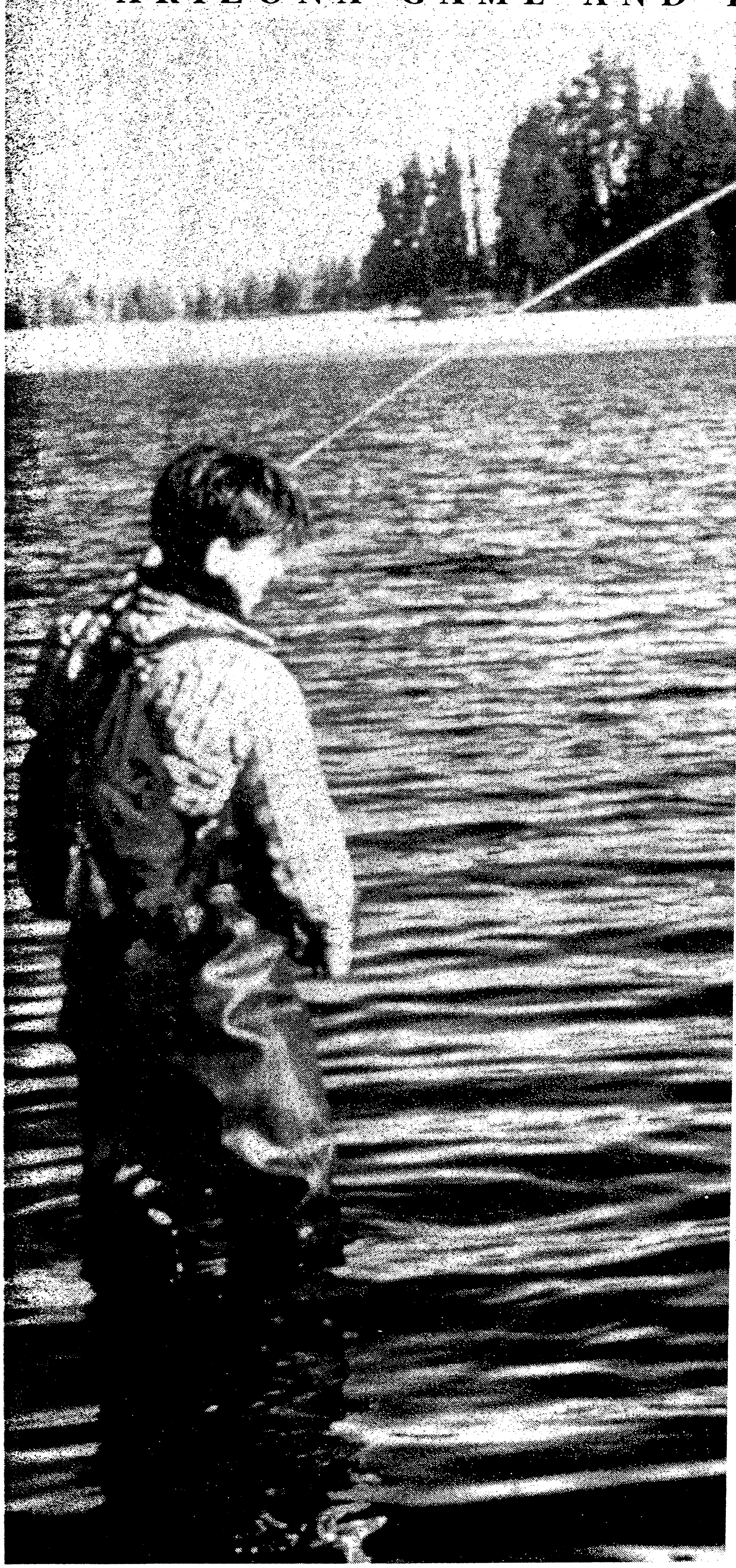
ARIZONA GAME AND FISH DEPARTMENT



RESEARCH BRANCH
TECHNICAL REPORT #12

INVESTIGATION OF TECHNIQUES TO ESTABLISH AND MAINTAIN ARCTIC GRAYLING AND APACHE TROUT LAKE FISHERIES

A Final Report

ROBERT W. CLARKSON
RICHARD J. DREYER

September 1992
Revised February 1996

FEDERAL AID IN SPORT FISH RESTORATION PROJECT

Arizona Game and Fish Department Mission

To conserve, enhance, and restore Arizona's diverse wildlife resources and habitats through aggressive protection and management programs, and to provide wildlife resources and safe watercraft and off-highway vehicle recreation for the enjoyment, appreciation, and use by present and future generations.

Arizona Game and Fish Department
Research Branch

Technical Report No. 12

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Suggested Citation:

Clarkson, R. W. and R. J. Dreyer. 1996. Investigation of techniques to establish and maintain Arctic grayling and Apache trout lake fisheries. Ariz. Game and Fish Dep. Tech. Rep. 12, Phoenix. 71pp.

ISSN 1052-7621
ISBN 0-917563-17-4

CONTENTS

ACKNOWLEDGEMENTS

We especially thank J. Novy and the Department Region I office for considerable logistic and office support during the field portion of this study. J. Walters, D. Kubly, R. Schweinsberg, J. deVos, J. Novy, S. Bryan, and others reviewed and improved earlier drafts of this document. V. Webb produced final layout and design, and helped with table formatting.

This report is a result of studies undertaken with support provided by the Federal Aid in Sport Fish Restoration Act Project F-14-R of the Arizona Game and Fish Department. The Act is popularly known as the Dingell-Johnson Act after its Congressional sponsors. The Act provides for manufacturers' tax on fishing rods, reels, creels, and artificial baits, lures, and flies, with the revenue earmarked for the states and territories solely for projects that would enhance sportfishing restoration. Thus, sport fishermen are the contributors to a program that benefits everyone. In addition to the Department's Federal Aid funding, financial support for the project was provided by the U.S. Forest Service. This assistance greatly aided the collection of data reported herein. First edition publication costs of this report were paid by Dingell-Johnson funds.

Investigation of Techniques to Establish and Maintain Arctic Grayling and Apache Trout Lake Fisheries

Robert W. Clarkson and Richard J. Dreyer

Abstract: We studied angler use, angler catch and harvest, and limnological and biological aspects of 2 high elevation lake fisheries in east-central Arizona from 1986-90 to evaluate a new "featured species" management concept. Two designated featured species, Arctic grayling (*Thymallus arcticus*) and Apache trout (*Oncorhynchus apache*), were stocked into Lee Valley Reservoir beginning in autumn 1986; Bear Canyon Lake received only Arctic grayling. Annual brook trout (*Salvelinus fontinalis*) stockings at both reservoirs ceased in 1986, and gear and bag restrictions were applied to both waters in 1987. Angler count surveys at Lee Valley Reservoir (14 surface hectares) indicated that angler use in 1987-90 dropped to approximately one-half the 1986 estimate of 20,000 angler hours, but remained within management-prescribed limits. Angler use at Bear Canyon Lake (26 hectares) was 3,700 hours in 1987, and 7,000 hours in 1988. Annual mean angler catch rates at Lee Valley Reservoir increased markedly over pre-study estimates to a maximum of 2.2 fish per hour in 1989, but harvest rates were near or below minimum management standards of 0.1 fish per hour. Mean annual catch rates at Bear Canyon Lake were less than 0.2 fish per hour; harvest was near zero. A large majority of anglers interviewed at Lee Valley Reservoir supported the new management direction and associated restrictions there, while only mild support for the new fishery was expressed by anglers at Bear Canyon Lake. These comparisons suggest that a put-grow-and-take Arctic grayling fishery at Bear Canyon Lake should be reconsidered. Analyses of benthic and planktonic food resources and salmonid feeding habits in Lee Valley Reservoir suggest that introduction of Arctic grayling altered zooplankton assemblage structure, and according to the trophic cascade hypothesis, possibly nutrient cycling and primary production (not measured). Alternatively, adverse physical-chemical conditions (high pH, low winter dissolved oxygen levels) associated with eutrophication of the reservoir may have influenced the observed biological changes. We consider physical-chemical effects to be the greatest impediment to the long-term success of the Lee Valley Reservoir "featured species" fishery.

Key words: Age, Apache trout, Arctic grayling, Arizona, growth, *Oncorhynchus apache*, survival, *Thymallus arcticus*, trophic relationships.

INTRODUCTION

In 1985 the Arizona Game and Fish Department (AGFD) developed its first 5-year statewide Coldwater Fisheries Strategic Plan (Stephenson 1985). That document contained a means for the AGFD to critically evaluate the direction of management programs, and identified management goals, objectives, and problems. The plan quantified existing supplies, use, and demand of coldwater fishery resources in Arizona and estimated projected future supplies and demand for those resources. Definitions, criteria, and standards of fishery management concepts were established.

The Coldwater Plan proposed a "featured species" management concept for the purpose of "providing the opportunity to catch species considered to be uncommon and unique." That concept was one for which future demand was expected to exceed supply, especially for lakes. The plan suggested use of Arctic grayling and Arizona's endemic Apache trout within the featured species management concept to increase supply of angling opportunities of this type.

Arctic grayling and Apache trout lake fisheries previously had been established in the state in the 1960s, 1970s, and early 1980s. Both were gradually fished out after culturing was abandoned. Only limited information from those fisheries experiences is available.

The AGFD designed a research project in 1986 to determine fishery management techniques necessary to establish and maintain lake fisheries for Arctic grayling. At the time, supplies of Apache trout were limited, and the species was originally not included in the study design. Beginning in 1988, Apache trout became available from the U.S. Fish and Wildlife Service Alchesay National Fish Hatchery, and the species was incorporated into the study. Management standards for lake-featured species fisheries were identified in the Coldwater Plan as: 1) exhibiting 1-7 angler days per surface acre per week; 2) capable of sustaining a harvest rate of 0.1-0.3 fish per hour; and 3) providing harvestable fish 9-12 inches in total length for Arctic grayling and 8-14 inches for Apache trout. Lee Valley Reservoir and Bear Canyon Lake, 2 impoundments with prior histories with Arctic grayling and Apache trout, were chosen as study areas.

Primary objectives of the study included determination of age, growth, and survival of stocked fishes; estimation of angler use, catch rates, and harvest; determination of angler attitudes towards the fishery; and potential for efficient egg-taking operations. Study objectives also included provisions for making management recommendations regarding bag and size limits, stocking times and rates, and gear restrictions. In addition, trophic relationships of Arctic grayling and Apache trout were investigated through examination of zooplankton, benthos, and feeding habits. The initial study design was also to evaluate effects of different stocking densities on many of these variables, but implementation was precluded due to problems with egg shipments and hatchery space.

STUDY WATERS

Lee Valley Reservoir

Physiography. Lee Valley Reservoir is situated at the base of the Mt. Baldy Wilderness Area in the Apache-Sitgreaves National Forest, southwestern Apache Co., Arizona (Figures 1 and 2). It is the state's highest elevation reservoir at 2,871 m above sea level. The basin drains approximately 2.7 km^2 of the east flank of Mt. Baldy within the Petran subalpine conifer forest biotic community (Brown 1982). Vegetation is predominately fir (*Abies* spp.), spruce (*Picea* spp.), ponderosa pine (*Pinus ponderosa*), and aspen (*Populus tremuloides*).

The area is characterized by cold winters and mild summers. Monthly mean air temperatures range from lows near -8°C between December and February to highs of 12°C in July. Extreme air temperatures have reached -41°C during winter and 29°C in summer (SCS 1990). Mean annual precipitation is 76 cm, with approximately half falling as snow between November and April. Most summer precipitation occurs between July and September (Sellers and Hill 1974). Mean annual evaporation is 112 cm (Young et al. 1990).

The reservoir is impounded by an earthfill/riprap dam constructed in 1899 along an unnamed tributary to the East Fork of the Little Colorado River (hence Lee Valley Creek). The dam impounds a volume at spillway elevation of approximately 518,000 m^3, with a surface area of approximately 18.1 hectares; mean surface area is approximately 14 hectares (Young et al. 1990). Maximum depth approaches 6 m; mean depth is 2.9 m. Mean annual inflow to the lake is approximately 579,000 m^3 with an additional 112,000 m^3 per year accounted for by direct precipitation. Mean annual seepage through the dam is 244,000 m^3 (Young et al. 1990).

Management History. The drainage basin of Lee Valley Reservoir historically was inhabited by Apache trout and bluehead mountain sucker (*Pantosteus discobolus*). Apparently speckled dace (*Rhinichthys osculus*) did not penetrate the basin to this elevation. In 1947 Apache trout X rainbow trout (*Oncorhynchus apache* X *Oncorhynchus mykiss*) hybrids were collected in the reservoir by AGFD personnel, although there are no records of rainbow trout ever being stocked. Brook trout (*Salvelinus fontinalis*) was introduced in 1953, followed by Arctic grayling in 1965 (Table 1). Fathead minnow (*Pimephales promelas*) was introduced sometime prior to 1978 (Novy and Lawry 1988). Apache trout stockings have been sporadic beginning in 1968 (Table 1).

Prior to 1986, the lake was managed primarily as a put-grow-and-take fishery for brook trout, with inconsistent stockings of Arctic grayling fry and fingerlings and Apache trout fingerlings and catchables. Prior to the initiation of this study, Arctic grayling were last stocked in 1976 and Apache trout in 1981. After 1986, brook trout stockings in the lake were discontinued, and their removal was encouraged by the AGFD.

The historic bag limit at Lee Valley Reservoir was 10 trout of any size until 1987, when statewide trout bag limits were reduced to 6 fish. In 1987, the 6 fish limit could include 1 Arctic grayling of 305 mm minimum size, and the lake was restricted to artificial fly and lure only. In 1989, a 1 fish limit (minimum size 305 mm) for Apache trout was added to the 6 fish aggregate, and in 1990 the overall limit was reduced to 2 fish in the aggregate to include not more than 1 Arctic grayling, 1 Apache trout, or 1 brook trout. Those regulations remain in effect at the present time.

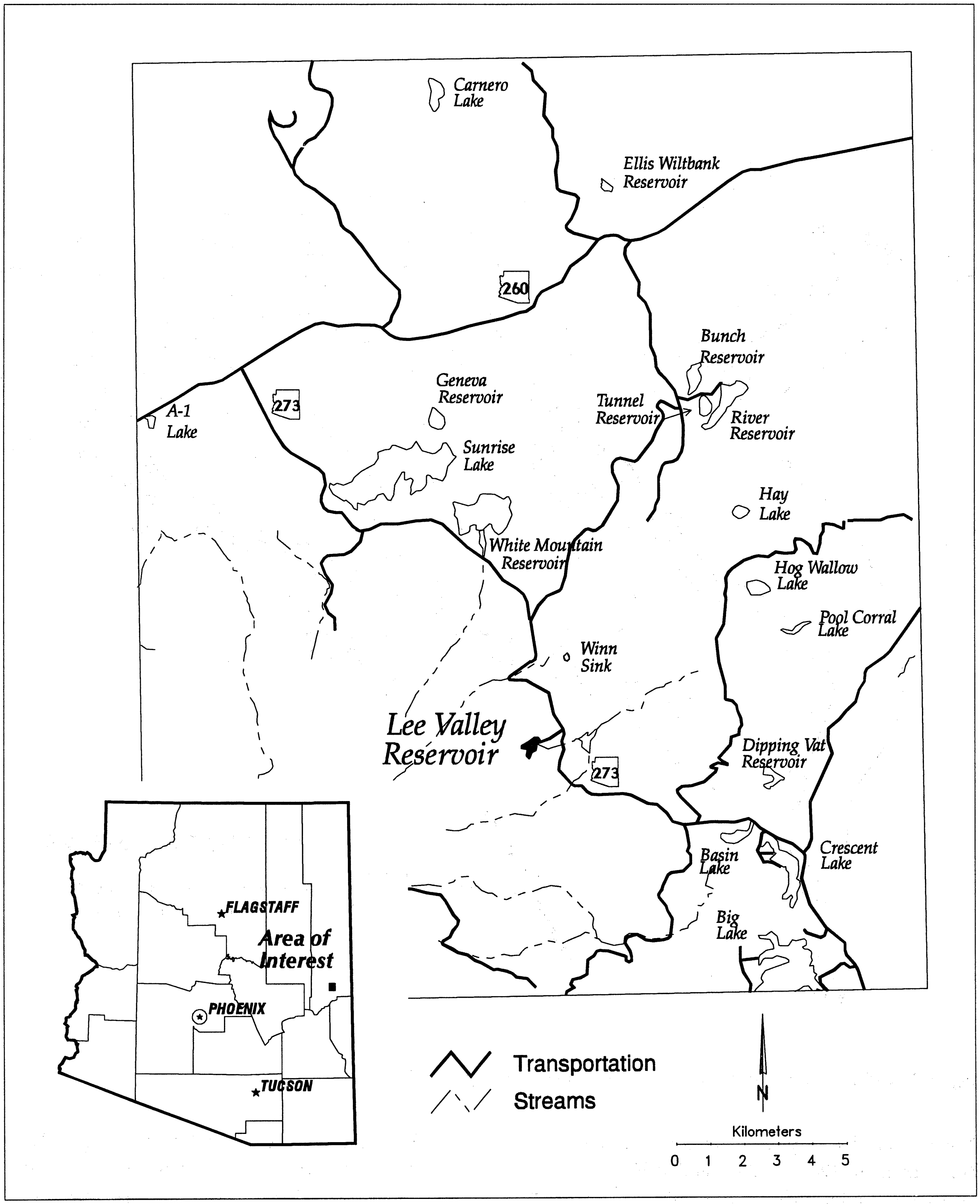


Figure 1. Location map of Lee Valley Reservoir, Apache County, Arizona, showing major features of the area.

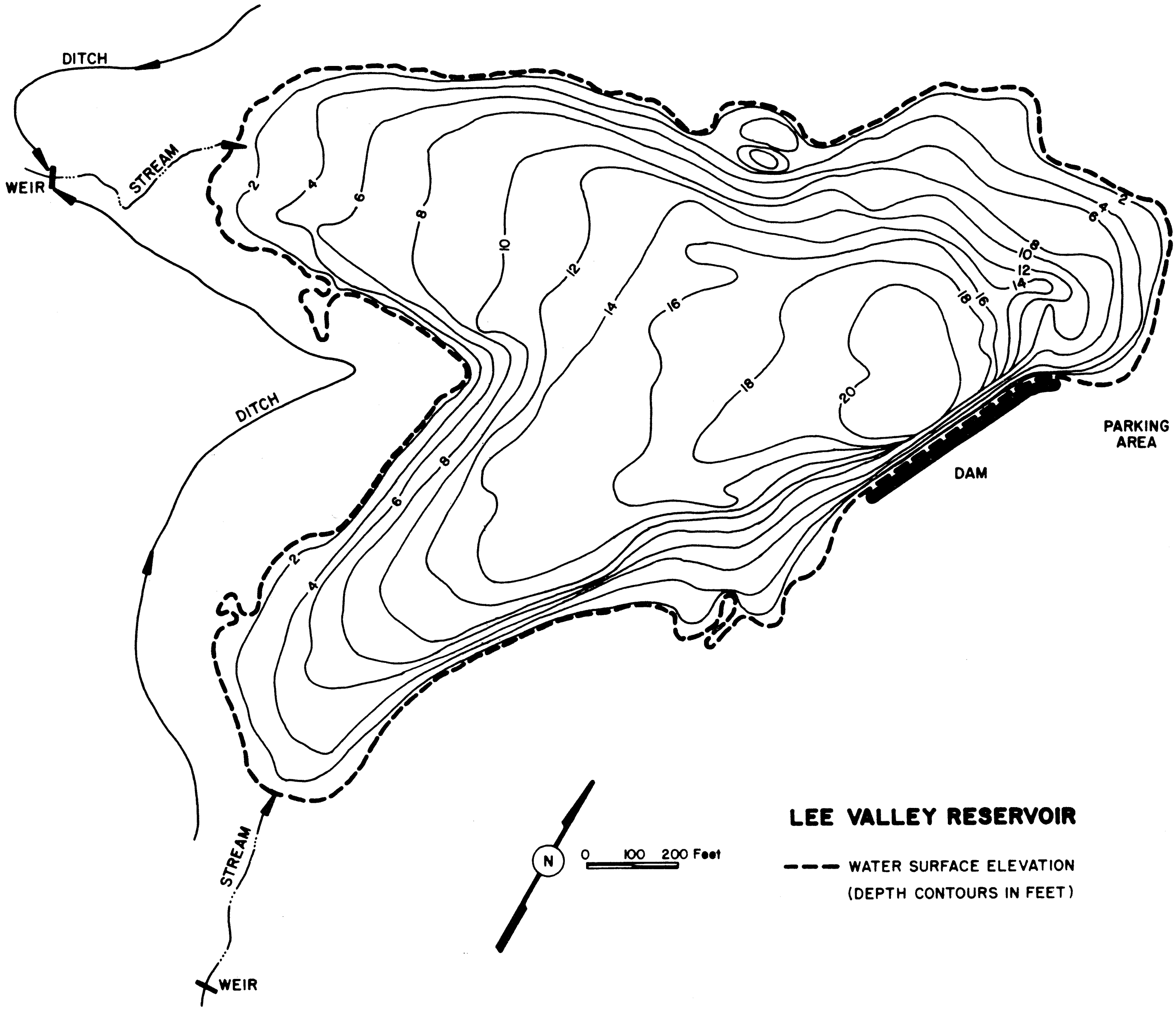


Figure 2. Bathymetric contour map of Lee Valley Reservoir, Apache County, Arizona.

Previous creel surveys conducted during the ice-free seasons in 1969-71, 1980, and 1986 showed that harvest rates (fish/hr) gradually declined from a high of 0.38 in 1969 to 0.25 in 1986 (Novy and Lawry 1988). Catch rates were not available except from 1986, which only slightly exceeded the harvest rate for that year (0.27 fish/hr). Estimated total angler effort was 16,166 angler hours for 1980 (3.8 angler days per surface acre per week), and 20,963 hours for 1986 (4.3 angler days per acre per week). Total harvest for those years was 4,377 and 5,400 fish, respectively. Harvest was comprised of 80% brook trout and 20% Apache trout in 1980, and 100% brook trout in 1986 (Novy and Lawry 1988).

Table 1. Historical stocking records for Lee Valley Reservoir, Apache Co., Arizona, 1953-85.

Year	Species	Size[a]	Number
1953	Brook Trout	Fry	40,000
1959	Brook Trout	Fingerling	55,000
1961	Brook Trout	Fry	25,000
1963	Brook Trout	Fingerling	15,000
1964	Brook Trout	Fingerling	15,000
1965	Grayling	Fry	5,000
	Brook Trout	Fingerling	15,000
1966	Grayling	Fingerling	10,305
	Brook Trout	Fingerling	11,790
1967	Brook Trout	Fingerling	18,000
1968	Apache Trout	Fingerling	2,500
	Brook Trout	Fingerling	10,000
1969	Grayling	Fingerling	10,000
	Brook Trout	Fingerling	10,000
1970	Grayling	Fry	10,000
		Fingerling	8,945
	Apache Trout	Fingerling	3,000
1971	Apache Trout	Fingerling	5,040
	Brook Trout	Fingerling	10,000
1972	Grayling	Fingerling	3,302
	Apache Trout	Fingerling	4,112
1973	Brook Trout	Fingerling	19,000
1974	Brook Trout	Fingerling	10,000
1975	Brook Trout	Fingerling	10,000
1976	Grayling	Fingerling	1,011
1977	Brook Trout	Fingerling	10,000
1978	Brook Trout	Fingerling	10,000
1979	Brook Trout	Fingerling	10,000
1980	Apache Trout	Catchable	567
	Brook Trout	Fingerling	10,000
1981	Apache Trout	Catchable	144
	Brook Trout	Catchable	2,496
		Fingerling	10,000
1982	Brook Trout	Fingerling	10,000
1983	Brook Trout	Subcatchable	2,500
		Fingerling	10,000
1984	Brook Trout	Fingerling	10,000
1985	Brook Trout	Fingerling	10,000

Subcatchable fish were between 102 and 152 mm; catchable fish were between 152 and 305 mm.

