date was following stocking of juvenile trout on June 6, 1988. Adult trout were sampled on ten dates during June-August 1988.

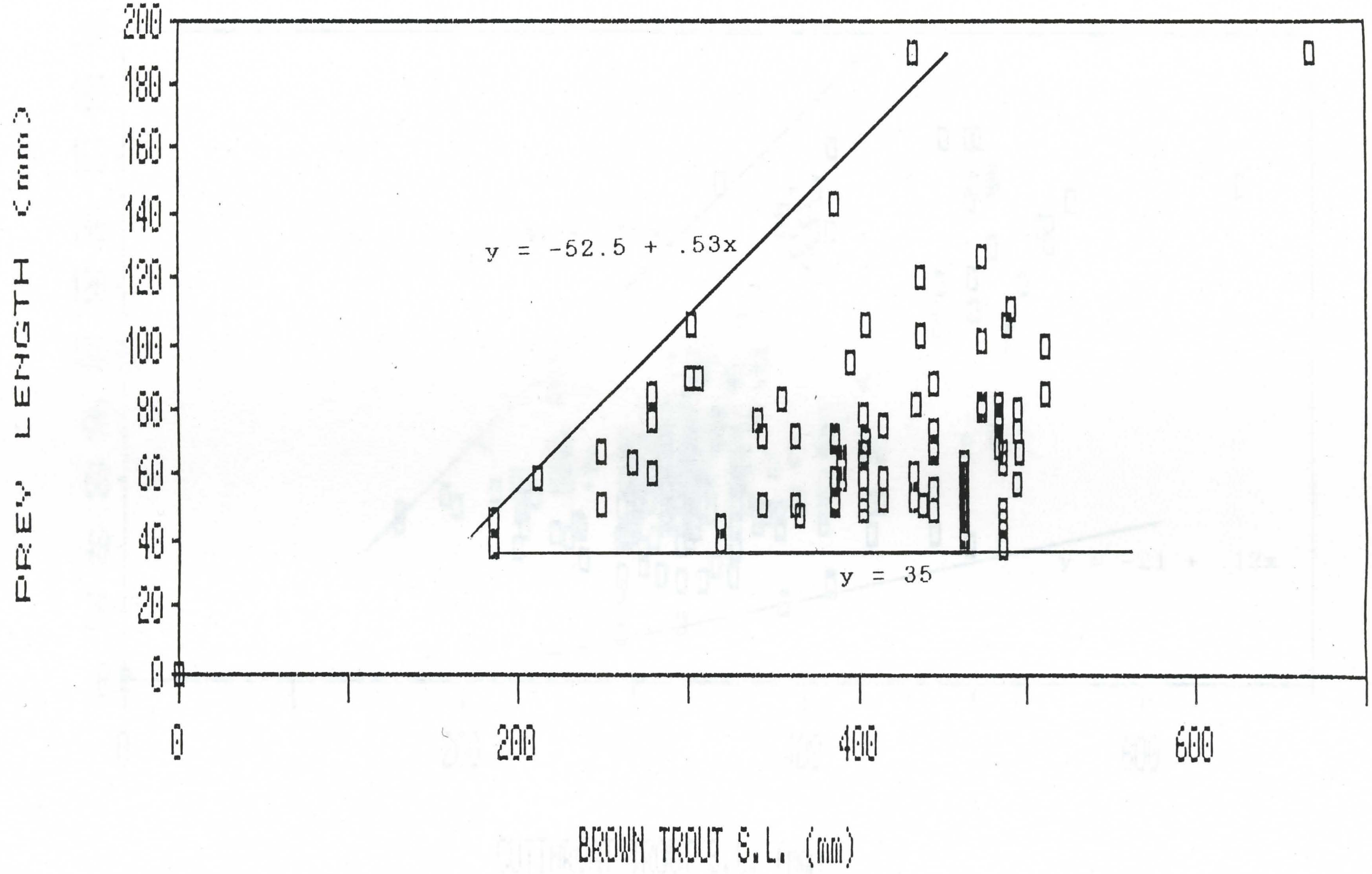

Figure 4. Size of prey fish found in stomachs of brown trout of different sizes from Causey Reservoir (1988) and East Canyon Reservoir (1986, 87). Prey species include rainbow trout, cutthroat trout, mottled sculpin, redside shiner, and fathead minnow. Solid lines indicate maximum and minimum prey size limits on brown trout diet.

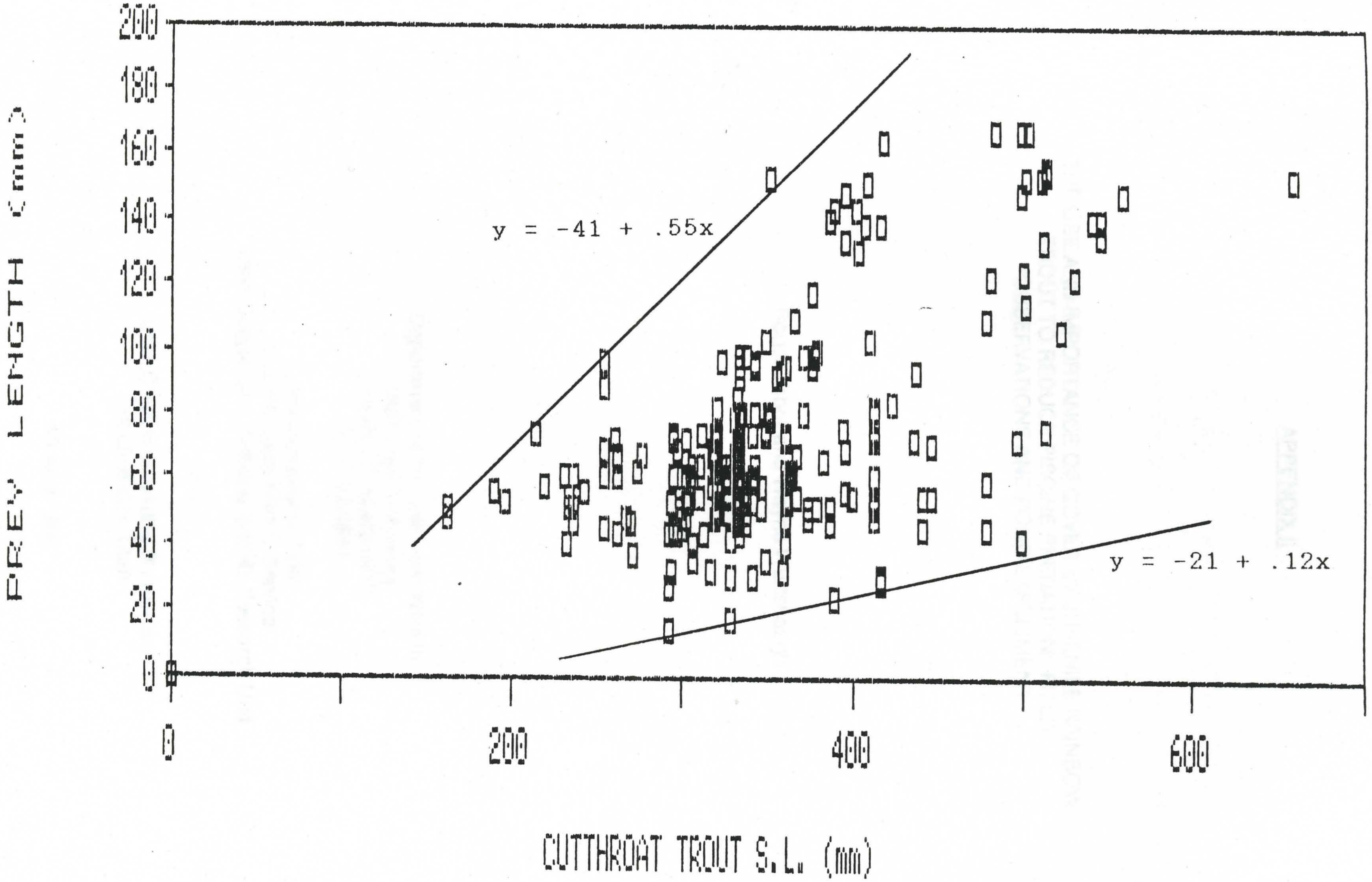

Figure 5. Size of prey fish found in stomachs of cutthroat trout of different sizes from Causey Reservoir (1988), East Canyon Reservoir (1987), and Bear Lake (1986,87). Prey species include rainbow trout, cutthroat trout, Bear Lake cisco, Bear Lake and mottled sculpin, and redside shiner. Solid lines indicate maximum and minimum prey size limits on cutthroat trout diet.

APPENDIX II

THE USE AND IMPORTANCE OF COVER BY JUVENILE RAINBOW TROUT TO REDUCE PISCINE PREDATION: FIELD OBSERVATIONS AND POND EXPERIMENT

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INTRODUCTION

Freshwater fish employ an array of behavioral and morphological adaptations as antipredation devices. An important behavioral adaptation often used is the movement to cover or refuge where predators cannot forage effectively (Glass 1971, Werner and Hall 1988). Several studies have shown that prey vulnerability will decrease as environmental complexity increases (Crowder and Cooper 1982, Savino and Stein 1982, Gotceitas and Colgan 1987). Structurally complex habitats that provide cover are often important "nursery areas" for the young of many fish species (Hall and Werner 1977, Orth et al. 1984). Consequently, the availability of cover can significantly increase the survival of juvenile fish (Aggus and Elliot 1975, Lowe-McConnell 1987, Werner and Hall 1988).

Juvenile fish that inhabit lakes and reservoirs are often restricted to littoral habitats or nursery areas for a certain period of time before moving offshore. Structurally complex habitats, such as aquatic macrophyte beds (Hall and Werner 1977, Mittelbach 1986), inundated vegetation (Aggus and Elliot 1975), and large boulders (Trendall 1988), are often important habitat of juvenile fish in lentic systems. These habitats can provide cover from predators (Werner and Hall 1988) as well as abundant forage (Whiteside et al. 1985).

In temperate lakes, diurnally active fish often shift from a daytime feeding area in midwater to resting on the bottom at night (Emery 1978, Helfman 1981). Most fish rest in relatively exposed locations but some juvenile fish have a strong affinity for shelter sites at night (Helfman 1981). Emery (1978) hypothesized that the large number of fish resting in exposed areas was due to the paucity of shelter sites. Another explanation proposed by Helfman (1981) was that freshwater systems generally lack abundant nocturnal predators.

Juvenile rainbow trout, <u>Oncorhynchus mykiss</u>, stocked in East Canyon Reservoir, Morgan, Utah, inhabit the littoral zone for 1.5 to 2 months in the reservoir before moving offshore to the pelagic zone (Wurtsbaugh and Tabor 1987). During the day, juvenile trout apparently select littoral areas of relatively high structural complexity, including inundated vegetation and large boulders. Because suitable prey, zooplankton, is often low in the littoral zone, use of this zone is believed to be for cover from diurnal predators such as piscivorous birds.

In many western reservoirs adult brown trout, Salmo trutta, are both nocturnally active (Eriksson 1978, Oswald 1978) and important predators of juvenile trout (Sharpe 1957, Stuber et al. 1985, Wurtsbaugh 1986). Because of nocturnal as well as diurnal predators, juvenile trout may select habitats which provide cover during both day and night. Little is known, however, about diel use of cover by juvenile trout or their ability to use cover effectively in lentic systems. The objectives of this study were: 1) to determine diel habitat selection of juvenile rainbow trout in two mid-elevation reservoirs, and 2) to experimentally test the importance of cover for these fish to avoid predation.

METHODS

Field Studies

East Canyon Reservoir (ECR) is a 277 hectare impoundment on East Canyon Creek. The reservoir has a mean depth of 23 m and a shoreline of 16 km. The Utah Division of Wildlife Resources (DWR) stocks the reservoir each spring with 300,000 ($\bar{x}$ individual mass = 5.7 grams; 80 fish/lb) rainbow trout. For the first two months after stocking the juvenile trout are preyed on by adult brown trout Salmo trutta, cutthroat trout Oncorhynhus clarki, and rainbow trout O. mykiss (Wurtsbaugh 1986). Juvenile trout are also vulnerable to predation by several species of piscivorous birds. Redside shiners Richardsonius balteatus, are the most numerous fish in this reservoir and are important forage for adult trout. Kokanee salmon O. nerka, Utah sucker Catostomus ardens, speckled dace Rhinichthys osculus, and fathead minnow Pimephales promelas are also present in the reservoir.

Causey Reservoir (CR) is a 58 ha impoundment on the South Fork of the Ogden River. The reservoir has a mean depth of 20 m and an11.8 km shoreline. Stocking of fish by Utah DWR has been variable. Different sizes of rainbow, cutthroat, and brook trout (Salvelinus fontinalis) are often stocked each year. In 1988, when the study was conducted, 30,010 ($\bar{x}$ = 3.2 g; 141 fish/lb) and 22,260 ($\bar{x}$ = 8.2 g; 55/lb) juvenile rainbow trout were stocked on June 6th. In Causey Reservoir, juvenile trout are vulnerable to adult brown and cutthroat trout (see Appendix I). However, unlike East Canyon Reservoir, few piscivorous birds have been observed at Causey Reservoir. Besides juvenile trout, mottled sculpin Cottus bairdi also provide forage for adult trout.

Habitat selection was determined through direct observation along shoreline transects. The location of transects was determined by randomly choosing shoreline sections from a map of the reservoir. Because of slow dispersal of the planted trout, transects done within two weeks of the stocking date were randomly selected from the half of the reservoir where the juvenile fish were planted. Transects done subsequently were chosen randomly from the entire reservoir shoreline. All transects were conducted within 35 days of stocking. In East Canyon Reservoir 30 m transects were used, whereas in Causey Reservoir 100 m transects were used to increase sample size. Thirty nine transects (4 in 1987, 35 in 1988) were done in East Canyon Reservoir and thirty transects were done in Causey Reservoir. Transects were done during day (dawn, day, and dusk) and night hours.

Observations of juvenile trout were made by two swimmers, equipped with snorkel and mask, swimming next to each other along the shoreline. The area surveyed ranged from the surface to about a depth of 2 m, depending on water clarity. The distance of each transect was measured by swimming along with a rope of a given length and having the other end attached to a fixed object. Observations consisted of counting fish and noting the habitat type with which each fish was associated. The relative abundance of various habitat types was estimated visually at 20 points along each transect line. Habitat was classified into seven categories: sand/mud (sediment size <2 mm), gravel (2mm-20mm), cobble (20mm-200mm), small boulders (200mm-500mm), large boulders (>500mm), bedrock, and inundated vegetation.

Selectivity for each substrate type was calculated using Manly's α (Manly 1974) where: $\alpha = r_i/n_i / \Sigma r_i/n_i$, and r_i is the proportion of fish associated with habitat i, and n_i is the proportion of habitat type i in the environment. Random use of habitat types occurs when $\alpha_i = 1/k$, where k is the total number habitat categories. Significant differences between and within time periods were tested for with a chi-square goodness of fit test (Manly 1974).

