POPULATION CHARACTERISTICS AND HABITAT USE OF A DEVELOPING WALLEYE POPULATION IN CANYON FERRY RESERVOIR, MONTANA

by

David Brent Yerk

A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Fish and Wildlife Management

MONTANA STATE UNIVERSITY
Bozeman, Montana

July 2000

APPROVAL

of a thesis submitted by

David Brent Yerk

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

Alexander V. Zale — Chairperson, Graduate Committee — 24 July 2000 (Date)

Approved for the Department of Ecology

Jay J. Rotella — Head, Ecology Department — 7-24-00 (Date)

Approved for the College of Graduate Studies

Bruce R. Mcleod — Graduate Dean — 7-24-00 (Date)

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a master's degree at Montana State University - Bozeman, I agree that the Library shall make it available to borrowers under rules of the Library.

If I have indicated my intention to copyright this thesis by including a copyright notice page, copying is allowable only for scholarly purposes, consistent with "fair use" as prescribed in the U.S. Copyright Law. Requests for permission for extended quotation from or reproduction of this thesis in whole or in parts may be granted only by the copyright holder.

Signature *David B York*

Date 07-21-2000

ACKNOWLEDGMENTS

I express my sincerest thanks and appreciation to the many field technicians that helped on this project over the years. Brad Flickinger, Brandon Watne, Scott Opitz, Troy Humphrey, Pete Johnson, Jerry Anderson, and Ryan Trenka all provided countless hours of field assistance. This project would not have been possible without their hard work and dedication.

I thank Montana Fish, Wildlife and Parks for providing me with this unique mid-career opportunity. The support of Ron Spoon, Dick Vincent, Howard Johnson, and Larry Peterman was key in pursuing this degree. I would especially like to acknowledge Ron Spoon for recognizing the need for this study, and more importantly, demonstrating the confidence in me to complete this research. I extend special thanks to Steve Carson for lending his mapping expertise.

Montana Fish, Wildlife & Parks and the Montana Cooperative Fisheries Research Unit at Montana State University provided funding and equipment to complete this work. My advisor, Dr. Alexander V. Zale, deserves special recognition for his guidance, support, and patience in the completion of this research and manuscript. Drs. Thomas E. McMahon and Robert A. Garrott provided valuable input into the design of this study and the preparation of this thesis. Special thanks to Dee Topp of the Ecology Department for always providing help with the smaller details of graduate school.

This thesis is dedicated to my close friend and fellow graduate student Matthew F. Clow, who lost his life pursuing his dream.

TABLE OF CONTENTS

TABLE OF CONTENTS - CONTINUED

TABLE OF CONTENTS - CONTINUED

Page

LIST OF TABLES

LIST OF TABLES - CONTINUED

LIST OF TABLES - CONTINUED

LIST OF TABLES - CONTINUED

LIST OF TABLES - CONTINUED

LIST OF FIGURES

LIST OF FIGURES - CONTINUED

LIST OF FIGURES - CONTINUED

LIST OF FIGURES - CONTINUED

LIST OF FIGURES - CONTINUED

LIST OF FIGURES - CONTINUED

LIST OF FIGURES - CONTINUED

ABSTRACT

Canyon Ferry Reservoir has consistently ranked as one of Montana's most popular recreational fisheries. Traditionally managed for rainbow trout *Oncorhynchus mykiss*, brown trout *Salmo trutta*, and yellow perch *Perca flavescens*, walleye *Stizostedion vitreum* were illegally introduced into Canyon Ferry Reservoir in the early 1980s and now threaten this and adjoining fisheries. Similar introductions in other western reservoirs have altered popular sport fisheries and have necessitated complex and expensive management strategies to mitigate the effects of walleye. I used historic data and standardized netting series from 1994 to 1999 to monitor expansion of the walleye population and changes in existing fisheries. Age, growth, condition, and food habits of Canyon Ferry walleye were examined to characterize this new population. Seasonal movements and habitat use of walleye were monitored using sonic telemetry. Movement rates were greatest pre-spawn and in early autumn. Fidelity to a single spawning area was exhibited in all three years of the telemetry study. Experimental netting and electrofishing conducted in other areas of the reservoir did not identify any additional walleye spawning areas. Netting trends and age data indicated this population is young and developing rapidly. Ages of walleye sampled during this study ranged from 0 to 16. Growth rates were high relative to most North American walleye stocks, indicative of a rapidly expanding population. Yellow perch and suckers *Catostomus* spp. were the preferred prey of walleye, accounting for 71% to 99% of their diet by weight annually. Standardized net catches of yellow perch increased sharply as a result of good recruitment in 1996. This year class probably helped buffer effects of walleye predation on other species. The walleye population in Canyon Ferry Reservoir is established and expanding; my data will provide a baseline to monitor this new population and help managers in formulating management strategies to maintain existing popular sport fisheries.

CHAPTER 1

GENERAL INTRODUCTION

The walleye *Stizostedion vitreum* has an extensive native range extending from Quebec southward along the west side of the Appalachian Mountains, west towards the Gulf coast of Alabama, north through Nebraska to North Dakota, northwest to the Mackenzie River near the Arctic coast, and southeast across James Bay to Quebec (Scott and Crossman 1973). Walleye have been widely introduced into waters both within and outside their native range (Colby et al. 1979).

Walleye are not native to Montana. The earliest published reference to their presence in Montana appeared in the Montana Fish and Game Commission's 1923-1924 biennial report. It stated that large numbers of 'great northern or wall-eyed pike' were present in Nelson Reservoir in Phillips County (Montana Fish and Game Commission 1923-1924). The origin of these fish is unknown; there are no records indicating that they were stocked by the Montana Fish and Game Department nor the U.S. Fish Commission (Gould 1995). A private individual or group likely introduced these walleye into Nelson Reservoir. The first introduction by a public agency occurred in 1933 when the Montana Fish and Game Department stocked walleye into the Missouri River below Great Falls (Gould 1995). This was nearly 50 years after rainbow trout *Oncorhynchus mykiss*, brown

trout *Salmo trutta*, and brook trout *Salvelinus fontinalis* were first introduced into Montana waters (Brown 1971).

Development of walleye fisheries in Montana was precipitated by the construction of several large reservoirs and improvements in culturing cool and warmwater fishes in the state. The U.S. Bureau of Reclamation (BOR), U.S. Army Corps of Engineers, and local irrigation districts constructed several large reservoirs in eastern and northcentral Montana in the Missouri River drainage in the early to mid-1900s, including Fort Peck, Nelson, Francis, Fresno, and Tiber reservoirs. These impoundments provided the relatively shallow, turbid coolwater environments preferred by walleye, and the species thrived upon introduction. As these fisheries developed and attracted anglers, there was increased demand on Montana's hatchery system to provide more walleye. This culminated in 1984 when walleye anglers successfully lobbied the Montana Legislature to fund expansion of the state's warmwater fish hatchery in Miles City.

The rapidly increasing popularity of walleye as a sportfish was not unique to Montana, but was occurring in other states throughout their native and introduced range as well (Conover 1986; Quinn 1992). This can be attributed to magazines and television programs specializing in walleye fishing, technological advances in fishing boats and equipment, a growing interest in competitive fishing tournaments, and the formation of local fishing clubs.

The founding of local chapters of the Walleyes Unlimited (WU) organization in Montana in the early 1980s led to organized efforts requesting increased walleye fishing opportunities. More specifically, WU was seeking to establish walleye fisheries in some of the traditional trout waters in the western portion of the state. To formally address these demands, Montana Fish, Wildlife & Parks (MFWP) contracted with Colby and Hunter (1989) to complete an environmental assessment on the introduction of walleye into new waters in the state. Because of lack of documented case histories and published literature relating walleye and trout interactions, the authors recommended a conservative approach. They concluded: 1) each proposed introduction should be handled on a case by case basis because of the inherent risks associated with introducing a prolific top-predator fish into new environments; and 2) a separate environmental assessment should be completed for each proposed introduction fully evaluating the potential risks specific to that water body. In the early 1980s, Idaho adopted an equally conservative policy addressing potential walleye introductions into salmonid waters (Idaho Department of Fish and Game 1982).

Canyon Ferry Reservoir, located on the upper Missouri River, was one of the primary waters that anglers pressured MFWP to introduce walleye. This reservoir was traditionally managed as a rainbow trout and yellow perch *Perca flavescens* fishery, and consistently ranked as one of Montana's most popular recreational fisheries as judged by statewide fishing pressure estimates (MFWP 1997). In the late 1980s, a declining rainbow trout fishery and growing public interest in establishing a walleye population in Canyon Ferry was the impetus for MFWP to develop a fisheries management plan for the reservoir and the associated upstream section of the Missouri River.

Because of the controversy surrounding a potential walleye introduction, MFWP carefully addressed this issue in the development of the Canyon Ferry Reservoir /

Missouri River Fisheries Management Plan. MFWP hosted a public workshop in 1991 investigating walleye-trout interactions. Biologists from several western states related their experiences in managing coexisting trout and walleye fisheries. Their observations reflected two consistent themes. First, at high population levels, walleye predation negatively affected trout and other fisheries. Second, walleye pioneered into upstream and downstream waters, sometimes moving great distances (MFWP 1991).

To further explore these issues and follow the guidelines recommended by Colby and Hunter (1989), an environmental assessment was completed specifically evaluating the potential effects of a walleye introduction on the existing Canyon Ferry fishery, as well as on fisheries upstream and downstream waters (McMahon 1992). McMahon (1992) reviewed existing data and other case histories and concluded: (1) conditions were highly favorable for development of a self-sustaining walleye population in Canyon Ferry; (2) this population would likely "boom and bust"—meaning it would expand very quickly, but then decrease in quality as the existing forage base declined; (3) a sizable walleye population would not be compatible with maintaining the existing rainbow trout and yellow perch fisheries; and (4) walleye would move into adjacent waters, especially downstream during high water years when surface spills occur at Canyon Ferry Dam.

MFWP sent out about 4,800 surveys in 1991 to identify the public's opinions and preferences concerning Canyon Ferry fisheries issues. The majority (77%) of the 1,830 respondents indicated that they preferred maintaining the existing rainbow trout and yellow perch fishery and generally opposed a walleye introduction, particularly if it were to pose a high risk to the existing fishery (MFWP 1992).

Following two years of preparation and extensive public involvement and review, the final draft of the Canyon Ferry Reservoir / Missouri River Fisheries Management Plan was presented to the MFWP Commission in October of 1992. The five-year plan (1993-1998) recommended that no new species be introduced into the reservoir and that management efforts be directed at enhancing existing fish species and their habitats in the reservoir / river system. The Commission unanimously approved the plan (MFWP 1992).