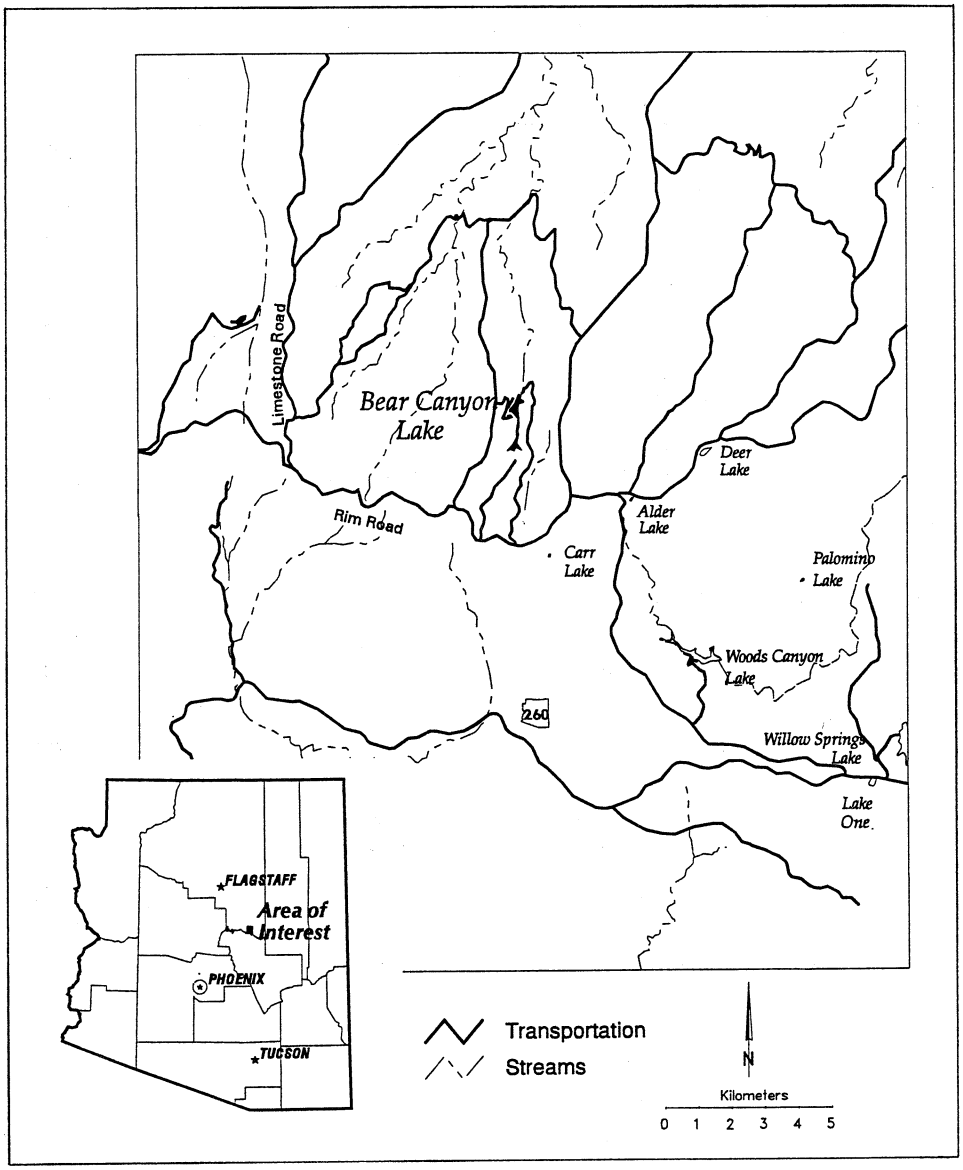


Figure 3. Location map of Bear Canyon Lake, Coconino County, Arizona, showing major features of the area.

Bear Canyon Lake

Physiography. Bear Canyon Lake is situated between Bear Beaver Ridge and Bear Willow Ridge atop the Mogollon Rim in the westernmost portion of Apache-Sitgreaves National Forest, Coconino Co., Arizona, at an elevation of 2,304 m (Fig. 3). The concrete spillway and earthen dam, built by the AGFD in 1964, impounds approximately 26 surface hectares. The lake is filled primarily by spring snowmelt from 2 unnamed, ephemeral tributaries in Bear Canyon. The lake is long and narrow, with steeply-sloped banks. Maximum depth is 17 m in front of the dam. The drainage basin above the dam is approximately 1.6 km^2, and lies within the Petran montane conifer forest biotic community (Brown 1982). Ponderosa pine is the dominant tree species in the area.

Mean air temperatures are near freezing from December through February, with minima typically between -5 and -10°C (Sellers and Hill 1974). Monthly mean air temperatures ranged between 12-20°C. Approximately 30% of the mean annual precipitation of 46 cm occurs between June and September, and most of the remainder falls as snow between December and March (Sellers and Hill 1974). Annual evaporation is approximately 155 cm (Cooley 1970).

Management History. Historically, native fishes only rarely penetrated the ephemeral Willow Creek drainage as high as the Bear Canyon Lake site. Species in adjacent perennial streams included speckled dace, Little Colorado spinedace (*Lepidomeda vittata*), roundtail chub (*Gila robusta*), Little Colorado River sucker (*Catostomus* sp.), and bluehead sucker. Trout are not native to the area.

Bear Canyon Lake was initially stocked with fry and fingerling Arctic grayling and fingerling and subcatchable cutthroat trout during 1965-66 (Table 2). Between 1967 and 1973, fingerling, subcatchable, and catchable Apache trout was the sole species stocked. Fingerling and subcatchable brook trout were stocked annually from 1977-85. A single stocking of fingerling and subcatchable rainbow trout occurred in 1984 (Table 2).

Bear Canyon Lake has always been restricted to artificial fly and lure-only fishing. Bag limits until 1987 were 10 trout of any size, at which time the bag was reduced to 6, including 1 Arctic grayling of 305 mm minimum size. Special regulations were eliminated in 1995.

Creel surveys conducted in 1969, 1972, and 1985 estimated harvest rates at 0.40, 0.23, and 0.16 fish/hr, respectively (AGFD data). Composition of the creel was 66% Arctic grayling, 34% cutthroat, and <1% Apache trout in 1969, 83% Apache trout and 17% Arctic grayling in 1972, and 88% rainbow trout and 12% brook trout in 1985. Catch rates and angler effort were only estimated in 1985, with means of 0.33 fish/hr and 4,659 angler hours (0.8 angler days per acre per week).

Table 2. Historical stocking records for Bear Canyon Lake, Coconino Co., Arizona, 1965-85.

Year	Species	Size[a]	Number
1965	Arctic Grayling	Fry	15,000
		Fingerling	5,500
	Cutthroat Trout	Fingerling	10,000
1966	Arctic Grayling	Fingerling	14,850
	Cutthroat Trout	Subcatchable	10,000
1967	Apache Trout	Subcatchable	3,768
1968	Apache Trout	Catchable	71
		Subcatchable	1,343
1969	Apache Trout	Fingerling	3,990
1970	Apache Trout	Fingerling	3,000
		Fingerling	2,450
1971	Apache Trout	Fingerling	8,500
1972	Apache Trout	Catchable	92
		Fingerling	7,641
1973	Apache Trout	Catchable	84
		Fingerling	7,986
1977	Brook Trout	Fingerling	25,000
	Brown Trout	Subcatchable	500
1978	Brook Trout	Fingerling	30,000
1979	Brook Trout	Fingerling	15,000
1980	Brook Trout	Subcatchable	4,500
		Fingerling	34,240
1981	Brook Trout	Fingerling	45,808
1982	Brook Trout	Fingerling	25,000
1983	Brook Trout	Fingerling	25,000
1984	Rainbow Trout	Subcatchable	4,400
		Fingerling	25,000
1985	Brook Trout	Fingerling	25,000

[a] Subcatchable fish were between 102 and 152 mm; catchable fish were between 152 and 305 mm.

METHODS

Fish Sampling and Population Estimates

Fish sampling was conducted monthly during the ice-free seasons (April or May to November or December) in 1987-90 at Lee Valley Reservoir and in 1987-88 at Bear Canyon Lake. Two-throated trap nets (122 cm square frame, 10 cm wide vertical opening, 7.6 m wings, 22.9 m lead, 6.4 mm mesh) were set perpendicular to shorelines, with leads tied to shore. Trap nets were set in late afternoon and checked the following morning. 30.5 X 1.5 m bag seines (6.4 and 19.0 mm mesh) typically were deployed by boat 30 m parallel from shore and beached using 30 m ropes tied to the seine poles. Total lengths to ±1 mm and weights to ±2 g were taken from a minimum of 50 fish of each species when possible, except fathead minnows.

Between 1988 and 1990, spring Peterson mark-recapture population estimates were made for the 1986 Arctic grayling cohort. A similar estimate was made for age-1 Apache trout in autumn 1988. Pectoral fin clips were made to net-captured fish over a 2-week period (angler-caught Arctic grayling were also fin-clipped in 1988). One week after marking, netting and occasional angling were used to examine fish for marks over a period of several weeks. Confidence limits of population estimates were applied using the binomial table in Appendix II of Ricker (1975). Robson and Regier (1964) provided guidelines for the numbers of marks and recaptures required to achieve desired precision levels.

Creel Surveys

Creel data presented here were obtained from stratified roving surveys similar to designs of Abramson and Tolladay (1959), Malvestuto et al. (1978), and Malvestuto (1983). Lee Valley Reservoir was surveyed during the ice-free seasons during 1987-90 and stratified into April-May, June-August, September-October, and November periods according to sub-seasonal variations in angler use. Similar stratification was applied to Bear Canyon Lake during surveys in 1987-88, except November (and December in 1987) was incorporated into the autumn stratum. Weekday and weekend day (including holidays) strata were established at both waters, and the angler day was divided into 2 diurnal sampling units (morning = mean sunrise of stratum to 1230 hrs, afternoon = 1231 hrs to 1/2 hour past mean sunset of stratum).

Each sampling unit received 3 angler counts evenly distributed within the sampling interval. This was accomplished by an instantaneous shore count from Lee Valley Reservoir and a walked shoreline circuit count at Bear Canyon Lake that required approximately 20 min. Mean count was multiplied by the number of hours within the sampling unit to provide an estimate of angler effort for that unit.

Angler interviews were conducted between counts to determine the time anglers started and stopped fishing (or time of interview for uncompleted trips) and number of fish caught and kept. Anglers were interviewed only if they had been fishing at least 1/2 hour. On most days, all anglers present were contacted. Robson (1961), Von Geldern and Tomlinson (1973), Malvestuto (1983), and Pierce and Bindman (1994) discussed assumptions of the method of angler contact for roving creel surveys.

During the first year of survey, sampling schedules for each fishery were determined by randomly assigning survey units to a pre-determined number of weekdays and weekend days on a monthly basis according to the number of available personnel. These "pre-survey" data were then used to estimate sample sizes necessary to obtain required precision levels for future angler use according to the method of Abramson and Tolladay (1959). Subsequent sampling effort was allocated to randomized seasonal or sub-seasonal schedules in proportion to the product of stratum size and stratum standard deviation (optimum allocation).

Methods of angler count expansions to total angler effort were performed according to stratified sampling techniques outlined in Abramson and Tolladay (1959). This method expands stratum mean counts and their variances to stratum effort estimates, which are added to yield total effort statistics based on procedures in Cochran (1953). Abramson and Tolladay (1959) presented complete methodology and formulae.

Catch rates were determined according to the "mean of ratios estimator" (modified from Von Geldern and Tomlinson 1973):

$$\frac{1}{n}\sum_{i}\frac{C}{f}$$

where n is the number of anglers interviewed, C is the number of fish caught (or kept if calculating harvest rates) by angler *i*, and *f* is the fishing effort of angler *i*.

Expanded effort estimates from the Abramson and Tolladay (1959) procedure were multiplied by mean catch and harvest rates to provide comparative measures of angler catch and harvest. Since the angler count and catch rate components used by this method were independent, random variables, the variance of their product was determined according to Goodman (1960):

$$V(xy) = \bar{x}^2 V(\bar{y}) + \bar{y}^2 V(\bar{x}) + V(\bar{x})V(\bar{y})$$

Degrees of freedom for computing confidence intervals were estimated from the value midway between the sample sizes of the product components.

Water Quality

Water quality measurements were taken each month during the ice-free seasons in 1987-90 at Lee Valley Reservoir and in 1987-88 at Bear Canyon Lake. Intermittent measurements were taken through the ice at Lee Valley Reservoir. Measurements were taken mid-lake in front of the dams at the surface and at 1 m intervals to the bottom. Water temperature, surface pH, dissolved oxygen, and conductivity were measured with a multiple-probe Hydrolab Model 4041. Water clarity was measured sporadically with a Secchi disc.

Trophic Relationships

Zooplankton. Zooplankton densities were estimated monthly at Lee Valley Reservoir and Bear Canyon Lake on the same schedule as water quality sampling. Triplicate Wisconsin net (80 μ mesh size) vertical tows were taken near the deepest part of each reservoir. The length of each tow was recorded, and samples were preserved in 5% formalin.

In the laboratory, sample volumes were brought to 100 ml, from which 1 ml subsamples were drawn with a Hensen-Stempel pipette. By examining the fluctuation of the sample mean with increasing numbers of subsamples (Elliott 1971), we established that the mean stabilized at 3 subsamples, and we standardized subsequent subsampling at that number. Subsamples were transferred into a Sedgwick-Rafter cell and covered with a coverslip. Slides were examined at 100X under a binocular microscope, and the numbers of organisms in respective taxa present in the entire cell were recorded. For each taxon, the mean and variance of the number of organisms per liter of water filtered (assuming 100% filtration efficiency) were calculated. Thus, estimates of zooplankton density are likely conservative, assuming less than 100% filtration efficiency. Taxonomic classifications were based on Pennak (1978).

Historic zooplankton densities from sampling performed by AGFD Region I personnel prior to initiation of this study were compared with 1987-90 results. Methodology of collection and analysis of pre-study samples were identical to those reported above.

Benthic Invertebrates. Two transects and a single mid-reservoir site were established in Lee Valley Reservoir in 1988-89 for sampling benthic invertebrates. One transect was oriented in a north by northeast direction in the northern bay over predominately gravel substrate, and the other was oriented similarly in the southern bay, over mostly detritus substrate (Fig. 2). The mid-reservoir site was near the deepest part of the reservoir in front of the dam and had a mostly clay substrate. Triplicate Petite Ponar dredge samples were taken at 1 m depth contours (beginning at 1 m depth) along each transect and at the mid-reservoir site during May, August, and November. Dredge samples were rinsed of fine materials through a 0.5 mm mesh-bottomed bucket. Organisms situated on larger inorganic materials were rinsed off, and the inorganics were discarded. Remaining materials were transferred to jars, and preserved in 5% formalin.

Organisms were sorted under magnification, identified to varying levels of taxonomy, and enumerated. Mean and variance of invertebrate densities were determined. Chironomid pupae, trichopteran larvae, Hydracarina, Corixidae, Coleoptera adults, and Anisoptera densities were low and were pooled for reporting purposes into an "other" invertebrates category. We did not collect benthic samples at Bear Canyon Lake. Taxonomic classifications were based on Merritt and Cummins (1978).

Salmonid Food Habits. We attempted to collect a minimum of 20 specimens each of Arctic grayling and Apache trout cohorts in Lee Valley Reservoir with a 30 m bag seine during May, August, and November, 1988-89. Similar sampling in 1987 also used other gear types, and also included Bear Canyon Lake. Arctic grayling collected from Lee Valley Reservoir in 1987 were classified by size in an attempt to discern ontogenetic changes in feeding behavior of these age-1 fish. However, since smaller fish were generally caught early in the year and larger fish caught late in the year, the effect of time (season) cannot be separated in these analyses. Specimens were weighed and measured, injected intraperitoneally with 10% formalin, and stored in 10% formalin.

In the laboratory, items in the stomach were separated into taxonomic, vascular plant detritus, inorganic, and filamentous algae categories. Unidentifiable materials were lumped as "unidentified." For fish and invertebrates, categories included taxa ranging from phyla to species, depending on their state of digestion and frequency in the stomachs. Insect categories were noted as immature (larvae, pupae, or nymphs) or adult life stages. Infrequently-occurring taxa were lumped into broader categories for reporting purposes. Taxonomic categories in stomachs that contained more than 200 individuals were subsampled and enumerated similarly to zooplankton enumeration procedures. For invertebrates, the number of intact individuals or non-repetitious body parts (e.g. head capsules) were recorded for each taxonomic category.

Stomach content volumes from 1987 were estimated by water displacement in small graduated cylinders. Visual estimation of relative volumes (Hynes 1950) was also performed. Due to a lack of precision in estimating volumes of smaller items in stomachs by the water displacement method, 1988-89 stomach content processing was performed gravimetrically. Following separation of stomach contents into categories, relative volumes were visually estimated. Groups were then placed into pre-weighed aluminum pans, excess moisture was blotted, and wet weights were determined on an electronic Mettler balance.

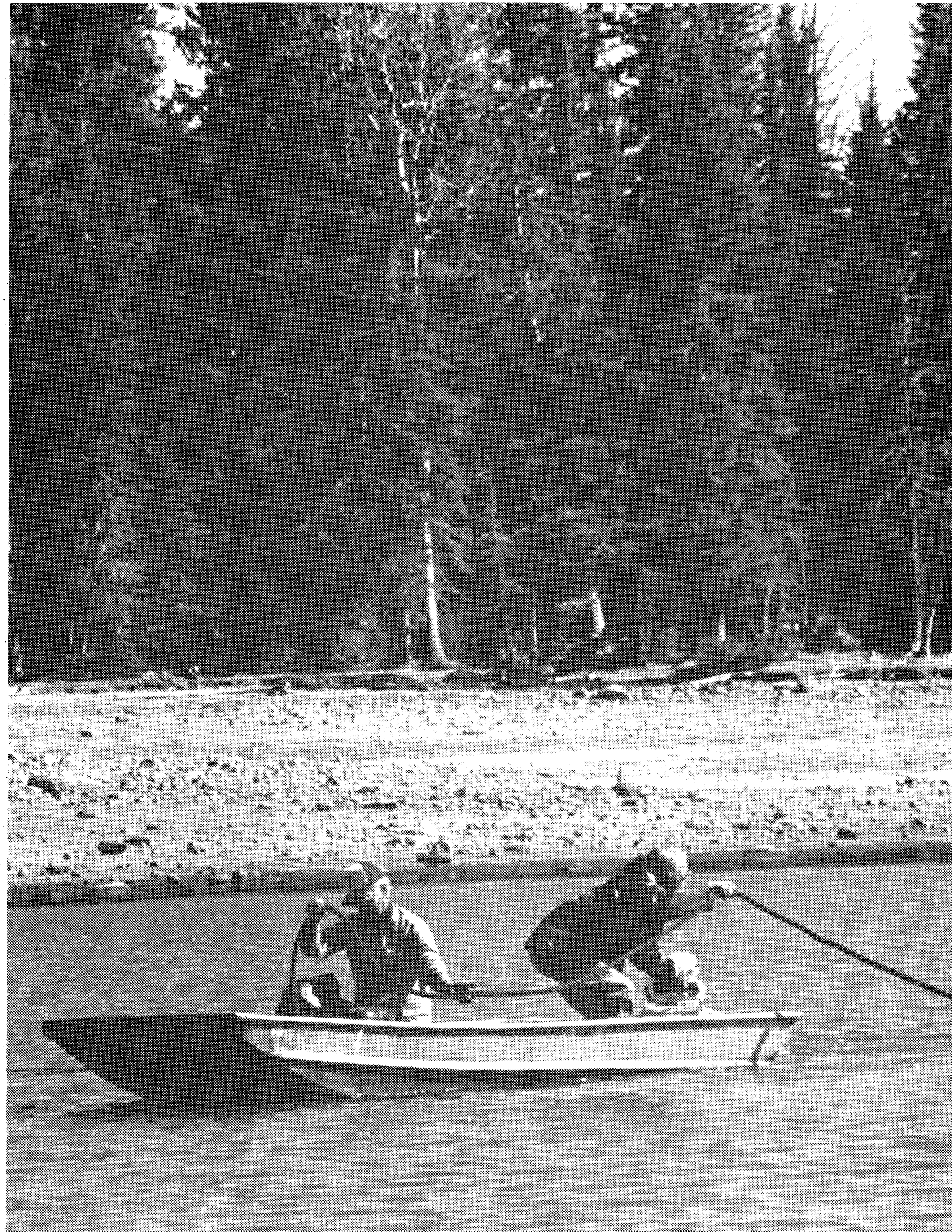
Diet Overlap. Relative weights of food categories found in stomachs from 1988-89 samples from Lee Valley Reservoir (excluding unidentified material) were used to determine food overlap among species and species cohorts according to the resource overlap (D) expression of Schoener (1968):

$$D = 1 - \frac{1}{2}\left(\sum_{i=1}^{s} |P_{ij} - P_{ik}|\right)$$

where P_{ij} and P_{ik} are the proportions of the food resource i used by species j and k, and s is the total number of different resources used by each species. This measure ranges from 0-1, where 1 indicates complete resource overlap and 0 indicates no overlap.

Equilibrium Yield

Mean lengths and weights, and instantaneous rates of growth, natural mortality, and fishing mortality were estimated for the 1986 Arctic grayling year class in Lee Valley Reservoir from November 1986 through November 1990. Fishing mortality was not adjusted for potential hooking mortality. These data were employed to construct an equilibrium yield table (Ricker 1958) that estimated remaining size and weight of the stock and predicted yield in weight and numbers to the angler population. Natural mortality estimates were iterated in conjunction with known fishing mortality estimates until remaining Ns (population size) determined from population estimates were approximated. Since the first population estimate did not take place until spring 1988, initial winter vs. summer natural mortality estimates were based on literature values and AGFD data (J. Novy, Ariz. Game and Fish Dep., pers. comm.). Subsequent winter and summer natural mortality estimates were decreased in the third and fourth year in this manner to coincide with population estimates.



RESULTS

Fish Stocking and Egg Take

Arctic grayling. Initial stockings of Arctic grayling at Lee Valley Reservoir and Bear Canyon Lake for the study were derived from eggs collected from spawning fish in Meadow Creek, a tributary stream of Meadow Lake, Wyoming, by the Wyoming Game and Fish Department, in spring 1986. Approximately 190,000 eggs were flown to Arizona and transferred to the AGFD's Pinetop Hatchery, Navajo County, Arizona, for rearing. Lee Valley Reservoir received approximately 43,000 fingerlings in November 1986, and approximately 34,000 fingerlings were planted in Bear Canyon Lake in October (Table 3). Eggs received from Alaska in 1986 (approximately 100,000) all died in shipment.

In 1987, 2,000 hatchery survivors of 525,000 Arctic grayling eggs flown from Alaska were provided to the White Mountain Apache Tribe for use in Reservation waters. One thousand of 70,000 Wyoming Arctic grayling eggs received in 1987 survived and were planted in autumn in Ackre Lake, a small impoundment in Apache Co., Arizona. Thus fish were not stocked in Lee Valley Reservoir or Bear Canyon Lake in 1987.

Complete mortality of 199,000 Alaska Arctic grayling eggs occurred in 1988. Of 212,000 Wyoming eggs received in 1988, 7,798 Arctic grayling were stocked into Lee Valley Reservoir in November 1988. Approximately 3,000 additional Wyoming survivors were held over the winter at the Pinetop Hatchery with the intent of marking and releasing them in the spring to estimate over-winter mortality. The surviving 1,519 that over-wintered in the hatchery were marked and released into Lee Valley Reservoir in April 1989 (Table 3). It was subsequently determined from netting that the 1988 cohort stocked in Lee Valley Reservoir the previous autumn was nearly completely lost during the 1988-89 winter. Thus, a mark-recapture population estimate could not be made.