We also examined zooplankton abundance and size to compare food availability between the two reservoirs. Zooplankton was collected on three dates (July 21, August 10, 24, 1988) in Causey Reservoir. Two samples were taken on each date. Samples were vertical tows from the bottom to the surface using a 30 cm diameter plankton net with a 153 μm mesh. In East Canyon Reservoir, zooplankton samples were collected on two dates (July 21 and September 23) in 1988. To increase the number of samples from ECR, we also used 1986 and 1987 samples from similar dates and study sites. We identified and enumerated the zooplankton and measured the first 50 Daphnia encountered in each sample. Food available to juvenile trout was estimated by the biomass of Daphnia greater than 1.1 mm in length (>99% of daphnids found in juvenile trout stomachs from ECR and CR were >1.1 mm). Dry weights of individual daphnids were calculated with the formula: ln wt. (mg) = -4.95 + 2.88 ln length (mm), adapted from Downing and Rigler (1984). Differences in biomass between the two reservoirs was analyzed with a Wilcoxon rank sum test (Hollander and Wolfe 1973).

We also determined the length-frequencies of Daphnia found in juvenile rainbow trout stomachs by measuring the first ten Daphnia in each trout stomach. Juvenile trout were collected on July 26 and August 11, 1988 from Causey Reservoir and May 27 and June 30, 1987. Forty juvenile trout from each reservoir were analyzed.

Pond Experiments

The importance of cover for the survival of juvenile rainbow trout was investigated with two pond experiments. The study site was a privately owned 1600 m^2 pond in Wellsville, Utah. The pond is uniformly shaped with a flat bottom and a maximum depth of 1.4 m. After the pond was dried and all vegetation and debris was removed the pond was divided into eight equal pie-shaped sections with small mesh netting 2.5 m in height and 7 mm square mesh). A continual flow of water was maintained through the pond with four inlet pipes placed evenly around the pond. Each section received a water flow of approximately 0.5 L/sec. Surface temperatures in the ponds ranged from 15 C at the start of each experiment to 21.5 C at the end of the experiments.

The experimental approach was a 2 X 2 factorial design with cover and predators as the two factors. The two levels were presence and absence of each factor. Each treatment was replicated once within each experiment. Treatments were assigned randomly for each experiment. Three types of structures were placed in each cover treatment: 1) wooden stakes (1.0 and 0.5 m high); 2) cement cinder blocks, and; 3) laundry baskets (0.1 m^3). These were placed near the edge of each pond where depth varied from approximately 20 to 100 cm. The total area of cover within each pond section was approximately 16 m^2.

Adult brown trout Salmo trutta were used as predators. Brown trout are generally considered to become piscivorous at lengths greater than 250 mm S.L. (Scott and Crossman 1973, Moyle 1976, Garman and Nielsen 1982). Adult trout were obtained from brood stock at Loa State Fish Hatchery, Loa, Utah. For two weeks before the experiments began, the brown trout were held in an earthen raceway and fed juvenile trout. Each pond section was stocked with juvenile rainbow trout that were obtained from Midway and Kamas State fish hatcheries.

Two sequential experiments (ten days each) were run during May-June, 1988. In the first experiment 200 juvenile rainbow trout were stocked into each section. Groups of 30 to 40 fish were counted, half were weighed to the nearest 0.1 g, and then all were stocked sequentially around the pond to each section. The following day the adult brown trout were placed in a holding cage, weighed and stocked into four sections. Each predation treatment received eight fish of similar sizes. After 10 d the pond was partially drained and the brown trout were removed with a large-mesh seine. The pond was then drained further until a small-mesh net could be used to remove the majority of juvenile trout. Finally, the pond was completely drained to get a total count of surviving fish. During the final draining of the pond in our second experiment a few fish escaped from one section. The total number of surviving fish for this section was estimated by adding the number of juvenile trout captured from the seine net to the number of fish expected to avoid the seine net (based on the mean seining efficiency rates of the other sections).

The fish removed from the pond were counted and 50 were randomly removed and weighed so that we could calculate growth rates. Instantaneous growth rates (GR) were calculated as:

$$GR\ (\%\ /day) = \frac{(\ln W_f - \ln W_i) \times 100}{T} \quad \text{where;}$$

W_f = Mean final wet weight of juvenile trout
W_i = Mean initial wet weight
T = duration of experiment (11 days)

The probability of mortality per day was estimated as μ in the model $N_t/N_o = e^{\mu t}$ (Werner and Hall 1988), where:

N_t = final population size
N_o = initial population size
t = duration of experiment (11 days)

The model assumes that mortality rates were proportional to population size at each interval. Results of growth and mortality rates were analyzed through a 2 X 2 factorial analysis of variance where significance was determined through a F test (Dowdy and Wearden 1983).

Behavioral observations were also done during the first experiment. We observed fish from shore with binoculars equipped with polarized lens. The location of juvenile trout was determined before and after the addition of brown trout predators. Fish were divided into the percent using inshore areas (within 3 m of shore) and percent offshore (> 3 m from shore) near the surface. We were unable to observe fish located offshore in mid- to bottom-waters. Behavioral observations were analyzed with a Wilcoxon rank sum test (Dowdy and Wearden 1983).

In the second experiment only enough juvenile trout were available to stock 180 fish (40 sampled for initial weights) in each section. Eleven brown trout predators were put into each of four sections to increase predation rates. Also, cover was modified slightly to be in both swallow and deep water to insure cover was available where preferred temperatures were located. Other procedures were the same as the first experiment.

RESULTS

Field Studies

During the day juvenile rainbow trout in the littoral zone of both East Canyon and Causey Reservoir selected the most structurally complex habitats--large boulders and vegetation ($P < .001$), while other substrates such as sand and gravel were avoided (Fig. 1A,C). In ECR no significant differences in habitat selection were detected between the dawn, day, and dusk periods ($P = .10$). The average number of juvenile trout observed in the littoral zone of ECR was 0.49 fish/m.

In contrast to our observations in ECR, we observed few fish in the littoral zone of CR from mid-morning to dusk. We swam seven transects during the dawn and early morning, but a total of only five trout were observed from five of the transects. The other two transects were near the stocking site and 289 fish were observed but no habitat selection was detected ($P = .12$). Fish were observed in small schools of 10 to 40 fish. During day and dusk the average number of juvenile trout seen in CR was 0.023 fish/m.

In both reservoirs, nighttime distribution of juvenile rainbow trout changed significantly from that in the daytime (Fig. 1B,D). At night juvenile trout no longer strongly selected structurally complex habitats. Fish were often found in exposed areas such as sand, gravel, and cobble. Trout observed at night had moved from the water column to near the substrate and they were easily approached and appeared to be resting. In East Canyon Reservoir the average number of trout observed increased slightly from 0.49 fish/m (daylight transects), to 0.54 fish/m (night transects). In contrast, in Causey Reservoir the average number increased markedly from 0.083 to 0.30 fish/m.

The mean biomass of Daphnia > 1.1mm in ECR was 97.4 mg/m^3, whereas the biomass in CR was 43.4 mg/l, and these results were significantly different (P = .009, Table 1). The number of Daphnia/L in ECR was lower but consisted of many large individuals, whereas in CR they were numerous but small (Fig. 2). In both reservoirs juvenile rainbow trout selected the largest Daphnia available (Fig. 3).

Pond Experiments

Effects of cover, predators, and their interaction on both mortality and growth rates were not significant in the first experiment (Table 2). Growth rates were low ($\bar{x}$ = 1.3%/ day) in all treatments (Fig. 5).

Behavioral observations indicated juvenile trout changed habitat use after the addition of piscine predators. During the first day of the experiment, when predators were absent, juvenile trout showed no significant preference for cover or inshore areas (P = .557). Upon the addition of predators, all fish observed in sections with predators were seen inshore, using cover if present, and not actively foraging. In sections without predators, in contrast, juvenile trout were located throughout the pond section and actively feeding at the surface. The distribution of juvenile trout between inshore and offshore areas was significantly dependent on presence of predators (P = .027).

In the second experiment predators, cover, and their interaction had a significant effect on the survival of juvenile fish (Table 2). The presence of brown trout increased mortality rates approximately six-fold. In sections with cover, the probability of mortality was 34% lower than in sections without cover (Fig. 4).

Growth was also significantly effected by the presence of predators in the second experiment (P = .022, Table 2). Growth rates were reduced 16% in sections with brown trout predators. In this experiment growth was rapid in all sections (mean = 6.15%/day)(Fig. 5). While seining the pond sections at the end of the experiment, large numbers of adult chironomids were observed on the water surface. The presence of chironomids probably provided juvenile fish with abundant forage and subsequently resulted in high growth rates.

DISCUSSION

Results from the second pond experiment demonstrated that juvenile rainbow trout can effectively use cover to avoid predators. Also, when predators were introduced, juvenile trout quickly changed habitats to more secure locations and reduced foraging activity. Even though food was abundant in the second experiment, growth was reduced by the presence of predators (Fig. 5).

In both pond experiments predation rates were generally lower than anticipated. Brown trout consumed 0.33 and 0.41 trout per day in the first and second experiments, respectively. The adult brown trout were habituated to eating pellets at the hatchery and their limited training with forage fish before the experiment was probably insufficient for them to learn how to effectively pursue and capture prey. The pond used in our study was privately owned and experiments could only be done until June 15, 1988. If experiments had continued, brown trout predation rates might have improved and the effect of cover better determined.

At night juvenile rainbow trout in both reservoirs rested in exposed areas in a manner similar to the behavior of other freshwater fish (Emery 1978, Helfman 1981). Structurally complex habitats had few fish at night. Thus, there was apparently no shortage of shelter sites. Juvenile trout rested close to the bottom, were motionless, and had reduced coloration. Therefore, juvenile trout may not be readily detected by nocturnal predators such as brown trout, even though brown trout are capable of foraging under low light conditions (Oswald 1978, Robinson 1979).

During the day juvenile rainbow trout that were in the littoral zone selected structurally complex habitats. They were also active and usually were much higher in the water column than at night. Complex habitats such as large boulders and inundated vegetation may provide cover from diurnal predators when juvenile trout are active.

The use of cover varied between the two reservoirs. Visual observations from shore as well as underwater observations in Causey Reservoir suggest most juvenile trout move offshore at dawn and remain there throughout the day and dusk time periods. In contrast, trout in East Canyon Reservoir remain in the littoral zone during the day. We have, however, observed offshore migrations of the juvenile fish in ECR (Wurtsbaugh and Tabor unpublished data).

Distribution and diel migrations of juvenile fish has often been related to the interaction of risk from predation and the location of foraging areas (Mittelbach 1981, Boesch and Turner 1884, Werner and Hall 1988). Several experimental studies have shown predators directly influence juvenile fish distribution (Savino and Stein 1982, Power et al. 1985, Mittelbach 1986). Predators may force juvenile fish to occupy suboptimal areas (Bray 1981, Werner and Hall 1988), and to limit feeding time (Schimitt and Holbrook 1985). Werner and Hall (1988) found bluegill, Lepomis macrochirrus, were able to assess the abundance of predaceous largemouth bass, Micropterus salmoides, and determine the profitability of moving out of macrophyte beds to forage on pelagic zooplankton.

Predation risk is apparently quite different between East Canyon Reservoir and Causey Reservoir. An important difference between the fauna of CR and ECR was the paucity of piscivorous birds at Causey Reservoir. During the first three weeks after stocking only one western grebe, four belted kingfishers and two California gulls were observed at Causey Reservoir. At East Canyon Reservoir 143 western grebes, 18 common mergansers, 39 Forester's terns, and 78 California gulls were present in July of 1987 (Tabor and Wurtsbaugh, unpublished data). Piscivorous bird abundance appeared similar in 1988 when the juvenile trout were stocked. In Causey Reservoir adult brown trout are the dominant predator on juvenile rainbow trout (see Appendix I), but brown trout are considered crepuscular and nocturnal feeders (Eriksson 1978, Oswald 1978). Therefore, juvenile trout in Causey Reservoir may assess activity of predators in the pelagic zone during the daytime and find it a profitable area to forage.

Diel migrations and distribution of juvenile salmonids may also be influenced by food availability. Juvenile salmonids may exhibit risk-prone behavior in order to grow as quickly as possible (Grant and

Noakes 1987). Wilzbach (1985) concluded that in the presence of predators, prey availability is relatively more important than cover in determining distribution of cutthroat trout in streams.

Food availability also appears to be significantly different between the two reservoirs. Daphnia makes up >95% of the diet of juvenile rainbow trout during their first month in the reservoir (Tabor and Wurtsbaugh, unpublished data). The size of Daphnia that juvenile trout forage on in East Canyon Reservoir have a higher caloric value per unit weight (Richman 1958) and are easier to detect (Confer et al. 1978, O'Brien 1979) than Daphnia preyed on in Causey Reservoir. Therefore, juvenile trout in Causey Reservoir may need longer periods of time to locate enough Daphnia to maintain high growth rates. Eggers (1978) found that in Lake Washington, which has abundant zooplankton, juvenile sockeye salmon foraged in risky epilimnetic waters only for short periods of time. In Alaskan lakes with low productivity juvenile salmon had to spend significantly more time foraging in dangerous areas.

RECOMMENDATIONS

Based on data from pond experiments and field studies, we believe cover in the littoral zone can be an important factor for the survival of juvenile rainbow trout. Because inundated vegetation and large boulders are particularly valuable habitats, the addition of rip-rap or other structures may be benficial. Leaving inundated trees in new reservoirs may also be useful. Stocking fish when the reservoir is at its highest level will usually maximize the amount of available cover because the high-water level often has more vegetation and structural complexity than deeper parts where sediments accumulate. In ECR habitat quality is reduced as the reservoir is lowered (W. Wurtsbaugh, unpublished data). Other studies have shown increases in recruitment of fishes when reservoirs or lakes have risen and inundated large areas of shoreline (Aggus and Elliot 1975, Bayley 1977).

Future research is needed to examine the interrelationship between cover, predators, and food availability. In ECR juvenile trout used cover extensively whereas in CR most trout appeared to move offshore for most of the day. Our basic question then is why habitat selection by juvenile trout differs between reservoirs. In order to answer this question, we proposed to continue field studies at ECR and CR and also, conduct laboratory experiments.

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Wurtsbaugh, W.A., and R.A. Tabor. 1987. Microhabitat selection and diel movements of juvenile rainbow trout (Salmo gairdneri) introduced into mid-elevation reservoirs in Utah. Proceedings of the Western Division of the American Fisheries Society. Salt Lake City, Utah.

Table 1. Abundance and sizes of <u>Daphnia</u> from East Canyon Reservoir and Causey Reservoir. In 1987 and 1988, two replicate zooplankton collections were made on each date.

RESERVOIR	DATE	DEPTH OF STATION (m)	NUMBER PER LITER	$\bar{x}$ LENGTH (mm)	PERCENT ≥ 1.1 mm	NUMBER PER LITER ≥ 1.1 mm	BIOMASS ≥ 1.1 mm (mg/m3)
CAUSEY	July 21,88	35	9.54	.91	24	2.29	36.85
		35	8.33	.97	26	2.17	40.92
	Aug 10,88	30	10.85	.92	22	2.33	39.47
		30	12.31	.91	20	2.46	40.44
	Aug 24,88	29	14.64	.93	18	2.64	55.99
		29	13.85	.96	12	1.66	47.06
EAST CANYON	July 3,86	49	7.24	1.58	79	5.65	231.45
	May 27,87	52	8.88	1.37	62	5.51	186.40
		52	6.96	1.23	64	4.43	93.19
	July 1,87	48	3.76	1.33	78	2.93	65.32
		48	5.21	1.32	80	4.17	85.68
	July 21,88	35	3.40	1.37	78	2.65	67.70
		35	3.96	1.33	70	2.77	69.25
	Sept 23,88	35	2.55	1.31	84	2.14	29.72
		35	2.21	1.22	80	1.77	48.28

Table 2. Results of ANOVA for the two pond experiments. Both factors, predators and cover, were done at two levels (presence and absence).