Despite MFWP's efforts to fully evaluate the implications of a potential walleye introduction, an illegal introduction had already occurred. MFWP biologists sampled a single walleye in autumn 1989 in a floating gill net series used to monitor rainbow trout population trends (Lere 1990). This was the first walleye ever collected in 34 years of systematic fish sampling in Canyon Ferry. A single walleye was sampled in each of the two following years. An age-0 individual was captured in a seine in 1990 and a yearling was caught in a gill net in 1991 (Lere 1992). Three more walleye were sampled in gill nets in 1992; the oldest was age 3. The status of walleye in Canyon Ferry was unclear at that time based on those few incidental catches in MFWP's standardized netting surveys. However, an aggressive mandate was adopted in the management plan addressing the establishment of new, undesired species because of the potential deleterious effects on the existing fishery identified in McMahon's (1992) assessment:

> "Should illegally introduced species become established in Canyon Ferry Reservoir or the Missouri River, MDFWP will take immediate action to determine the status of the population and evaluate the possible consequences to existing fisheries. As determined necessary by MDFWP, utilize removal methods or reservoir level manipulations to minimize impacts of illegally introduced fish species on resident populations" (MFWP 1992).

MFWP set gill nets in June 1993 specifically targeting walleye to gain a better understanding of their status in Canyon Ferry. Fourteen walleye were sampled in seven nets; all were less than four years old. It was evident that a walleye population was developing in Canyon Ferry.

My study addressed the actions mandated in the management plan. It provides the baseline information needed by managers to evaluate the potential to control or eradicate walleye from Canyon Ferry Reservoir. This research may also lead to the development of management strategies for maintaining trout and yellow perch fisheries in the presence of an expanding walleye population. Complete documentation of the effects of this illegal introduction in Canyon Ferry will better enable Montana and other states to handle future illegal introductions. At the very least, the aggressive dissemination of this information may help to curtail similar introductions by educating the general public to the potential far-reaching consequences of such actions.

Objectives of my study were to: 1) collect baseline data on the newly developing walleye population; 2) monitor and document any changes in the existing Canyon Ferry fisheries; 3) document seasonal movements and distribution of walleye in Canyon Ferry Reservoir with emphasis on identifying spawning areas; and 4) determine if telemetry can be used to identify all or most walleye spawning areas in Canyon Ferry Reservoir.

LITERATURE CITED

Brown, C. J. D. 1971. Fishes of Montana. Big Sky Books, Bozeman, MT.

Colby, P., and C. Hunter. 1989. Environmental assessment of the introduction of walleye beyond their current range in Montana. Montana Fish, Wildlife and Parks, Helena.

Colby, P. J., R. E. McNichol, and R. A. Ryder. 1979. Synopsis of biological data on the walleye *Stizostedion v. vitreum* (Mitchill 1818). Food and Agriculture Organization (FAO) Fish. Synop. 119. Rome, Italy.

Conover, M. C. 1986. Stocking cool-water species to meet management needs. Pages 31-39 *in* R. H. Stroud, editor. Fish culture in fisheries management. American Fisheries Society, Bethesda, Maryland.

Gould, W. R. 1995. A report of the early distribution and sources of walleye *Stizostedion vitreum* in Montana. Montana Fish, Wildlife and Parks, Helena.

Idaho Department of Fish and Game. 1982. Evaluation of walleye for an expanded distribution in Idaho. Idaho Department of Fish and Game, Boise.

Lere, M. 1990. Statewide fisheries investigations, survey and inventory of coldwater lakes, mid-Missouri reservoirs study. Montana Fish, Wildlife and Parks. Job progress report F-46-R-3, II-f, Helena.

Lere, M. 1992. Statewide fisheries investigations, survey and inventory of coldwater lakes, Canyon Ferry, Hauser, Holter reservoirs study. Montana Fish, Wildlife and Parks. Job progress report F-46-R-5, II-f, Helena.

McMahon, T. E. 1992. Potential impacts of the introduction of walleye to the fishery of Canyon Ferry Reservoir and adjacent waters. Montana Fish, Wildlife and Parks, Helena.

Montana Fish and Game Commission. 1923-1924. Biennial Report. Montana Fish and Game Department, Helena.

Montana Fish, Wildlife and Parks. 1991. Video proceedings of the walleye - trout interaction workshop. March 2, 1991, Helena.

Montana Fish, Wildlife and Parks. 1992. Canyon Ferry Reservoir / Missouri River fisheries management plan, January 1993 - January 1998, Helena.

Montana Fish, Wildlife and Parks. 1997. Montana statewide angling pressure 1997. Helena.

Quinn, S. P. 1992. Angler perspectives on walleye management. North American Journal of Fisheries Management 12:367-378.

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin 184.

CHAPTER 2

STATUS AND POPULATION CHARACTERISTICS OF A DEVELOPING WALLEYE POPULATION IN CANYON FERRY RESERVOIR, MONTANA

INTRODUCTION

The appearance of walleye *Stizostedion vitreum* in Canyon Ferry Reservoir during the late 1980s was apparently the result of an illegal introduction. Over the past 20 years Montana Fish, Wildlife and Parks (MFWP) has documented over 400 such introductions throughout the state involving 47 different species; 11 of these introductions were walleye (J. Vashro, MFWP, personal communication).

Walleye introductions in western reservoirs have not been without their costs. In many waters, managers have struggled with maintaining a balance between this top predator and its prey base (Colby and Hunter 1989; McMahon and Bennett 1996). Forage depletions often result in the presence of a moderate to high density walleye population, frequently leading to the decline or loss of popular sport fisheries through increased predation (McMillan 1984). Additionally, walleye have commonly pioneered into adjacent waters both upstream and downstream far from point of introduction, at times colonizing major portions of large river systems (McMillan 1984, 1991; Nigro 1991). Thus, managers must often contend not only with the local implications of a walleye introduction, but system-wide effects as well (Colby and Hunter 1989; McMahon and Bennett 1996).

McMahon's (1992) risk assessment identified a likely forage depletion and potential downstream effects as two of the major considerations of a walleye introduction into Canyon Ferry Reservoir (Chapter 1). These risks are of particular concern to managers as the long-term effects of this introduction may result in irreversible changes to several of Montana's most important recreational fisheries. Canyon Ferry consistently ranks as the most popular fishery in the state, providing nearly 100,000 angler days annually. Hauser and Holter reservoirs each support about 70,000 angler days a year and commonly rank in the top ten for statewide fishing pressure. The Missouri River below Holter Dam is one of Montana's most heavily fished rivers, second only to the Big Horn River. This reservoir / river complex accounted for four of the top ten most popular recreational fisheries in Montana in 1997 and 11% of the total statewide fishing pressure (MFWP 1997).

Prior to the initiation of this study in 1994, MFWP had sampled a total of 21 walleye in Canyon Ferry from 1989 to 1993. The purpose of my research was to collect baseline information on this newly developing population. This data will assist managers in understanding the development of this population and help in evaluating the potential implications to existing fisheries within this reservoir / river complex.

The objectives of this study were to: 1) describe the development of the illegally introduced walleye population in Canyon Ferry; 2) determine the relative abundance, age composition, food habits, growth rates, size structure, and condition of this population; and 3) monitor and document any changes to the existing fisheries.

STUDY AREA

Canyon Ferry is the largest and uppermost impoundment of a three reservoir chain including Hauser and Holter reservoirs on the upper Missouri River (Figure 1). Impounded in 1954, it is located in Lewis & Clark and Broadwater counties in southwest Montana. The upper end of the reservoir is located about 40 km downstream of the origin of the Missouri River at the confluence of the Jefferson, Gallatin, and Madison rivers near Three Forks, Montana. Canyon Ferry Dam is located on the north end of the reservoir and is about 23 km east of Helena, Montana. The United States Bureau of Reclamation (BOR) operates Canyon Ferry as a water storage reservoir and regulates water levels for flood control, irrigation, municipal water supply, power production, and recreation. Because it is a storage reservoir, it controls the flow regime of the two lower, run-of-the-river reservoirs (Hauser and Holter) and the Missouri River below Holter Dam.

Canyon Ferry has an elevation at full-pool of 1158 m, surface area of 14,238 ha, and storage capacity of 2.53×10^9 m^3. The reservoir is 40.2 km long and has a maximum width of 7.2 km (Rada and Wright 1979). Canyon Ferry's total shore length is about 122 km and has a shoreline development factor of 2.9 (Rada 1974). It has mean and maximum depths of 17.8 m and 50.1 m, respectively. The annual drawdown is about

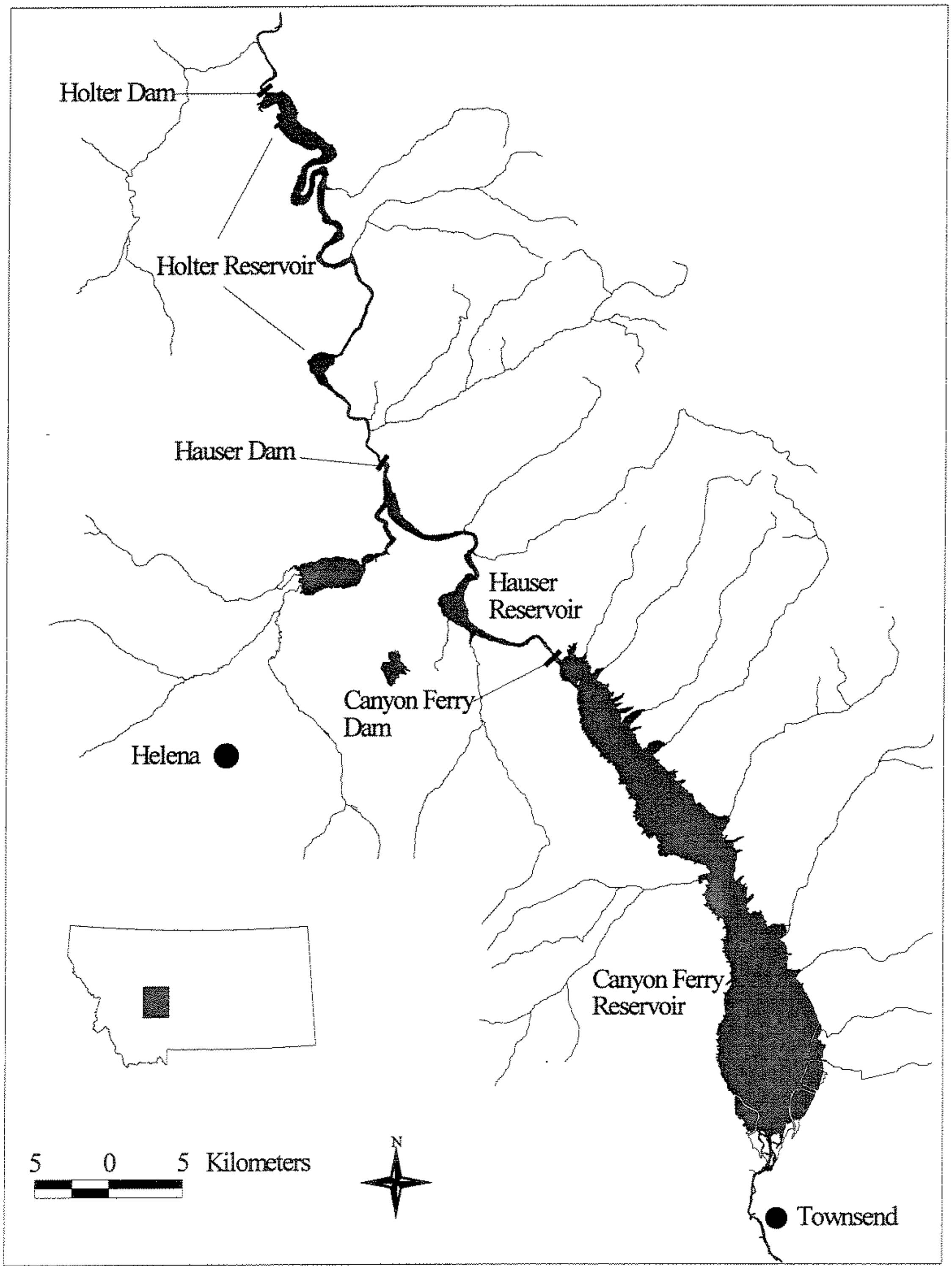


Figure 1. Map of Canyon Ferry Reservoir, Montana, showing downstream Hauser and Holter reservoirs and associated dams.