Table 3. Fish stockings in Lee Valley Reservoir (1986-89) and Bear Canyon Lake during the study period (1986-90).

LEE VALLEY RESERVOIR

Year	Species	Size[a]	Number	Stocked
1986	Grayling	Fingerling	43,672	Nov 18
1988	Grayling	Fingerling	7,798	Nov 9
	Apache Trout	Subcatchable	4,000	Apr 21
			1,071	Jun 8
1989	Grayling	Fingerling	1,519	Apr 5
	Apache Trout	Subcatchable	5,540	Jun 8

BEAR CANYON LAKE

Year	Species	Size[a]	Number	Stocked
1986	Arctic Grayling	Fingerling	34,000	Oct 8
1989	Cutthroat Trout	Fingerling	25,000	Jun 7
	Rainbow Trout	Subcatchable	2,500	May 17
	Rainbow Trout	Subcatchable	5,000	Jun 22
1990	Arctic Grayling	Catchable	1,503	Oct 23
	Brook Trout	Fingerling	15,000	Jun 11
	Rainbow Trout	Subcatchable	2,500	May 1
			2,000	Jun 11
			3,000	Jul 25
			2,500	Aug 16

[a] Subcatchable fish were between 102 and 152 mm; catchable fish were between 152 and 305 mm.

In spring 1989, the 1986 Arctic grayling cohort (age-3) made a spawning run on lower Lee Valley Creek. Approximately 880,000 eggs were stripped from approximately 500 females that were captured during the egg-take operation. Eggs were fertilized from a similar number of males and taken to the Pinetop Hatchery.

A low lake volume in autumn 1989 precluded stocking of Arctic grayling fingerlings obtained from the 1989 egg take, and they were held over-winter at the hatchery. Most fish from this cohort were killed in March 1990 from collapse of the headbox at the Pinetop Hatchery. No Arctic grayling were stocked in Lee Valley Reservoir or Bear Canyon Lake in 1989.

A spawning run of age-4 Arctic grayling from the 1986 cohort did not occur in 1990. However, approximately 900,000 eggs were collected from the cohort through capture in trap nets. Eggs taken in 1990 were reared at the AGFD's Canyon Creek Hatchery in Gila County, Arizona. Approximately 22,000 fingerlings were stocked in Chevelon Canyon Lake, Coconino County, Arizona, in autumn 1990. Because of continued low lake levels at Lee Valley Reservoir in 1990 and fear of a winterkill, 1,968 age-4 Arctic grayling (~50% of the population) were captured in trap nets and seines in autumn 1990, and 1,503 were released into Bear Canyon Lake and 465 into Ackre Lake (Table 3).

Apache Trout. Initial stockings of Apache trout during the study in Lee Valley Reservoir occurred as 2 plants of subcatchable age-1 fish in April (4,000) and June (1,071) 1988 (Table 3). Most of those fish died over the 1988-89 winter. Another 5,540 subcatchable age-1 Apache trout were planted in May of 1989. All Apache trout were received from the Alchesay National Fish Hatchery near McNary, Apache Co., Arizona.

Creel Surveys

Angler Effort. Angler use (mean number of anglers per day) at Lee Valley Reservoir was greatest during summer strata in all years except 1987, when the April-May stratum was utilized the heaviest (Tables 4-7). There was no similar pattern observable at Bear Canyon Lake (Tables 8-9).

Annual levels of angler pressure at Lee Valley Reservoir were greatest in 1987 and 1989 at approximately 2.4 and 2.7 angler days per surface acre per week, respectively, but they did not reach levels estimated in 1980 and 1986 (3.6 and 4.7 days per acre per week, respectively) (Novy and Lawry 1988). Bear Canyon Lake annual angler use was 1.0 angler days per surface acre per week in 1987, and 0.5 days per acre per week in 1988.

Catch, Harvest and Success Rates. Mean annual angler catch rates of all species at Lee Valley Reservoir increased from 0.81 fish/hr in 1987 to a high of 2.20 fish/hr in 1989, after which the mean rate fell to 1.66 fish/hr (Tables 10-13). These rates are rivaled in Arizona only perhaps by certain sunfish (Centrarchidae) fisheries or frequently stocked put-and-take trout fisheries.

Arctic grayling were first caught in 1987 in July at a rate of 0.27 fish/hr, rose to 1.23 fish/hr in September, and dropped to 0.41 fish/hr in November (Fig. 4), for a mean annual rate of 0.48 fish/hr. Mean annual Arctic grayling catch rates in 1988-90 ranged from 1.58-1.68 fish/hr. Highest Arctic grayling catches in 1988 were recorded in July at 2.43 fish/hr (Fig. 4). In 1989, highest catch rates of 4.39 and 3.45 fish/hr occurred in May and November, respectively. High 1990 rates of 2.42 fish/hr occurred in June (Fig. 4).

Mean annual catch rate for Apache trout in 1988 (the first year stocked) was 0.32 fish/hr. Apache trout catch rates doubled in 1989 to a mean of 0.62 fish/hr. The highest monthly rates for this species occurred in June and July of both years (Fig. 4). The mean annual catch rate for 1990 was less than 0.01 fish/hr.

Mean annual catch rate for brook trout was 0.33 fish/hr in 1987, and declined from a high of 0.60 fish/hr in May to a low of 0.05 fish/hr in November (Fig. 4). Brook trout catch rates declined in 1988 to an annual mean rate of 0.09 fish/hr, again with a decline from highs in the spring (Fig. 4). In 1989 and 1990, brook trout catch rates were less than 0.01 fish/hr.

Mean angler success (proportion of anglers who caught fish) at Lee Valley Reservoir was 50% in 1987, 70% in 1988-89, and 62% in 1990 (Tables 10-13). Highest success in 1987 occurred in September at 69%. Highest rates in 1988 were 88% during June and July. In 1989, highest success (>80%) was in May, June, and November, and in 1990 the greatest angling success was in September (80%). Greatest angler success was usually coincident with highest Arctic grayling catch rates (Fig. 4). Annual mean catch rates of successful anglers ranged from 1.62-3.11 fish/hr (Tables 10-13).

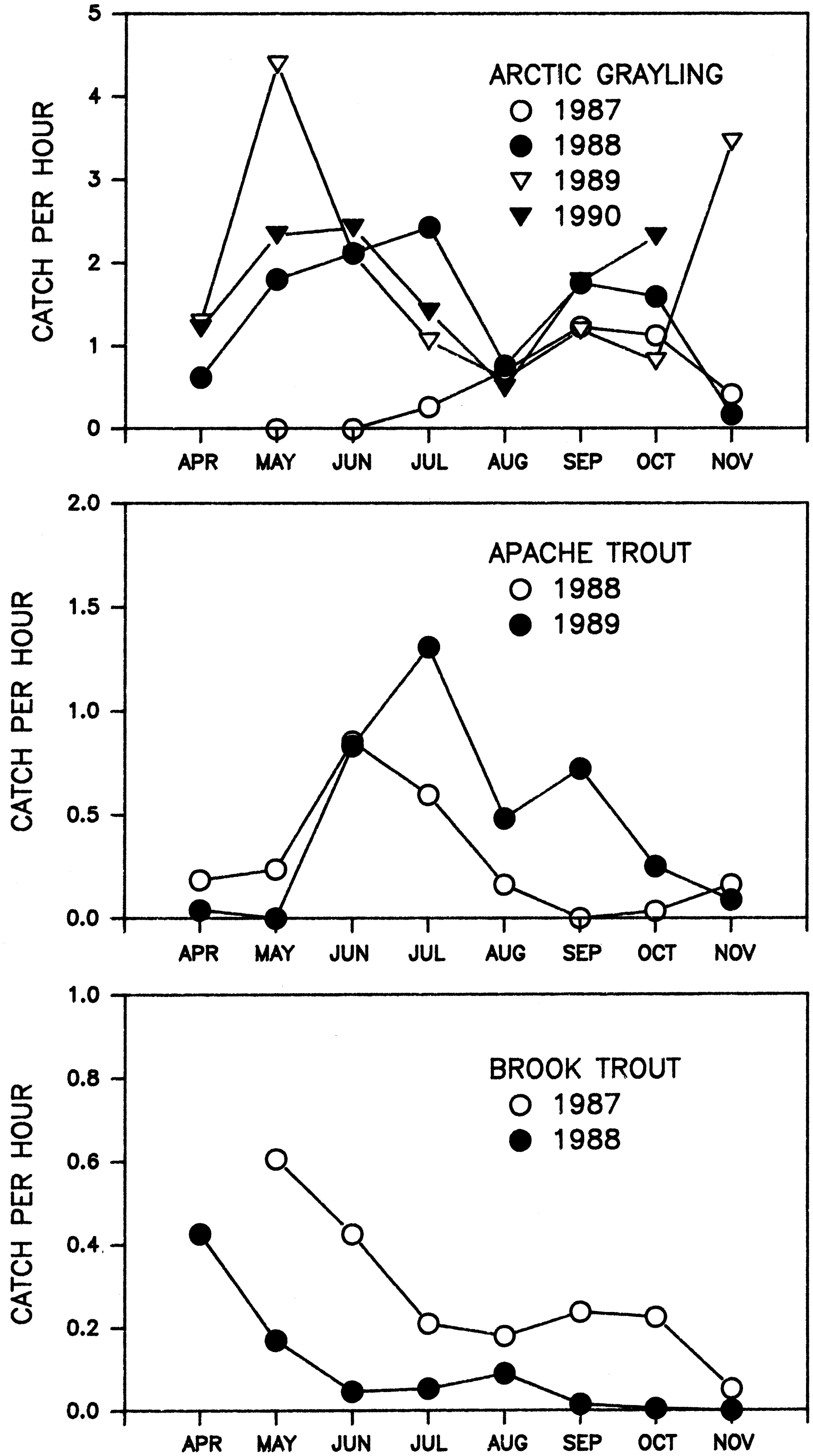


Figure 4. Mean monthly angler catch rates (fish/hr) for Arctic grayling, Apache trout, and brook trout from Lee Valley Reservoir, 1987-90.

Table 4. Stratum angler count statistics and expansions to angler hours from the method of Abramson and Tolladay (1959) for Lee Valley Reservoir in 1987. WD=weekday, WE=weekend (including holidays), AM=morning, PM=afternoon, n=number of days sampled, N_h=number of days in stratum. See text for further explanation.

Season	WD/WE	AM/PM	Mean count	Count SD	n	N_h	Stratum hours	Angler hours	Hours SD	Half-width 95% C.I.
Apr-May	WD	AM	5.13	3.761	5	32	7.50	1,231.99	902.616	64.22%
	WD	PM	3.17	0.707	2	32	6.62	670.83	149.792	30.95%
	WE	AM	9.89	6.993	3	15	7.50	1,112.50	786.690	80.02%
	WE	PM	3.83	1.232	4	15	6.62	380.65	122.348	31.50%
Jun-Aug	WD	AM	5.12	2.198	11	65	7.58	2,523.22	1,083.102	25.37%
	WD	PM	3.58	2.006	11	65	6.09	1,603.75	899.870	33.16%
	WE	AM	3.81	2.108	12	27	7.58	778.85	431.505	31.35%
	WE	PM	3.10	1.969	7	27	6.90	576.64	366.825	47.13%
Sep-Oct	WD	AM	1.81	0.716	7	41	6.75	500.78	198.181	29.32%
	WD	PM	1.70	1.378	7	41	5.63	392.96	318.084	59.96%
	WE	AM	4.33	3.932	3	20	6.75	585.00	530.847	102.69%
	WE	PM	3.33	2.717	5	20	5.63	375.33	305.945	71.45%
Nov	WD	AM	0.00	1.000	0	20	5.63	0.00	112.600	--
	WD	PM	0.67	0.667	1	20	4.83	64.40	64.403	196.00%
	WE	AM	0.00	1.000	1	10	6.13	0.00	61.300	--
	WE	PM	1.67	1.667	1	10	4.83	80.50	80.502	196.00%
All cases			3.20	2.420	80	460	6.46	10,877.40	6,414.610	12.92%

Table 5. Stratum angler count statistics and expansions to angler hours from the method of Abramson and Tolladay (1959) for Lee Valley Reservoir in 1988. Column headings defined in Table 4.

Season	WD/WE	AM/PM	Mean count	Count SD	n	N_h	Stratum hours	Angler hours	Hours SD	Half-width 95% C.I.
Apr-May	WD	AM	0.52	0.690	7	36	7.50	141.43	186.327	97.67%
	WD	PM	0.67	0.667	3	36	6.62	158.89	158.888	113.16%
	WE	AM	2.24	2.898	7	17	7.50	285.36	369.457	95.91%
	WE	PM	2.83	2.531	4	17	6.62	318.86	284.873	87.55%
Jun-Aug	WD	AM	2.47	1.363	10	65	7.57	1,213.74	670.467	34.24%
	WD	PM	4.33	2.468	6	65	6.88	1,937.85	1,103.511	45.57%
	WE	AM	5.58	2.217	4	27	7.57	1,141.17	453.214	38.92%
	WE	PM	3.44	2.143	3	27	6.88	639.83	398.084	70.41%
Sep-Oct	WD	AM	0.83	0.638	4	41	6.75	230.62	176.650	75.07%
	WD	PM	3.08	2.025	4	41	5.63	711.72	467.500	64.37%
	WE	AM	4.00	2.521	6	20	6.75	540.00	340.335	50.43%
	WE	PM	3.00	1.656	4	20	5.63	337.80	186.409	54.08%
Nov	WD	AM	0.33	0.471	4	13	6.18	26.78	37.872	138.61%
	WD	PM	0.00	0.000	1	13	3.87	0.00	0.000	---
	WE	AM	1.50	0.707	2	5	6.18	46.35	21.849	65.33%
	WE	PM	0.00	1.500	0	5	4.87	0.00	36.525	---
All cases			2.18	1.700	69	448	6.50	7,730.40	4,891.961	14.93%

Table 6. Stratum angler count statistics and expansions to angler hours from the method of Abramson and Tolladay (1959) for Lee Valley Reservoir in 1989. Column headings defined in Table 4.

Season	WD/WE	AM/PM	Mean count	Count SD	n	N_h	Statum hours	Angler hours	Hours SD	Half-width 95% C.I.
Apr-May	WD	AM	0.67	0.882	3	49	7.50	245.01	324.098	149.69%
	WD	PM	1.78	1.711	3	49	6.62	576.68	554.852	108.88%
	WE	AM	3.83	1.139	4	21	7.50	603.74	179.330	29.11%
	WE	PM	7.67	4.675	4	21	6.62	1,065.82	649.863	59.75%
Jun-Aug	WD	AM	3.54	1.992	8	65	7.57	1,742.69	979.918	38.97%
	WD	PM	4.85	3.860	11	65	6.88	2,168.25	1,726.058	47.04%
	WE	AM	10.41	6.460	4	27	7.57	2,129.07	1,320.359	60.78%
	WE	PM	7.50	1.894	6	27	6.88	1,393.20	351.904	20.21%
Sep-Oct	WD	AM	0.58	0.569	4	41	6.75	161.43	157.554	95.65%
	WD	PM	0.72	1.290	6	41	5.63	166.71	297.678	142.88%
	WE	AM	8.25	5.174	4	20	6.75	1,113.75	698.463	61.46%
	WE	PM	7.00	4.055	3	20	5.63	788.20	456.616	65.56%
Nov	WD	AM	0.11	0.193	3	16	6.18	10.99	19.034	196.07%
	WD	PM	0.78	1.072	3	16	4.87	60.61	83.491	155.89%
	WE	AM	0.89	0.839	3	10	6.18	54.93	51.844	106.80%
	WE	PM	0.33	0.333	3	10	4.87	16.23	16.232	113.16%
All cases			3.68	3.468	72	498	6.50	12,297.31	7,867.293	14.78%

Table 7. Stratum angler count statistics and expansions to angler hours from the method of Abramson and Tolladay (1959) for Lee Valley Reservoir in 1990. Column headings defined in Table 4.

Season	WD/WE	AM/PM	Mean count	Count SD	n	N_h	Stratum hours	Angler hours	Hours SD	Half-width 95% C.I.
Apr-May	WD	AM	1.78	1.575	3	43	7.50	573.34	508.034	100.27%
	WD	PM	0.60	0.494	5	43	6.62	170.80	140.736	72.23%
	WE	AM	6.78	7.876	3	18	7.50	915.00	1,063.314	131.50%
	WE	PM	3.60	4.663	5	18	6.62	428.98	555.655	113.54%
Jun-Sep	WD	AM	3.48	2.441	7	65	7.58	1,712.72	1,202.582	52.02%
	WD	PM	3.36	2.706	13	65	6.90	1,506.51	1,213.731	43.80%
	WE	AM	5.93	2.686	9	27	7.58	1,212.79	549.778	29.62%
	WE	PM	4.00	2.517	3	27	6.90	745.20	468.843	71.20%
Oct-Dec	WD	AM	2.56	3.097	3	41	6.75	707.26	857.150	137.14%
	WD	PM	31.11	2.219	3	41	5.63	718.14	512.304	80.73%
	WE	AM	3.33	2.547	7	20	6.75	450.00	343.886	61.15%
	WE	PM	4.00	2.957	4	20	5.63	450.00	332.902	72.43%
All cases			3.54	1.640	65	428	6.83	9,590.74	7,748.914	19.79%

Table 8. Stratum angler count statistics and expansions to angler hours from the method of Abramson and Tolladay (1959) for Bear Canyon Lake in 1987. Column headings defined in Table 4.

Season	WD/WE	AM/PM	Mean count	Count SD	n	N_h	Stratum hours	Angler hours	Hours SD	Half-width 95% C.I.
Apr-May	WD	AM	1.56	1.388	3	32	7.45	371.90	330.90	100.68%
	WD	PM	0.67	1.500	1	32	6.67	143.00	320.16	438.81%
	WE	AM	6.17	3.064	2	15	7.45	689.50	342.40	68.82%
	WE	PM	3.67	3.771	2	15	6.67	367.18	377.29	142.41%
Jun-Sep	WD	AM	0.55	0.711	14	86	7.35	346.14	449.68	68.05%
	WD	PM	0.10	0.745	16	86	6.67	55.18	427.52	379.62%
	WE	AM	3.27	1.738	15	36	7.35	864.37	459.74	26.92%
	WE	PM	3.56	2.967	9	36	6.67	854.83	712.44	54.45%
Oct-Dec	WD	AM	0.13	0.298	5	40	6.28	32.66	74.86	200.93%
	WD	PM	0.13	0.298	5	40	5.10	27.19	60.81	196.02%
	WE	AM	0.33	0.471	4	21	6.28	43.52	62.12	139.87%
	WE	PM	0.39	0.680	6	21	5.10	41.77	72.83	139.52%
All cases			1.83	1.469	82	460	6.59	3,837.24	3,690.74	22.53%

Table 9. Stratum angler count statistics and expansions to angler hours from the method of Abramson and Tolladay (1959) for Bear Canyon Lake in 1988. Column headings defined in Table 4.

Season	WD/WE	AM/PM	Mean count	Count SD	n	N_h	Stratum hours	Angler hours	Hours SD	Half-width 95% C.I.
Apr-May	WD	AM	0.60	0.894	5	32	7.45	143.04	213.22	130.66%
	WD	PM	1.33	0.943	2	32	6.67	284.58	201.23	98.00%
	WE	AM	2.40	4.493	5	15	7.45	268.20	502.12	164.10%
	WE	PM	3.89	3.168	3	15	6.67	389.08	316.97	92.19%
Jun-Sep	WD	AM	1.08	1.316	4	86	7.35	684.75	831.78	119.04%
	WD	PM	1.27	1.461	5	86	6.67	726.60	837.83	101.07%
	WE	AM	5.92	3.213	4	36	7.35	1,565.56	850.19	53.22%
	WE	PM	4.05	2.050	7	36	6.67	971.91	492.15	37.51%
Oct-Dec	WD	AM	0.11	0.193	3	40	6.28	27.91	48.36	196.07%
	WD	PM	0.00	0.000	3	40	5.10	0.00	0.00	---
	WE	AM	3.33	3.712	3	21	6.28	439.60	489.51	126.01%
	WE	PM	13.67	19.975	3	21	5.10	1,463.70	2,139.32	165.39%
All cases			2.18	3.451	47	460	6.59	6,964.93	6,922.68	23.28%

Table 10. Mean catch rates (fish/hr; all species) for all anglers and successful anglers; and percent angler success at Lee Valley Reservoir, 1987.

	All anglers			Successful anglers			
Month	Mean	SD	n	Mean	SD	n	Percent successful
Apr	--	--	--	--	--	--	--
May	0.60	1.181	119	1.18	1.434	61	51.3
Jun	0.42	1.350	88	1.28	2.126	29	33.0
Jul	0.47	0.962	73	1.44	1.202	24	32.9
Aug	0.88	1.143	106	1.58	1.114	59	55.7
Sep	1.47	2.643	74	2.13	2.961	51	68.9
Oct	1.35	1.756	60	2.07	1.801	39	65.0
Nov	0.46	0.798	7	1.62	0.228	2	28.6
All cases	0.81	1.572	527	1.62	1.901	265	50.3

Table 11. Mean catch rates (fish/hr; all species) for all anglers and successful anglers; and percent angler success at Lee Valley Reservoir, 1988.

	All anglers			Successful anglers			
Month	Mean	SD	n	Mean	SD	n	Percent successful
Apr	1.24	1.776	30	2.18	1.878	17	56.7
May	2.21	2.227	38	2.80	2.149	30	78.9
Jun	3.01	2.612	42	3.42	2.518	37	88.1
Jul	3.08	3.580	81	3.46	3.618	72	88.9
Aug	1.01	1.536	49	2.06	1.635	24	49.0
Sep	1.77	3.664	38	2.80	4.310	24	63.2
Oct	1.63	2.258	59	2.67	2.363	36	61.0
Nov	0.33	0.286	3	0.50	0.012	2	66.7
All cases	2.09	2.825	340	2.94	2.955	242	71.2

Table 12. Mean catch rates (fish/hr; all species) for all anglers and successful anglers; and percent angler success at Lee Valley Reservoir, 1989.

	All anglers			Successful anglers			
Month	Mean	SD	n	Mean	SD	n	Percent successful
Apr	1.33	1.644	34	2.05	1.641	22	64.7
May	4.40	5.086	59	5.19	5.14	50	84.7
Jun	2.92	3.322	64	3.53	3.346	53	82.8
Jul	2.36	4.460	103	3.29	4.970	74	71.8
Aug	1.08	2.224	115	1.86	2.660	67	58.3
Sep	1.91	2.183	67	2.50	2.182	51	76.1
Oct	1.07	1.348	32	2.02	1.220	17	53.1
Nov	3.54	2.728	16	4.36	2.333	13	81.2
All cases	2.20	3.481	490	3.11	3.782	347	70.8

Table 13. Mean catch rates (fish/hr; all species) for all anglers and successful anglers; and percent angler success at Lee Valley Reservoir, 1990.

	All anglers			Successful anglers			
Month	Mean	SD	n	Mean	SD	n	Percent successful
Apr	1.26	2.028	38	2.23	2.269	21	55.3
May	2.33	3.696	62	3.71	4.086	39	62.9
Jun	2.42	3.381	64	3.37	3.569	46	71.9
Jul	1.43	1.973	86	2.27	2.070	54	62.8
Aug	0.50	0.792	84	1.16	0.834	36	42.9
Sep	1.78	1.992	35	2.22	1.994	28	80.0
Oct	2.32	2.351	55	3.12	2.220	41	74.5
Nov	--	--	--	--	--	--	--
All cases	1.66	2.543	424	2.65	2.779	265	62.5

Angler harvest rates (number of fish kept/hr) at Lee Valley Reservoir were greatest in 1987 (0.22), and consisted only of brook trout. Estimated harvest in 1987 was 2,400 (Table 14). Total harvest rates fell to 0.06 fish/hr in 1988; only approximately 450 fish were harvested that year. Harvest rates in 1989 and 1990 rose to 0.11 and 0.12 fish/hr, respectively, and were comprised solely of Arctic grayling. Mean harvest estimates in those years were 1,332 and 1,164 fish, respectively (Table 14). Apache trout never grew to legal size during the course of study, although a few were harvested illegally in 1988 (annual mean rate <0.01 fish/hr).