	MORTALITY (Probability of mort./day)		GROWTH (% weight increase/day)	
Source	F-statistic	P	F-statistic	P
Experiment 1				
PREDATOR	3.422	.138	0.145	.72
COVER	0.197	.68	0.12	.75
Interaction	0.168	.70	2.42	.20
Experiment 2				
PREDATOR	551.70	<.0001	13.213	.022
COVER	27.40	.0064	0.75	.44
Interaction	9.06	.04	0.26	.62

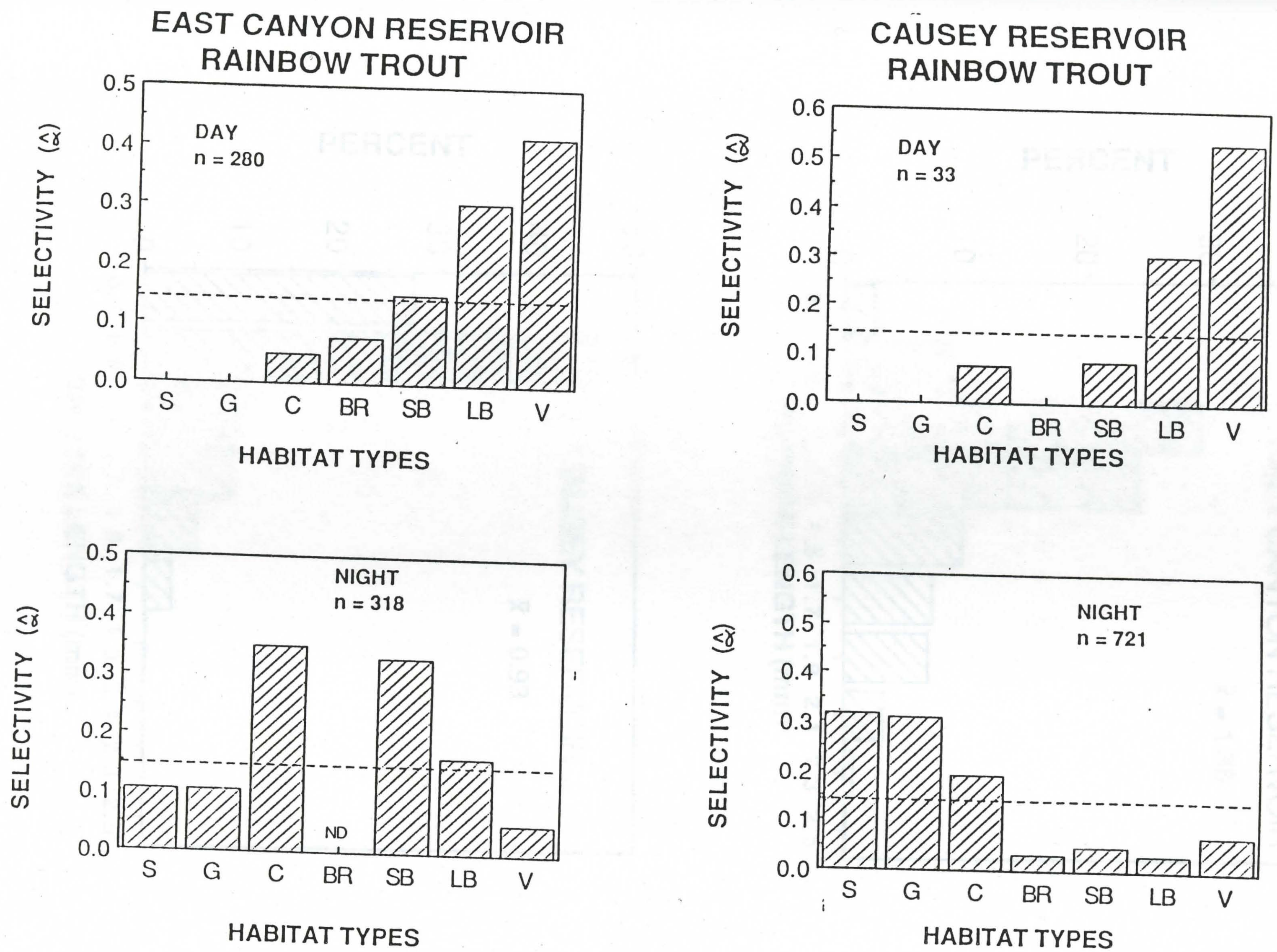

Figure 1. Selectivity values (Manly's α) for habitat types used by juvenile rainbow trout during the day (A,C) and night (B,D) in East Canyon Reservoir and Causey Reservoir, Utah; The dashed lines indicate the level of selectivity if all habitat types were used at random. Habitat complexity increases from left to right; S, sand; G, gravel; C, cobble; SF, small boulders; LB, large boulders; BR, bedrock; V, inundated vegetation.

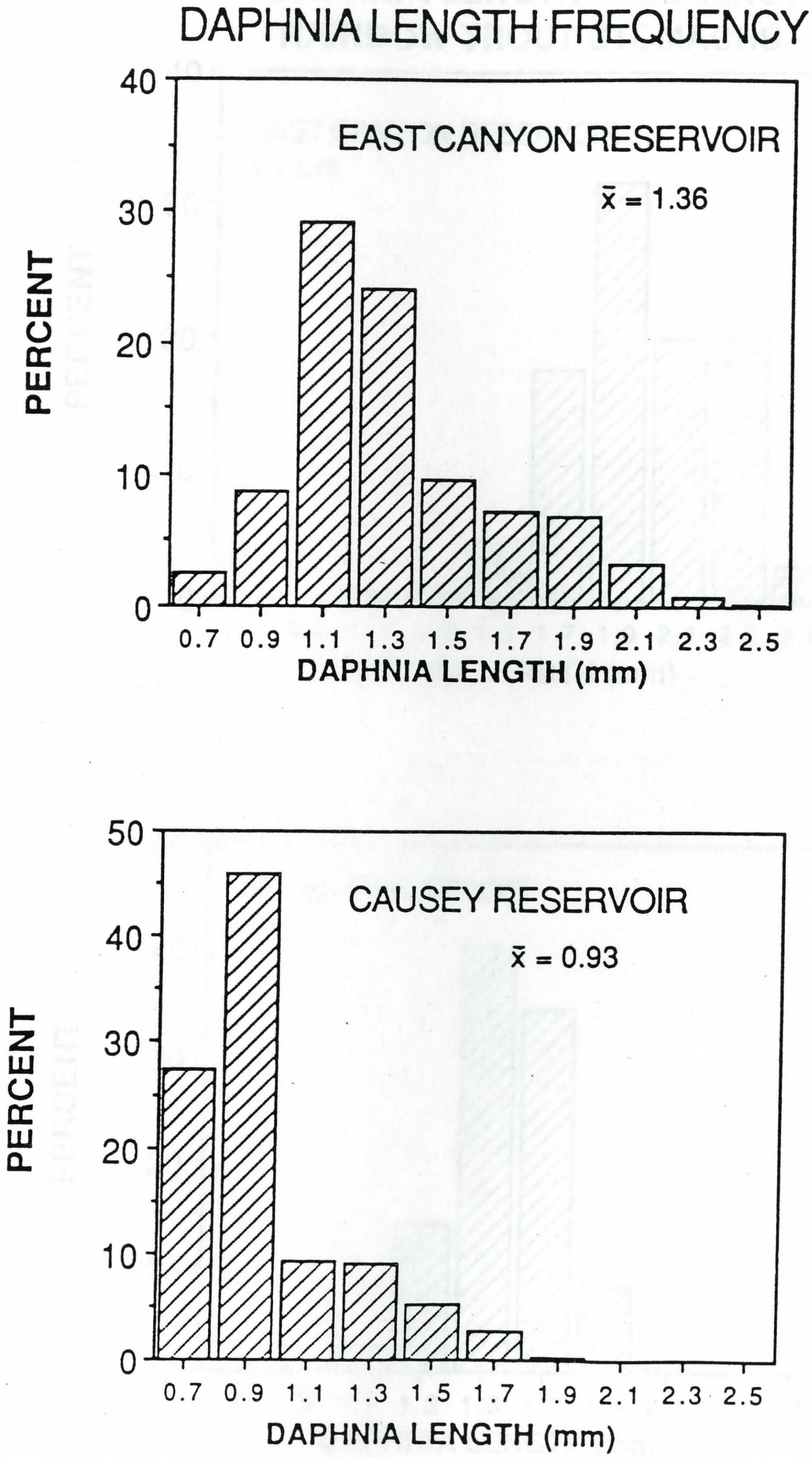

Figure 2. Mean length ($\bar{x}$, mm) and size-frequency distributions of Daphnia from the water column in two northern Utah reservoirs. Daphnia size-frequency from ECR represents a total of 600 measurements from 12 samples (1986-1988). Size-frequency from CR represents a total of 300 measurements from 6 samples (1988).

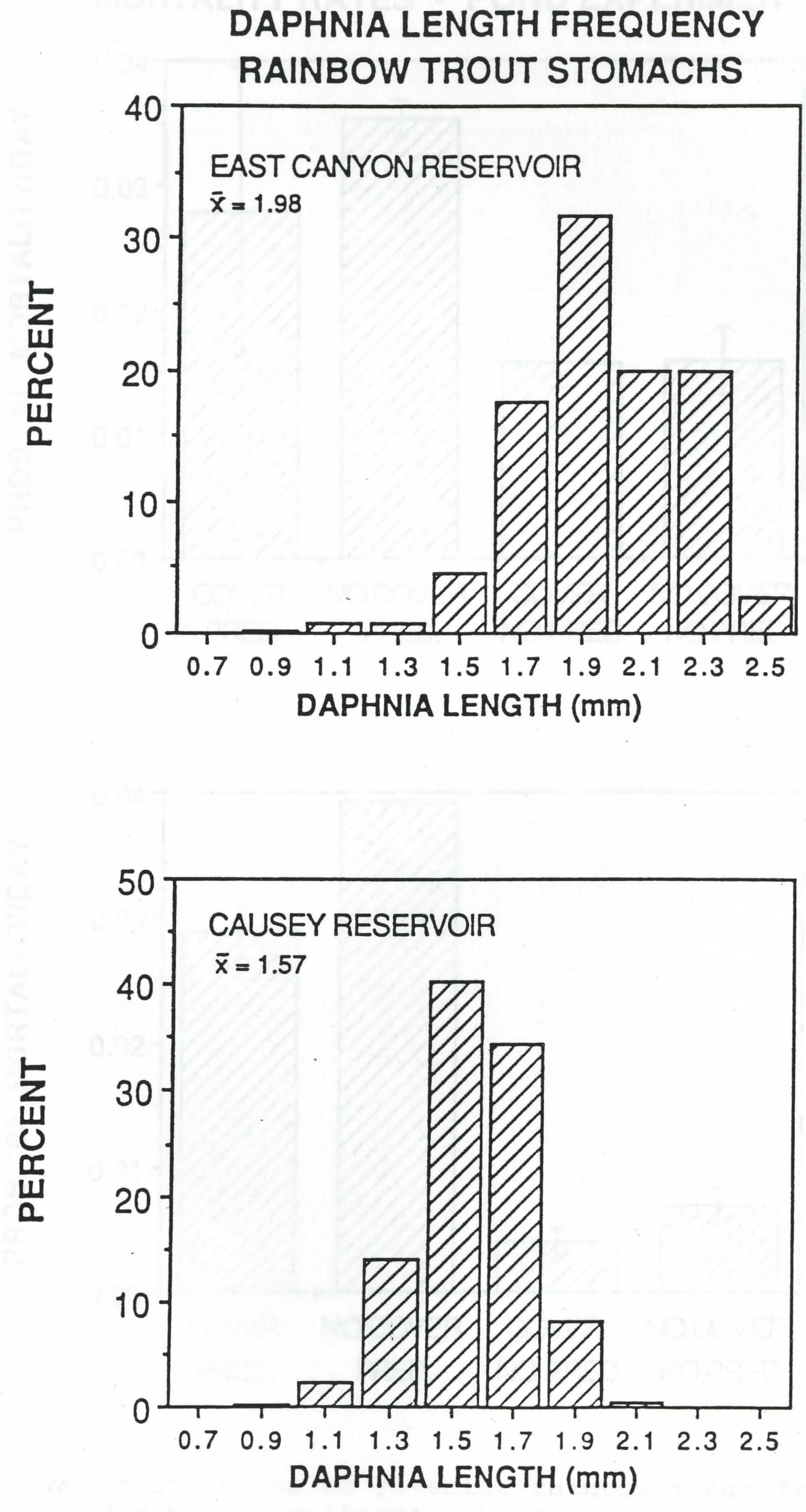

Figure 3. Mean length ($\bar{x}$, mm) and size-frequency distributions of Daphnia in juvenile rainbow trout stomachs from two northern Utah reservoirs. Forty fish from each reservoir were sampled and 10 Daphnia were measured for each fish stomach.