3.6 m and hydraulic retention averages about 135 days, but can range from 50 to 200 days depending on the flow regime and reservoir elevation (Priscu 1987).

The north and south ends of the reservoir contrast markedly. The broad, southern (upper) portion of Canyon Ferry is characterized by relatively shallow (< 15 m), uniform depths with gently sloping shorelines and few bays. Strong wind events are common on this end of the reservoir, particularly during spring and autumn. The shoreline substrate is mostly small cobble with localized areas of sand and mud; off-shore substrate is predominately mud and silt deposited from the Missouri River. The north (lower) end of Canyon Ferry is much narrower and deeper. It has numerous small bays with steeply sloping, rocky shorelines, particularly off the points of bays. There are also several rocky islands on the north half of the reservoir, some of which are submerged when the reservoir is at full-pool. Generally, there is greater habitat complexity on the north end of the reservoir compared to the southern half.

Canyon Ferry Reservoir fills rapidly during spring run-off in late May and June, reaches its maximum storage in July, then gradually is drawn down to minimum storage levels by the following spring. The Missouri River provides nearly all water input into the reservoir except for a few small perennial tributaries (Duck, Confederate, Beaver, and Magpie creeks) that contribute only minimal inflow. Most water discharge at the dam occurs through three 4.1-m diameter power penstocks at a depth of 28 m. Additional water is released at a depth of 33 m into a pump intake to supply the Helena Valley Regulating Reservoir with irrigation and municipal water. During spring run-off when discharge exceeds the capacity of the power penstocks, excess water is released through four radial gates at the surface and through four 2.1-m diameter river outlets at a depth of 44 m.

The upper end of Canyon Ferry does not stratify because of shallow depths, strong wind activity, and the influence of the Missouri River. The mid and lower portions of the reservoir develop a weak thermocline during the summer, generally at a depth of 12 to 25 m (Horn and Boehmke 1998). It is a dimictic reservoir, turning over in early to mid-October and again in the spring at ice-out. Canyon Ferry is typically ice covered from mid-December through March. The shallower, upper end of the reservoir is the first area to ice-up and is the first portion of the reservoir to become ice-free in the spring, in part because of the warmer water inflows from the Missouri River.

Canyon Ferry is a productive reservoir and has been classified as slightly eutrophic (Rada and Wright 1979) to hyper-eutrophic (Horn and Boehmke 1998) based on chlorophyll *a* and total phosphorus values. The phytoplankton assemblage is dominated by blue-green algae, and current densities are similar to what they were historically (Horn and Boehmke 1998). Peak densities of phytoplankton typically occur in mid-summer (Wright 1958, Rada 1974, Priscu 1987, Horn and Boehmke 1998).

There are 22 species of zooplankton present in Canyon Ferry (Horn and Boehmke 1998). Rotifers are the dominant group numerically, whereas cladocerans account for the greatest total biomass. The cladoceran *Daphnia* spp. is the primary prey of planktivorous fishes in Canyon Ferry (Lere 1990). *Daphnia* typically reach peak densities in mid-May to early June at over 20 per liter, then average about 8-10 per liter during the remainder of the ice-free period (Wright 1980, Lere 1991). Their densities can vary greatly from year to year depending upon climatic conditions and water inflows.

There are 22 species of fish present in Canyon Ferry Reservoir (Table 1). Non-native species are the most abundant game fishes in the reservoir, whereas native species represent the majority of the non-game fish assemblage. Rainbow trout are the most popular game fish and are maintained by an annual stocking program. Yellow perch and white suckers are the most abundant non-game species.

Table 1. Native status and relative abundance of game and non-game fish species present in Canyon Ferry Reservoir, Montana, as of 1999.

Game fish species		Status	Relative abundance
Rainbow trout	*Oncorhynchus mykiss*	non-native	abundant
Walleye	*Stizostedion vitreum*	non-native	abundant
Mountain whitefish	*Prosopium williamsoni*	native	common
Brown trout	*Salmo trutta*	non-native	common
Burbot	*Lota lota*	native	common
Brook trout	*Salvelinus fontinalis*	non-native	rare
Westslope cutthroat trout	*Oncorhynchus clarki lewisi*	native	rare
Northern pike	*Esox lucius*	non-native	rare
Smallmouth bass	*Micropterus dolomieui*	non-native	rare
Largemouth bass	*Micropterus salmoides*	non-native	rare
Non-game fish species		Status	Relative abundance
White sucker	*Catostomus commersoni*	native	abundant
Longnose sucker	*Catostomus catostomus*	native	abundant
Longnose dace	*Rhinichthys cataractae*	native	abundant
Mottled sculpin	*Cottus bairdi*	native	abundant
Yellow perch	*Perca flavescens*	non-native	abundant
Common carp	*Cyprinus carpio*	non-native	abundant
Fathead minnow	*Pimephales promelas*	native	common
Stonecat	*Noturus flavus*	native	common
Utah chub	*Gila atraria*	non-native	common
Flathead chub	*Platygobio gracilis*	native	rare
Mountain sucker	*Catostomus platyrhynchus*	native	rare
Bluegill	*Lepomis macrochirus*	non-native	rare

METHODS

Population Monitoring of Reservoir Fishes

Standardized Sampling

Three established baseline data sets were used to monitor the development of the walleye population in Canyon Ferry Reservoir and changes in existing fisheries. Standardized baseline sampling completed annually during the 1994 through 1999 study period included a sinking gill net series, a floating gill net series, and a beach seine series.

The sinking gill net series consisted of 17 overnight sets in June and 16 overnight sets in August using experimental-mesh sinking gill nets (38.1 m x 1.8 m with equal length panels of 19- ,25- ,38- , 45- , and 51-mm bar mesh). Established in 1955, this series was set periodically primarily to monitor yellow perch population trends.

The floating gill net series consisted of 15 overnight sets in spring and 18 overnight sets in autumn using experimental-mesh floating gill nets (38.1 m x 1.8 m with equal length panels of 19- ,25- ,38- , 45- , and 51-mm bar mesh). This netting series was established in 1986 and was set annually to monitor rainbow trout population trends.

The beach seine series was conducted in August and consisted of 60 sampling sites. This series was standardized in 1991 and originally consisted of 30 sites and the use of a shallower seine (1.8 m). In 1994, it was expanded to 60 sites located throughout the reservoir, and a deeper seine (30.5 m x 3.0 m seine with 6 mm bar mesh) was employed to more efficiently sample age-0 walleye (B. Hill, MFWP, personal communication).

I established a separate standardized netting series in 1996 to specifically monitor the walleye population in Canyon Ferry. These nets were set in depths and habitats similar to those used by telemeterized walleye (Chapter 3). Netting was completed in late September and consisted of 15 overnight sets located throughout the reservoir using experimental-mesh sinking gill nets (38.1 m x 1.8 m with equal length panels of 19, 25, 38, 45, and 51 mm bar mesh). This series was designated the 'walleye netting series' and was set 1996 through 1999. Netting locations for all standardized sampling series are illustrated on maps in the Appendix.

All fish sampled in the sinking net series and the walleye netting series were identified to species and measured to the nearest 0.1 inch total length (TL). Fish captured in the floating net series were identified and measured to the nearest 0.1 inch TL and weighed to the nearest 0.01 pound. Lengths and weights were converted to metric units (i.e., mm and g). Sexual condition (e.g., gravid, ripe, spent) of walleye was noted during the spawning period. Immature walleye were sexed by the criteria suggested by Colby et al. (1979).

<u>Non-standardized Sampling</u>

I completed intensive gill netting in Canyon Ferry Reservoir specifically to live-capture adult walleye for implanting with ultrasonic transmitters during 1994 and 1995. Experimental-mesh sinking gill nets were set in shoreline areas throughout the reservoir in the spring of 1994 and autumns of 1994 and 1995. Autumn netting targeted areas used by already-telemeterized walleye in an attempt to maximize catches of adults. Gill nets and trap nets were used to sample walleye during the 1995 through 1998 spawning periods to meet other objectives of this study (Chapter 4). I collected the same information from walleye sampled in non-standardized netting as was reported above. Length and weight data were not collected from any other species sampled.

Netting Analyses

Catch-per-unit-effort (CPUE) rates were determined by calculating the mean number of fish sampled per net. Relative abundances and CPUE rates were calculated for individual species for each netting series and compared to existing data sets to evaluate any changes in reservoir fish populations (Rehwinkel 1986; Lere 1992). One-way analysis of variance (ANOVA) was used to test for significant differences in net catches among years. Fish other than walleye captured during the non-standardized netting were identified and counted. Live-captured game fish were released. CPUE rates were determined for all species sampled in the non-standardized netting and compared between the 1994 and 1995 autumn sampling periods.

Length frequency distributions of white suckers and yellow perch sampled in the sinking net series were plotted to characterize the population structure of these forage species. Descriptive statistics (i.e., median length and range) were calculated for this data to monitor any changes in the size structure of these populations.

Forage fish production was monitored with beach seine data. Relative numbers of age-0 yellow perch, cyprinids, and suckers (combined total of white and longnose) captured per seine haul were compared to an existing data set (Lere 1992) to evaluate the production of these fishes during the study. Numbers of age-0 walleye sampled were also monitored to develop an index of abundance and determine relative strength of individual year classes. The median TL (mm) of age-0 walleye captured in beach seines was calculated to monitor juvenile growth rates.

Walleye Population Characteristics

Length and Weight Statistics

Descriptive statistics (i.e., median length, median weight, and range) were summarized by individual years for all walleye sampled during the study. Linear regression was used to model the length-weight relationship of the Canyon Ferry walleye population.

Relative stock density (RSD) is a numerical descriptor of length frequency data (Anderson and Neuman 1996). Traditional RSDs (the proportion of stock-length fish that are equal to or longer than the defined minimum lengths of size categories) are most useful for making intercomparisons between populations (Gablehouse 1984). Incremental RSDs (the proportion of stock-length fish that are between the defined minimum lengths for the size categories) are recommended for long-term monitoring of a single population (Gablehouse 1984; Willis et al. 1993). Incremental RSD values were calculated for all walleye sampled in experimental-mesh sinking gill nets during autumn netting efforts. This data was used to monitor the size structure of the developing population and follow strong and weak year classes over time. Additionally, incremental RSDs will provide a tool for monitoring flushing losses of Canyon Ferry walleye into

Hauser and Holter reservoirs. English units measurement data were used to calculate RSD indices to minimize "rounding" errors (Willis et al. 1993). Lengths used for stock (S) - quality (Q), quality - preferred (P), preferred - memorable (M), memorable - trophy (T), and trophy categories were 10.0 - 14.9, 15.0 - 19.9, 20.0 - 24.9, 25.0 - 29.9, and greater than 30-in TL, respectively (Gablehouse 1984). Confidence intervals were calculated for incremental RSD values according to Gustafson (1988).