Bear Canyon Lake catch rates exceeded 0.18 fish/hr in only 1 month during 1987-88 (Tables 15-16). The majority of catches were of brook trout. No catches were recorded in the last 4 months of 1988 based on interviews of 77 anglers. Mean annual angler success rates were 6.1 and 4.5%, respectively, for 1987 and 1988 (Tables 15-16). Mean annual catch rates of successful anglers were 1.25 and 1.12 fish/hr for 1987 and 1988 (Tables 15-16). Harvest rates in 1987 and 1988 were 0.04 and 0.02 fish/hr, and were comprised of brook trout in 1987 (155), and brook trout (107) and Arctic grayling (54) in 1988.

Angler Interviews. Summaries of the responses of anglers to management questions at Lee Valley Reservoir and Bear Canyon Lake between 1987 and 1990 are presented in Appendix A. In general, a sizeable majority of anglers responded favorably to the gear restrictions, bag limits, species choice, and fishing trip quality at Lee Valley Reservoir. Dissatisfaction with many of those same issues was expressed by Bear Canyon Lake anglers.

Age and Growth

Lee Valley Reservoir. Mean length and weight of the initial stocking of fingerling Arctic grayling in November 1986 at Lee Valley Reservoir were 61 mm (total length) and 2 g. Growth of this cohort was followed from May 1987 through October 1990, although growth of the 1988 cohort made the two difficult to distinguish by 1990 (Figures 5-8). Mean length of the 1986 Arctic grayling age class was 76 mm following ice-out in May 1987, and by the end of the 1987 ice-free season, this cohort had grown to a mean length of 236 mm (Table 17, Fig. 5). Mean weights were 3.5 g in May and 107.8 g in November. Mean growth rates were 26.6 mm/month and 17.4 g/month.

In May 1988, mean length and weight of this cohort (now age-2) were 272 mm and 188 g, a mean over-winter growth of 36 mm and 80 g (Table 17, Fig. 6). The 1986 age class attained a mean length of 301 mm (just under the legal size limit) by November 1988, but a portion of the population was being harvested at that time (Table 14). Mean weight in November was 219 g, a mean gain of approximately 5 g/month since May 1988. Corresponding mean growth in length over this period was 5 mm.

Table 14. Species harvest rates, angler effort, and harvest estimates for Lee Valley Reservoir, 1987-90.

		Harvest rate			X	Angler hours			=	Harvest	
Year	Species	Mean	SD	n		Mean	SD	n		Mean	Half-width 95% C.I.
1987	Brook Trout	0.22	0.568	527		10,877	6,414.6	80		2,404	811.0
1988	Brook Trout	0.04	0.200	340		7,730	4,892.0	69		316	261.5
	Grayling	0.02	0.120	340		7,730	4,892.0	69		132	156.6
1989	Grayling	0.11	0.292	490		12,297	7,867.3	72		1,332	675.1
1990	Grayling	0.12	0.360	425		9,591	7,748.9	64		1,164	504.6

Table 15. Mean catch rates (fish/hr; all species) for all anglers, successful anglers, and percent angler success at Bear Canyon Lake, 1987.

	All anglers			Successful anglers			
Month	Mean	SD	n	Mean	SD	n	Percent successful
Apr	--	--	--	--	--	--	--
May	0.08	0.347	51	1.41	0.468	3	5.9
Jun	0.18	0.735	102	1.71	1.615	11	10.8
Jul	0.04	0.216	81	1.00	0.655	3	3.7
Aug	0.04	0.227	117	1.02	0.799	4	3.4
Sep	0.05	0.207	85	0.73	0.352	6	7.1
Oct	0.02	0.090	23	0.43	0.000	1	4.3
Nov	0.00	0.000	2	0.00	0.000	0	0.0
All cases	0.08	0.406	461	1.25	1.138	28	6.1

Table 16. Mean catch rates (fish/hr; all species) for all anglers, successful anglers, and percent angler success at Bear Canyon Lake, 1988.

	All anglers			Successful anglers			
Month	Mean	SD	n	Mean	SD	n	Percent successful
Apr	0.52	0.740	6	1.04	0.751	3	50.0
May	0.12	0.388	43	1.28	0.348	4	9.3
Jun	0.06	0.346	30	1.89	0.000	1	3.3
Jul	0.02	0.143	90	0.74	0.331	3	3.3
Aug	0.00	0.000	21	0.00	0.000	0	0.0
Sep	0.00	0.000	28	0.00	0.000	0	0.0
Oct	0.00	0.000	26	0.00	0.000	0	0.0
Nov	0.00	0.000	2	0.00	0.000	0	0.0
All cases	0.05	0.257	246	1.12	0.535	11	4.5

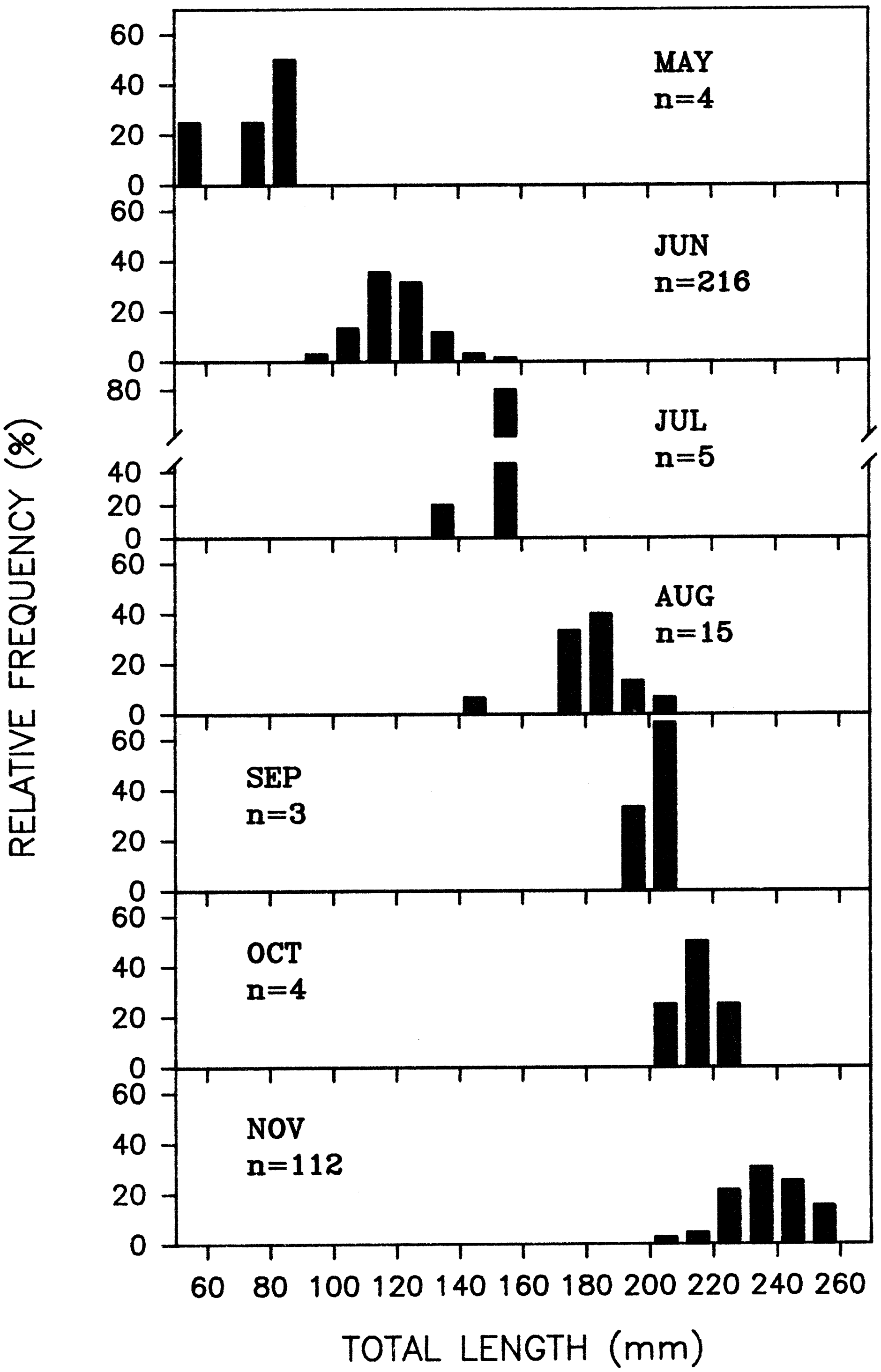


Figure 5. Monthly length-frequency histograms of age-1 Arctic grayling from Lee Valley Reservoir, 1987.

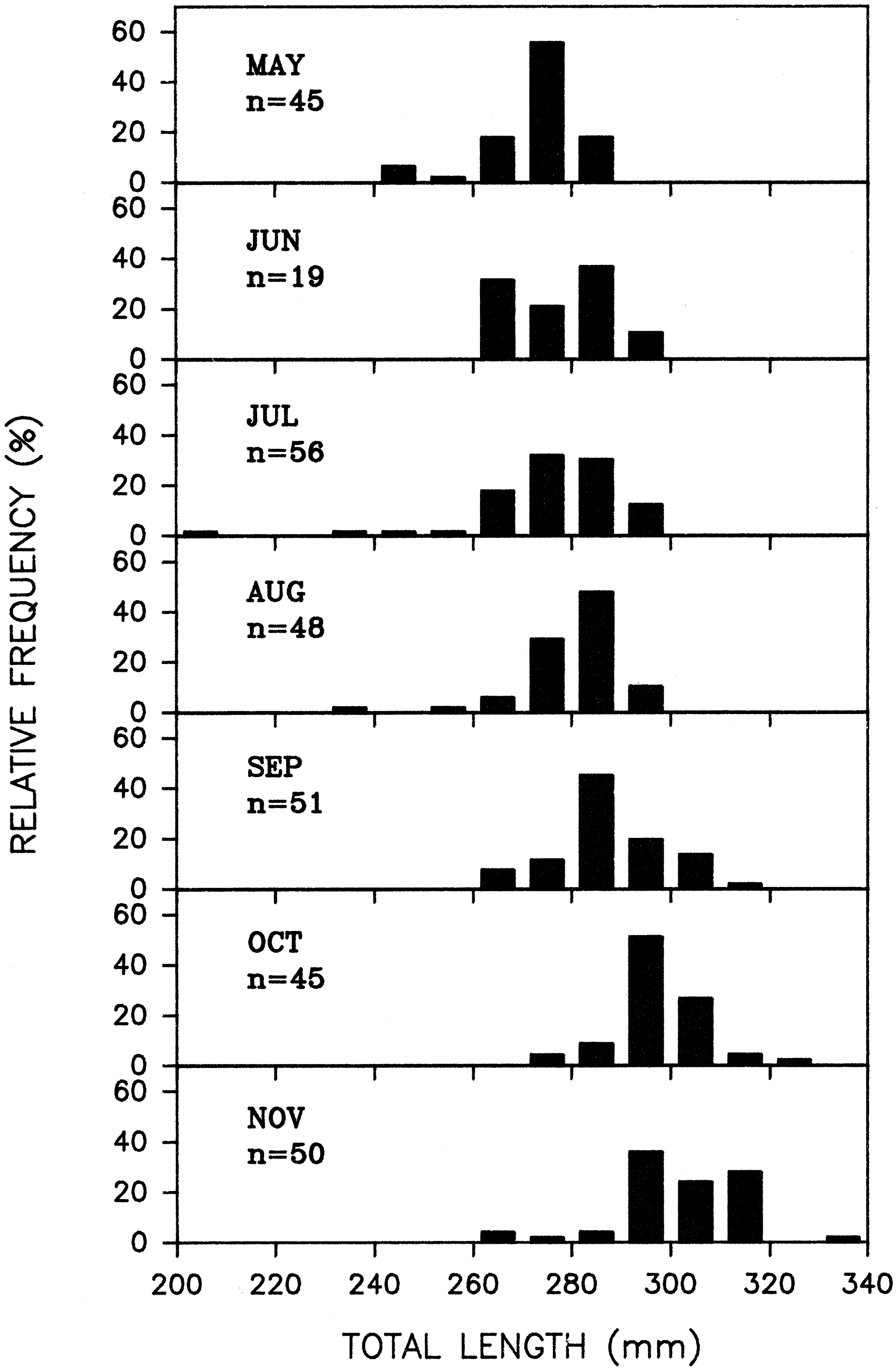


Figure 6. Monthly length-frequency histograms of age-2 Arctic grayling from Lee Valley Reservoir, 1988.

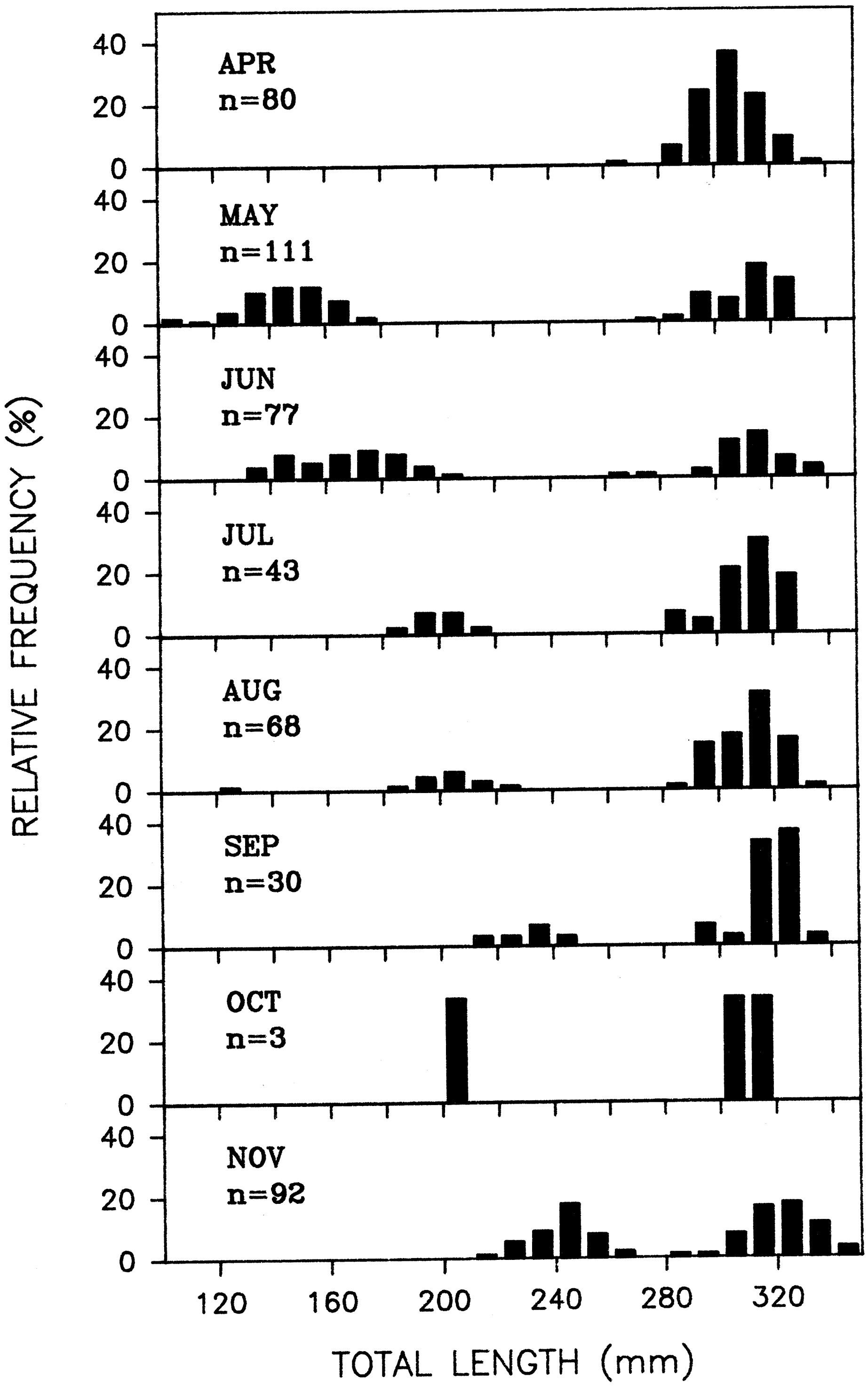


Figure 7. Monthly length-frequency histograms of age-1 and age-3 Arctic grayling from Lee Valley Reservoir, 1989.

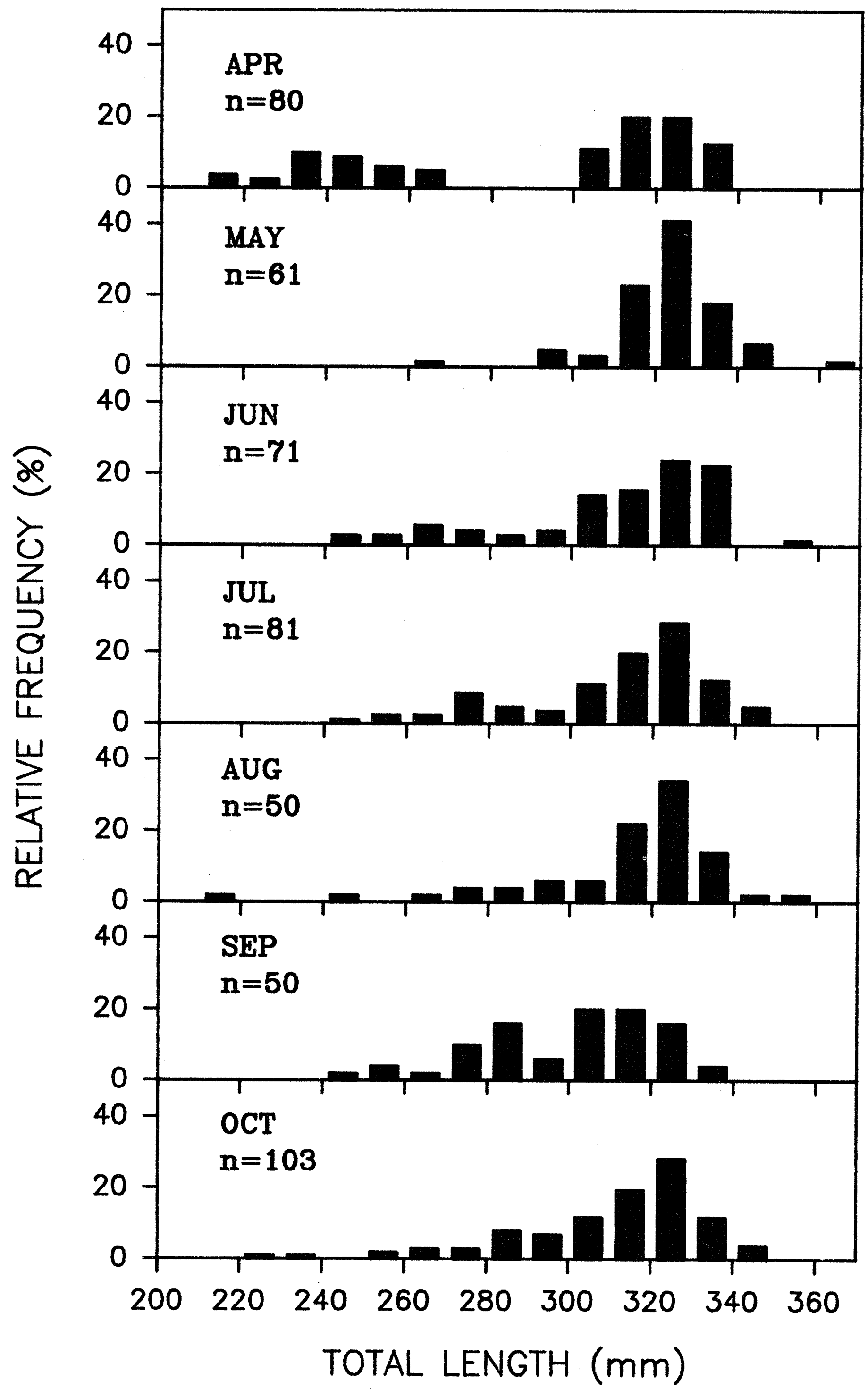


Figure 8. Monthly length-frequency histograms of age-2 and age-4 Arctic grayling from Lee Valley Reservoir, 1990.

Table 17. Mean monthly total lengths and weights of the 1986 Arctic grayling age class from Lee Valley Reservoir, 1987-90.

		Length (mm)			Weight (g)		
Year	Month	Mean	SD	n	Mean	SD	n
1987	May	76	12.9	4	3	1.0	4
	Jun	119	11.2	216	14	4.6	109
	Jul	149	10.3	5	30	4.6	3
	Aug	181	12.3	15	50	12.2	15
	Sep	199	2.5	3	68	2.0	3
	Oct	213	8.3	4	83	12.5	4
	Nov	235	12.2	112	107	18.0	112
1988	May	271	9.2	45	187	40.7	45
	Jun	276	10.3	19	175	24.4	19
	Jul	275	15.4	56	--	--	--
	Aug	273	41.7	48	177	24.7	47
	Sep	287	10.9	51	194	24.3	51
	Oct	290	45.2	45	212	19.7	44
	Nov	301	13.2	50	218	27.2	50
1989	Apr	303	11.5	80	223	24.2	80
	May	310	12.7	56	226	25.4	56
	Jun	310	14.6	32	234	29.5	32
	Jul	310	11.5	35	251	25.8	35
	Aug	310	10.4	56	230	29.3	56
	Sep	316	9.5	25	245	31.1	25
	Oct	309	12.0	2	224	11.3	2
	Nov	320	12.0	53	251	30.0	53
1990	Apr	319	10.5	51	254	22.4	51

Mean gain in weight of the 1986 Arctic grayling cohort over the winter of 1988-89 was 4 g. Mean gain in length between November 1988 and April 1989 was 3 mm (Table 17). Mean growth between April and November 1989 was 16 mm and 29 g. Mean lengths remained constant between May and August, and mean weight dropped 21 g in August from the previous month. During this same period, a stocking of 1,519 age-1 Arctic grayling grew more than 16 mm/month and almost 14 g/month (Fig. 7, Table 18), slightly below the rates observed for age-1 Arctic grayling in 1987.

The 1986 Arctic grayling age class added a mean of 3 g over the 1989-90 winter; growth in length was negligible (Table 17). Tracking of growth of the 1986 cohort through 1990 was not possible due to length overlaps of the 1988 Arctic grayling cohort, but Fig. 8 suggests that mean growth in length was low. Frequency

Table 18. Mean monthly total lengths and weights of the 1988 Arctic grayling age class from Lee Valley Reservoir, 1989-90.

		Length (mm)			Weight (g)		
Year	Month	Mean	SD	n	Mean	SD	n
1989	May	142	25.8	55	28	10.1	55
	Jun	132	69.0	45	31	19.5	45
	Jul	199	8.0	8	68	7.6	8
	Aug	194	26.6	12	83	38.6	12
	Sep	231	11.2	5	102	12.0	5
	Oct	205	00.0	1	60	00.0	1
	Nov	241	11.0	39	110	16.3	39
1990	Apr	241	15.1	29	106	21.6	29

distributions of weights also indicated few, if any, gains. It was similarly not possible to monitor the 1988 cohort in 1990, with the exception that overwinter growth between November 1989 and April 1990 was negligible (Table 18).

Maximum recorded length of Arctic grayling in Lee Valley Reservoir during the study was 365 mm. Mean lengths of angler-harvested fish were 306, 317, and 326 mm in 1988, 1989, and 1990, respectively.

Mean length and weight gains of age-1 Apache trout stocked in 1988 were 86 mm and 86 g over 6 months, to a November mean length and weight of 234 mm and 127 g (Fig. 9, Table 19). Growth rates of age-1 Apache trout stocked into Lee Valley Reservoir in 1989 were similar to those planted in 1988; mean growth over 5 months was 86 mm and 80 g, and mean length and weight by November were 227 mm and 118 g (Fig. 10, Table 19).