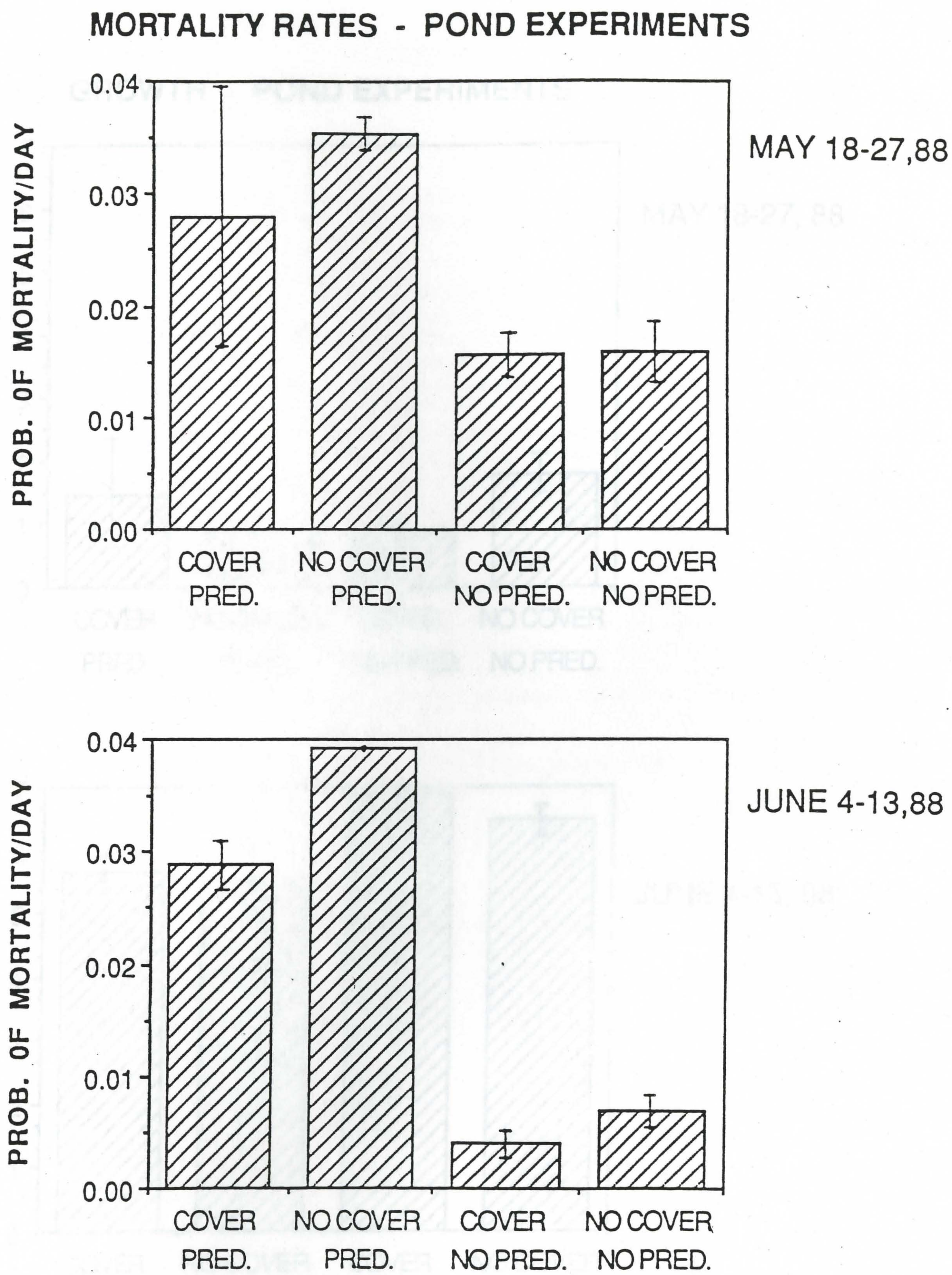

Figure 4. Mortality rates of juvenile rainbow trout from two sequential 10 day pond experiments. Each treatment was replicated once. Ranges are indicated by the vertical bars. Pred. = Predators (presence of adult brown trout).

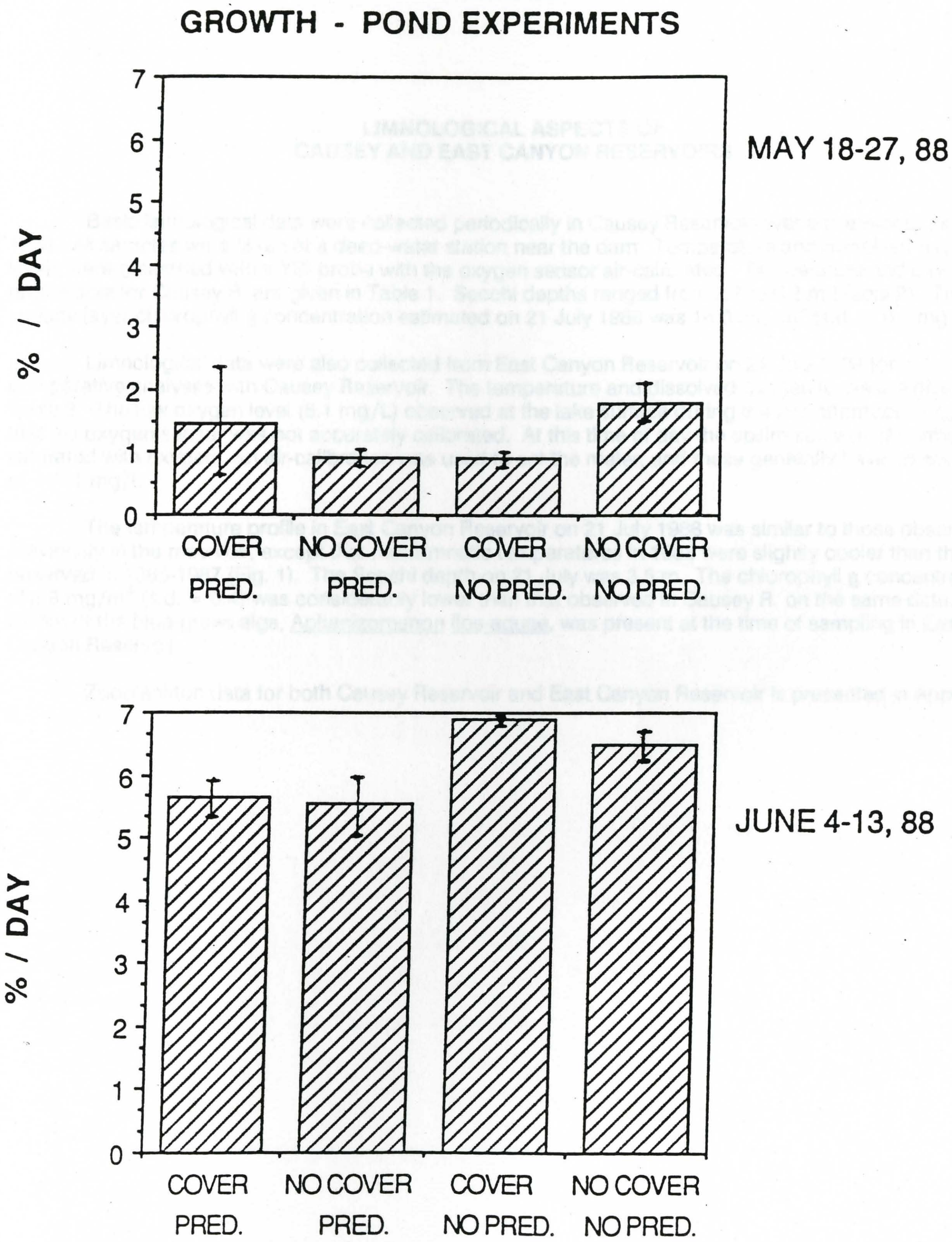

Figure 5. Growth rates of juvenile rainbow trout from two sequential 10 day experiments. Growth is expressed as percent of weight increased per day. Each treatment was replicated once. Ranges are indicated by vertical bars. Pred. = Predators (presence of adult brown trout).

APPENDIX III

LIMNOLOGICAL ASPECTS OF CAUSEY AND EAST CANYON RESERVOIRS

Basic limnological data were collected periodically in Causey Reservoir over a five month period in 1988. All samples were taken at a deep-water station near the dam. Temperature and dissolved oxygen levels were measured with a YSI probe with the oxygen sensor air-calibrated. Temperature and oxygen profile data for Causey R. are given in Table 1. Secchi depths ranged from 2.7 to 6.2 m (Table 2). The surface layer chlorophyll a concentration estimated on 21 July 1988 was 14.0 mg/m^3 (s.d. = 0.5 mg/m^3).

Limnological data were also collected from East Canyon Reservoir on 21 July 1988 for comparative analyses with Causey Reservoir. The temperature and dissolved oxygen levels are given in Table 3. The low oxygen level (6.1 mg/L) observed at the lake surface during the late afternoon suggests that the oxygen sensor was not accurately calibrated. At this time of day the epilimnion would normally be saturated with oxygen. An air-calibration was used to set the meter, and these generally have an accuracy of +/- 1 mg/L.

The temperature profile in East Canyon Reservoir on 21 July 1988 was similar to those observed previously in the reservoir, except that metalimnetic temperatures in 1988 were slightly cooler than those observed in 1985-1987 (Fig. 1). The Secchi depth on 21 July was 3.5 m. The chlorophyll a concentration of 3.8 mg/m^3 (s.d. = 0.4) was considerably lower than that observed in Causey R. on the same date. A bloom of the blue-green alga, *Aphanizomenon flos-aquae*, was present at the time of sampling in East Canyon Reservoir.

Zooplankton data for both Causey Reservoir and East Canyon Reservoir is presented in Appendix II.

TABLE 1. CAUSEY RESERVOIR TEMPERATURE AND OXYGEN PROFILES, 1988. DEPTH - meters, TEMP - °C, OXYGEN - mg/l.

JUNE 9

DEPTH	TEMP	OXYGEN
Air	15.3	-
0.0	15.6	8.2
1.0	15.3	9.2
2.0	15.2	9.8
3.0	15.1	8.6
4.0	12.2	8.4
5.0	11.2	7.6
6.0	10.5	7.3
8.0	9.4	6.7
10.0	8.5	5.7
12.0	7.7	4.8
14.0	7.4	4.2
16.0	7.0	3.2
18.0	6.9	1.6
20.0	6.6	1.7
25.0	6.1	1.4
30.0	5.3	1.7
35.0	5.0	1.2
40.0	4.8	1.2
45.0	4.7	1.1
50.0	4.7	1.1
55.0	4.7	2.5

JUNE 22

DEPTH	TEMP	OXYGEN
Air	-	-
0.0	22.1	8.3
1.0	21.8	9.4
2.0	18.5	12.5
3.0	17.4	12.4
4.0	16.4	11.0
5.0	15.5	10.6
6.0	14.5	12.0
8.0	13.0	11.4
10.0	10.7	9.7
12.0	9.7	8.3
14.0	8.9	7.7
16.0	8.3	7.3
18.0	7.8	7.1
20.0	7.5	7.3
25.0	6.9	7.5
30.0	5.3	7.1
35.0	5.0	6.8
40.0	4.8	6.1
45.0	4.8	5.8
50.0	4.8	2.7

JULY 1

DEPTH	TEMP	OXYGEN
Air	-	-
0.0	19.7	7.4
1.0	19.8	7.7
2.0	19.8	7.7
3.0	19.7	7.5
4.0	18.5	8.5
5.0	17.5	8.8
6.0	16.8	9.0
7.0	16.0	9.5
8.0	15.3	10.1
9.0	14.5	10.5
10.0	13.6	10.1
12.0	12.1	9.0
14.0	10.7	7.7
16.0	9.9	6.9
18.0	9.1	6.2
20.0	8.8	5.8
25.0	6.7	5.1
30.0	5.3	4.7
35.0	5.1	4.5
40.0	4.9	4.3
45.0	4.9	4.1

JULY 8

DEPTH	TEMP	OXYGEN
Air	33.3	-
0.0	20.8	7.5
1.0	20.6	7.6
2.0	20.0	8.0
3.0	19.9	7.9
4.0	18.7	10.6
5.0	17.8	11.3
6.0	17.3	11.0
8.0	16.2	10.9
10.0	15.4	10.3
12.0	13.9	10.2
14.0	12.9	9.2
16.0	12.0	8.5
18.0	11.1	7.0
20.0	10.3	6.4
25.0	6.0	4.5
30.0	5.3	4.2
35.0	5.1	4.0
40.0	4.9	3.8
45.0	4.9	3.1

JULY 12

DEPTH	TEMP	OXYGEN
Air	27.0	-
0.0	20.6	7.5
1.0	20.6	7.9
2.0	20.5	8.0
3.0	19.7	10.2
4.0	18.7	12.5
5.0	18.3	12.2
6.0	17.7	13.1
8.0	16.7	12.0
10.0	15.7	10.6
12.0	15.0	10.1
14.0	13.9	9.6
16.0	13.1	9.1
18.0	12.2	7.8
20.0	11.4	6.2
22.0	10.3	4.5
25.0	6.7	4.0
30.0	5.4	4.0
35.0	5.2	4.0
40.0	4.9	3.8

JULY 21

DEPTH	TEMP	OXYGEN
Air	33.3	-
0.0	21.2	7.6
1.0	20.5	7.8
2.0	20.3	8.0
3.0	20.1	8.2
4.0	19.8	12.0
5.0	18.5	13.0
6.0	18.1	12.9
8.0	16.9	10.7
10.0	16.2	8.8
12.0	15.8	8.0
14.0	15.3	7.5
16.0	15.0	6.5
18.0	14.5	7.0
20.0	13.4	6.1
22.0	7.4	3.5
25.0	7.8	3.4
30.0	5.5	3.4
35.0	5.0	3.1
40.0	5.1	1.7

JULY 27

DEPTH	TEMP	OXYGEN
Air	29.5	-
0.0	21.8	7.8
1.0	21.6	8.0
2.0	20.9	8.4
3.0	20.3	9.1
4.0	19.7	10.9
5.0	19.0	9.0
6.0	18.5	8.9
8.0	17.4	8.7
10.0	16.7	8.4
12.0	16.2	7.8
14.0	15.7	7.0
16.0	15.4	6.6
18.0	15.0	5.7
20.0	10.2	1.6
25.0	5.9	2.2
30.0	5.5	2.6
35.0	5.1	2.2
40.0	5.1	0.7

AUGUST 10

DEPTH	TEMP	OXYGEN
0.0	20.3	6.7
1.0	20.0	6.8
2.0	19.2	6.9
3.0	19.1	7.0
4.0	19.0	7.1
5.0	18.4	5.6
6.0	18.1	4.7
8.0	17.6	3.9
10.0	16.8	5.0
12.0	16.4	5.4
14.0	16.0	5.6
16.0	14.5	2.4
18.0	7.5	0.4
20.0	6.4	0.4
25.0	6.0	0.7
28.0	5.6	0.7

AUGUST 24

DEPTH	TEMP	OXYGEN
0.0	18.5	8.7
1.0	18.1	8.9
2.0	18.0	8.9
3.0	17.9	8.9
4.0	17.8	8.9
5.0	16.9	6.8
6.0	16.6	6.0
8.0	16.1	6.1
10.0	15.7	6.5
12.0	15.3	7.3
14.0	14.9	7.8
16.0	8.7	1.7
18.0	6.9	0.6
20.0	6.6	0.4
22.0	6.5	0.3
25.0	6.2	0.2

NOVEMBER 11

DEPTH	TEMP	OXYGEN
0.0	6.9	8.2
2.0	7.0	7.9
4.0	7.0	7.8
6.0	7.0	7.8
8.0	7.0	7.7
10.0	6.9	7.6
12.0	6.9	7.6
15.0	6.9	7.6
20.0	6.9	7.5
25.0	6.7	7.3
30.0	6.6	4.6
32.0	6.1	0.4
34.0	6.0	0.2
35.0	6.0	0.2

Table 2. Secchi depth June-November 1988, Causey Reservoir

Date	Depth (m)
June 9	6.15
June 22	3.10
July 1	4.75
July 12	4.70
July 21	3.90
July 27	2.70
August 10	5.95
August 24	4.50
November 12	4.50

Table 3. East Canyon Reservoir temperature and oxygen profile, July 21, 1988

Depth (m)	Temp (C)	Oxygen (mg/l)
0	22.0	6.1
1	21.8	6.2
2	20.9	6.4
3	20.7	6.4
4	20.5	6.4
5	19.6	5.6
6	19.6	5.3
8	14.7	4.3
10	10.4	3.8
12	7.8	3.9
14	6.7	3.9
16	6.3	3.8
18	6.0	3.7
20	5.6	3.5
25	5.1	3.4
30	4.4	2.7
35	4.0	1.4