Age Determination

Dorsal spines were the principal structure used for aging the larger (> 20.0 in TL) walleye because of the inherent difficulty in accurately aging older walleye with scales (Campbell and Babaluk 1979; Erickson 1983; Beamish and McFarlane 1987; Marwitz and Hubert 1995). The first three anterior spines were removed at the base of the dorsal fin from each walleye with side-cutting pliers. Care was taken to make a perpendicular cut across all three spines so that no annuli were lost. Cross-sections were taken within 0.5 cm from the base of the spine to avoid removing the first annulus (Carnevale 1977). Collected spines were stored in individual envelopes labeled with TL, weight, sex, date, sampling gear, and location.

The anterior-most spine (typically the smallest of the three) was separated from the other two and discarded in the laboratory (Marwitz 1994). The second spine was mounted and cross-sectioned; the third spine was retained as a backup in case of unclear annuli or damage to the second spine. Spines were mounted individually in wooden molds lined with wax. Fiberglass resin was poured into the mold until the spine was completely covered and allowed to harden for a minimum of 24 h. Four 0.5 to 1.0 mm cross-sections were cut from the base of each spine with a Dremel® tool with a 2.5 cm diameter cutting disk. Spine sections were polished with mineral oil and then viewed with transmitted light at 48x magnification with a microfilm reader. Spine annuli were identified and ages estimated following the criteria established by Mackay et al. (1990). Ages of walleye sampled in the spring were advanced one year although annulus formation was generally not complete until late May or early June. This was done to coincide with the calendar year to simplify data analyses.

Thirty dorsal spine samples were randomly selected and aged by an independent reviewer without prior knowledge of the size of the walleye or the age I assigned the fish. Precision of our independent age estimates was compared.

Scale samples were collected from most walleye handled during the study. Scales were removed from below the lateral line and above the posterior insertion of the left pectoral fin (Campbell and Babaluk 1979) and impressed on acetate sheets by Wayne Black, MFWP Scale Laboratory, Bozeman, MT. When aging questions arose with the dorsal spine methodology, I referenced the respective scale sample to assist in assigning an accurate age. All smaller walleye (< 20.0 in TL) collected from 1997 to 1999 were aged exclusively with scales. Scales were viewed with a microfilm reader at 24x magnification and annuli were identified by the criteria established by Jearld (1983).

All walleye sampled from 1994 through 1999 were aged with either scales, spine cross sections, or both techniques. Age structure of the different components of the Canyon Ferry Reservoir walleye population were summarized. Age data were summarized seasonally because of size-selective sampling bias inherent with the different sampling techniques employed. Data collected in spring 1995 were not included in summaries because only 10 walleye were sampled. Relative strength of individual year classes represented in the spawning population were compared with those of walleye sampled in the autumn netting.

Growth

Lengths at age were back-calculated for walleye sampled from 1994 through 1996 using the aged dorsal spine sections. Distances (mm) from the focus to successive annuli and the section edge were measured to the nearest 1 mm while projected at 48x magnification on a microfilm reader. Consistency in measuring all sections along the same radius was important because walleye spine sections are asymmetrical. Slight deviations from this radius can produce large errors in back-calculated lengths (Carnevale 1977). I took measurements on the left-anterior portion of the sections from the focus to the most distal edge of the spine (Figure 2).

Annular measurements were entered into an Excel® spreadsheet. A regression of total length to spine radius was used to back-calculate total lengths at age using the Whitney and Carlander (1956) "body proportional" method. Francis (1990) further refined this method by determining the following back-calculation formula when the body-scale (spine) relationship is linear:

$$L_i = [\ (c + dS_i) \ / \ (c + dS_c)\ ]\ L_c$$

where L_i is total length and S_i is radius measurement at time of formation of the *i*th

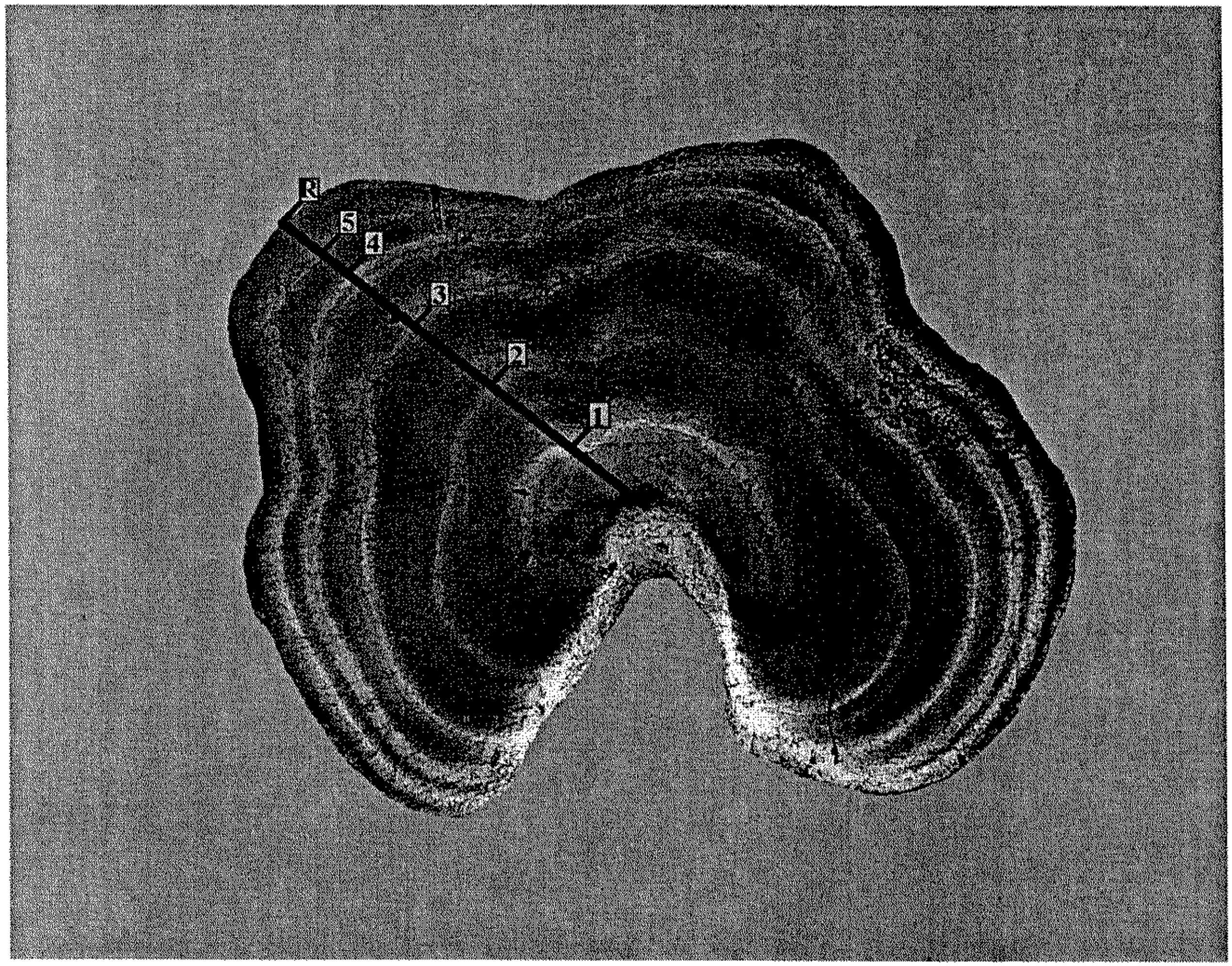


Figure 2. Dorsal spine cross-section of age-5 walleye sampled in Canyon Ferry Reservoir, Montana, in autumn 1995. Solid line represents plane that annuli measurements were taken for back-calculating total lengths at age. Numbers represent successive annuli. Radius edge (R) denotes outside edge of spine section.

annulus, L_c is total length and S_c is total spine radius at time of capture, and *c* is the y intercept and *d* the slope derived from the regression equation.

Back-calculated lengths at age were determined for individual years and compared. A grand mean of back-calculated total lengths was calculated for individual age classes to determine annual growth increments.

Relative Weight

Relative weight (W_r) is a body condition index that provides a physiological measure of relative "plumpness" or "robustness" based on length-weight data (Wege and Anderson 1978; Liao et al. 1995). W_r was computed for all walleye sampled during the study using the formula:

$$W_r = 100 \bullet W / W_s$$

where W is the observed individual weight (g) and W_s is standard weight. Standard weight was determined from the revised formula of Murphy et al. (1990):

$$\log_{10} W_s \text{ (g)} = -5.453 + 3.180 \log_{10} \text{TL (mm)}.$$

W_r is recognized as a valuable assessment tool for monitoring the general ecological health of a population (Liao et al. 1995; Anderson and Neumann 1996; Marwitz and Hubert 1997). However, mean W_r calculated for a single population or stock may "mask" length-specific trends of condition (Murphy et al. 1991; Porath and Peters 1997). Populations are better monitored by determining mean W_r for specific length groups. Mean W_r values were determined for individual RSD length categories for all walleye sampled in experimental-mesh sinking gill nets during autumn netting efforts.

Declines in W_r for individual RSD length groups among years may have indicated changes in prey availability. One-way analysis of variance (ANOVA) was used to test for significant differences in mean W_r for RSD length groups among years. Significance was determined at $P < 0.05$. When significant differences were detected, Tukey's multiple comparison test was used to discern which means were different (Zar 1984). All statistical analyses were performed with SPSS for Windows (1999).

Food Habits

Stomach contents were collected from all walleye sampled in the summer and autumn. Walleye captured during the spring spawning period were inspected for distended stomachs and food items were saved if present. Stomachs were removed in the field by severing the esophagus (Bowen 1983). Contents were stripped into a plastic vial and preserved in 80% denatured ethyl alcohol.

Vial contents were strained from the preservative with a finely woven cotton mesh (< 400 μm) net in the laboratory. Contents were rinsed in tap water, placed in either a Petri dish or dissecting tray, and separated and identified. Prey items not identifiable to species by visual inspection were searched for diagnostic bones to aid in identification (Frost et al. 1996). Flesh not containing diagnostic bones was categorized as "unidentified." Individual prey items were blotted briefly (15 s) with a paper towel and weighed on an electronic balance (0.01 g). Fork lengths (mm) of prey fish with head and caudal fin intact were measured. Frequency of occurrence, mean aggregate percent by weight, and mean individual percent by number were calculated for individual prey items and analyzed by individual years (Hyslop 1980).