Bear Canyon Lake. The morphometry of Bear Canyon Lake severely restricted sampling with trap nets, and suitable seining areas were nonexistent. Insufficient Arctic grayling were captured to determine accurate estimates of growth. Two specimens captured in May 1987 were 69 and 89 mm, a single specimen captured in July 1987 was 134 mm, and mean length of 6 specimens captured in August 1987 was 162 mm, with a range of 158-165 mm. Catches of Arctic grayling from Bear Canyon Lake in 1988 were restricted to April, July, and November, at which times mean lengths were 231, 258, and 272 mm, respectively. These lengths-at-age were approximately 10% less than Lee Valley Reservoir Arctic grayling (Table 17).

Population Estimates, Mortality, and Equilibrium Yield

The Arctic grayling population estimate in 1988 at Lee Valley Reservoir was 11,969 (95% confidence limits 9,744-14,682; Table 20), 28% survival since November 1986. Since no mortality due to fishing (harvest) was observed during this period, losses can be attributed solely to natural mortality. In spring 1989, the population estimate was 8,189 (6,228-10,767), 68% survival since spring 1988. A small portion of this reduction in population size was attributable to angler harvest (Table 14). The final estimate made for Arctic grayling at Lee Valley Reservoir (1990) showed 5,355 (4,719-6,077) fish of the 1986 year class remaining, 65% survival from 1989. Approximately 47% of 1990 annual mortality was attributable to removal by angling (Table 14).

Approximately 1,865 (1,646-2,113) of 5,071 Apache trout stocked into Lee Valley Reservoir in spring 1988, survived until October 1988 (Table 20). All deaths were attributable to natural (or hooking) mortality. If expanded to an annual mortality rate, 97-112% of the fish would be dead at the end of 1 year. Inadequate numbers of

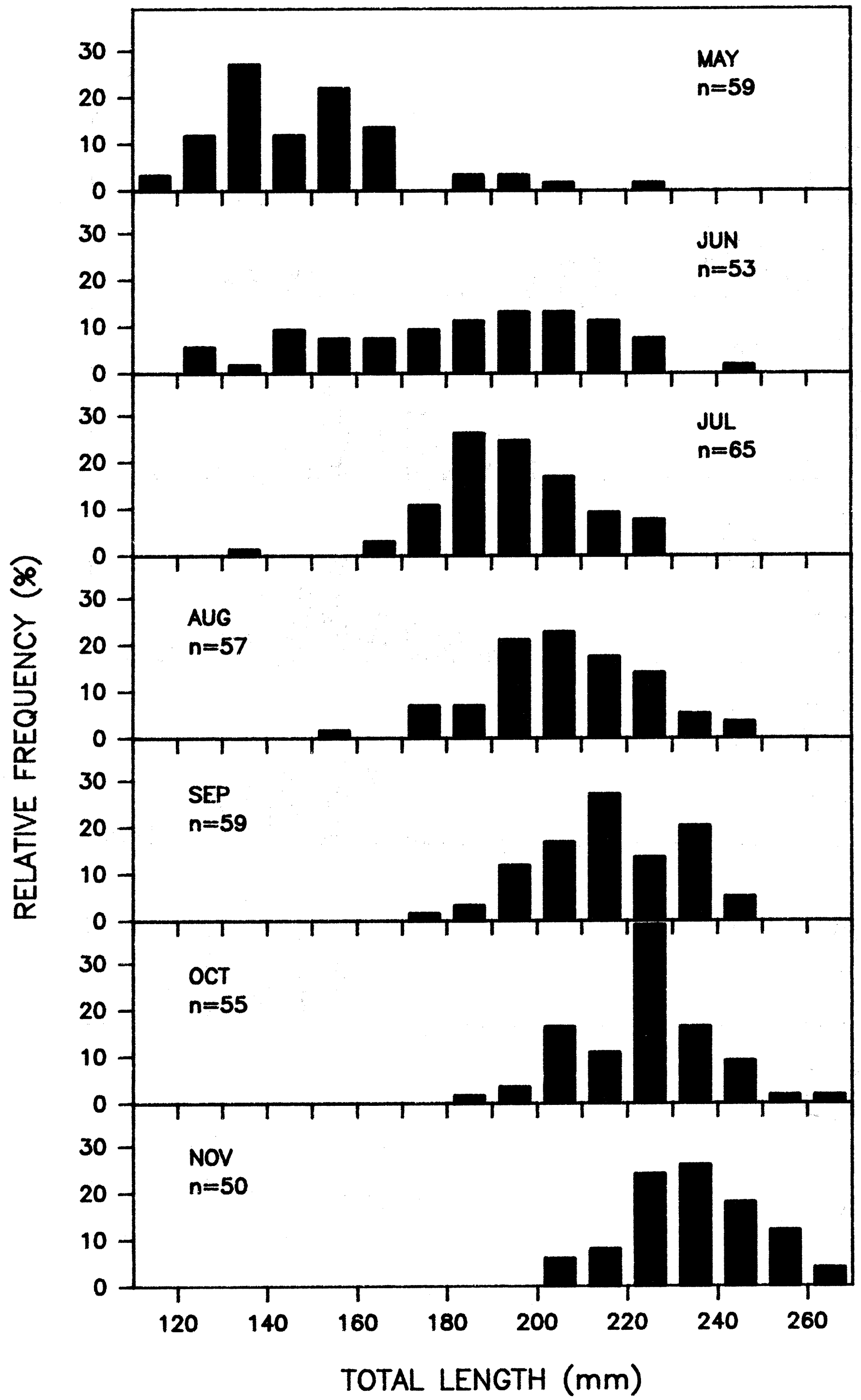


Figure 9. Monthly length-frequency histograms of age-1 Apache trout from Lee Valley Reservoir, 1988.

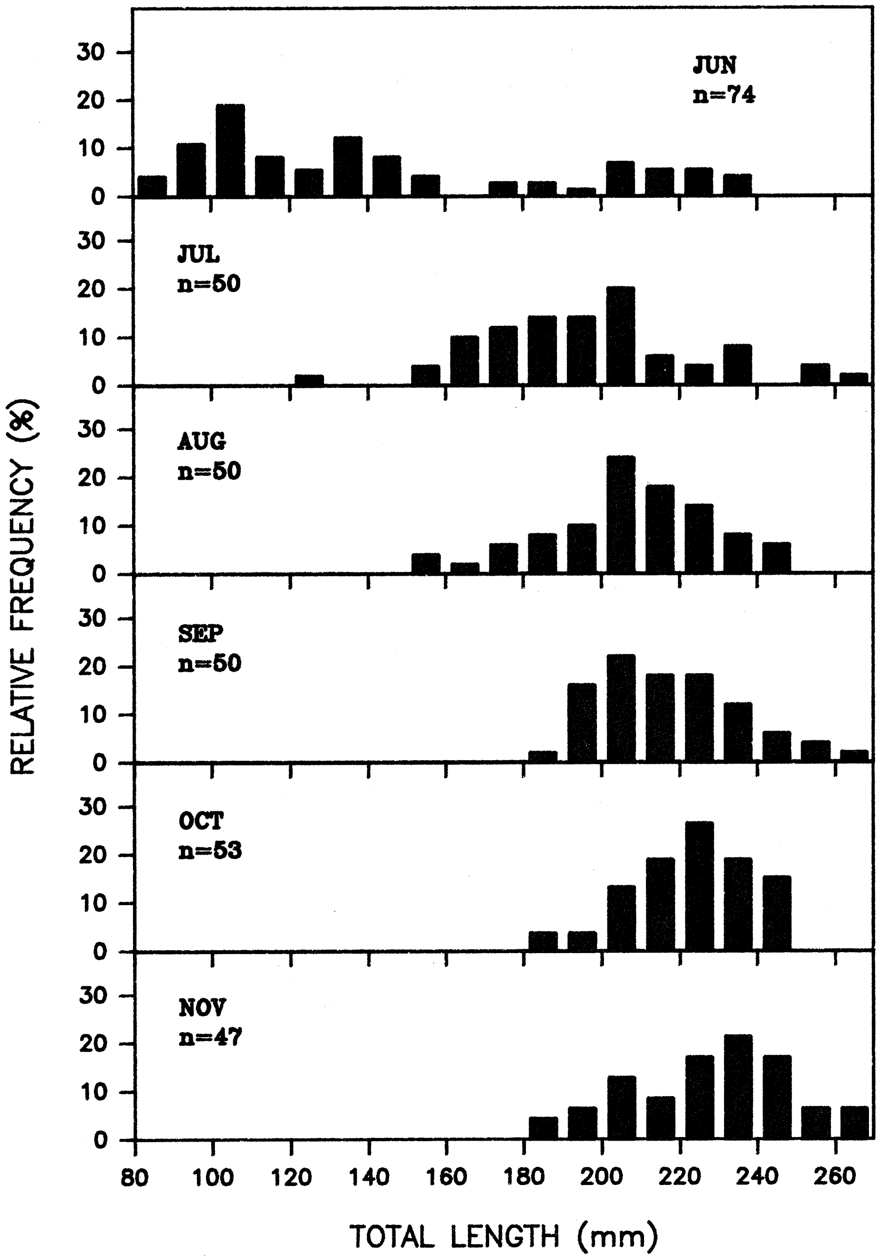


Figure 10. Monthly length-frequency histograms of age-1 Apache trout from Lee Valley Reservoir, 1989.

Table 19. Monthly mean lengths and weights of the 1987 and 1988 Apache trout age classes stocked in Lee Valley Reservoir in 1988 and 1989, respectively.

		Length (mm)			Weight (g)		
Year	Month	Mean	SD	n	Mean	SD	n
1988	May	148	21.6	59	40	21.9	57
	Jun	182	30.1	53	64	30.4	53
	Jul	193	16.6	65	--	--	--
	Aug	205	18.2	57	83	20.3	57
	Sep	215	16.2	59	97	23.3	39
	Oct	222	15.6	55	107	22.6	55
	Nov	234	15.6	50	126	28.3	50
1989	Jun	126	62.7	83	37	44.1	83
	Jul	180	58.0	54	83	51.5	54
	Aug	206	22.8	50	99	31.6	50
	Sep	216	17.5	50	110	31.7	50
	Oct	221	15.2	53	109	23.4	53
	Nov	227	20.7	47	117	33.6	47

Table 20. Peterson mark-recapture estimates for Arctic grayling and Apache trout from Lee Valley Reservoir, 1988-90.

Species	Time of estimate	No. marked	No. examined for marks	No. recaptures	Population (N=MC/R)	95% confidence interval
Grayling	May 1988	1,676	657	92	11,969	9,744 - 14,682
	May 1989	1,600	261	51	8,189	6,228 - 10,767
	April 1990	947	1,357	240	5,355	4,719 - 6,077
Apache Trout	October 1988	816	562	246	1,865	1,646 - 2,113

Arctic grayling were sampled at Bear Canyon Lake to make population estimates.

Initial over-winter mortality appeared to be the largest single mortality event in the history of the Lee Valley Reservoir 1986 Arctic grayling cohort (Table 21). Instantaneous growth rates were greatest during the first year, and maximum weight of the stock occurred in the second year. We estimated total yield to the angler at the end of 1990 at 546 kg and 2,618 fish (Table 14).

Water Quality

Lee Valley Reservoir. Water temperatures recorded at Lee Valley Reservoir ranged from 1-19°C; some weak summer thermal stratification was observed in this shallow (<6 m) body of water (Fig. 11). Dissolved oxygen levels exhibited few consistent patterns across years (Fig. 12).

Table 21. Instantaneous rates of growth (G), natural mortality (M), and fishing mortality (F) estimates for Arctic grayling from Lee Valley Reservoir, 1986-1990, according to seasonal incidence; and the computation of equilibrium yield in successive fishing seasons. See text for further explanation.

Date	Age	Total Length	Wt	$\log_e$(wt)	G	M	F	G-F-M	Weight Change Factor	N	Weight of Stock (kg)	Average wt (kg)	Yield wt	Yield N
Nov 86	0.5	61	2	0.693						43,000	86			
					0.693	0.60	0.00	0.093	1.097			78	0.0	0
May 87	1.0	76	4	1.386						17,200	69			
					3.296	0.13	0.00	3.166	23.712			843.0	0.0	0
Nov 87	1.5	235	108	4.682						14,964	1,617			
					0.554	0.20	0.00	0.354	1.425			1,934.0	0.0	0
May 88	2.0	272	188	5.236						11,971	2,251			
					0.153	0.13	0.01	0.013	1.013			2,253.0	22.5	120
Nov 88	2.5	301	219	5.389						10,295	2,255			
					0.018	0.20	0.00	-0.182	0.834			2,083.0	0.0	0
May 89	3.0	304	223	5.407						8,236	1,836			
					0.122	0.10	0.16	-0.138	0.871			1,692.5	270.8	1,318
Nov 89	3.5	320	252	5.529						6,095	1,536			
					0.012	0.12	0.00	-0.108	0.898			1,452.0	0.0	0
May 90	4.0	320	255	5.541						5,363	1,368			
					~0.0	0.10	0.22	-0.320	0.726			1,149.0	252.8	1,180
Nov 90	4.5	~320	~255	~5.541						3,647	~930			

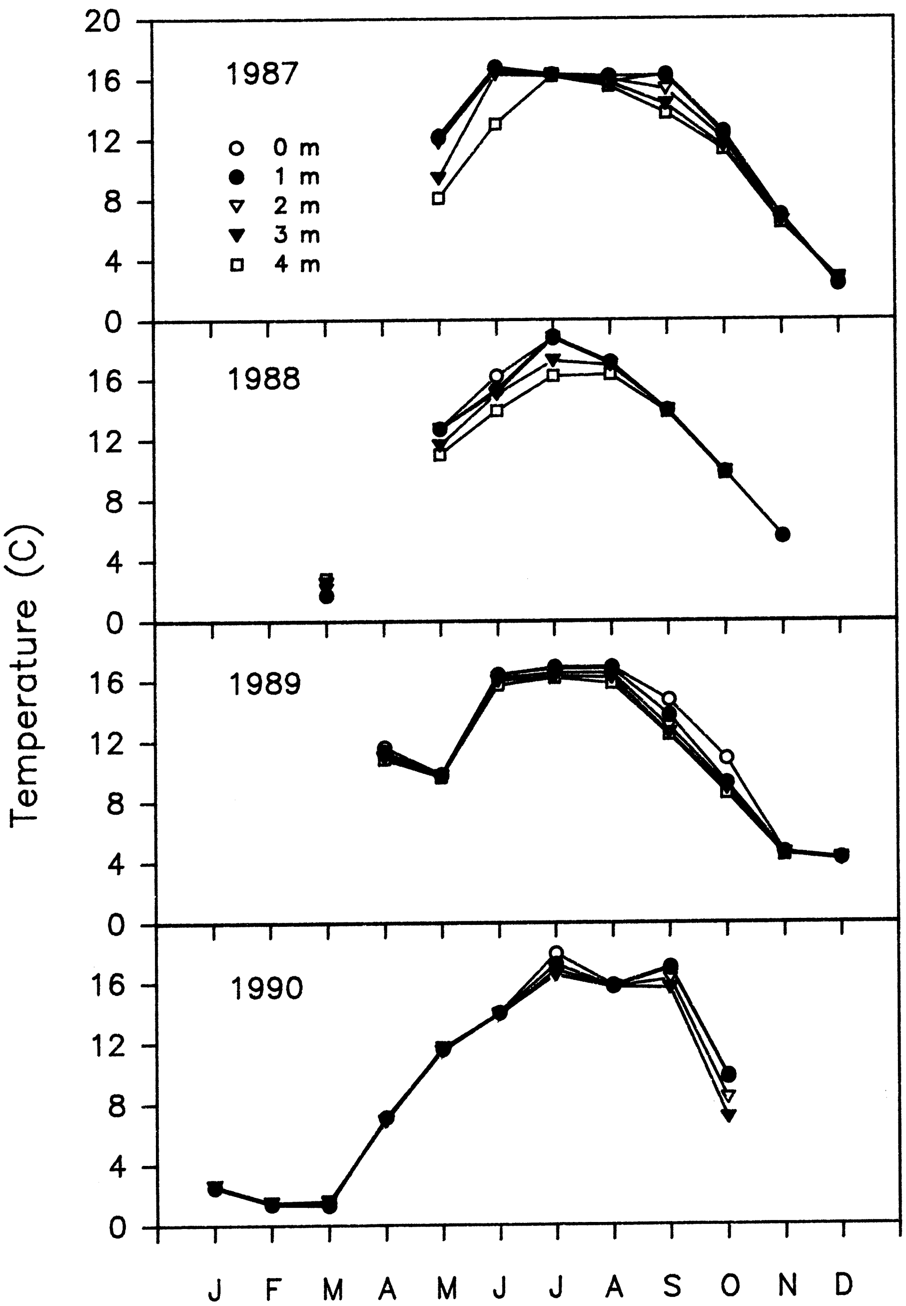


Figure 11. Water temperature profiles from Lee Valley Reservoir, 1987-90.

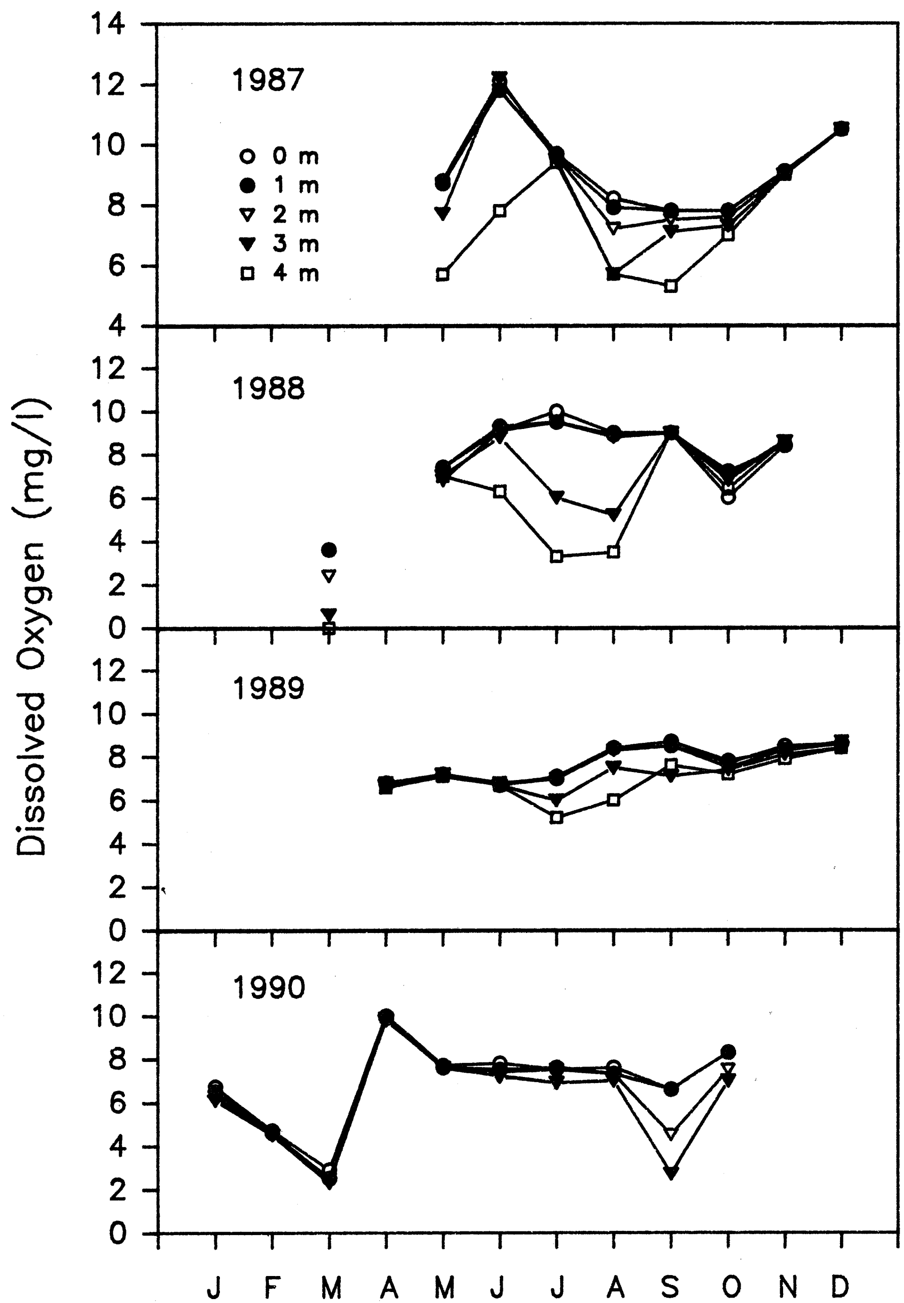


Figure 12. Dissolved oxygen profiles from Lee Valley Reservoir, 1987-90.

Oxygen levels under the ice in March during the 2 years of measure fell to levels marginal for fish survival (<4 mg/l); some winterkill of Arctic grayling and Apache trout was observed during the course of study.

pH levels in Lee Valley Reservoir ranged between 6.0 and 9.6 (Fig. 13). Highest levels were

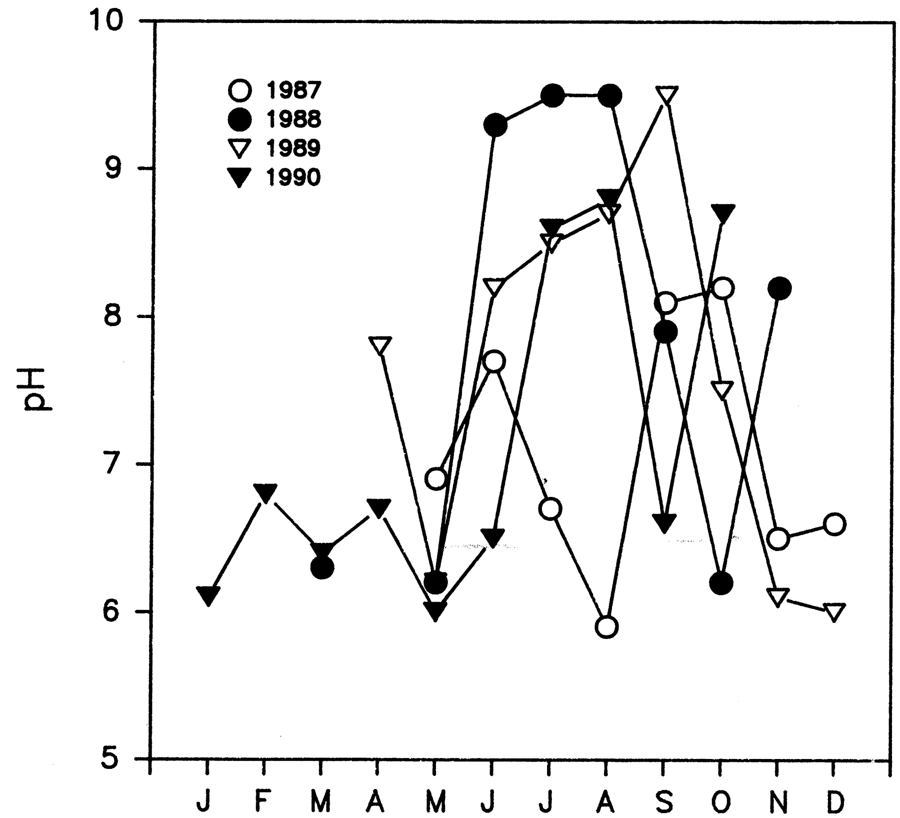


Figure 13. Surface pH from Lee Valley Reservoir, 1987-90.

coincident with observable algal blooms. The 3-month period in 1988 when pH remained above 9.0 likely caused mortality of a large proportion of the Apache trout population; Arctic grayling ceased growth during the same period (Table 17).