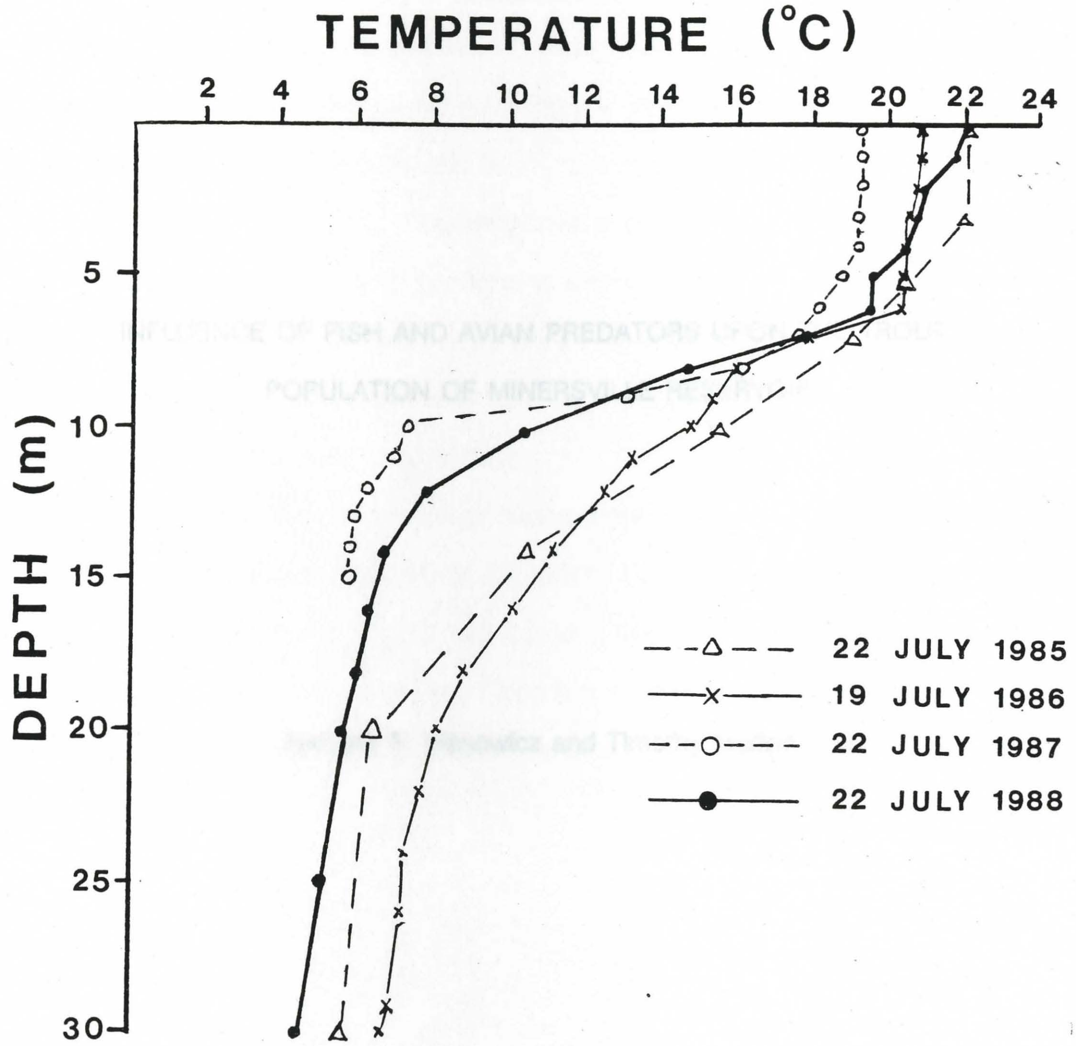

Figure 1. Temperature profiles in East Canyon Reservoir during late July, 1985-1988. Epilimnetic temperatures during 1988 were similar to those in other years, while metalimnetic temperatures were somewhat cooler.

APPENDIX IV

INFLUENCE OF FISH AND AVIAN PREDATORS UPON THE TROUT POPULATION OF MINERSVILLE RESERVOIR

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Abstract

Losses to predation of rainbow trout (Oncorhynchus mykiss) planted into a southern Utah reservoir were investigated. Fingerling predation by adult trout and avian predators was 0.6% and 43.7%, respectively, for the two week period following the early spring plant in 1988. Mortality of fingerlings stocked in late June was 0.4% and 30.1% due to piscivorous fish and birds, respectively, for the two week post-stocking period. Fingerling trout and Utah chub (Gila atraria) comprised 25.3% and 7.0% of the diet of avian predators, respectively, although chub abundance far exceeded that of trout in the reservoir. Abundance of piscivorous birds was associated both spatially and chronologically with fingerling trout in the reservoir. High predation rates are likely due to greater susceptibility of hatchery-raised trout to predation.

Losses of larger trout to avian predators during the eight month study period were 41.0% of the adult and subadult population. Adult trout comprised 77.8% of the diet, by biomass, of the dominant avian predator. Mortality of adult and subadult trout from nongame bird predation exceeded annual angler harvest in the study. Fingerling survival can be enhanced by altering stocking chronology, but predation on adult fish cannot be improved without impacting the nongame bird use patterns.

INTRODUCTION

Survival is an important factor affecting the success of fish stocking programs. Return of trout plants to the angler requires that fish survive and remain in the reservoir. Several factors influence trout survival including genetics (Reisenbickler and McIntyre 1977), size and age of stocked fish (Parker 1986), suitability of receiving waters (Smith 1968), stress incurred in transfer (Reisenbickler and McIntyre 1977), emigration (Cordone and Nicola 1970, McAfee 1966), as well as natural mortality (Sharpe 1957). All of these factors are interactive and may occur simultaneously. Minimizing stocking losses requires the identification of the major factors influencing mortality and implementing means to avoid or reduce those sources contributing to losses.

Previous studies of fish survival in Utah reservoirs have addressed genetic variation (Hudy and Berry 1983) and transfer stress (W. Wurtsbaugh, pers. comm.). However, few studies have addressed mortality or emigration as factors reducing fingerling trout survival. Because of the small size of fish stocked in "put-grow-and-take" stocking programs, early losses may arise from natural mortality. A major source of natural mortality of fish planted into reservoirs is predation by both fish and fish-eating birds.

There are many reports of trout predation upon stocked fingerling trout. Sharpe (1957) reported that rainbow trout constituted 66% of the diet of brown trout in Shadow Mountain Reservoir, Colorado, and concluded that brown trout predation was the cause of serious losses of rainbow trout fingerlings which were planted yearly into the lake. A 385 mm rainbow trout taken from a California reservoir had consumed 32 fingerlings planted 2 hours earlier (Borgeson in McAfee 1966). Stuber et al. (1985) identified trout predation as a major source of planted fingerling mortality in Dillon Reservoir, Colorado. He concluded that fishery managers should be wary of stocking rainbow trout fingerlings into impoundments where substantial populations of predatory fish exist.

Another source of mortality among stocked trout is avian predation. Birds have high metabolic rates and require large quantities of food relative to their body size (Ruggerone 1986). The double-crested cormorant has been reported to consume nearly one-third of its body weight in fish per day

(Robertson 1974), and Bowmaker (1963) found cormorants to digest a fish meal in as little as 3 hours. Most species of avian piscivores are opportunistic in their feeding habits, feeding on whatever size and species of fish are most readily available (Salyer and Lagler 1940, Timken and Anderson 1969, Knopf and Kennedy 1981, Dombeck et al. 1984).

Although many species of avian predators feed on fish almost exclusively, their impact on commercial and sport species of fish is debatable. Several researchers have claimed that avian predation on economically-important fish is insignificant (e.g. Mattingley 1927, Scattergood 1950, Bowmaker 1963, Timken and Anderson 1969, Robertson 1974), but other studies have shown at least circumstantial evidence that relatively large numbers of fingerling trout may be consumed by piscivorous birds (e.g., Fraser 1972, Carline et al. 1976, Myers and Perterka 1976, Ayles et al. 1976, Ruggerone 1986). White (1939) attributed a great increase in the number of salmon smolts in a Nova Scotia river to intensive control of fish-eating birds in the area. Very few studies, however, have examined the effects of avian predators on reservoirs, and most that did relied only upon literature to determine the composition and consumptive capability of observed birds. Alexander (1977) stated that because of high variability in predator diet composition, studies to assess the impact of predators on trout populations should, ideally, be based on direct information from the particular body of water being studied.

The purpose of this study was to determine the impact of fish and avian predators on newly-planted rainbow trout in Minersville Reservoir, Utah. A systematic approach was developed including three study objectives: 1) determination of the distribution of fingerling trout relative to potential predators; 2) estimation of the consumption by predators; and 3) estimation of the mortality of fingerling trout due to predators.

STUDY SITE

Minersville Reservoir is a eutrophic, 400 ha impoundment located in Beaver County, Utah (elevation 1677 m). Mean and maximum depths at high water are 8.1 and 13.4 m, respectively, though mean annual drawdown is nearly 50% of the total lake volume. The major inflows to the reservoir are Indian Creek and Beaver River and its outflow is the Beaver River.

Fish species present in Minersville Reservoir are the rainbow trout (Oncorhynchus mykiss), cutthroat trout (Oncorhynchus clarki), Utah chub (Gila atraria), and minor populations of largemouth bass (Micropterus salmoides) and black crappie (Pomoxis nigromaculatus).

For the purposes of study design Minersville Reservoir was stratified into three approximately equal-sized study areas (Figure 1). Each area was further subdivided into 365 m square grid sections. A total of 31 shoreline and 14 offshore sections cover the entire reservoir.

METHODS

Field Work

Fingerling rainbow trout were planted into Minersville Reservoir on two occasions in 1987 and three occasions in 1988 (Table 1). Each fingerling plant was spray-marked with various-colored pigments prior to stocking to identify stocking source. Fingerling cutthroat trout were planted twice in 1987. Size of planted fish ranged from 78 to 105 mm total length. All fish were planted at the boat ramp near the dam both years.

The relative abundance and distribution of planted fingerling trout throughout the reservoir was determined by shoreline electrofishing, using a pulsed DC electroshocker mounted on a 16 ft flat-bottom boat. Fingerlings were sampled on 13 occasions in 1987 and 17 occasions in 1988. Sampling was more frequent after stocking dates but otherwise evenly distributed from March to August. Eight to ten shoreline study sections, distributed among all three areas, were sampled per night. The initial section sampled was selected at random and every sixth section was then sampled in two circuits around the reservoir. Electrofishing began approximately one hour after sunset and typically lasted about 4 hours. Sampling effort was set at 10 minutes of electrofishing per site, and all sampling was done as close to shore as possible. All fingerling trout captured were counted, measured for total length, stocking date determined, and returned to the water. Because of the large numbers of Utah chubs electroshocked, numbers were estimated at each site in 1988.

Distribution and diet of adult and subadult rainbow and cutthroat trout in Minersville Reservoir was determined by sampling with experimental gill nets during the spring and summer of 1987 and

1988. Nets were set at dusk and fish were collected the following morning. In 1987 nine nets were set per sampling date: one floating net in an inshore section and a floating and diving net pair in an offshore section within each of the three reservoir study areas. Stomachs of all adult and subadult trout were collected and preserved in 5% formalin, and total fish length recorded. Utah chubs were counted and measured. In 1988 the gillnetting effort was concentrated in area 1, which was the only area in which predation was observed the previous year. A total of ten nets, six inshore floaters and two offshore floater/diver net pairs were set for three straight days following the second spring plant of fingerlings (April 12-14) and the summer plant (June 6-8). Sampling locations within study area 1 were randomly selected.

The abundance of avian piscivores at Minersville Reservoir in 1988 was determined by visual counts. Counts were taken three times a day (at 0900, 1200, and 1700 hours) every three days from March 3 to July 17, and weekly until November 26. All observations were made through a tripod-mounted spotting scope from the same four sites overlooking the entire reservoir.

Birds were sampled in 1988 to determine avian diets. On April 17, eleven double-crested cormorants (Phalacrocorax auritus), five western grebes (Aechmophorus occidentalis), and two California gulls (Larus californicus) were collected. Five cormorants, nine grebes, and one red-breasted merganser (Mergus serrator) were collected on April 24. Because piscivorous birds fed in early morning and late afternoon (Knopf and Kennedy 1981) all birds were collected following these time periods. Stomachs of all sampled birds were removed, tagged, and preserved in 10% formalin.

A fish trap was constructed and used to sample the reservoir spillway to determine the incidence of out-migration of fingerling rainbow trout. The apparatus consisted of two panels which directed all incoming fish into a center trap with a removable top. Fish were netted from the trap, identified, and counted and the apparatus checked for maintenance at least once daily. The trap was installed on March 21 and dismantled on September 14, 1988.

Laboratory Work

Contents of collected fish stomachs were analyzed in the laboratory. Both compound and dissecting microscopes were used for identification and measurements of all ingested remains of fish. Skeletal structure keys were used to successfully identify highly decomposed remains.

Contents of collected bird stomachs were identified in the laboratory and total length of all ingested fish recorded. All fish were easily identified as fingerling trout, Utah chub, or adult rainbow and cutthroat trout. To obtain estimates of individual prey biomass fish lengths were extrapolated to weight from tables in Piper et al. (1986).

Statistical Analysis

Daily fingerling consumption rates of rainbow trout in 1987 and rainbow and cutthroat trout in 1988 were computed from sampled fish. Total consumption of fingerlings by rainbow and cutthroat trout was calculated (Equation 1) for two- 14 day periods following the April and June plants of both years: April 13-26 and June 17-30 of 1987, and April 12-25 and June 6-19 of 1988.

$$(1) \quad T_i = C_i * N_i$$

where T_i = estimate of number of fingerling trout consumed by fish species i,

C_i = daily consumption of fingerlings by fish species i,

N_i = number of individuals of fish species i, for the 14 day period.

An estimate of the abundance of rainbow and cutthroat trout within the reservoir (N_i) was obtained from mark-and-recapture population estimate studies conducted in the fall of 1987 and 1988 by Utah Division of Wildlife Resources and Utah Cooperative Fisheries and Wildlife Research Unit personnel. An adjusted form of the Modified Peterson equation was developed and used as the estimator (D. Hepworth, Utah Division of Wildlife Resources, personal communication). Daily consumption rates (C_i) were based on frequency of fingerlings in fish stomachs and digestion rates (see Wurtsbaugh 1987).

Although birds tended to feed in the morning and afternoon hours, we were unable to determine the exact feeding activity of individual birds prior to collection; thus it was doubtful that we had sampled completely satiated individuals. To eliminate any resultant error, diet information was utilized only to determine prey composition, whereas, total biomass consumption was determined from previous studies. The following formula, Equation 2, was utilized to estimate fingerling trout consumption by birds for the same four- 14 day periods listed above:

$$(2)\quad T_j = A_j * C_j * N_j$$

where T_j = estimate of fingerling trout biomass (kg) consumed by bird species j,

A_j = proportion by mass (kg) of fingerling trout in the stomach of bird species j,

C_j = daily consumption of fish (kg) by bird species j from the literature,

N_j = total number of bird days for bird species j during 14 day period.