RESULTS

Population Trends of Reservoir Fishes

Walleye

No walleye had ever been sampled in MFWP's sinking net series the eight previous times it was set from 1955 to 1984. Five walleye were sampled in these nets in 1994, which was the first time this series was set in its entirety since 1984. The number of walleye sampled in this netting series remained low (range 6 - 37 individuals) in subsequent years, but rose sharply in 1998 to 160 (Figure 3). In 1999, the walleye catch in these nets declined to 60. Catches of walleye in this netting series differed significantly among years (ANOVA; $P < 0.001$). Walleye CPUE was significantly higher in 1998 than in all other years (Tukey; $P < 0.05$); net catch rates of walleye did not differ significantly among other years of the study (Tukey; $P > 0.05$). Walleye accounted for less than 3% of total fish sampled in the sinking net series each year during this study, except in 1998 when they made up 7.3% of the total catch (Table 2).

Floating gill nets do not typically sample walleye effectively, but walleye were consistently observed in this netting series in the later years of this study. Walleye catches in these nets were relatively low (range 0 - 9), but showed an increasing trend

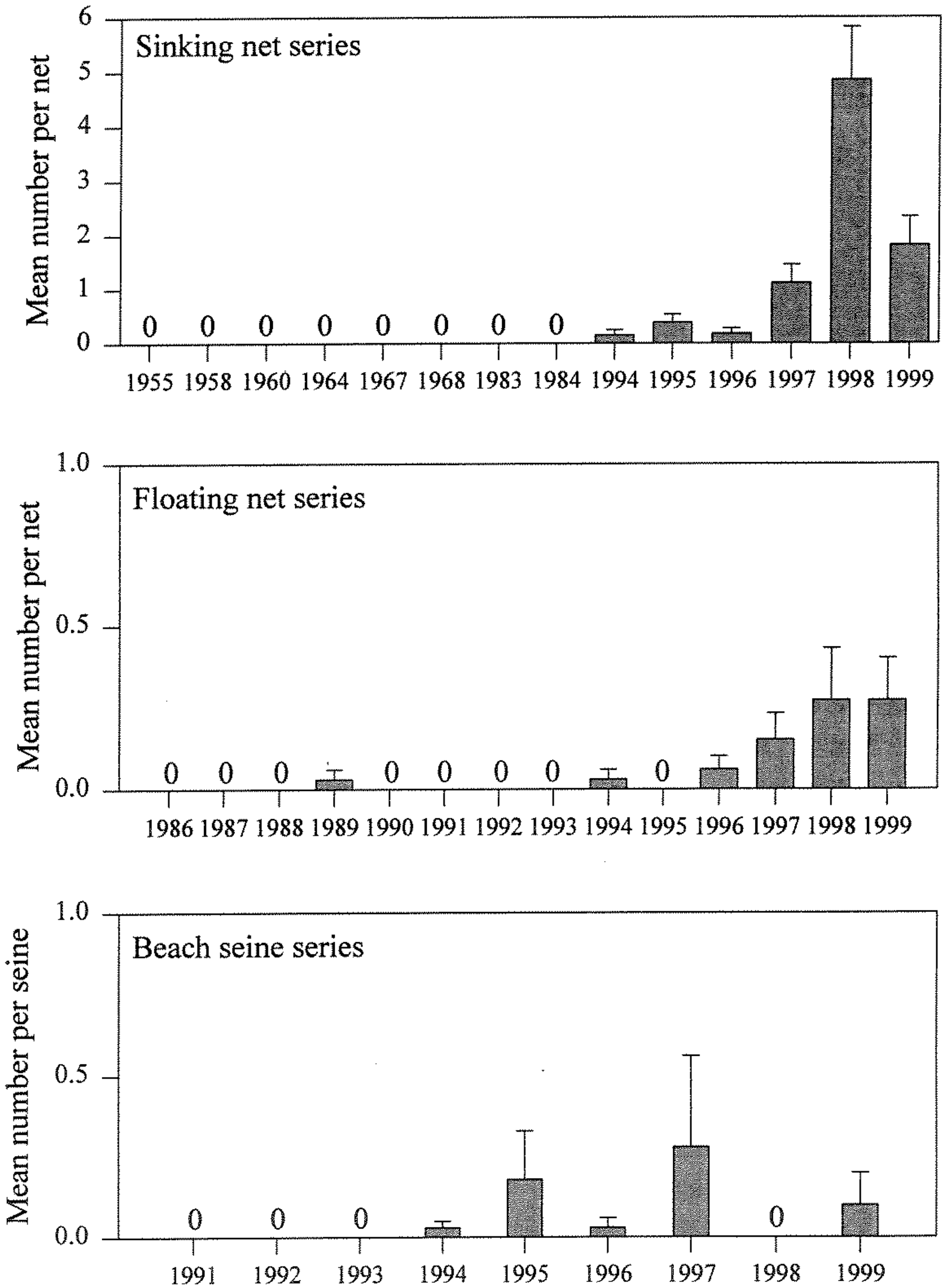


Figure 3. Trends of walleye catch rates in standardized sampling series, Canyon Ferry Reservoir, Montana.

Table 2. Total number sampled (n), mean number per net, and percentage of total catch for all fish sampled in sinking net series in Canyon Ferry Reservoir, Montana, 1955 - 1999. "Other" category includes burbot (until 1984), Utah chubs, and stonecats.

Year		Rainbow trout	Brown trout	Yellow perch	White suckers	Longnose suckers	Common carp	Mountain whitefish	Burbot	Walleye	Other
1955	n:	63	103	250	6,341	1,328	450	121	-	0	35
	n/net:	1.9	3.1	7.6	192.1	40.2	13.6	3.7	-	0	1.1
	% of catch:	0.7	1.2	2.8	73.0	15.3	5.2	1.4	-	0	0.4
1958	n:	16	73	1,422	4,258	105	210	11	-	0	53
	n/net:	0.5	2.2	43.1	129.0	3.2	6.4	0.3	-	0	1.6
	% of catch:	0.2	1.2	23.1	69.3	1.7	3.4	0.2	-	0	0.9
1960	n:	22	51	796	3,444	106	168	11	-	0	19
	n/net:	0.7	1.5	24.1	104.4	3.2	5.1	0.3	-	0	0.6
	% of catch:	0.5	1.1	17.3	74.6	2.3	3.6	0.2	-	0	0.4
1964	n:	22	65	2,613	1,875	98	198	8	-	0	6
	n/net:	0.7	2.0	79.2	56.8	3.0	6.0	0.2	-	0	0.2
	% of catch:	0.5	1.3	53.5	38.4	2.0	4.0	0.2	-	0	0.1
1967	n:	24	78	1,016	1,286	166	200	38	-	0	17
	n/net:	0.7	2.4	30.8	39.0	5.0	6.1	1.1	-	0	0.5
	% of catch:	0.8	2.8	36.0	45.5	5.9	7.1	1.3	-	0	0.6
1968	n:	86	91	2,105	945	246	138	31	-	0	9
	n/net:	2.6	2.8	63.8	28.6	7.5	4.2	0.9	-	0	0.3
	% of catch:	2.4	2.5	57.7	25.9	6.7	3.8	0.8	-	0	0.2

Table 2. Continued.

Year		Rainbow trout	Brown trout	Yellow perch	White sucker	Longnose sucker	Common carp	Mountain whitefish	Burbot	Walleye	Other
1983	n:	29	60	2,353	1,600	74	49	54	-	0	19
	n/net:	0.9	1.8	71.3	48.5	2.2	1.5	1.6	-	0	0.6
	% of catch:	0.7	1.4	55.5	37.8	1.7	1.2	1.3	-	0	0.4
1984	n:	13	77	2,055	1,736	203	40	160	1	0	62
	n/net:	0.4	2.3	62.3	52.6	6.1	1.2	4.8	<0.1	0	1.9
	% of catch:	0.3	1.8	47.3	39.9	4.7	0.9	3.7	<0.1	0	1.4
1994	n:	90	26	334	1,471	69	69	49	10	5	22
	n/net:	2.7	0.8	10.1	44.6	2.1	2.1	1.5	0.3	0.1	0.7
	% of catch:	4.2	1.2	15.6	68.6	3.2	3.2	2.3	0.5	0.2	1.0
1995	n:	71	16	541	1,512	147	36	37	22	13	5
	n/net:	2.1	0.5	16.4	45.8	4.4	1.1	1.1	0.7	0.4	0.1
	% of catch:	3.0	0.7	22.6	63.0	6.1	1.5	1.5	0.9	0.5	0.2
1996	n:	90	16	566	1,531	103	54	19	15	6	13
	n/net:	2.7	0.5	17.1	46.4	3.1	1.6	0.6	0.4	0.2	0.4
	% of catch:	3.7	0.7	23.5	63.4	4.3	2.2	0.8	0.6	0.3	0.5
1997	n:	43	15	804	1,198	130	51	15	12	37	14
	n/net:	1.3	0.5	24.4	36.3	3.9	1.5	0.5	0.4	1.1	0.4
	% of catch:	1.9	0.6	34.7	51.7	5.6	2.2	0.6	0.5	1.6	0.6
1998	n:	36	9	587	1,194	120	62	2	12	160	11
	n/net:	1.1	0.3	17.8	36.2	3.6	1.9	0.1	0.4	4.8	0.3
	% of catch:	1.6	0.4	26.8	54.4	5.5	2.9	0.1	0.5	7.3	0.5
1999	n:	62	6	1,541	919	103	31	0	4	60	7
	n/net:	1.8	0.2	46.7	27.8	3.1	0.9	0	0.1	1.8	0.2
	% of catch:	2.3	0.2	56.4	33.6	3.8	1.1	0	0.1	2.2	0.3

from 1996 to 1998 (Figure 3). Walleye accounted for less than 4% of the overall catch for each spring and autumn sampling period (Table 3), similar to the sinking net series.

Walleye catch rates in the walleye netting series increased sharply from 2.1 (SE = 0.80) walleye per net in 1996 to 10.4 (SE = 2.01) in 1998. Younger age classes (age 1 and age 2) of walleye produced in 1996 and 1997 accounted for 95% of the 1998 catch (Figure 4). Catch rates declined to 6.5 (SE = 1.80) walleye per net in 1999, as yearlings were nearly absent from the sample. The 1996 and 1997 year classes continued to dominate the catch in 1999 (Figure 4). Walleye CPUE in this netting series differed significantly among years (ANOVA; $P = 0.005$). Net catch rates of walleye in 1997 and 1998 were significantly higher than those observed in 1996 (Tukey; $P < 0.05$); 1999 net catches did not differ significantly from any other year (Tukey; $P > 0.05$).

Although efforts to monitor walleye recruitment were intensified (i.e., number of sampling sites was doubled to 60 and a deeper seine was used) during this study, few age-0 walleye were sampled in the beach seining series (Figure 3; Table 4). Two age-0 walleye were sampled in this series in 1994, 11 in 1995, two in 1996, 17 in 1997, and six in 1999. None were sampled in 1998. Median TL of age-0 walleye was 140 mm (range 109 - 160) in late August when this sampling was completed.