Conductivities ranged between 40-61 µS/cm, with highest levels recorded during winter 1989-90, when lake levels were low. Secchi depth measurements ranged from 0.4-3.7 m. Water clarity was generally lowest immediately following ice-out in the spring. The highest recorded secchi depth occurred prior to ice-over in November 1989.

Bear Canyon Lake. Summer temperature stratification at Bear Canyon Lake in 1987 was pronounced (Fig. 14). Monthly oxygen profiles revealed the presence of a relatively oxygen-rich lens near the thermocline at 8-11 m during most months (Fig. 14). Epilimnion oxygen levels always exceeded 6 mg/l. Winter or summer fish kills resulting from low oxygen have not been reported from Bear Canyon Lake.

Surface pH ranged from 5.7-6.1 with the exception of July, when pH rose to 7.0 (Fig. 14). Conductivities ranged from 28-33 µS/cm.

Trophic Relationships

Zooplankton. Zooplankton samples collected in 1983-85 from Lee Valley Reservoir were dominated by *Daphnia* (Appendix B). Cyclopoid copepod adults and nauplii exhibited low densities, but rotifers and other cladocerans and copepods for the most part were poorly represented. An increase in rotifer density and a decrease in *Daphnia* density occurred in 1987. Also in 1987, *Bosmina* and cyclopoid copepod densities increased substantially above pre-1987 levels.

Daphnia densities increased to near pre-1987 levels in 1988-90, while rotifer densities in 1988 decreased to near pre-1987 levels (Appendix B). Rotatoria densities returned to pre-1987 levels in July 1989, where they remained through 1990. *Bosmina* numbers fluctuated, ranging from absent in March 1988 samples to as high as 1,101/l in September 1990, the highest density of any taxonomic group observed. Total zooplankton densities usually followed seasonal trends observed for *Daphnia*.

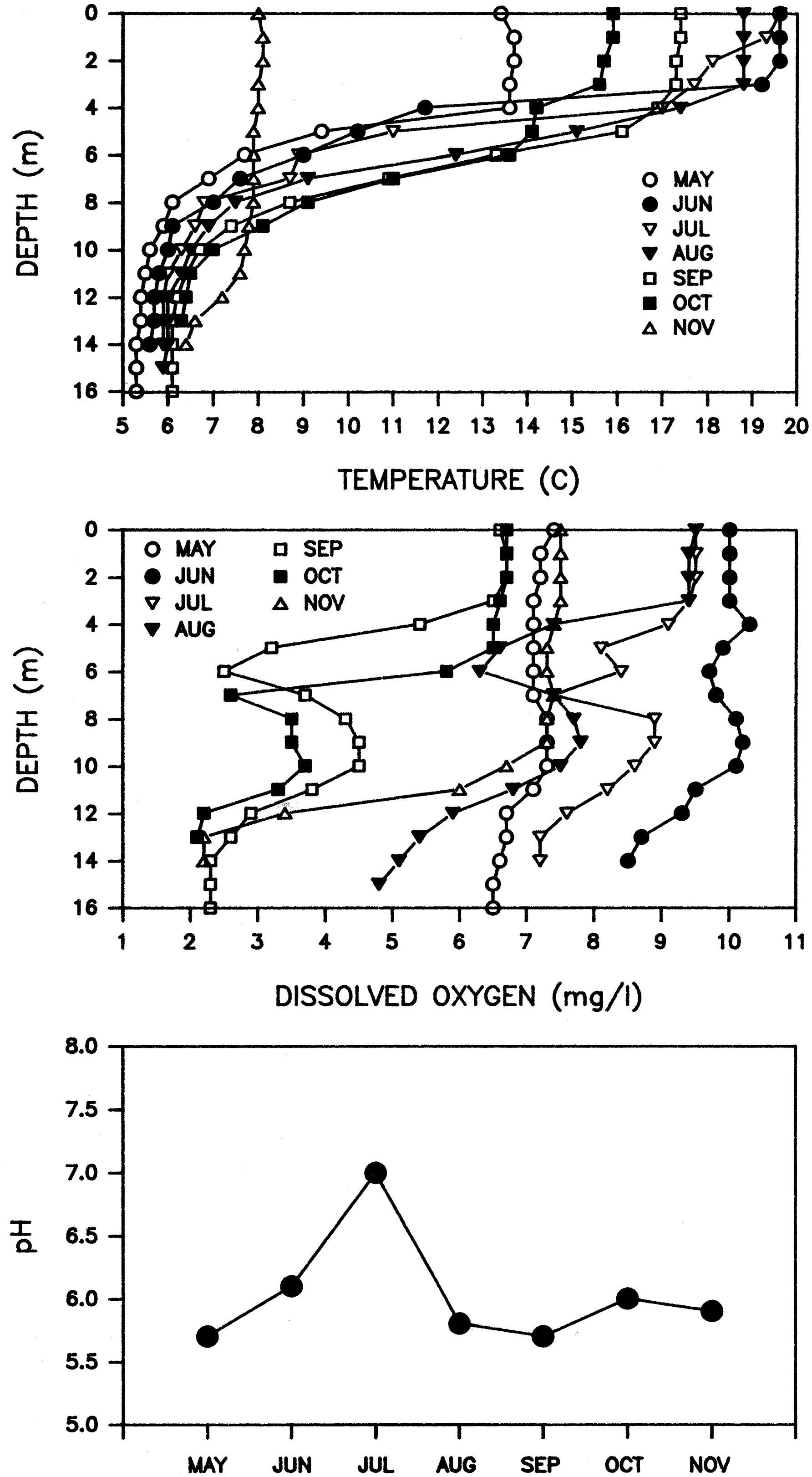


Figure 14. Temperature and dissolved oxygen profiles, and surface pH from Bear Canyon Lake, 1987.

Zooplankton densities in Bear Canyon Lake were approximately an order of magnitude less than those from Lee Valley Reservoir (Appendix B). Cyclopoid copepods were numerically dominant, followed by *Bosmina* and *Daphnia*. Chydorid cladocerans were not collected from Bear Canyon Lake.

Benthic Invertebrates. In Lee Valley Reservoir, most dredge samples were dominated numerically by oligochaete worms, with densities up to 11,644 individuals/m^2 at mid-reservoir (Appendix C). Fingernail clams (*Pisidium* sp.) also reached relatively high population densities, ranging from 0-1,544/m^2. *Hyalella azteca* densities ranged from 0-1,328/m^2, and leeches (Hirudinea) ranged from 0-1,896/m^2. Both the lowest and highest total invertebrate densities were sampled at mid-reservoir, ranging from 222 individuals/m^2 in August 1988 to 12,578/m^2 in August 1989.

Snail (*Valvata humeralis*) densities were highest over mostly gravel bottoms along the north transect. Oligochaete densities were highest on clay bottoms at the mid-reservoir site. However, only *Pisidium* ($P<0.01$) and the lumped "other" invertebrates category ($P<0.05$) displayed significant differences in ranked densities among transects. *Pisidium* densities were highest along the north transect, and "other" invertebrates densities were highest at mid-reservoir (Appendix C).

Fish Feeding Habits. Frequently-occurring items in Arctic grayling stomachs at Lee Valley Reservoir in 1987-89 included adult and immature Diptera and Cladocera (Appendix D). Nematodes were common in stomachs in all years but 1989. Plant material was frequently ingested by the 1986 cohort (ages 1-3), but not by the 1988 cohort (age-1). *Hyalella azteca* was common in all but 1989 age-1 Arctic grayling stomachs. Snails were found in significant numbers only in stomachs of age-3 Arctic grayling. Fish were never utilized by Arctic grayling at Lee Valley Reservoir.

Apache trout stomach contents from Lee Valley Reservoir in 1988-89 were primarily comprised of unidentified material, cladocerans, unidentified dipterans, amphipods, fish (probably fathead minnows), plant detritus, and inorganic materials (Appendix D). To our knowledge, ours are the first records of piscivory for Apache trout.

Food habits of 12 age-1 Arctic grayling in Bear Canyon Lake in 1987 were similar to those observed for Arctic grayling in Lee Valley Reservoir, except that inorganic materials were conspicuous in stomachs from Bear Canyon Lake (Appendix D). Brook trout in Bear Canyon Lake fed primarily on beetles, crayfish (*Procambarus clarki*), and adult dipterans. They also showed a relatively high use of fish and fish eggs in their diet. Brook trout in Lee Valley Reservoir relied less on adult Diptera and Coleoptera compared to Bear Canyon Lake, and more on snails and amphipods (Appendix D).

Diet Overlap. When using relative weights of identifiable food categories in the stomachs, resource-overlap indices between age-2 Arctic grayling and age-1 Apache trout in 1988 were 0.61 for May, 0.41 for August, and 0.68 for November in Lee Valley Reservoir. When using relative volumes, values were 0.63, 0.51, and 0.67, respectively. The shift in food resource utilization apparent in August was primarily from differential consumption of cladocerans, and to a lesser extent, amphipods. Cladocera accounted for a larger percentage of relative weight and volume in Apache trout stomachs in August, while Arctic grayling consumed more *Hyalella* than Apache trout during that period (Appendix D).

In 1989, dietary overlap based on relative weights (values based on relative volume in parentheses) of fish and invertebrate food categories between age-1 Arctic grayling and age-1 Apache trout in Lee Valley Reservoir was 0.50 (0.55) in August, and 0.63 (0.64) in November. Overlap between age-3 Arctic grayling and age-1 Apache trout was 0.17 (0.18) and 0.63 (0.61) for August and November, respectively. Resource overlap indices between the age-1 and age-3 Arctic grayling cohorts in 1989 were 0.31 (0.35) in May, 0.07 (0.07) in August, and 0.79 (0.84) in November.

Based on analysis of component food categories that comprise the Schoener (1968) resource overlap index, the large shift in uses of food resources between Arctic grayling cohorts in August 1989 was with adult and pupal dipterans, amphipods, and inorganic materials. Although Apache trout were examined only from August and November in 1989, the largest differences in food usage in August between Apache trout and age-1 Arctic grayling was for Cladocera, inorganic material, and fish. For the Apache trout and age-3 Arctic grayling comparison, the largest August differences in use were between adult and pupal Diptera, Cladocera, Amphipoda, Gastropoda, and fish.

DISCUSSION

Age and Growth

A considerable body of literature exists that reference growth-at-age for Arctic grayling. Most estimates from lake studies are of back-calculations from scale annuli, which are purported to be exceptionally easy to decipher for younger fish (Creaser and Creaser 1935). However, Brown (1943) found a high incidence of false annuli, and Kruse (1959) reported many missed first annuli.

Growth rates of the 1986 age class in Lee Valley Reservoir to age-4 exceeded those in 12 of 13 Wyoming lakes studied by Curtis (1977), where the fish were considered faster growing than more northerly stocks. Growth to age-4 at Lee Valley Reservoir exceeded that observed in Meadow Lake, Wyoming, the source of the Lee Valley Reservoir stock (Curtis 1977). Small sample sizes past age-1 prevented a similar comparison with Bear Canyon Lake Arctic grayling. Mean length of age-1 fish at Bear Canyon Lake was approximately 10% less than same-aged Arctic grayling in Lee Valley Reservoir, but growth through age-1 in Bear Canyon Lake was similar to Arctic grayling growth in lakes studied by Curtis (1977). Based on low concentrations of calcium carbonate, total phosphate, and nitrate in its inflow waters, Kemmerer (1965) predicted poor fish production in Bear Canyon Lake.

Within the native range of Arctic grayling, total lengths exceeding 450 mm are rare (Armstrong 1986, Brown 1943, Curtis 1977, Reed and McCann 1971). Maximum lengths of Arctic grayling from previous surveys at Lee Valley Reservoir rarely exceeded 400 mm, and maximum size recorded in our surveys was 365 mm. Growth rate of the 1986 Arctic grayling cohort in Lee Valley Reservoir slowed considerably after their third year. This depression was coincident with the second stocking of Arctic grayling in Lee Valley Reservoir. We have no data to predict maximum lengths possible at Bear Canyon Lake.

Age at sexual maturity of Arctic grayling is 2 or 3 years in Montana (Curtis 1977), and 4-8 years in Arctic waters (Armstrong 1986, Bishop 1971, Wojcik 1953). Age at maturity was 3 years in Lee Valley Reservoir. We were unable to detect sexual maturity of age-3 Arctic grayling in Bear Canyon Lake in 1988, the last year in which sampling was undertaken.

Age-1 Apache trout at Lee Valley Reservoir were nearly identical in length at the end of their second summer to Arctic grayling of the same age, but it is unknown if Apache trout would achieve keepable size (305 mm) before age-3 as did a portion of the Arctic grayling population. Because of a high susceptibility to over-winter mortality, near-legal length Apache trout may be needed for stocking purposes if harvests are expected.

Trophic Relationships

The high reliance on zooplankton by large Arctic grayling in Lee Valley Reservoir was unique to feeding studies of Arctic grayling we examined. It is possible that a low abundance of large food organisms in our study waters forced Arctic grayling to forage on zooplankton, or that zooplankton were so abundant as to render foraging costs minimal. Because Arctic grayling in Bear Canyon Lake also fed on zooplankton (Appendix D) despite their low availability (Appendix B), the former explanation is more likely.

We hypothesize that introduction of 43,000 age-0 Arctic grayling into Lee Valley Reservoir in late autumn 1986 was responsible for the 1987 shift in *Daphnia-Bosmina*-Rotatoria population dynamics. The hypothesized mechanism for the shift was selective consumption of large-bodied *Daphnia* by Arctic grayling (Appenidx D), thereby suppressing *Daphnia* densities and allowing smaller *Bosmina* and rotifer populations to expand due to reduced levels of competition for their common food resources. According to the trophic cascade hypothesis of Carpenter et al. (1985), changes in lake community structure that may arise from alterations of predator-prey interactions affect nutrient cycling and primary production. The hypothesis predicts that primary production should be less in *Daphnia*-dominated lakes because nutrients are recycled at lower rates (Kitchell and Carpenter 1993).

It is also possible that abiotic or other unmeasured biotic factors were responsible for observed changes in the plankton community. For example, we did not measure oxygen conditions under the ice during most years, nor did we sample algal populations, the primary food source for much of the zooplankton community. We were unable to discern the effects of physical conditions, known to have killed fishes on zooplankton species. Finally, unpredictable annual and seasonal fluctuations in zooplankton community densities and composition are known to occur in habitats similar to Lee Valley Reservoir (Pennak 1949, 1978).

Feeding habits of Apache trout are known only from a single stream on the White Mountain Apache Reservation, where they fed primarily on benthic invertebrates (Harper 1976, 1978). In Lee Valley Reservoir, their diet is omnivorous, and they will also eat fish. Apache trout feed on organisms found at both the surface and bottom (Appendix D). The Apache trout is thus very generalized in its foraging strategy, at least in Lee Valley Reservoir.

Diet overlap indices from Lee Valley Reservoir in 1988-89 suggest that strong interactions occur between Apache trout and Arctic grayling, and between different-aged Arctic grayling cohorts, during summer. However, Ross (1986) concluded that descriptive studies of resource partitioning come closest to demonstrating competition when documenting niche shifts under varying resource levels. Observed decreases in resource overlap consistently apparent in our August data (and especially in the 1989 Arctic grayling cohort comparison) do not appear to be associated with periods of reduced resource availability (Appendix B and C). This pattern is opposite that expected if competition was occurring.

Angling and Equilibrium Yield

Although survey methodologies differed, a two-fold difference in angler use between a 1986 estimate (Novy and Lawry 1988) and our estimates suggests that management changes initiated in 1987 altered angler use patterns at Lee Valley Reservoir. Abolishment of an established, quality brook trout fishery with a 6-fish bag limit and few gear restrictions, and implementation of a fledgling Arctic grayling/Apache trout fishery with a smaller bag limit and artificial fly and lure only restrictions undoubtedly were major causes of the decrease. However, angler use during 1987-90 was within the range of acceptable management standards for a featured species lake fishery (Stephenson 1985).

Except for the 1987 rate of 0.22 brook trout per angler hour, fish harvest rates at Lee Valley Reservoir were near (1989 and 1990) or below (1988) the minimum management standard of 0.1 fish per hour prescribed for a featured species lake fishery (Stephenson 1985). The trend of increased harvest with age of the Arctic grayling/Apache trout fishery suggests that this measure will increase as the fishery matures. Exceptional catch and success rates of the featured species illustrate the potential of the Lee Valley Reservoir fishery.

Angler attitude surveys demonstrated clear and sustained support for the Lee Valley Reservoir featured species fishery. One of the intents of the featured species management concept is to increase the diversity of fishery types in the state, and Lee Valley Reservoir appears to fulfill that interest.

A spring stocking program using age-1 Arctic grayling is theoretically capable of more than doubling the expected annual yield compared to a similar stocking of age-0 fingerlings in autumn, due to losses from winterkill (Table 22). By stocking 5,000 Arctic grayling in spring, yield theoretically should approximate the maximum annual harvest observed in our creel surveys (Table 14). Thus, this may be a good program to initiate and test over time. This suggestion assumes that hatchery space is available. If it is not, and fall stockings of age-0 fish must be practiced, a higher stocking number would be required to provide anglers with enough to harvest at present rates.

The initial stocking of 43,000 fingerling Arctic grayling to Lee Valley Reservoir in autumn 1986 was approximately 1,200 per hectare (4.9 kg/hectare), which exceeded our stocking recommendation manyfold. That stocking, however, sustained the fishery for 4 years.

Although stocked Apache trout never grew to legal size before succumbing to winterkill, mean catch rates in 1988 and 1989 of 0.32 and 0.62 fish/hr demonstrated the lake fishery potential of Apache trout. A successful, limited-season trophy lake fishery for Apache trout has been practiced at Christmas Tree Lake on the White Mountain Apache Nation since the 1960s (Rinne et al. 1979).

We recommend continued monitoring of the Lee Valley Reservoir fishery to determine if angler pressure, harvest patterns, growth, or size, bag, or gear restrictions change over time and affect parameters of the equilibrium yield table. Updated data should be used to refine the table as needed. Manipulation of parameters such as fishing mortality to assess effects of proposed regulation changes is also easily accomplished with such tables.

Table 22. Natural mortality (M), fishing mortality (F), and theoretical equilibrium yield estimates for Arctic grayling stocked into Lee Valley Reservoir in autumn at age-0.5 versus spring stocking at age-1, based on the estimated mortality rates shown in Table 21.

			Stocked in Autumn (Age-0.5)		Stocked in Spring (Age 1)	
Age	M	F	N	Yield N	N	Yield N
0.5			5,000			
	0.60	0.00		0		
1			2,000		5,000	
	0.13	0.00		0		0
1.5			1,740		4,350	
	0.20	0.00		0		0
2			1,392		3,480	
	0.13	0.01		14		35
2.5			1,197		2,993	
	0.20	0.00		0		0
3			958		2,394	
	0.10	0.16		153		383
3.5			709		1,772	
	0.12	0.00		0		0
4			624		1,559	
	0.10	0.22		137		343
4.5			424		1,060	
	0.12	0.00		0		0
5			373		933	
	0.10	0.22		82		205
5.5			254		634	
	0.12	0.00		0		0
6			224		558	
	0.10	0.22		49		123
6.5			152		379	
	0.12	0.00		0		0
7			134		334	
	0.10	0.22		29		73
7.5			91		227	
	0.20	0.00		0		0
8			73		182	
	0.13	0.22		16		40
8.5			49		118	
	1.00	0.00		0		0
Total yield				480		1,202

Bear Canyon Lake was removed as a research study site in 1989 due to low angler use (just marginal according to management standards of Stephenson [1985]), poor catch rates (below management standards), and difficulties with sampling fish. Relatively slow growth rates of fishes in this low productivity, nutrient-poor headwater lake (Kemmerer 1965) perhaps makes it better suited to catchable or subcatchable plants than as fingerling grow-out. Poor angler support for management changes at Bear Canyon Lake indicate that the featured species concept did not work well there.

Water Quality

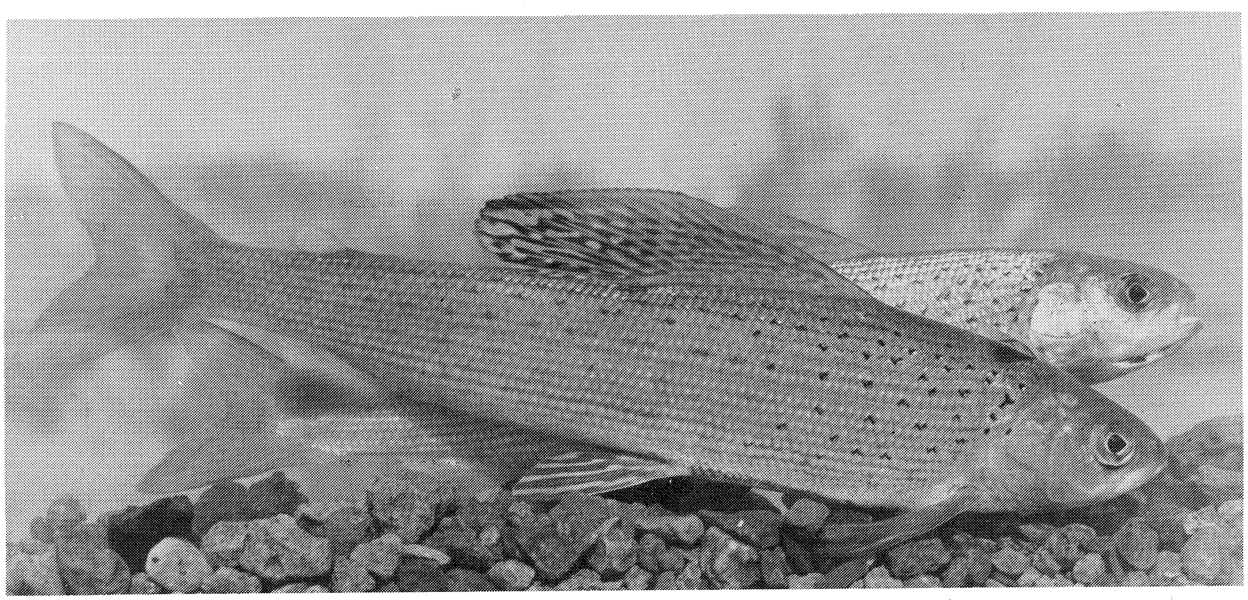
The combination of high productivity and low buffering capacity of Lee Valley Reservoir poses the most serious barrier to the long-term sustenance of an Arctic grayling-Apache trout fishery. Algal blooms that caused pH levels to exceed 9.5 during spring-summer 1988 and August 1989 likely created serious physiological problems for Arctic grayling and especially Apache trout. Late autumn algal blooms probably contributed to a partial winterkill during 1989-90. Both of these types of events have been recorded previously in Lee Valley Reservoir, and are problems of other shallow lakes in the area (J. Novy, Ariz. Game and Fish Dep., pers. comm.).

High rates of planktivory may be followed by blooms of colonial algae (Carpenter et al. 1993), and it is thus possible that stocking of planktivorous Arctic grayling exacerbated algal bloom problems in Lee Valley Reservoir. This potential effect should be considered in other Arizona lakes where Arctic grayling may be stocked.

There are several alternatives to relieve such symptoms in these lakes. A technique to address one of the effects (high pH swings) would be to add a buffering agent to the lake such as calcium carbonate (lime). The factors that address the potential success or failure of such a method are beyond the scope of this report, but they were reviewed by Boyd (1990).

A second type of symptom treatment might be inactivation of in-lake nutrients to perhaps prevent or ameliorate algal blooms. This method involves complexing, chelating, and precipitating inorganic and particulate phosphorus to a metallic salt through addition of sodium aluminate or aluminum sulfate. This method assumes that phosphorus is the limiting nutrient. Cooke and Kennedy (1981) addressed the advantages and disadvantages of this technique.

A more comprehensive potential solution to the water quality problems of Lee Valley Reservoir would be to reduce and control nutrient loadings, assuming they are in excess, through management of erosion and non-point sources. An obvious source of both is cattle grazing, easily managed through fencing of sensitive areas in the watershed. A research study of nutrient budgets in Lee Valley Reservoir seems potentially profitable.