Because of the difficulty to effectively sample satiated birds, literature estimates of fish consumption were used. Basal metabolic rate (BMR) for nonpasserine birds is a power function of body weight: $M = 78.3 W^{0.724}$, where M = kilocalories per 24 h and W = body weight in kilograms (Lasiewski and Dawson 1967). By using an average adult body weight of 1860 g (Ross 1977), and an energy value (of salmon fry) of 910 cal/g (Brett 1973), a double-crested cormorant would require 123 kcal/d to survive for an extended period of time. Average biomass of all fish consumed by sampled cormorants was only 89 g/bird/day (Table 2), or 81 kcal/d, thus suggesting that sampled birds were not satiated when shot. If we were to assume that the single sampled bird with the greatest biomass in its stomach was representative of a satiated bird, then a more reasonable estimate of daily consumption is obtained. The most fish eaten by a single cormorant in a day was 678 g, very close to the literature estimate of 666 g and well above the BMR requirement. By using the maximum rate in the consumption formula, results were nearly identical those previously calculated in the literature.

Because bird consumption of larger trout was probably constant, an estimate of the number of adult and subadult trout consumed for an extended time period is possible. Consumption estimates were made for the entire season between March 2 and October 2.

RESULTS

Distribution and Abundance

Fingerling trout were planted into Minersville Reservoir near the dam in area 1. Throughout the season most fingerlings remained in area 1 following stocking (Figure 2). Very few planted fish moved into area 3. Utah chub abundance was invariably higher than fingerling abundance throughout the year (Figure 3). Chubs were observed to be common along the entire shoreline of the reservoir.

Electroshocking catch per unit effort in 1988 dropped to less than 1 fingerling/h on May 25. A mark-and-recapture population estimate conducted at Minersville Reservoir in September corroborated the loss of planted fish from the lake (D. Hepworth, DWR, pers. commun.). Estimated survival of spring-planted fingerlings to the fall was less than 1%, compared to 31.0% survival of June-planted fish (D. Hepworth, UDWR, unpublished data). Survival of April and June plants in 1987 was 1.6% and 62.0%, respectively.

Season-long distribution of adult and subadult rainbow trout was computed from 1987 gillnetting information. Fish were evenly distributed throughout each of the three study areas in April and May (Figure 4). By late summer, abundance in area 1 decreased with a subsequent rise in fish captured in areas 2 and 3. Most fish were captured near the surface as opposed to the deeper offshore regions of the reservoir (Figure 5). Captures in both inshore and offshore nets were generally equal throughout the season.

Four species of birds comprised the bulk of the avian piscivore population at Minersville Reservoir: the double-crested cormorant, western grebe, common (Mergus merganser) and red-breasted mergansers, and the common loon (Gavia immer) (Figure 6). In addition, lesser numbers of the following fish-eating species were observed: American white pelican (Pelicanus erthrorhynchos), great blue heron (Ardea herodias), black-crowned night heron (Nycticorax nycticorax), caspian tern (Sterna caspia), Forster's tern (Sterna forsteri), and California gull. Total abundance of the four predominant species reflects distinct migratory patterns, the majority of birds passing through in late March with a smaller pulse occurring in late October (Figure 7).

Piscivorous birds showed a distinct feeding pattern, spending a disproportionate amount of time feeding in area 1 during early spring (Figure 8). We believe that this pattern may under-represent the use of area 1. Although bird counts were designed to coincide with feeding periods, we noticed that many of the birds had finished feeding by the time it was light enough to begin counts and were sighted loafing in area 3.

Predation

Fingerling predation rates of adult and subadult rainbow and cutthroat trout during all four study periods were no greater than 0.7 percent (Table 2). Trout preyed on slightly fewer chubs than fingerlings. Fingerling consumption by predacious fish was also relatively low; April-planted fish suffered 0.7% and 0.6% mortality from fish predation in 1987 and 1988, respectively, and mortality of June plants was 0.6% and 0.4 percent. The size range of predacious rainbow trout was 418 to 480 mm total length and 269-312 mm for cutthroat trout. No fish sampled had more than one fingerling trout in its stomach, although we found two small chubs in the stomach of a 463 mm rainbow trout.

Double-crested cormorant and western grebe stomachs contained an average of 1.8 and 1.5 fingerlings, respectively (Table 3). Because both species feed during two distinct daily periods and digestion of a meal is likely completed before the onset of the following feeding period, the amount of fish in the stomachs of sampled birds can be doubled to yield diet composition.

Fingerling trout comprised 18.7% of the diet, by biomass, of the double-crested cormorants sampled (Table 3). If cormorants typically consume 666 g fish/day (Davenport 1974, Bowmaker 1963, Scattergood 1950) their daily feeding rate would have been 125 g fingerlings/bird. During the 14-day period from April 12-25 cormorants would have consumed 134 kg, or 17.3% of the spring-planted fingerlings (Table 4). Sixty-nine percent of the diet of western grebes was fingerling trout, and grebes consumed 204 kg, or 26.4% of the spring plant. Together, both species consumed 338 kg, or 43.7 % of all spring-planted fingerlings within two weeks of the second spring plant. Estimated consumption of summer-planted fingerlings from June 6-19 by cormorants and grebes was 24 kg (3.1%) and 209 kg (27.0%), respectively.

Cormorants sampled in area 1 consumed a higher percentage of fingerlings than those sampled in the other two areas (Figure 9). Through all three study areas fingerling consumption decreased with increasing chub and adult trout consumption. No chubs were found in stomachs of cormorants sampled in area 1. Among all birds sampled, only one bird had two different prey types in its stomach.

Adult and subadult rainbow and cutthroat trout comprised 77.8% of the biomass in the diet of double-crested cormorants. Estimated consumption of larger trout during the eight month study period (March 2- October 2) was 50,745 individuals, or 41.0% of the estimated fall population by cormorants alone. Although none of the western grebes sampled in this study had consumed adult trout, another avian piscivore, the common loon, is reported to consume large fish. If we assume that loon feeding rates are similar to the cormorant (based on literature studies loons probably consume considerably more fish) their consumption of large trout would be 6,982 individuals, or 5.6 % of the estimated population.

Emigration

Emigration of spring-planted fingerlings from Minersville reservoir was estimated at only 10 individuals (Figure 10). The spillway was not opened until May 4, 23 days after the April plant of fish, and seepage was minimal during that time. Loss of June plants was higher, 238 individuals, but still constituted less than 1% of the total planted. Cutthroat trout stocked the previous year were observed to leave the reservoir at a higher rate than fingerling rainbow trout.

DISCUSSION

Fingerling trout losses to fish predators in Minersville Reservoir were relatively low. Only the largest of adult rainbow trout fed on fingerlings in this study. Cutthroat trout consumed fish at a smaller size and at a greater rate but also appeared to utilize other prey items more than fish.

Emigration of planted trout from the reservoir was also low. Typically, the spillway gates remain closed until early May, thus blocking emigration of spring-plants until the fish were well distributed. Although the spillway was open for the remainder of the season summer-planted fish appeared to distribute quickly enough to avoid entrainment.

Our data suggested that the greatest source of fingerling trout mortality was the result of consumption by fish-eating birds. Spring-planted fingerling trout were slow to distribute around the reservoir, possibly selecting for the cobble/boulder substrate cover in area 1. The majority of piscivorous birds fed in that same area, and consumed a higher proportion of fingerlings than birds feeding in other areas.

Cormorants and grebes appeared to select for hatchery-reared trout over the more abundant Utah chub in the lake. Domesticated trout obviously have difficulties in coping with predators in the wild. Several studies reported that wild trout had higher survival than hatchery-reared trout when placed into the same system (e.g. Vincent 1960, Flick and Webster 1964). Schuck (1948) suggested that low survivability of domestic trout may be due to hatchery conditions which allow nearly complete protection against predators, thus depriving young fish of learned predator avoidance responses. Hatchery-reared trout may develop detrimental behavioral traits such as schooling tendency, lack of wariness, and a preference for surface waters (Vincent 1960, Fraser 1974). These traits are particularly detrimental immediately following planting as domestic trout must make rapid behavioral adjustments to conditions in the wild (Fraser 1974). Vincent (1960) found that domestic stock subadult brook trout had acquired little wariness even 4 months after being planted into a pond. Ayles et al. (1976) observed fingerling trout showing signs of severe stress after stocking, spinning and jumping erratically on the surface; behaviors that would likely attract avian predators. Vincent (1960) reported that domestic trout reared on pelleted diets in hatcheries were attracted to surface disturbances and failed to hide when approached. This might increase fingerling trout vulnerability to predacious diving birds swimming on the surface of the reservoir.

Fingerling trout losses to avian predators was no doubt greater than that estimated for the two-week periods following stocking. Birds continued to feed after that time period, and in addition many fish were probably injured or lost due to damage inflicted by unsuccessful bird attacks. White suggested that wounds inflicted by birds' beaks during an unsuccessful attempt at capture could lead to fungus infection. Numerous fingerling and adult trout sampled by electrofishing at Minersville reservoir had vertical slash or puncture wounds similar to bird-caused wounds on fish described by Alexander (1977). Also, Black and Barrett (1957) argue that continual flight from predators might lead to either a fatal oxygen debt or a lethal build up of lactic acid. Although only cormorants and grebes were sampled in this study it is likely that other bird species consume significant numbers of fingerlings also. The combined predation of mergansers, loons, herons, terns, gulls, and pelicans is likely to add to the mortality of fingerling trout.

Unless changes in management strategy are made, avian predation may continue to cause high fish mortality. The abundance of avian piscivores residing at Minersville Reservoir in the spring appears to be increasing according to earlier counts (S. Hedges, Bureau of Land Management, pers. commun.), and cormorants were observed to nest on the reservoir for the first time in 1988. Large numbers of fingerlings have been planted into the lake in March and/or April for the past five years and survival of these plants has been very low (D. Hepworth, UDWR, pers. commun.). Predacious bird abundance peaks in early spring as many birds use the lake as a staging site during northward migration. A new planting regime could be adopted to reduce fingerling losses due to avian predation. One possible solution is to delay the stocking of fingerlings until May or June when cormorant and grebe populations are at a minimum (Figure 5). Moreover, if fish size is inversely related to susceptibility to predation (Milinski 1986) then planting larger trout may also increase returns.

Although management strategies can be adopted to reduce fingerling losses to predation, avian predators also consumed a substantial number of adult and subadult trout. Together, cormorant and loon consumption was 235% higher than angler harvest in 1988 (D. Hepworth, UDWR, unpublished data). Because the diet biomass of cormorants was dominated by adult and subadult trout, fish losses in Minersville Reservoir will continue to be substantial even in the presence of efforts to reduce fingerling mortality shortly after stocking.

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Table 1. Fingerling trout plants in 1987 and 1988. RBT- = rainbow trout, CTT = cutthroat trout.

DATE	SPECIES	KILOGRAMS	NUMBER
4/13/87	RBT	601	75,439
6/15-17/87	RBT	1,047	97,779
5/26-29/87	CTT	1,408	60,051
6/8/87	CTT	692	21,493
3/21/88	RBT	322	39,143
4/12/88	RBT	451	35,830
6/6/88	RBT	980	110,862

Table 2. Predation rates and total consumption of fingerling trout by adult and subadult rainbow and cutthroat trout in 1987 and 1988. Values in parentheses indicate 95% confidence intervals.

Period					
4/13-26/87	RBT	3 / 420 = 0.007	0	560 (384,764)	0.7%
6/17-30/87	RBT	2 / 467 = 0.004	0.004	217 (146,304)	0.2%
4/12-25/88	RBT	0 / 70 = 0	0	0	0
	CTT	3 / 241 = 0.012	0.004	0	0
6/6-19/88	RBT	1 / 51 = 0.02	0.02	90 (43,146)	0.1%
	CTT	2 / 207 = 0.01	0	356 (216,638)	0.3%

Table 3. Summary of stomach contents of double-crested cormorants and western grebes sampled at Minersville Reservoir in 1988.

	Double-crested cormorant	Western grebe
Number of stomachs analyzed	16	14
Average number of fingerlings in stomachs	1.8	1.5
Average fingerling consumption (#/bird/day)	3.6	3.0
Average size of consumed fingerlings (mm)	92	91
Average adult trout consumption	1.1	0
Average size of consumed adults (mm)	218	
Average Utah chub consumption	0.3	0.8
Maximum fingerling consumption (g)	121	67
Maximum total fish consumption (g)	684	67
Diet percentage by biomass		
Fingerling trout	18.7	69.7
Adult/subadult trout	77.8	
Utah chub	3.6	30.3

Table 4. Predation rates and total consumption of fingerling trout by double-crested cormorants and western grebes in 1988.

Bird species	Spring Plant (21 Mar. and 12 Apr.)	Summer (6 June)
Double-crested cormorant	12,970 (17.3%)	3,437 (3.1%)
Western grebe	19,793 (26.4%)	29,933 (27.0%)
Total	32,763 (43.7%)	33,370 (30.1%)

FIGURE 1. Delineation of the three study areas at Minersville Reservoir, Beaver County, Utah.

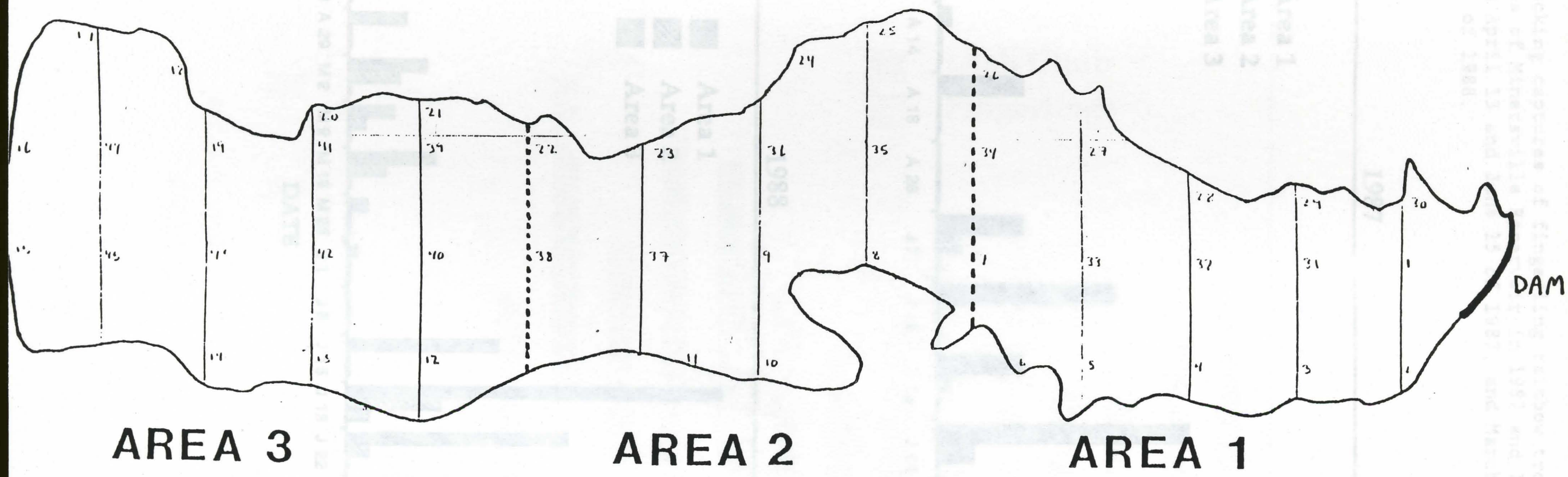

FIGURE 2. Electroshocking captures of fingerling rainbow trout in three study areas of Minersville Reservoir in 1987 and 1988. Fish were planted on April 13 and June 15 of 1987, and March 21, April 12, and June 6 of 1988.