Walleye CPUE rates were higher in the non-standardized netting than in the standardized netting series in 1994 and 1995. Exploratory net sets targeting spawning walleye in the spring of 1994 resulted in seven juvenile walleye sampled in 72 net sets (mean = 0.1, SE = 0.03). After the spawning area was identified, 41 adult walleye were

Table 3. Total number sampled, mean number per net, and percentage of total catch for all fish sampled in spring (spr) and autumn (aut) floating net series in Canyon Ferry Reservoir, Montana, 1994 - 1999.

		1994		1995		1996		1997		1998		1999	
		spr	aut	spr	aut	spr	aut	spr	aut	spr	aut	spr	aut
Rainbow trout	n:	203	415	179	198	214	186	79	177	121	165	175	183
	n/net:	13.5	23.1	11.9	11.0	14.3	10.3	7.9	9.8	8.1	9.2	11.7	10.2
	% of catch:	84.2	93.3	71.9	88.8	79.9	79.8	47.6	82.7	65.4	82.5	66.5	76.6
Brown trout	n:	3	9	8	3	7	4	4	5	4	12	6	5
	n/net:	0.2	0.5	0.5	0.2	0.5	0.2	0.4	0.3	0.3	0.7	0.4	0.3
	% of catch:	1.3	2.0	3.2	1.4	2.6	1.7	2.4	2.3	2.2	6.0	2.3	2.1
Yellow perch	n:	0	0	1	0	0	0	1	0	0	0	0	0
	n/net:	0	0	0.1	0	0	0	0.1	0	0	0	0	0
	% of catch:	0	0	0.4	0	0	0	0.6	0	0	0	0	0
White sucker	n:	3	5	13	7	12	19	17	6	13	4	12	4
	n/net:	0.2	0.3	0.9	0.4	0.8	1.1	1.7	0.3	0.9	0.2	0.8	0.2
	% of catch:	1.3	1.2	5.2	3.1	4.5	8.2	10.2	2.8	7.0	2.0	4.6	1.7
Longnose sucker	n:	0	1	1	0	2	0	2	1	0	2	0	0
	n/net:	0	0.1	0.1	0	0.1	0	0.2	0.1	0	0.1	0	0
	% of catch:	0	0.2	0.4	0	0.7	0	1.2	0.5	0	1.0	0	0
Common carp	n:	30	13	46	11	31	19	62	20	26	13	36	43
	n/net:	2.0	0.7	3.1	0.6	2.1	1.1	6.2	1.1	1.7	0.7	2.4	2.4
	% of catch:	12.4	2.9	18.5	4.9	11.6	8.2	37.4	9.3	14.1	6.5	13.7	18.0
Utah chub	n:	2	1	1	4	2	3	0	1	15	1	28	1
	n/net:	0.1	0.1	0.1	0.2	0.1	0.2	0	0.1	1.0	0.1	1.9	0.1
	% of catch:	0.8	0.2	0.4	1.8	0.7	1.3	0	0.5	8.1	0.5	10.6	0.4
Walleye	n:	0	1	0	0	0	2	1	4	6	3	6	3
	n/net:	0	0.1	0	0	0	0.1	0.1	0.2	0.4	0.2	0.4	0.2
	% of catch:	0	0.2	0	0	0	0.8	0.6	1.9	3.2	1.5	2.3	1.3

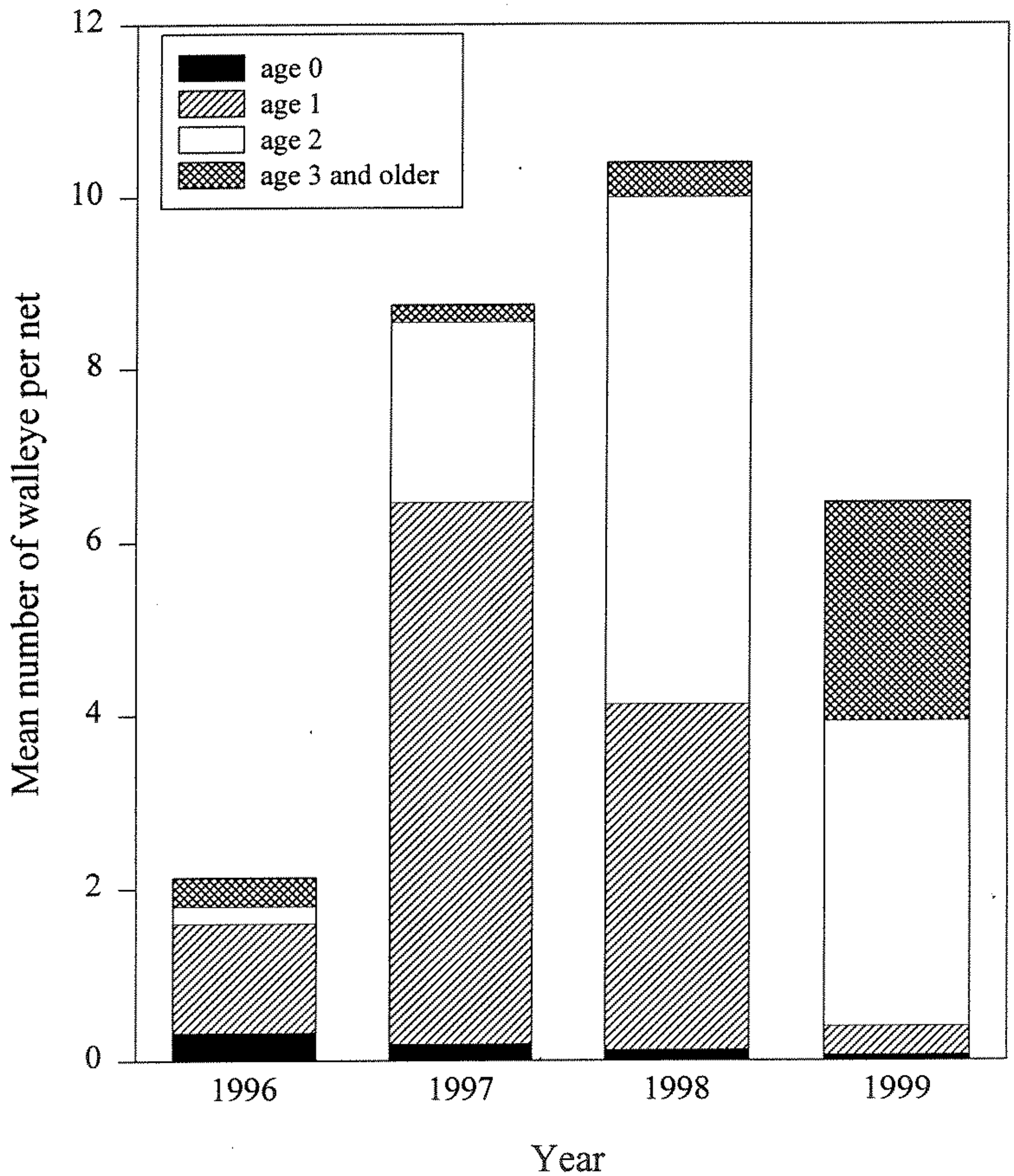


Figure 4. Mean net catch by age of walleye sampled in standardized walleye netting series, Canyon Ferry Reservoir, Montana, 1996 - 1999.

Table 4. Total and mean catch rates of age-0 yellow perch, sucker spp., cyprinids, and walleye in beach seines in Canyon Ferry Reservoir, Montana, 1991 - 1999. Catches of sucker spp. and cyprinids were not recorded (NR) in 1991 and 1992.

			Total catch				Mean number per seine			
		Tows	Yellow perch	Sucker spp.	Cyprinids	Walleye	Yellow perch	Sucker spp.	Cyprinids	Walleye
1991	Upper	10	29,672	NR	NR	0	2,967.2	NR	NR	0
	Middle	10	6,890	NR	NR	0	689.0	NR	NR	0
	Lower	10	8,148	NR	NR	0	814.8	NR	NR	0
	Total	30	44,710	NR	NR	0	1,490.3	NR	NR	0
1992	Upper	10	8,284	7,206	12	0	828.4	720.6	1.2	0
	Middle	10	6	168	2	0	0.6	16.8	0.2	0
	Lower	10	15,276	2,023	1	0	1,527.6	202.3	0.1	0
	Total	30	23,566	9,397	15	0	785.5	313.2	0.5	0
1993	Upper	10	15,205	399	0	0	1,520.5	39.9	0	0
	Middle	10	6,095	2,847	4	0	609.5	284.7	0.4	0
	Lower	10	6,196	907	1	0	619.6	90.7	0.1	0
	Total	30	27,496	4,153	5	0	916.5	138.4	0.2	0
1994	Upper	20	895	729	52	0	44.8	36.5	2.6	0
	Middle	20	231	2,632	0	0	11.6	131.6	0	0
	Lower	20	652	2,741	0	2	32.6	137.1	0	0.1
	Total	60	1,778	6,102	52	2	29.6	101.7	0.9	<0.1

Table 4. Continued.

			Total catch				Mean number per seine			
		Tows	Yellow perch	Sucker spp.	Cyprinids	Walleye	Yellow perch	Sucker spp.	Cyprinids	Walleye
1995	Upper	20	7,180	717	9	0	359.0	35.9	0.5	0
	Middle	20	8,082	519	6	0	404.1	25.9	0.3	0
	Lower	20	18,452	4,819	0	11	922.6	241.0	0	0.5
	Total	60	33,714	6,055	15	11	561.9	100.9	0.3	0.2
1996	Upper	20	4,259	5,094	183	0	212.9	254.7	9.1	0
	Middle	20	457	3,815	35	2	22.8	190.7	1.7	0.1
	Lower	20	6,441	10,591	8	0	332.0	529.5	0.4	0
	Total	60	11,157	19,500	226	2	185.9	325.0	3.8	<0.1
1997	Upper	20	3,582	123	2	0	179.1	6.1	0.1	0
	Middle	20	3,355	2,280	40	0	167.7	114.0	2.0	0
	Lower	20	5,299	6,283	12	17	264.9	314.1	0.6	0.8
	Total	60	12,236	8,686	54	17	203.9	144.8	0.9	0.3
1998	Upper	20	4,140	2,904	180	0	207.0	145.2	9.0	0
	Middle	20	879	3,935	105	0	43.9	196.7	5.2	0
	Lower	20	8,519	6,509	259	0	425.9	325.4	12.9	0
	Total	60	13,538	13,348	544	0	225.6	222.5	9.1	0
1999	Upper	20	3,036	1,665	59	0	151.8	83.2	2.9	0
	Middle	20	614	2,494	126	0	30.7	124.7	6.3	0
	Lower	20	5,026	10,531	51	6	251.3	526.5	2.5	0.3
	Total	60	8,676	14,690	236	6	144.6	244.8	3.9	0.1

sampled in 18 nets (mean = 2.3, SE = 0.59). This spawning population was sampled annually for the duration of the study. These results are discussed in detail in Chapter 4.

The non-standardized sampling completed in autumns of 1994 and 1995 was based on known habitat use of telemeterized walleye and was my best effort at sampling individuals. Walleye CPUE rates averaged 1.0 (SE = 0.14) walleye per net (67 walleye sampled in 68 nets) in 1994 and 1.1 (SE = 0.14) walleye per net (119 walleye sampled in 106 nets) in 1995 (Figure 5). Walleye comprised 2.4% of the total catch in these nets in 1994 and 3.4% in 1995 (Tables 5, 6).