Arctic Grayling collected during this study.

MANAGEMENT OPTIONS

1. Investigate and implement methods of controlling causes or symptoms of nutrient eutrophication at Lee Valley Reservoir. If late autumn algal blooms cannot be controlled, winterkills will remain a problem in maintaining the fishery.

2. Maintain current bag and gear restrictions at Lee Valley Reservoir. Attitude surveys of anglers using the reservoir demonstrate support for such regulations.

3. To maintain current levels of angler harvest at Lee Valley Reservoir, stock approximately 5,000 age-1 Arctic grayling in the spring. Our data suggests that over-winter mortality of age-0 fish is high.

4. Expect poor over-winter survival of Apache trout in Lee Valley Reservoir. Because Apache trout did not grow to catchable size before over-wintering, it may be necessary to stock catchable-sized Apache trout if significant harvest rates are expected. Assuming Apache trout are eventually harvested similarly to Arctic grayling, stock 5,000 age-1 Apache trout in the spring.

5. Maintain recommended stocking rates and associated management practices over time. A well-managed fishery requires continuity; equilibrium-yield fishery practices are thrown into disequilibrium when planned stockings are missed or numbers fluctuate wildly. Growth rates, catch rates, and angler pressure all may be affected by inconsistent stockings.

6. Periodically conduct creel surveys to monitor angler use, catch rates, harvest, and attitudes towards the fishery at Lee Valley Reservoir. If levels of angler harvest change significantly, alter stocking rates, gear restrictions, bag limits, or size limits in conjunction with equilibrium yield models.

7. Periodically monitor growth rates of Arctic grayling and Apache trout to identify potential trophic problems with the fishery.

8. Encourage use of Lee Valley Reservoir as a family fishery; exceptional catch rates should be taken advantage of for teaching children fishing techniques and ethics.

9. Annually conduct Arctic grayling egg-take operations in Lee Valley Creek or from trap net collections. Split egg takes among 2 or more hatcheries for culture if possible to reduce chances of age class failure. Develop alternate egg sources for Arctic grayling.

10. Ensure that adequate supplies of Apache trout can be provided consistently from federal hatcheries. If those sources are not reliable, renew culturing for the species at state hatcheries.

11. Poor growth and catch rates of Arctic grayling in Bear Canyon Lake, in combination with relatively low angler satisfaction with gear and bait restrictions, suggest that the reservoir should perhaps be managed as a put-and-take fishery with relaxed regulations. If such changes are implemented, the new fishery should be allowed to stabilize for a period of years, following which another intensive creel survey should be conducted to evaluate catch and harvest rates and angler satisfaction.

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Appendix A1. Numbers and percentages of anglers interviewed that fished from boat, shore, waded, or used float tubes at Lee Valley Reservoir (1987-90) and Bear Canyon Lake (1987-88).

Lee Valley Reservoir	1987	1988	1989	1990
Boat	304 (57.7%)	125 (36.8%)	140 (28.7%)	67 (15.8%)
Shore	198 (37.6%)	165 (48.5%)	204 (41.8%)	223 (52.6%)
Wading	25 (4.7%)	50 (14.7%)	112 (23.0%)	110 (25.9%)
Float Tube	--	--	32 (6.5%)	24 (5.7%)
Total	527	340	488	424

Bear Canyon Lake	1987	1988
Boat	32 (6.9%)	17 (6.9%)
Shore	429 (93.1%)	227 (92.3%)
Wading	--	2 (0.8%)
Total	461	246

Appendix A2. Numbers and percentages of interviewed anglers at Lee Valley Reservoir that fished with flies, lures, flies and lures, or bait, 1989-90.

Lee Valley Reservoir	1989	1990
Fly	322 (65.7%)	272 (64.0%)
Lure	117 (23.9%)	119 (28.0%)
Fly and Lure	51 (10.4%)	2 (0.5%)
Bait	--	32 (7.5%)
Total	490	425

Appendix A3. Numbers and percentages of angler responses to the question "How would you rate your fishing trip today?" from Lee Valley Reservoir (1987-90) and Bear Canyon Lake (1987-88).

Lee Valley	1987	1988	1989	1990
Poor	236 (44.8%)	81 (23.8%)	121 (24.7%)	120 (28.2%)
Fair	133 (25.2%)	66 (19.4%)	108 (22.0%)	88 (20.7%)
Good	100 (19.0%)	108 (31.8%)	115 (23.5%)	104 (24.4%)
Very Good	24 (4.6%)	34 (10.0%)	65 (13.3%)	46 (10.8%)
Excellent	19 (3.6%)	41 (12.1%)	68 (13.9%)	46 (10.8%)
Perfect	15 (2.8%)	10 (2.9%)	13 (2.7%)	22 (5.2%)
Total	527	340	490	

Bear Canyon	1987	1988
Poor	288 (62.5%)	120 (48.8%)
Fair	90 (19.5%)	81 (32.9%)
Good	57 (12.4%)	35 (14.2%)
Very Good	10 (2.2%)	7 (2.8%)
Excellent	7 (1.5%)	2 (0.8%)
Perfect	9 (2.0%)	1 (0.4%)
Total	461	246

Appendix A4. Numbers and percentages of angler responses to the question "How satisfied were you with the number of fish you caught today?" from Lee Valley Reservoir (1987-90) and Bear Canyon Lake (1987-88).

Lee Valley	1987	1988	1989	1990
Very Satisfied	61 (11.6%)	99 (29.1%)	174 (35.5%)	139 (32.6%)
Somewhat Satisfied	120 (22.8%)	132 (38.8%)	137 (28.0%)	97 (22.8%)
Somewhat Unsatisfied	103 (19.5%)	30 (8.8%)	54 (11.0%)	22 (5.2%)
Very Unsatisfied	243 (46.1%)	79 (23.2%)	125 (25.5%)	168 (39.4%)
Total	527	340	490	426

Bear Canyon	1987	1988
Very Satisfied	10 (2.2%)	1 (0.4%)
Somewhat Satisfied	45 (9.8%)	33 (13.4%)
Somewhat Unsatisfied	154 (33.4%)	109 (44.3%)
Very Unsatisfied	252 (54.7%)	103 (41.9%)
Total	461	246

Appendix A5. Numbers and percentages of angler responses to the question "How satisfied were you with the kinds (species) of fish you caught today?" from Lee Valley Reservoir (1987-90) and Bear Canyon Lake (1987-88).

Lee Valley	1987	1988	1989	1990
Very Satisfied	146 (55.3%)	129 (37.4%)	256 (73.6%)	215 (81.1%)
Somewhat Satisfied	72 (27.3%)	190 (55.1%)	59 (17.0%)	37 (14.0%)
Somewhat Unsatisfied	23 (8.7%)	16 (4.6%)	22 (6.3%)	8 (3.0%)
Very Unsatisfied	23 (8.7%)	10 (2.9%)	11 (3.2%)	5 (1.9%)
Total	264	345	348	265

Bear Canyon	1987	1988
Very Satisfied	35 (54.7%)	6 (25.0%)
Somewhat Satisfied	26 (40.6%)	13 (54.2%)
Somewhat Unsatisfied	2 (3.1%)	4 (16.7%)
Very Unsatisfied	1 (1.6%)	1 (4.2%)
Total	64	24

Appendix A6. Numbers and percentages of angler responses to the question "How satisfied were you with the size of fish you caught today?" from Lee Valley Reservoir (1987-90) and Bear Canyon Lake (1987-88).

Lee Valley	1987	1988	1989	1990
Very Satisfied	111 (42.0%)	47 (19.2%)	167 (48.0%)	189 (71.3%)
Somewhat Satisfied	62 (23.5%)	126 (51.4%)	116 (33.3%)	62 (23.4%)
Somewhat Unsatisfied	58 (22.0%)	56 (22.9%)	47 (13.5%)	10 (3.8%)
Very Unsatisfied	33 (12.5%)	16 (6.5%)	18 (5.2%)	4 (1.5%)
Total	264	245	348	265

Bear Canyon	1987	1988
Very Satisfied	8 (12.5%)	0 (0.0%)
Somewhat Satisfied	18 (28.1%)	14 (58.3%)
Somewhat Unsatisfied	27 (42.2%)	9 (37.5%)
Very Unsatisfied	11 (17.2%)	1 (4.2%)
Total	64	24

Appendix A7. Numbers and percentages of angler responses to the question "Do you favor or oppose regulations prohibiting bait fishing on this lake?" from Lee Valley Reservoir (1987-90) and Bear Canyon Lake (1987-88).

Lee Valley	1987	1988	1989	1990
Favor	373 (82.5%)	259 (89.6%)	398 (88.4%)	358 (89.7%)
Oppose	40 (8.8%)	13 (4.5%)	20 (4.4%)	21 (5.3%)
No Opinion	39 (8.6%)	17 (5.9%)	32 (7.1%)	20 (5.0%)
Total	452	289	450	399

Bear Canyon	1987	1988
Favor	238 (53.5%)	142 (58.9%)
Oppose	159 (35.7%)	73 (30.3%)
No Opinion	48 (10.8%)	26 (10.8%)
Total	445	241

Appendix A8. Numbers and percentages of angler responses to the question "Do you favor or oppose the introduction of Arctic grayling to this lake?" from Lee Valley Reservoir and Bear Canyon Lake, 1987-88.

Lee Valley	1987	1988
Favor	344 (76.1%)	254 (87.9%)
Oppose	32 (7.1%)	7 (2.4%)
No Opinion	76 (16.8%)	28 (9.7%)
Total	452	289

Bear Canyon	1987	1988
Favor	195 (43.8%)	132 (54.8%)
Oppose	13 (2.9%)	10 (4.1%)
No Opinion	237 (53.3%)	99 (41.1%)
Total	445	241

Appendix A9. Numbers and percentages of angler responses to the questions "Do you favor or oppose the 12-inch minimum size limit for grayling and Apache trout on this lake?" and "Do you favor or oppose the one-fish bag limit for grayling and Apache trout on this lake?" from Lee Valley Reservoir, 1989-90.

12" Size Limit	1989	1990
Favor	421 (93.6%)	377 (94.5%)
Oppose	22 (4.9%)	16 (4.0%)
No Opinion	7 (1.6%)	6 (1.5%)
Total	450	399

One Fish Bag Limit	1989	1990
Favor	333 (74.0%)	313 (78.4%)
Oppose .	99 (22.0%)	75 (18.8%)
No Opinion	18 (4.0%)	11 (2.8%)
Total	450	399

Appendix B1. Mean densities per liter (standard deviation in parentheses) of zooplankton taxa in Lee Valley Reservoir, 1983-1985, estimated from vertical 80 μ mesh Wisconsin net tows.

	1983			1984				1985	
Category	Aug	Sep	Nov	Feb	Mar	Sep	Oct	May	Jun
Rotatoria	0.32 (0.79)	0.00 (0.00)	0.00 (0.00)	2 (1.4)	0.00 (0.00)	0.80 (1.2)	0.32 (0.79)	2 (2.2)	3 (2.6)
Cladocera									
Chydoridae	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	10 (7.9)	45 (17.0)	0.00 (0.00)	0.00 (0.00)
Daphnia spp.	590 (107.7)	242 (53.1)	145 (17.7)	40 (13.3)	171 (26.3)	651 (196.0)	619 (120.0)	165 (51.6)	147 (29.0)
Bosmina spp.	0.00 (0.00)	0.00 (0.00)	1 (0.99)	0.00 (0.00)	0.00 (0.00)	1 (2.0)	0.96 (1.1)	0.00 (0.00)	3 (3.2)
Copepoda-Calanoida									
Diaptomidae	4 (1.4)	43 (18.1)	6 (4.3)	6 (2.8)	0.32 (0.79)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.36 (0.87)
Copepoda-Cyclopoida									
nauplii	8 (2.9)	32 (20.8)	24 (6.2)	1 (1.6)	0.00 (0.00)	2 (2.0)	10 (4.0)	79 (14.3)	43 (11.2)
adults	6 (4.2)	54 (21.5)	6 (4.7)	25 (11.8)	10 (4.0)	11 (6.4)	61 (8.4)	134 (35.0)	193 (37.8)
All cases	620 (109.0)	417 (90.5)	200 (23.2)	78 (23.0)	181 (28.6)	678 (202.7)	737 (128.5)	380 (87.4)	393 (65.4)

Appendix B2. Mean densities per liter (standard deviation in parentheses) of zooplankton taxa in Lee Valley Reservoir, 1987, estimated from vertical 80 μ mesh Wisconsin net tows. Unless otherwise noted, pooled estimates are based on 3 replicate tow samples, with 3 subsamples from each replicate (n=9).

Category	May 18*	Jun 16	Jul 14	Aug 11	Sep 9	Oct 6	Nov 3	Dec 12
Rotatoria	406 (208.0)	10 (7.1)	25 (6.5)	6 (3.6)	11 (8.7)	60 (18.7)	105 (27.9)	190 (40.0)
Cladocera								
Chydoridae	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	10 (6.3)	1 (1.9)	1 (1.5)
Daphnia spp.	11 (7.6)	41 (24.1)	22 (14.9)	85 (29.3)	63 (60.4)	97 (53.5)	35 (29.5)	93 (51.7)
Bosmina spp.	2 (3.5)	0.27 (0.80)	8 (4.7)	101 (59.3)	26 (16.8)	6 (8.8)	0.24 (0.71)	0.48 (0.94)
Copepoda-Calanoida Diaptomidae	0.00 (0.00)	0.00 (0.00)	0.27 (0.80)	0.00 (0.00)	6 (9.7)	9 (10.3)	4 (2.6)	6 (2.4)
Copepoda-Cyclopoida								
nauplii	74 (39.3)	77 (9.2)	69 (23.7)	76 (14.5)	97 (24.4)	116 (16.7)	33 (10.1)	13 (4.3)
adults	24 (12.9)	67 (11.7)	50 (20.3)	31 (18.8)	24 (16.2)	29 (15.0)	1 (1.4)	5 (2.8)
All cases	522 (243.5)	215 (34.7)	185 (58.1)	299 (98.1)	227 (92.0)	327 (71.0)	180 (52.1)	309 (60.0)

* total sample size=17

Appendix B3. Mean densities per liter (standard deviation in parentheses) of zooplankton taxa in Lee Valley Reservoir, 1988, estimated from vertical 80 μ mesh Wisconsin net tows. Pooled estimates are based on 3 replicate tow samples, with 3 subsamples from each replicate (n=9).

Category	Mar 9	May 23	Jun 16	Jul 18	Jul 26	Aug 15	Sep 13	Oct 14	Nov 15
Rotatoria	3	0.36	0.95	0.48	0.09	0.00	0.13	0.13	1
	(3.6)	(0.53)	(1.4)	(1.1)	(0.27)	(0.00)	(0.40)	(0.40)	(1.8)
Cladocera									
Chydoridae	0.00	0.12	0.12	37	0.00	47	9	2	0.80
	(0.00)	(0.36)	(0.36)	(20.3)	(0.00)	(15.9)	(3.5)	(1.1)	(1.0)
Daphnia spp.	29	274	105	110	19	254	265	244	131
	(11.8)	(54.8)	(18.0)	(31.3)	(5.1)	(50.8)	(53.7)	(48.2)	(27.7)
Bosmina spp.	0.00	0.12	0.36	97	69	33	60	43	71
	(0.00)	(0.36)	(0.53)	(34.0)	(15.5)	(6.7)	(10.7)	(13.6)	(12.9)
Copepoda-Calanoida									
Diaptomidae	20	1	0.71	15	0.40	33	27	41	91
	(5.1)	(1.4)	(0.93)	(10.1)	(0.69)	(10.8)	(8.4)	(8.2)	(25.2)
Copepoda-Cyclopoida									
nauplii	6	15	6	9	1	15	9	1	34
	(3.2)	(7.8)	(5.0)	(4.9)	(0.81)	(9.9)	(3.9)	(2.0)	(15.1)
adults	65	196	21	73	14	57	16	36	39
	(20.3)	(32.6)	(8.5)	(27.0)	(3.7)	(9.9)	(5.7)	(13.0)	(9.6)
All cases	122	486	135	343	104	439	386	366	368
	(30.6)	(80.3)	(26.0)	(108.0)	(21.0)	(66.0)	(70.8)	(57.0)	(64.6)

Appendix B4. Mean densities per liter (standard deviation in parentheses) of zooplankton taxa in Lee Valley Reservoir, 1989, estimated from vertical 80 μ mesh Wisconsin net tows. Pooled estimates are based on 3 replicate tow samples, with 3 subsamples from each replicate (n=9).

Category	Apr 13	May 17	Jun 16	Jul 17	Aug 15	Sep 14	Oct 17	Nov 13	Dec 12
Rotatoria	0.80 (0.60)	0.00 (0.00)	0.00 (0.00)	26 (13.0)	17 (12.0)	40 (13.0)	37 (14.4)	42 (14.4)	50 (16.0)
Cladocera									
Chydoridae	0.53 (0.87)	0.00 (0.00)	0.27 (0.80)	3 (2.7)	7 (4.1)	43 (11.7)	132 (39.0)	11 (9.3)	0.36 (0.71)
Daphnia spp.	112 (100.4)	65 (18.7)	166 (70.5)	161 (29.4)	98 (27.2)	192 (48.6)	250 (70.0)	225 (53.0)	341 (90.0)
Bosmina spp.	111 (162.0)	0.27 (0.80)	1 (2.3)	32 (12.2)	37 (11.0)	0.76 (1.0)	3 (2.6)	2 (2.3)	1 (2.0)
Copepoda-Calanoida									
Diaptomidae	0.27 (0.80)	8 (2.7)	3 (2.9)	2 (2.6)	8 (5.5)	32 (11.1)	36 (13.3)	45 (13.0)	85 (17.3)
Copepoda-Cyclopoida									
nauplii	368 (113.0)	31 (15.7)	4 (3.5)	17 (6.5)	17 (10.0)	26 (8.2)	10 (3.5)	10 (5.4)	9 (6.6)
adults	81 (24.4)	175 (25.4)	29 (8.5)	16 (5.0)	21 (7.8)	23 (12.1)	33 (13.2)	7 (3.4)	6 (3.6)
All cases	673 (184.7)	279 (36.0)	203 (79.4)	258 (35.7)	205 (34.5)	357 (67.0)	502 (119.0)	343 (74.0)	493 (108.4)

Appendix B5. Mean densities per liter (standard deviation in parentheses) of zooplankton taxa in Lee Valley Reservoir, 1990, estimated from vertical 80 μ mesh Wisconsin net tows. Pooled estimates are based on 3 replicate tow samples, with 3 subsamples from each replicate (n=9).

Category	Jan 19	Feb 16	Mar 6	Mar 24	Apr 4	Apr 13	May 14	Jun 15	Jul 16	Aug 14	Sep 14	Oct 13
Rotatoria	52 (9.9)	48 (15.8)	48 (18.6)	33 (9.2)	38 (16.0)	38 (10.0)	20 (6.4)	20 (16.7)	12 (6.0)	43 (29.2)	38 (13.5)	38 (13.4)
Cladocera												
Chydoridae	0.00 (0.00)	0.00 (0.00)	0.18 (0.53)	0.53 (0.80)	0.50 (1.1)	0.18 (0.53)	0.46 (0.69)	11 (6.0)	15 (6.0)	2 (2.9)	14 (8.5)	1 (1.4)
Daphnia spp.	244 (92.7)	308 (70.0)	61 (25.0)	75 (19.0)	14 (7.9)	57 (29.4)	34 (9.1)	369 (114.6)	53 (12.7)	139 (48.0)	106 (35.8)	131 (46.7)
Bosmina spp.	3 (1.6)	6 (2.8)	2 (1.7)	5 (3.0)	1 (1.1)	4 (2.4)	1 (1.8)	65 (14.7)	330 (58.6)	541 (182.0)	1,101 (380.6)	203 (39.0)
Copepoda-Calanoida												
Diaptomidae	104 (25.8)	41 (8.1)	37 (9.3)	15 (5.0)	10 (6.0)	7 (3.7)	0.31 (0.61)	0.18 (0.53)	1 (1.4)	5 (3.0)	8 (8.1)	12 (7.9)
Copepoda-Cyclopoida												
nauplii	10 (5.2)	21 (9.8)	56 (10.3)	49 (14.1)	53 (16.7)	74 (22.7)	264 (94.3)	5 (4.8)	50 (12.0)	12 (4.1)	28 (29.0)	58 (21.5)
adults	82 (25.0)	44 (9.6)	282 (37.3)	247 (66.3)	406 (109.0)	330 (64.1)	412 (44.4)	254 (26.6)	171 (35.5)	66 (29.5)	124 (37.0)	193 (35.4)
All cases	495 (131.2)	469 (66.8)	485 (59.9)	424 (80.4)	522 (107.5)	510 (101.4)	731 (113.4)	723 (107.4)	631 (97.0)	809 (231.3)	1,395 (411.2)	635 (91.8)

Appendix B6. Mean densities per liter (standard deviation in parentheses) of zooplankton taxa in Bear Canyon Lake, 1987, estimated from vertical 80 μ mesh Wisconsin net tows. Pooled estimates are based on 3 replicate tow samples, with 3 subsamples from each replicate (n=9).

Category	May 22	Jun 17	Jul 15	Aug 13	Sep 11	Oct 7	Nov 13
Rotatoria	8 (3.0)	2 (0.89)	1 (0.84)	0.62 (0.86)	0.04 (0.07)	0.10 (0.18)	0.00 (0.0)
Cladocera							
Chydoridae	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Daphnia spp.	1 (0.25)	1 (1.0)	2 (1.0)	2 (0.96)	2 (1.2)	6 (2.4)	12 (7.2)
Bosmina spp.	13 (3.0)	5 (3.7)	5 (3.1)	8 (2.7)	2 (1.2)	3 (1.8)	4 (4.0)
Copepoda-Calanoida							
Diaptomidae	0.05 (0.09)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Copepoda-Cyclopoida							
nauplii	8 (4.7)	5 (3.0)	7 (4.9)	6 (.67)	3 (1.6)	53 (45.9)	27 (9.6)
adults	4 (1.4)	2 (1.7)	2 (.29)	3 (1.2)	3 (1.4)	7 (3.0)	8 (6.1)
All cases	34 (5.5)	15 (8.5)	18 (8.7)	20 (4.5)	10 (5.3)	68 (51.7)	53 (26.4)

Appendix C1. Mean densities per square meter of benthic invertebrate taxa in Lee Valley Reservoir, May 1988, estimated from Petite Ponar dredge samples. Pooled estimates are based on 3 replicate dredge samples taken at each 1 m depth increment along north and south transects. Mid-reservoir estimates are based on a single triplicate sample near the deepest part of the reservoir.

	Middle			North			South		
Taxon	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n
Gastropoda									
Valvata numeralis	15	25.7	3	800	751.6	9	672	887.6	9
Diptera									
Chironomidae	15	25.7	3	30	38.5	9	84	68.3	9
Heleidae	1,200	555.1	3	1,062	392.2	9	968	515.3	9
Oligochaeta	459	168.3	3	291	276.8	9	64	109.1	9
Hirudinea	178	44.4	3	602	390.7	9	593	759.1	9
Amphipoda									
Hyalella azteca	0	0.0	3	84	84.5	9	10	29.6	9
Nematoda	0	0.0	3	20	59.3	9	59	62.9	9
Pelecypoda									
Pisidium spp.	533	540.7	3	1,951	2,510.6	9	202	376.5	9
Other	0	0.0	3	25	32.3	9	5	14.8	9
All cases	2,400	992.8	3	4,865	2,976.3	9	2,657	1,655.3	9

Appendix C2. Mean densities per square meter of benthic invertebrate taxa in Lee Valley Reservoir, August 1988, estimated from Petite Ponar dredge samples. Pooled estimates are based on 3 replicate dredge samples taken at each 1 m depth increment along north and south transects. Mid-reservoir estimates are based on a single triplicate sample near the deepest part of the reservoir.