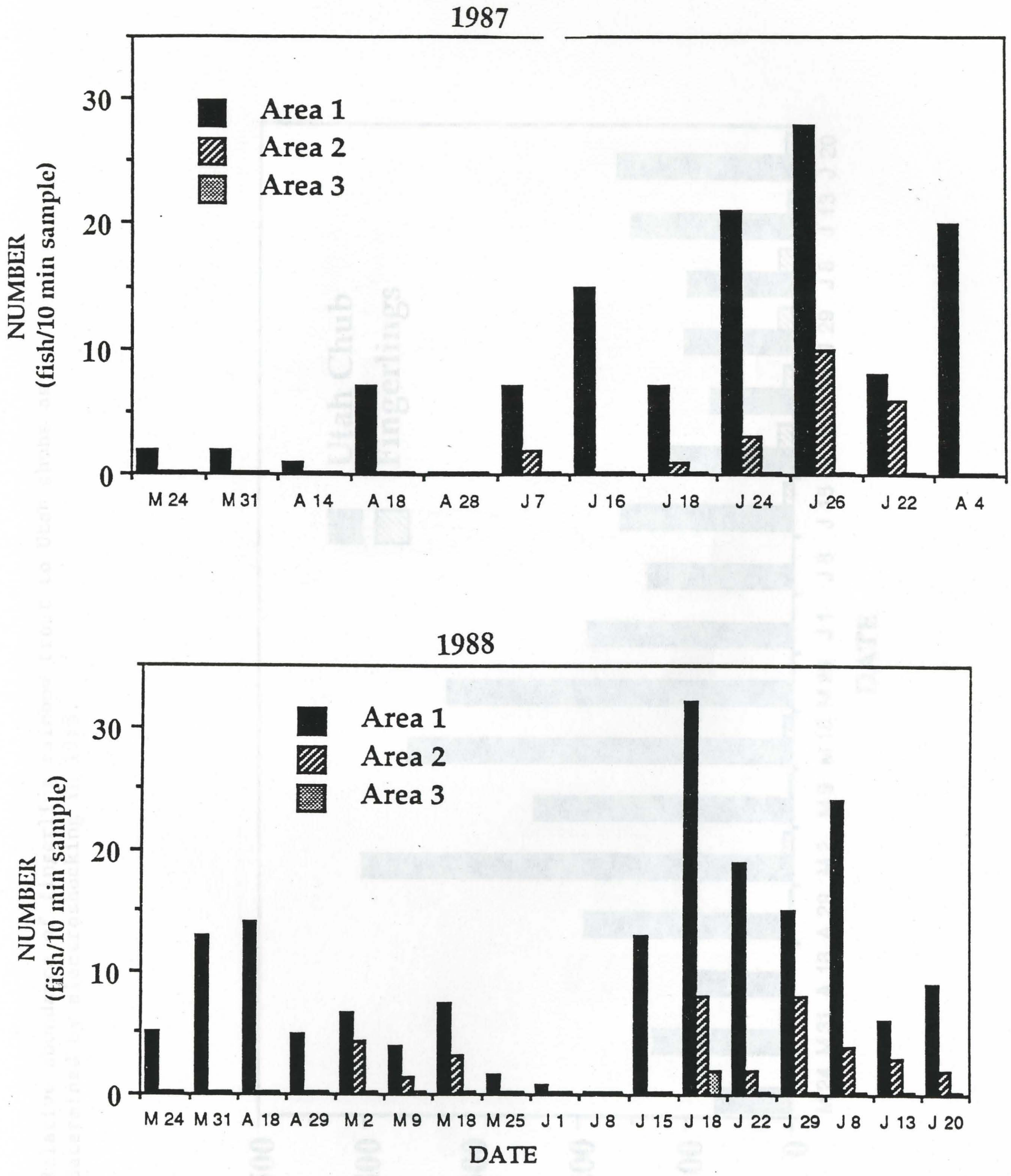

FIGURE 3. Relative abundance of fingerling rainbow trout to Utah chubs as determined by electroshocking in 1988.

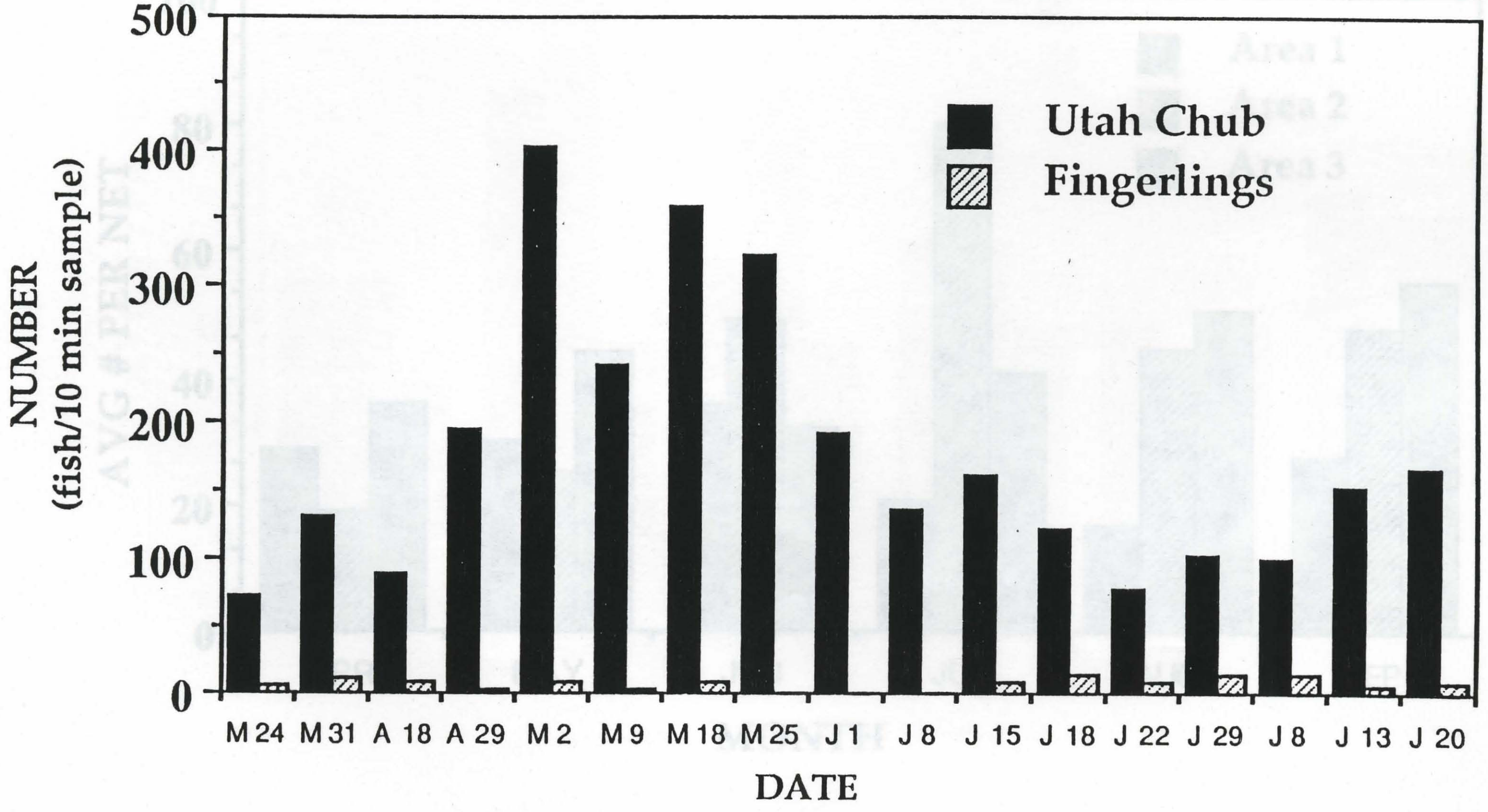

FIGURE 4. Gillnet captures of adult and subadult rainbow trout in three study areas of Minersville Reservoir in 1987.

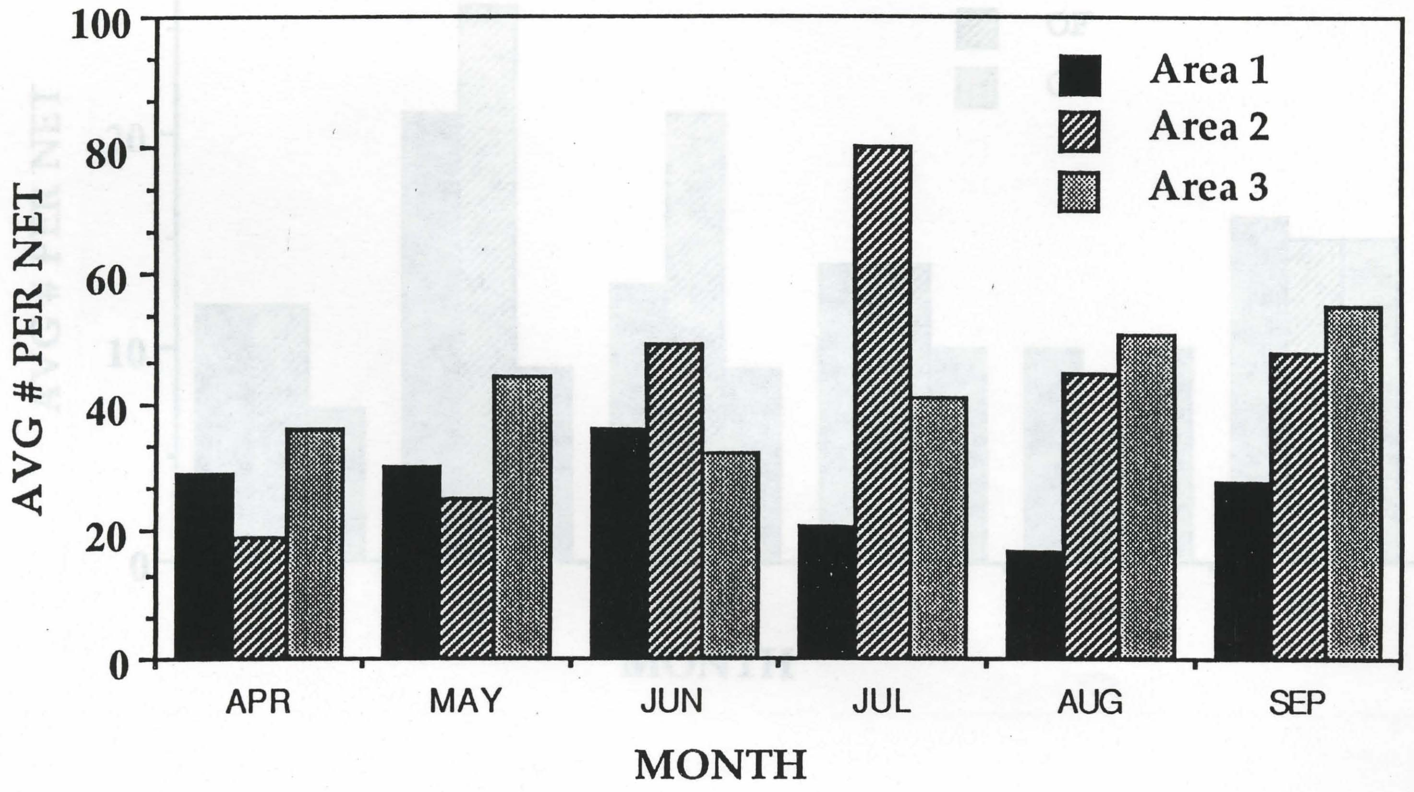

FIGURE 5. Gillnet captures of adult and subadult rainbow trout within three net set locations in 1987. IF= inshore floating net, OF= offshore floating net, OD= offshore diving (bottom) net.

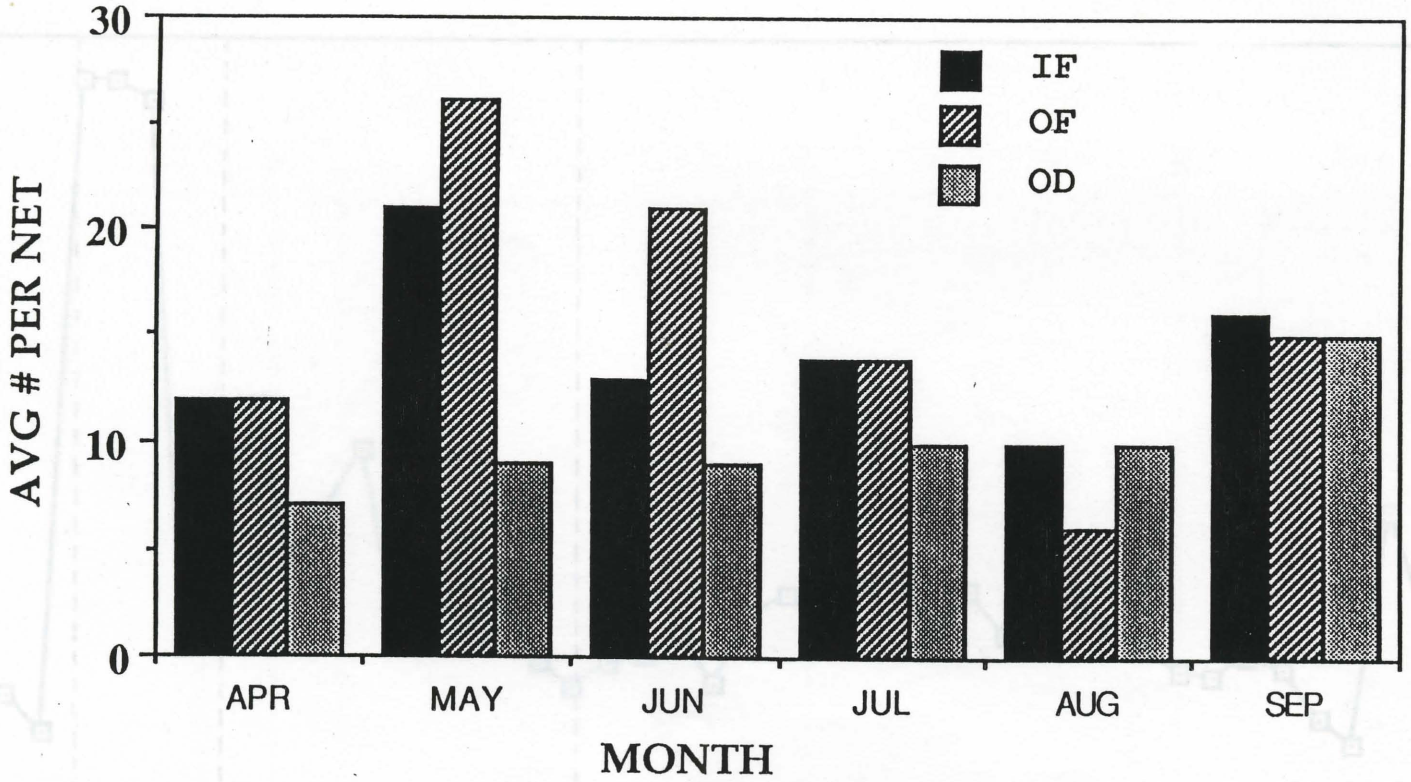

FIGURE 6. Abundance of four species of piscivorous birds at Minersville Reservoir from March 3 to November 26, 1988.