Yellow Perch

Mean CPUE rates of yellow perch in the sinking net series in 1994 were the lowest since the series was first set in 1955, averaging 10.1 (SE = 2.24) per net. Catch rates exhibited a slightly increasing trend through 1998, then more than doubled to 46.7 (SE = 10.34) yellow perch per net in 1999 (Figure 6). CPUE of yellow perch in this netting series differed significantly among years (ANOVA; $P < 0.001$). Net catch rates of yellow perch in 1999 were significantly higher than all other years of the study period (Tukey; $P < 0.05$); other years did not differ significantly (Tukey; $P > 0.05$). The relative contribution of yellow perch to the overall catch in this series was much reduced in the 1994 through 1998 sampling, but attained levels in 1999 (56.4%) comparable to the historic high proportion in 1968 (57.7%; Table 2).

Length-frequency distributions of yellow perch sampled in the sinking net series from 1994 through 1998 indicated a relatively uniform distribution of size classes. A

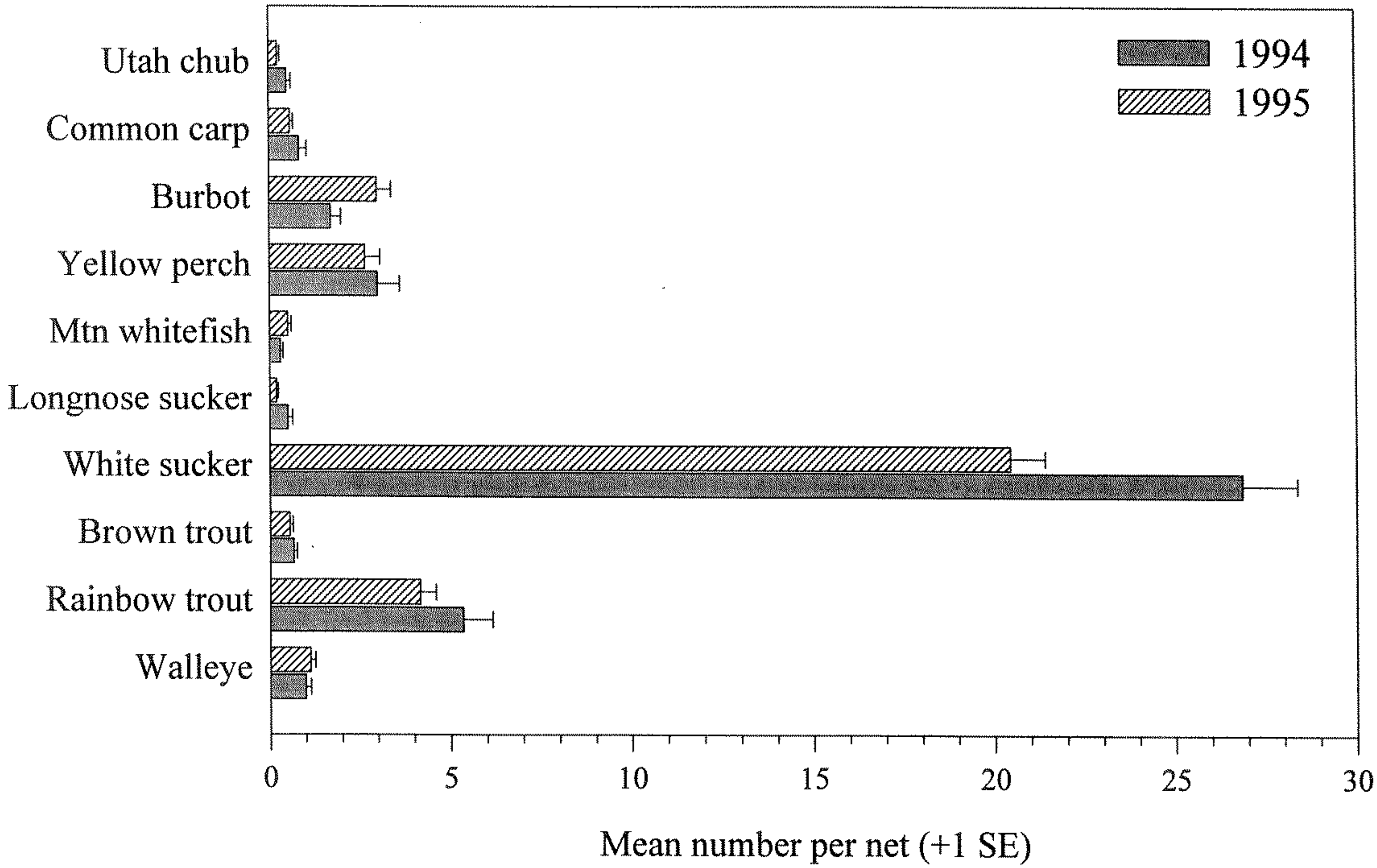


Figure 5. Mean number (+1 SE) of fish sampled in gill nets (non-standardized) specifically targeting walleye in Canyon Ferry Reservoir, Montana, autumns 1994 and 1995.

Table 5. Sampling information, individual net catches, total and mean (SE) catches, and percent of total catch for individual species sampled in experimental-mesh sinking gill nets set targeting walleye during autumn 1994, Canyon Ferry Reservoir, Montana.

Date	Number of nets	Water temp (C)	Walleye	Rainbow trout	Brown trout	Yellow perch	White sucker	Longnose sucker	Common carp	Mtn. whitefish	Burbot	Utah chub
18 Oct	6	13.5	13	23	2	32	185	14	5	0	3	2
19 Oct	6	13.0	4	8	1	8	115	0	5	6	0	0
20 Oct	6	12.5	11	20	4	21	209	4	2	0	6	3
21 Oct	6	12.5	9	18	2	23	218	7	6	1	2	1
01 Nov	8	10.5	6	86	3	19	233	2	4	2	17	6
03 Nov	6	9.5	4	35	4	55	237	1	4	2	4	8
04 Nov	6	9.5	1	118	2	5	106	1	18	7	4	1
09 Nov	6	9.0	5	15	5	17	170	1	5	1	30	2
10 Nov	6	9.0	8	14	8	13	134	1	2	0	19	2
11 Nov	6	9.5	4	9	6	7	93	2	1	1	21	6
17 Nov	6	8.5	2	17	7	4	126	1	5	0	10	2
Total:	68		67	363	44	204	1,826	34	57	20	116	33
n/net:			1.0	5.3	0.6	3.0	26.8	0.5	0.8	0.3	1.7	0.5
			(0.14)	(0.81)	(0.10)	(0.61)	(1.52)	(0.14)	(0.21)	(0.07)	(0.28)	(0.12)
% of catch:			2.4	13.1	1.6	7.4	66.1	1.2	2.1	0.7	4.2	1.2

Table 6. Sampling information, individual net catches, total and mean (SE) catches, and percent of total catch for individual species sampled in experimental-mesh sinking gill nets set targeting walleye during autumn 1995, Canyon Ferry Reservoir, Montana.

Date	Number of nets	Water temp (C)	Walleye	Rainbow trout	Brown trout	Yellow perch	White sucker	Longnose sucker	Common carp	Mtn. whitefish	Burbot	Utah chub
18 Oct	4	13.0	9	26	3	4	104	1	2	4	3	2
19 Oct	4	13.0	5	18	2	7	77	1	1	0	7	1
20 Oct	6	13.0	11	44	1	12	155	3	8	4	10	2
24 Oct	6	12.0	18	54	2	11	131	0	1	2	3	1
25 Oct	6	13.0	5	36	0	5	128	2	1	0	10	1
26 Oct	6	13.0	5	43	3	5	107	1	3	1	3	0
28 Oct	4	11.0	1	38	2	3	49	0	0	3	5	1
29 Oct	4	11.5	1	32	1	2	51	2	3	2	5	1
04 Nov	4	9.5	3	16	0	2	111	0	1	4	5	1
05 Nov	4	9.5	1	21	2	1	101	0	4	0	6	2
06 Nov	6	9.5	7	7	1	12	113	0	2	1	15	0
09 Nov	6	9.0	12	13	3	11	99	0	5	2	11	1
14 Nov	6	8.0	2	15	4	12	94	5	1	3	20	2
15 Nov	6	9.0	2	16	4	12	141	0	3	4	34	0
16 Nov	6	8.0	9	10	1	15	108	1	6	0	31	0
17 Nov	6	8.0	3	6	3	23	119	1	1	0	20	0
18 Nov	6	8.0	10	20	18	48	165	0	11	7	43	7
19 Nov	6	7.0	7	7	1	27	71	0	1	3	16	2
30 Nov	4	5.5	1	14	5	22	137	0	2	9	15	1
01 Dec	6	6.5	7	5	1	48	105	2	6	4	54	0
Total:	106		119	441	57	282	2,166	19	62	53	316	25
n/net:			1.1	4.2	0.5	2.7	20.4	0.2	0.6	0.5	3.0	0.2
			(0.14)	(0.43)	(0.09)	(0.41)	(0.96)	(0.06)	(0.09)	(0.10)	(0.40)	(0.06)
% of catch:			3.4	12.5	1.6	8.0	61.2	0.5	1.8	1.5	8.9	0.7