	Middle			North			South		
Taxon	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n
Gastropoda									
Valvata numeralis	0	0.0	1	563	852.7	12	437	482.4	12
Diptera									
Chironomidae	0	0.0	1	15	28.9	12	26	40.0	12
Heleidae	0	0.0	1	130	195.5	12	207	134.4	12
Oligochaeta	44	0.0	1	1,093	1,208.0	12	504	376.3	12
Hirudinea	0	0.0	1	1,896	1,934.2	12	844	558.0	12
Amphipoda									
Hyalella azteca	0	0.0	1	619	1,302.6	12	578	1,135.2	12
Nematoda	178	0.0	1	89	280.5	12	11	20.1	12
Pelecypoda									
Pisidium spp.	0	0.0	1	1,107	1,209.1	12	148	206.2	12
Other	0	0.0	1	0	0.0	12	4	12.8	12
All cases	222	0.0	1	5,512	3,940.2	12	2,759	1,183.9	12

Appendix C3. Mean densities per square meter of benthic invertebrate taxa in Lee Valley Reservoir, November 1988, estimated from Petite Ponar dredge samples. Pooled estimates are based on 3 replicate dredge samples taken at each 1 m depth increment along north and south transects. Mid-reservoir estimates are based on a single triplicate sample near the deepest part of the reservoir.

	Middle			North			South		
Taxon	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n
Gastropoda									
Valvata numeralis	0	0.0	1	348	632.5	12	167	210.3	12
Diptera									
Chironomidae	133	0.0	1	85	127.8	12	215	158.4	12
Heleidae	0	0.0	1	493	616.0	12	707	705.7	12
Oligochaeta	2,311	0.0	1	882	1,512.4	12	1,048	1,173.4	12
Hirudinea	0	0.0	1	819	971.8	12	178	177.8	12
Amphipoda									
Hyalella azteca	0	0.0	1	170	277.1	12	44	94.8	12
Nematoda	44	0.0	1	4	12.8	12	4	12.8	12
Pelecypoda									
Pisidium spp.	0	0.0	1	648	1,118.8	12	200	354.8	12
Other	0	0.0	1	7	25.7	12	11	27.6	12
All cases	2,488	0.0	1	3,456	3,020.9	12	2,574	2,139.2	12

Appendix C4. Mean densities per square meter of benthic invertebrate taxa in Lee Valley Reservoir, May 1989, estimated from Petite Ponar dredge samples. Pooled estimates are based on 3 replicate dredge samples taken at each 1 m depth increment along north and south transects. Mid-reservoir estimates are based on a single triplicate sample near the deepest part of the reservoir.

	Middle			North			South		
Taxon	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n
Gastropoda									
Valvata numeralis	0	0.0	1	241	416.7	12	115	218.9	12
Diptera									
Chironomidae	0	0.0	1	7	25.7	12	7	25.7	12
Heleidae	533	0.0	1	785	692.0	12	300	275.4	12
Oligochaeta	6,044	0.0	1	1,170	1,262.7	12	1,181	842.9	12
Hirudinea	0	0.0	1	778	1,084.8	12	52	67.9	12
Amphipoda									
Hyalella azteca	0	0.0	1	4	12.8	12	19	51.8	12
Nematoda	0	0.0	1	15	28.9	12	56	89.1	12
Pelecypoda									
Pisidium spp.	0	0.0	1	1,544	3,013.5	12	22	51.9	12
Other	0	0.0	1	11	38.5	12	4	12.8	12
All cases	6,577	0.0	1	4,555	5,807.1	12	1,756	922.7	12

Appendix C5. Mean densities per square meter of benthic invertebrate taxa in Lee Valley Reservoir, August 1989, estimated from Petite Ponar dredge samples. Pooled estimates are based on 3 replicate dredge samples taken at each 1 m depth increment along north and south transects. Mid-reservoir estimates are based on a single triplicate sample near the deepest part of the reservoir.

	Middle			North			South		
Taxon	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n
Gastropoda									
Valvata numeralis	0	0.0	1	96	199.5	12	59	152.0	12
Diptera									
Chironomidae	889	0.0	1	219	436.5	12	359	725.7	12
Heleidae	0	0.0	1	293	336.6	12	193	123.3	12
Oligochaeta	11,644	0.0	1	2,874	1,866.9	12	3,448	3,395.2	12
Hirudinea	0	0.0	1	326	401.7	12	711	624.8	12
Amphipoda									
Hyalella azteca	0	0.0	1	163	397.2	12	4	12.8	12
Nematoda	0	0.0	1	19	35.2	12	30	43.8	12
Pelecypoda									
Pisidium spp.	0	0.0	1	885	1,827.3	12	967	1,307.6	12
Other	44	0.0	1	0	0.0	12	4	12.8	12
All cases	12,577	0.0	1	4,875	3,880.3	12	5,775	3,567.2	12

Appendix C6. Mean densities per square meter of benthic invertebrate taxa in Lee Valley Reservoir, November 1989, estimated from Petite Ponar dredge samples. Pooled estimates are based on 3 replicate dredge samples taken at each 1 m depth increment along north and south transects. Mid-reservoir estimates are based on a single triplicate sample near the deepest part of the reservoir.

	Middle			North			South		
Taxon	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n
Gastropoda									
Valvata numeralis	--	--	--	519	543.9	9	138	232.5	9
Diptera									
Chironomidae	--	--	--	158	207.4	9	1,096	1,822.5	9
Heleidae	--	--	--	1,165	1,153.2	9	800	716.0	9
Oligochaeta	--	--	--	3,358	2,600.2	9	3,886	3771.9	9
Hirudinea	--	--	--	514	473.0	9	1,106	1,231.8	9
Amphipoda									
Hyalella azteca	--	--	--	1,328	2,439.4	9	0	0.0	9
Nematoda	--	--	--	25	50.2	9	0	0.0	9
Pelecypoda									
Pisidium spp.	--	--	--	1,926	1,613.7	9	143	142.0	9
Other	--	--	--	0	0.0	9	0	0.0	9
All cases	--	--	--	8,993	6,633.8	9	7,170	5,097.5	9

Appendix D1. Numbers of stomachs examined and empty from salmonid food habit analyses, 1987.

	Number examined	Number empty
Lee Valley Reservoir		
Arctic grayling (≤125 mm)	60	4
Arctic grayling (126-200 mm)	23	0
Arctic grayling (>200 mm)	30	0
Brook trout (146-360 mm)	14	6
Total	127	10
Bear Canyon Lake		
Arctic grayling (133-177 mm)	12	0
Brook trout (204-268 mm)	8	1
Total	20	1

Appendix D2. Frequencies of occurrence, relative volumes, and mean numbers of organisms found in stomachs of Arctic grayling, Lee Valley Reservoir, 1987.

	≤125 mm			126-200 mm			>200 mm		
Category	% freq	% rel. volume[a]	No./ stom	% freq	% rel. volume[a]	No./ stom	% freq	% rel. volume[a]	No./ stom
Diptera-adults	87.5	30.9	33.0	95.7	27.4	37.6	53.3	4.9	8.5
Diptera-immature	48.2	Tr	1.9	39.1	Tr	1.7	43.3	Tr	1.6
Coleoptera-adults	3.6	Tr	<0.1	13.0	Tr	0.1	10.0	Tr	0.1
Hemiptera Corixidae-adults	0.0	0.0	0.0	0.0	0.0	0.0	30.0	Tr	0.4
Cladocera-adults	5.4	3.6	12.4	0.0	0.0	0.0	33.3	19.0	179.1
Cladocera-eggs	1.8	Tr	---	0.0	0.0	---	40.0	5.4	---
Amphipoda *Hyalella azteca*	10.7	Tr	0.6	30.4	Tr	0.8	76.7	35.9	173.0
Hirudinea	1.8	Tr	1.2	0.0	0.0	0.0	30.0	Tr	2.2
Nematoda	28.6	Tr	0.6	69.6	16.0	1.3	40.0	8.5	<0.1
Gastropoda *Valvata humeralis*	0.0	0.0	0.0	4.3	Tr	<0.1	36.7	3.9	3.3
Other invertebrates	10.7	Tr	0.1	13.0	Tr	0.2	46.7	Tr	0.8
Fish remains	0.0	0.0	---	0.0	0.0	---	0.0	0.0	---
Inorganic material	0.0	0.0	---	0.0	0.0	---	10.0	Tr	---
Plant detritus	73.2	9.2	---	95.7	11.0	---	46.7	6.0	---
Algae	12.5	Tr	---	4.3	Tr	---	0.0	0.0	---
Unidentified material	94.6	50.0	---	91.3	41.5	---	70.0	11.9	---

[a] Tr <2.0%

Appendix D3. Frequencies of occurrence, relative volumes, and mean numbers of organisms found in stomachs of brook trout in Lee Valley Reservoir, and brook trout and Arctic grayling in Bear Canyon Lake, 1987.

	Lee Valley brook trout			Bear Canyon brook trout			Bear Canyon Arctic grayling		
Category	% freq	% rel. Volume[a]	No./ stom	% freq	% rel. volume[a]	No./ stom	% freq	% rel. volume[a]	No./ stom
Diptera-adults	25.0	Tr	1.0	85.7	40.7	26.3	83.3	24.4	33.6
Diptera-immature	0.0	0.0	0.0	0.0	0.0	0.0	50.0	Tr	3.0
Coleoptera-adults	25.0	Tr	0.2	71.4	14.0	2.6	50.0	Tr	0.7
Hemiptera Corixidae-adults	12.5	Tr	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Cladocera	0.0	0.0	0.0	0.0	0.0	0.0	8.3	8.2	4.6
Amphipoda *Hyalella azteca*	37.5	7.9	9.6	0.0	0.0	0.0	16.7	Tr	0.3
Decapoda *Procambarus clarki*	12.5	Tr	---	71.4	28.9	---	0.0	0.0	---
Hirudinea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nematoda	0.0	0.0	0.0	0.0	0.0	0.0	50.0	15.2	---
Gastropoda *Valvata humeralis*	37.5	18.2	3.9	0.0	0.0	0.0	0.0	0.0	0.0
Other invertebrates	25.0	3.2	0.2	28.6	9.3	3.1	0.0	0.0	0.0
Fish remains	12.5	12.5	---	0.0	0.0	---	0.0	0.0	---
Fish eggs	37.5	37.5	---	0.0	0.0	---	0.0	0.0	---
Inorganic material	0.0	0.0	---	14.3	Tr	---	8.3	8.3	---
Plant detritus	0.0	0.0	---	14.3	Tr	---	75.0	13.1	---
Algae	0.0	0.0	---	0.0	0.0	---	0.0	0.0	---
Unidentified material	37.5	19.1	---	14.3	6.7	---	83.3	28.0	---

[a] Tr <2.0%

Appendix D4. Numbers of stomachs examined and empty, and percent stomach fullness from Arctic grayling food habit analyses, Lee Valley Reservoir, 1987.

	May			August			November		
Species	Number examined	Number empty	% full	Number examined	Number empty	% full	Number examined	Number empty	% full
1988									
Arctic grayling (age-2)	22	1	54.6	26	0	50.7	25	0	44.4
Apache trout (age-1)	26	2	24.8	25	5	28.9	25	0	39.9
1989									
Arctic grayling (age-1)	12	0	85.4	7	0	75.0	25	0	40.2
Arctic grayling (age-3)	25	0	70.1	19	0	47.3	25	0	44.4
Apache trout (age-1)	---	---	---	20	0	31.0	22	1	31.7

Appendix D5. Frequencies of occurrence, relative weights and volumes, and mean numbers of organisms found in stomachs of age-2 Arctic grayling in Lee Valley Reservoir, 1988.

	May				August				November			
Category	% freq	% rel. weight[a]	% rel. volume[a]	No./ stom	% freq	% rel. weight[a]	% rel. volume[a]	No./ stom	% freq	% rel. weight[a]	% rel. volume[a]	No./ stom
Diptera-unidentified	85.7	48.0	62.8	---	64.0	21.7	25.2	---	12.0	2.8	6.8	---
Chironomidae-larvae	33.3	Tr	Tr	6.4	48.0	Tr	Tr	7.5	4.0	Tr	Tr	0.2
Chironomidae-pupae	9.5	2.6	2.2	6.2	12.0	Tr	Tr	0.6	0.0	0.0	0.0	0.0
Trichoptera-larvae	0.0	0.0	0.0	0.0	4.0	Tr	Tr	<0.1	4.0	Tr	Tr	0.1
Coleoptera-adults	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.0	7.8	7.1	1.0
Hemiptera												
Corixidae-adults	28.6	Tr	Tr	0.5	4.0	Tr	Tr	<0.1	56.0	13.8	16.2	19.3
Cladocera	0.0	0.0	0.0	0.0	24.0	14.2	23.0	1247.8	12.0	9.4	11.3	76.7
Amphipoda												
Hyalella azteca	38.1	Tr	Tr	2.2	52.0	9.1	14.6	36.5	28.0	Tr	Tr	1.0
Hirudinea	47.6	5.6	2.8	5.5	36.0	Tr	Tr	2.2	20.0	3.4	3.7	21.6
Nematoda	38.1	7.1	6.6	0.5	24.0	8.3	4.9	0.1	28.0	Tr	Tr	0.5
Gastropoda												
Valvata humeralis	9.5	Tr	Tr	0.5	36.0	Tr	Tr	2.1	44.0	3.0	Tr	1.6
Terrestrial insects	4.8	Tr	Tr	<0.1	8.0	Tr	Tr	1.1	8.0	Tr	Tr	0.1
Other invertebrates	9.5	Tr	Tr	0.1	20.0	Tr	Tr	3.5	36.0	Tr	Tr	1.3
Fish remains	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---
Inorganic material	4.8	Tr	Tr	---	36.0	7.8	4.4	---	56.0	13.4	3.1	---
Plant detritus	76.2	29.4	17.2	---	76.0	29.8	19.8	---	84.0	36.7	35.9	---
Unidentified material	4.8	3.5	4.6	---	16.0	4.3	2.9	---	24.0	5.7	12.0	---

[a] Tr <2.0%

Appendix D6. Frequencies of occurrence, relative weights and volumes, and mean numbers of organisms found in stomachs of age-3 Arctic grayling in Lee Valley Reservoir, 1989.

	May				August				November			
Category	% freq	% rel. weight[a]	% rel. volume[a]	No./ stom	% freq	% rel. weight[a]	% rel. volume[a]	No./ stom	% freq	% rel. weight[a]	% rel. volume[a]	No./ stom
Diptera-unidentified	0.0	0.0	0.0	---	5.3	5.1	5.2	---	36.0	Tr	Tr	---
Chironomidae-larvae	32.0	Tr	Tr	2.2	0.0	0.0	0.0	0.0	84.0	Tr	2.3	19.8
Chironomidae-pupae	68.0	Tr	Tr	5.8	5.3	Tr	Tr	0.1	0.0	0.0	0.0	0.0
Trichoptera-larvae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coleoptera-adults	4.0	Tr	Tr	<0.1	0.0	0.0	0.0	0.0	16.0	Tr	Tr	0.2
Hemiptera												
Corixidae-adults	32.0	Tr	Tr	3.0	15.8	Tr	Tr	0.3	28.0	Tr	Tr	1.9
Cladocera	44.0	42.1	31.0	1,931.3	0.0	0.0	0.0	0.0	76.0	49.8	61.3	4,033.2
Amphipoda												
Hyalella azteca	8.0	Tr	Tr	0.1	73.7	4.9	6.8	13.3	44.0	2.6	2.8	10.8
Hirudinea	60.0	3.4	4.4	8.8	0.0	0.0	0.0	0.0	32.0	5.6	4.9	18.5
Nematoda	20.0	Tr	Tr	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gastropoda												
Valvata humeralis	56.0	7.2	6.1	25.6	52.6	3.5	3.3	6.9	28.0	5.8	Tr	3.2
Terrestrial insects	4.0	Tr	Tr	<0.1	0.0	0.0	0.0	0.0	4.0	Tr	Tr	<0.1
Other invertebrates	32.0	Tr	Tr	1.0	5.3	Tr	Tr	0.1	8.0	Tr	Tr	0.1
Fish remains	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---
Inorganic material	16.0	Tr	Tr	---	47.4	8.7	5.4	---	28.0	3.4	Tr	---
Plant detritus	92.0	24.7	12.8	---	52.6	9.9	7.2	---	68.0	19.0	6.6	---
Unidentified material	88.0	38.4	40.4	---	94.7	67.4	71.7	---	20.0	8.7	13.4	---

[a] Tr <2.0%

Appendix D7. Frequencies of occurrence, relative weights and volumes, and mean numbers of organisms found in stomachs of age-1 Arctic grayling in Lee Valley Reservoir, 1989.

	May				August				November			
Category	% freq	% rel. weight[a]	% rel. volume[a]	No./ stom	% freq	% rel. weight[a]	% rel. volume[a]	No./ stom	% freq	% rel. weight[a]	% rel. volume[a]	No./ stom
Diptera-unidentified	0.0	0.0	0.0	---	57.1	57.1	57.0	---	24.0	5.0	2.1	---
Chironomidae-larvae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	84.0	3.5	2.4	19.0
Chironomidae-pupae	0.0	0.0	0.0	0.0	14.3	2.0	2.9	10.1	4.0	Tr	Tr	0.3
Trichoptera-larvae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coleoptera-adults	8.3	Tr	Tr	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hemiptera												
Corixidae-adults	16.7	Tr	Tr	0.6	0.0	0.0	0.0	0.0	32.0	Tr	Tr	0.4
Cladocera	100.0	98.2	99.2	6,390.1	14.3	14.3	14.3	364.3	80.0	50.2	65.3	5,084.6
Amphipoda												
Hyalella azteca	0.0	0.0	0.0	0.0	14.3	Tr	Tr	0.1	20.0	Tr	Tr	3.0
Hirudinea	8.3	Tr	Tr	0.1	0.0	0.0	0.0	0.0	64.0	6.7	4.2	11.2
Nematoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gastropoda												
Valvata humeralis	8.3	Tr	Tr	0.1	0.0	0.0	0.0	0.0	8.0	Tr	Tr	0.3
Terrestrial insects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other invertebrates	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	Tr	Tr	1.3
Fish remains	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---
Inorganic material	0.0	0.0	0.0	---	0.0	0.0	0.0	---	28.0	2.8	3.1	---
Plant detritus	8.3	Tr	Tr	---	0.0	0.0	0.0	---	36.0	10.6	6.2	---
Unidentified material	0.0	0.0	0.0	---	28.6	26.5	25.7	---	40.0	18.9	14.8	---

[a] Tr <2.0%

Appendix D8. Frequencies of occurrence, relative weights and volumes, and mean numbers of organisms found in stomachs of age-1 Apache trout in Lee Valley Reservoir, 1988.

	May				August				November			
Category	% freq	% rel. weight[a]	% rel. volume[a]	No./ stom	% freq	% rel. weight[a]	% rel. volume[a]	No./ stom	% freq	% rel. weight[a]	% rel. volume[a]	No./ stom
Diptera-unidentified	50.0	36.3	40.8	---	55.0	32.9	28.9	---	12.0	4.0	4.1	---
Chironomidae-larvae	25.0	3.2	Tr	2.9	40.0	Tr	2.6	13.0	4.0	Tr	Tr	0.1
Chironomidae-pupae	16.7	4.8	4.2	0.3	10.0	Tr	Tr	0.4	0.0	0.0	0.0	0.0
Trichoptera-larvae	4.2	Tr	Tr	<0.1	10.0	2.4	Tr	0.2	8.0	6.0	6.7	0.2
Coleoptera-adults	8.3	3.7	4.2	0.1	5.0	Tr	Tr	<0.1	28.0	5.1	2.6	0.6
Hemiptera												
Corixidae-adults	4.2	Tr	Tr	0.1	15.0	Tr	Tr	0.9	64.0	12.9	9.5	2.6
Cladocera	6.7	14.5	12.5	341.3	70.0	55.9	64.0	4,617.2	12.0	7.9	11.2	68.7
Amphipoda												
Hyalella azteca	12.5	4.9	4.3	0.1	10.0	2.1	2.2	3.5	20.0	Tr	2.4	0.7
Hirudinea	4.2	5.6	Tr	<0.1	0.0	0.0	0.0	0.0	4.0	Tr	Tr	0.4
Nematoda	4.2	4.0	3.7	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gastropoda												
Valvata humeralis	8.3	5.2	4.3	0.3	15.0	Tr	Tr	0.2	4.0	Tr	Tr	0.2
Terrestrial insects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other invertebrates	0.0	0.0	0.0	0.0	10.0	Tr	Tr	0.2	28.0	Tr	Tr	0.4
Fish remains	4.2	3.1	4.0	---	0.0	0.0	0.0	---	8.0	7.0	7.2	---
Inorganic material	0.0	0.0	0.0	---	5.0	Tr	Tr	---	24.0	5.9	3.8	---
Plant detritus	33.3	11.6	9.0	---	0.0	0.0	0.0	---	36.0	16.3	17.4	---
Unidentified material	12.5	7.9	11.0	---	5.0	Tr	Tr	---	44.0	31.7	34.1	---

[a] Tr <2.0%

Appendix D9. Frequencies of occurrence, relative weights and volumes, and mean numbers of organisms found in stomachs of age-1 Apache trout in Lee Valley Reservoir, 1989.

	May				August				November			
Category	% freq	% rel. weight	% rel. volume	No./ stom	% freq	% rel. weight[a]	% rel. volume[a]	No./ stom	% freq	% rel. weight[a]	% rel. volume[a]	No./ stom
Diptera-unidentified	---	---	---	---	0.0	0.0	0.0	---	19.0	4.7	4.7	---
Chironomidae-larvae	---	---	---	---	5.0	Tr	Tr	0.8	61.9	2.1	Tr	6.8
Chironomidae-pupae	---	---	---	---	5.0	Tr	Tr	<0.1	0.0	0.0	0.0	0.0
Trichoptera-larvae	---	---	---	---	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coleoptera-adults	---	---	---	---	5.0	Tr	Tr	<0.1	0.0	0.0	0.0	0.0
Hemiptera												
Corixidae-adults	---	---	---	---	30.0	2.6	3.9	2.7	4.8	Tr	Tr	<0.1
Cladocera	---	---	---	---	35.0	30.5	33.8	871.7	47.6	33.4	40.8	2,696.7
Amphipoda												
Hyalella azteca	---	---	---	---	65.0	16.6	14.6	26.0	57.1	5.5	2.2	4.9
Hirudinea	---	---	---	---	10.0	Tr	Tr	1.0	33.3	7.6	7.5	5.7
Nematoda	---	---	---	---	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gastropoda												
Valvata humeralis	---	---	---	---	40.0	7.4	4.4	4.7	19.0	Tr	Tr	0.7
Terrestrial insects	---	---	---	---	0.0	0.0	0.0	0.0	9.5	Tr	Tr	0.1
Other invertebrates	---	---	---	---	0.0	0.0	0.0	0.0	19.0	Tr	Tr	1.2
Fish remains	---	---	---	---	5.0	Tr	3.0	---	28.6	22.3	22.7	---
Inorganic material	---	---	---	---	10.0	Tr	Tr	---	33.3	3.4	Tr	---
Plant detritus	---	---	---	---	10.0	6.7	5.5	---	23.8	2.6	Tr	---
Unidentified material	---	---	---	---	60.0	32.8	34.0	---	38.1	15.5	17.2	---

[a] Tr <2.0%

NOTES

Clarkson, R. W., and R. J. Dreyer. 1996. **Investigation of Techniques to Establish and Maintain Arctic Grayling and Apache Trout Lake Fisheries**. Arizona Game and Fish Dep. Tech. Rep. 12, Phoenix. 71pp.

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Key words: Age, Apache trout, Arctic grayling, Arizona, growth, *Oncorhynchus apache*, survival, *Thymallus arcticus*, trophic relationships.

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Layout, design, and typesetting by Vicki L. Webb
Photos by:
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Richard Dryer (Cover)
Jim Warnecke (Page 42)

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