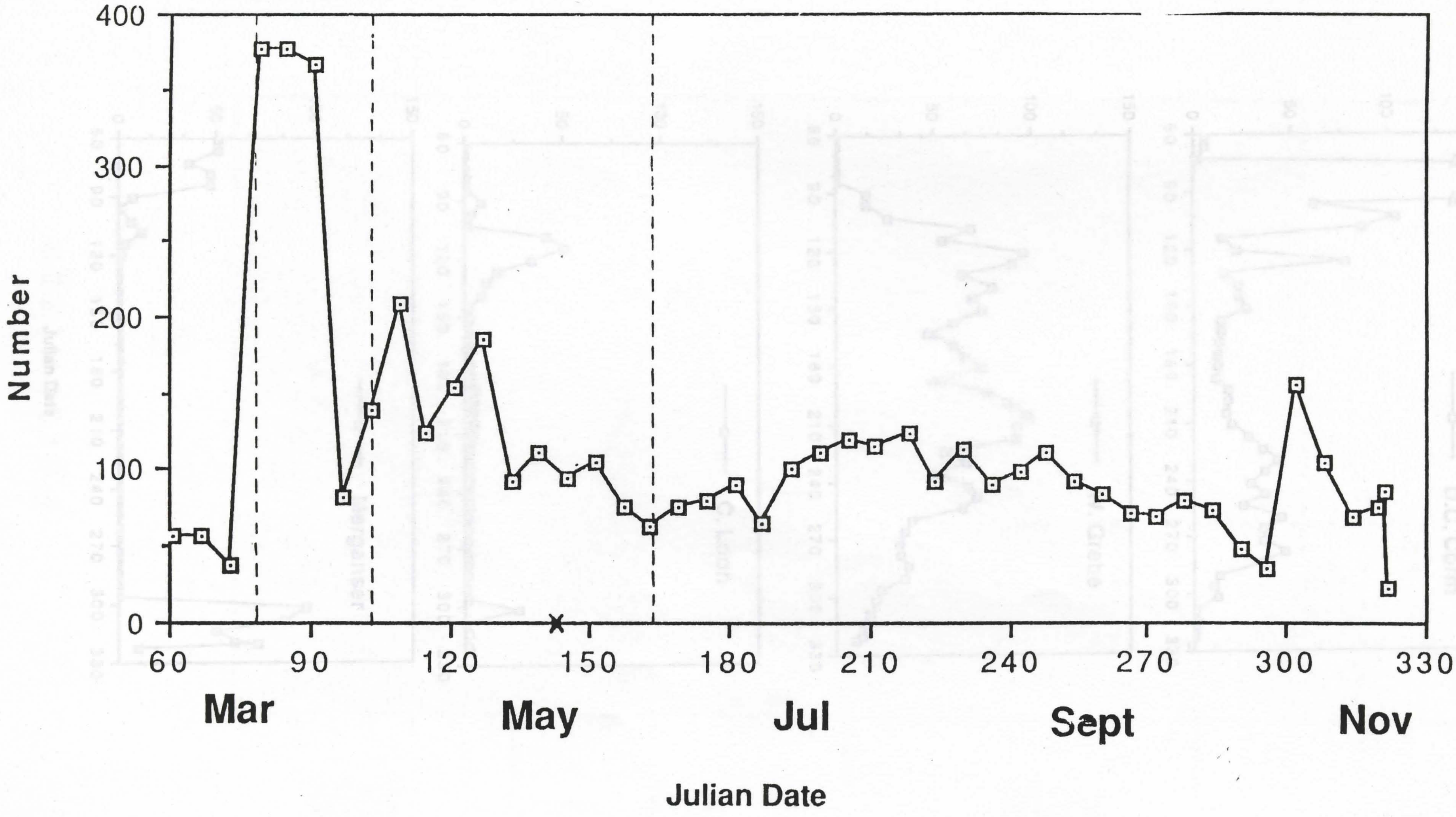

FIGURE 7. Combined abundance of four species of piscivorous birds (double-crested cormorant, western grebe, common loon, and common and red-breasted merganser) at Minersville Reservoir from March 3 to November 26, 1988.

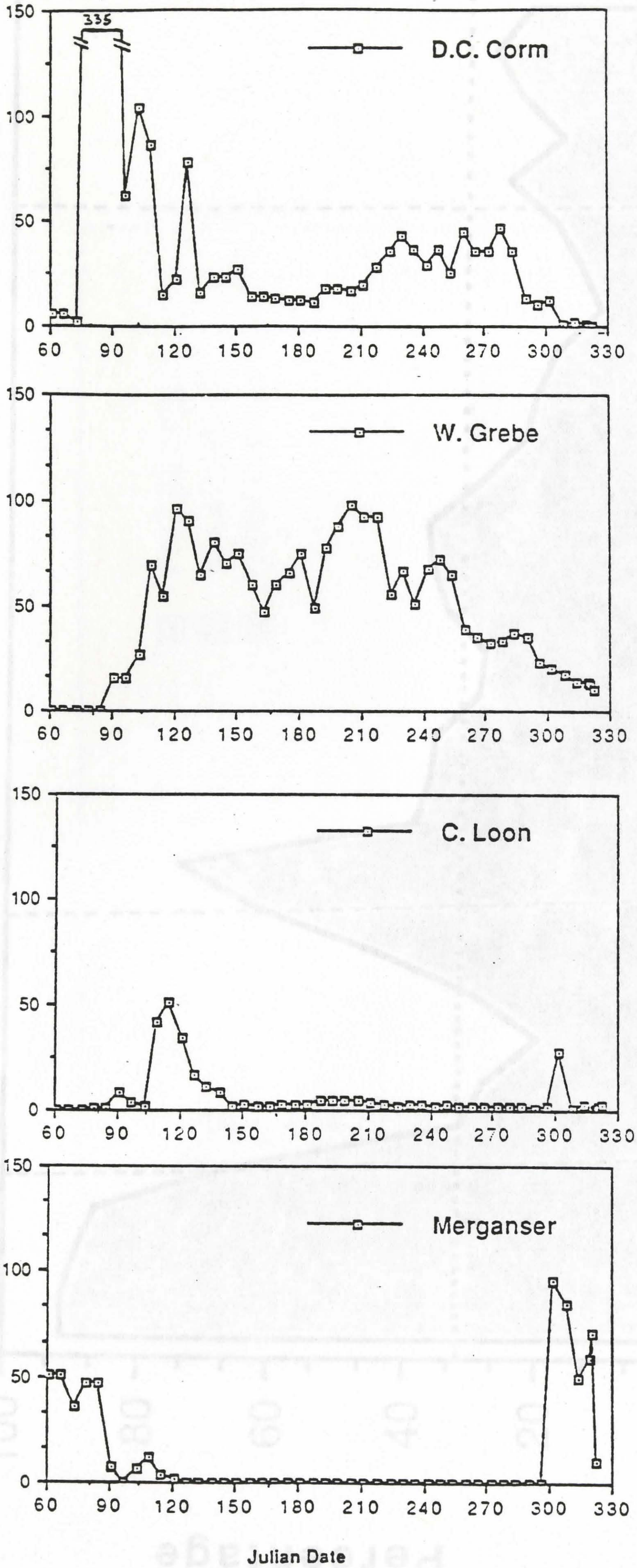

FIGURE 8. Percentage of cormorants and grebes feeding in study area 1 from March 3 to June 30, 1988. Dashed vertical lines indicate fingerling stocking dates, dotted horizontal lines indicate the percentage of the total reservoir which area 1 covers.

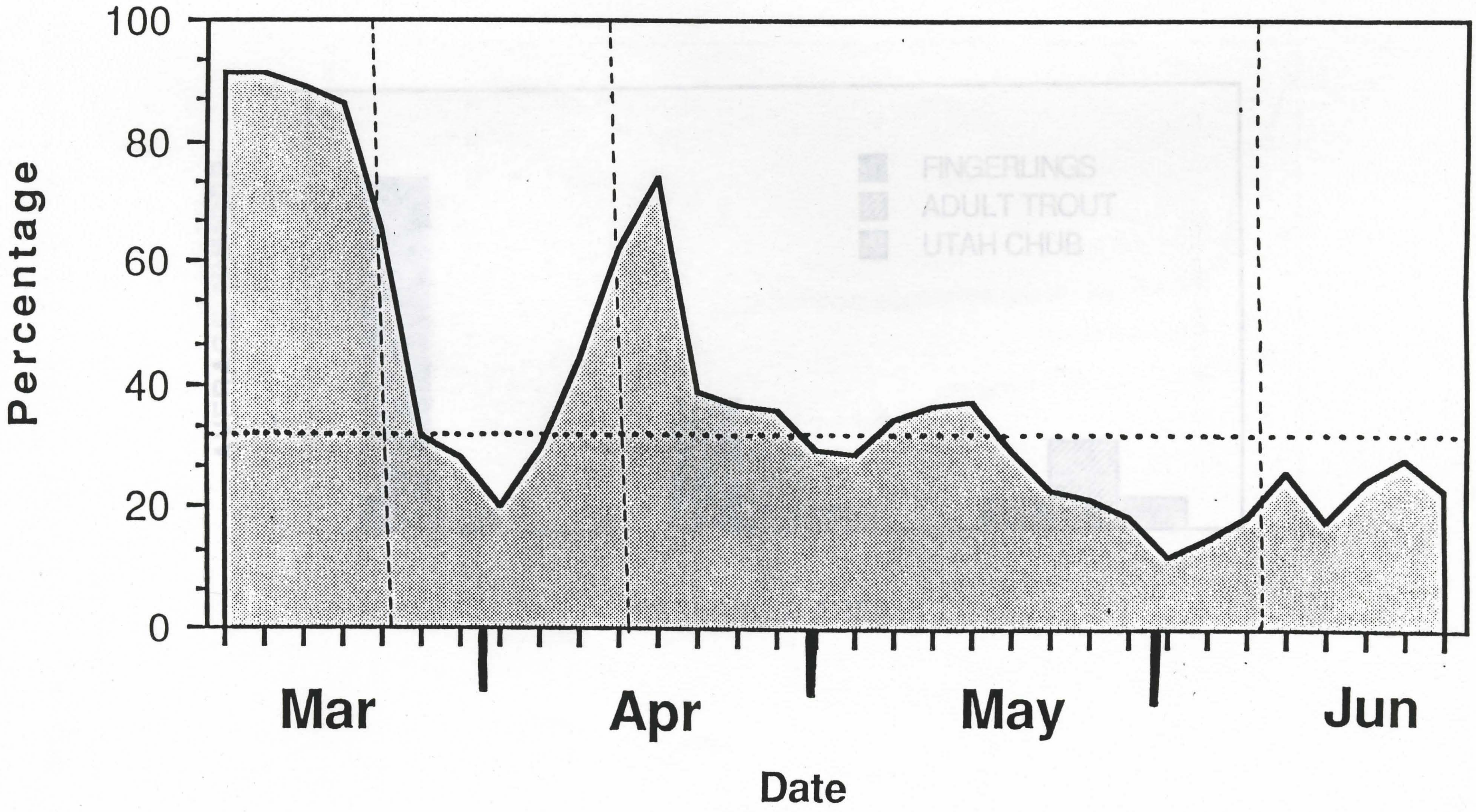

FIGURE 9. Fish consumption by double-crested cormorants sampled at three reservoir study areas in 1988.

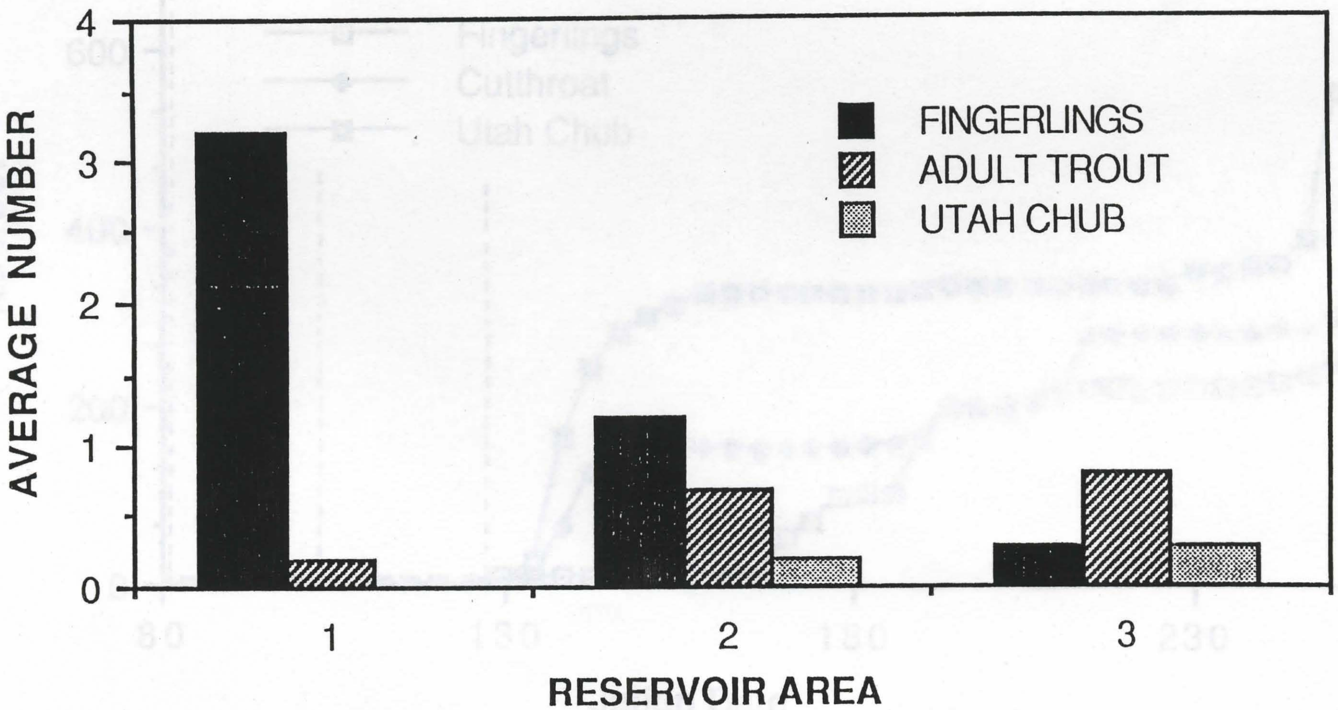

FIGURE 10. Emigration of fish from Minersville Reservoir from March 21 to September 14, 1988. Vertical lines indicate fingerling stocking dates.