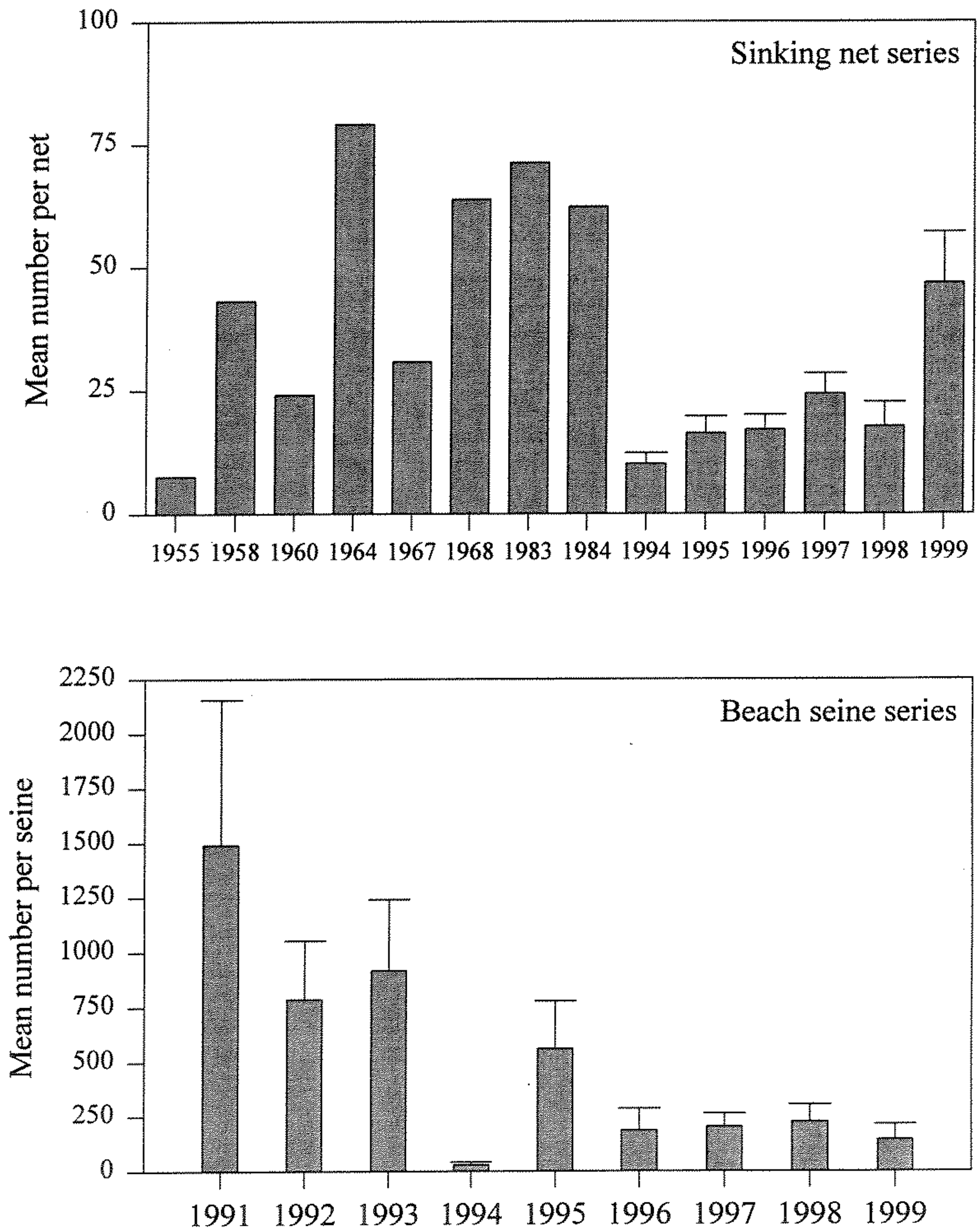


Figure 6. Trends of yellow perch catch rates in standardized sampling series, Canyon Ferry Reservoir, Montana. Sinking net series catch rates include all yellow perch sampled. Beach seine series catch rates summarize catches of age-0 yellow perch. Vertical lines represent +1 standard error.

large cohort of smaller perch accounted for the sharp increase in the net catch rates in 1999 (Figure 7). Yellow perch sampled in this netting series in 1999 exhibited the lowest median length (173 mm TL) and greatest size range (112 - 325 mm TL) observed during this study (Table 7).

Table 7. Number sampled, median total length (TL), and range of yellow perch sampled in sinking gill net series in Canyon Ferry Reservoir, Montana, 1994 - 1999.

Year	Number sampled	Median TL (mm)	Range (mm)
1994	334	208	132 - 292
1995	541	211	124 - 300
1996	566	176	124 - 297
1997	804	193	119 - 312
1998	587	185	127 - 272
1999	1,541	173	112 - 325

Gill net catch rates of yellow perch in the non-standardized netting in the spring of 1994 and autumns of 1994 and 1995 were much lower than the mean CPUE rates of yellow perch in the sinking net series (i.e., summer sampling). Mean CPUE rates in the non-standardized netting in autumns of 1994 and 1995 were consistent, averaging about three yellow perch per net (Figure 5). Catch rate of yellow perch in the spring 1994 walleye netting was similar to those observed in the autumn 1994 and 1995 sampling (Tables 5, 6, 8).

Yellow perch production was variable during this study (Figure 6). Mean CPUE rates of age-0 yellow perch ranged from 29.6 (SE = 12.90) per seine haul in 1994 to 561.9 (SE = 216.47) in 1995 (Table 4). The 1994 catch rate was the lowest observed in the

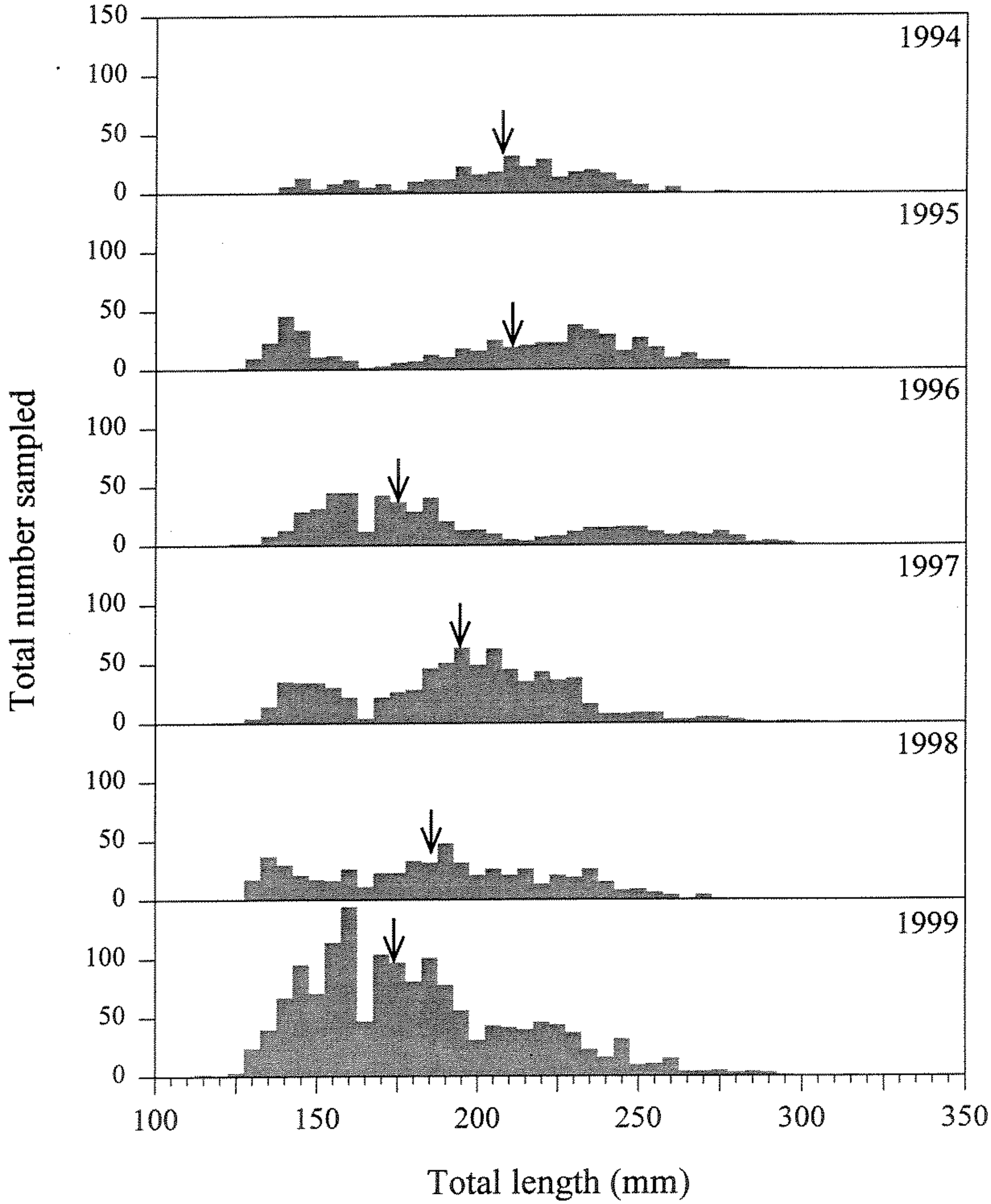


Figure 7. Length-frequency distributions (↓ median TL) of yellow perch sampled in sinking gill net series, Canyon Ferry Reservoir, Montana, 1994 - 1999.

Table 8. Sampling information, individual net catches, total and mean (SE) catches, and percent of total catch for individual species sampled in experimental-mesh sinking gill nets set targeting walleye during spring 1994, Canyon Ferry Reservoir, Montana.

Date	Number of nets	Water temp (C)	Walleye	Rainbow trout	Brown trout	Yellow perch	White sucker	Longnose sucker	Common carp	Mtn. whitefish	Burbot	Utah chub
08 Apr	8	4.5	0	4	2	2	84	1	13	13	11	1
09 Apr	6	4.5	2	5	4	8	42	6	0	5	13	0
11 Apr	8	4.0	1	8	2	6	25	4	0	11	13	0
12 Apr	8	4.5	0	13	8	14	53	3	0	16	21	0
14 Apr	4	8.0	1	3	0	23	93	8	3	2	0	0
15 Apr	7	8.0	0	20	3	57	139	4	10	17	3	1
16 Apr	7	9.5	0	8	1	47	173	5	5	9	2	0
19 Apr	8	5.5	4	18	4	3	94	5	1	12	10	0
20 Apr	8	8.0	0	5	8	15	156	0	9	38	15	0
21 Apr	8	11.5	0	3	7	61	214	18	0	6	28	5
28 Apr	8	8.0	15	89	2	95	84	4	6	28	15	66
29 Apr	4	8.5	8	72	2	27	19	3	17	7	1	37
30 Apr	2	11.5	9	32	0	8	26	0	6	5	1	19
01 May	2	11.0	8	37	2	8	25	2	8	4	0	13
04 May	2	11.5	0	36	2	11	21	0	38	10	0	28
Total:	90		48	353	47	385	1,248	63	116	183	133	170
n/net:			0.5	3.9	0.5	4.3	13.9	0.7	1.3	2.0	1.5	1.9
			(0.15)	(0.64)	(0.08)	(0.58)	(1.03)	(0.12)	(0.34)	(0.22)	(0.19)	(0.45)
% of catch:			1.7	12.9	1.7	14.0	45.4	2.3	4.2	6.7	4.8	6.2

beach seining series data set. The 1996 through 1999 seine CPUE rates were relatively stable, averaging around 200 age-0 yellow perch per seine haul (Figure 6).

White Suckers

Mean CPUE rates of white suckers in the sinking net series changed little since 1964, averaging about 30 to 50 per net (Figure 8). Catch rates during this study remained within that range until 1999, when they declined to 27.8 (SE = 2.17) white suckers per net. Catches of white suckers in this netting series differed significantly among years (ANOVA; $P < 0.001$). White sucker CPUE was significantly less in 1999 than in the earlier (1994 - 1996) years of the study (Tukey; $P < 0.05$); net catch rates of white suckers did not differ significantly among years from 1994 to 1998 and from 1997 to 1999 (Tukey; $P > 0.05$). Relative contribution of white suckers to total number of fish sampled in the sinking net series decreased from 68.6% in 1994 to 33.6% in 1999 (Table 2).

Length-frequency distributions of white suckers sampled in the sinking net series indicated an apparent shift in the size structure of this population. There was a marked decline in the number of smaller white suckers sampled in these nets during this study. Net catches of white suckers less than 250 mm TL decreased from 20.8% of the total catch in 1995 to 7.7% in 1999 (Figure 9). Median total length of white suckers sampled in these nets showed an increasing trend during this study, although size ranges remained consistent (Table 9).

Mean CPUE rates of white suckers in the non-standardized netting were lower than those observed in the sinking net series (Tables 2, 5, 6, 8). Catch rates were lowest

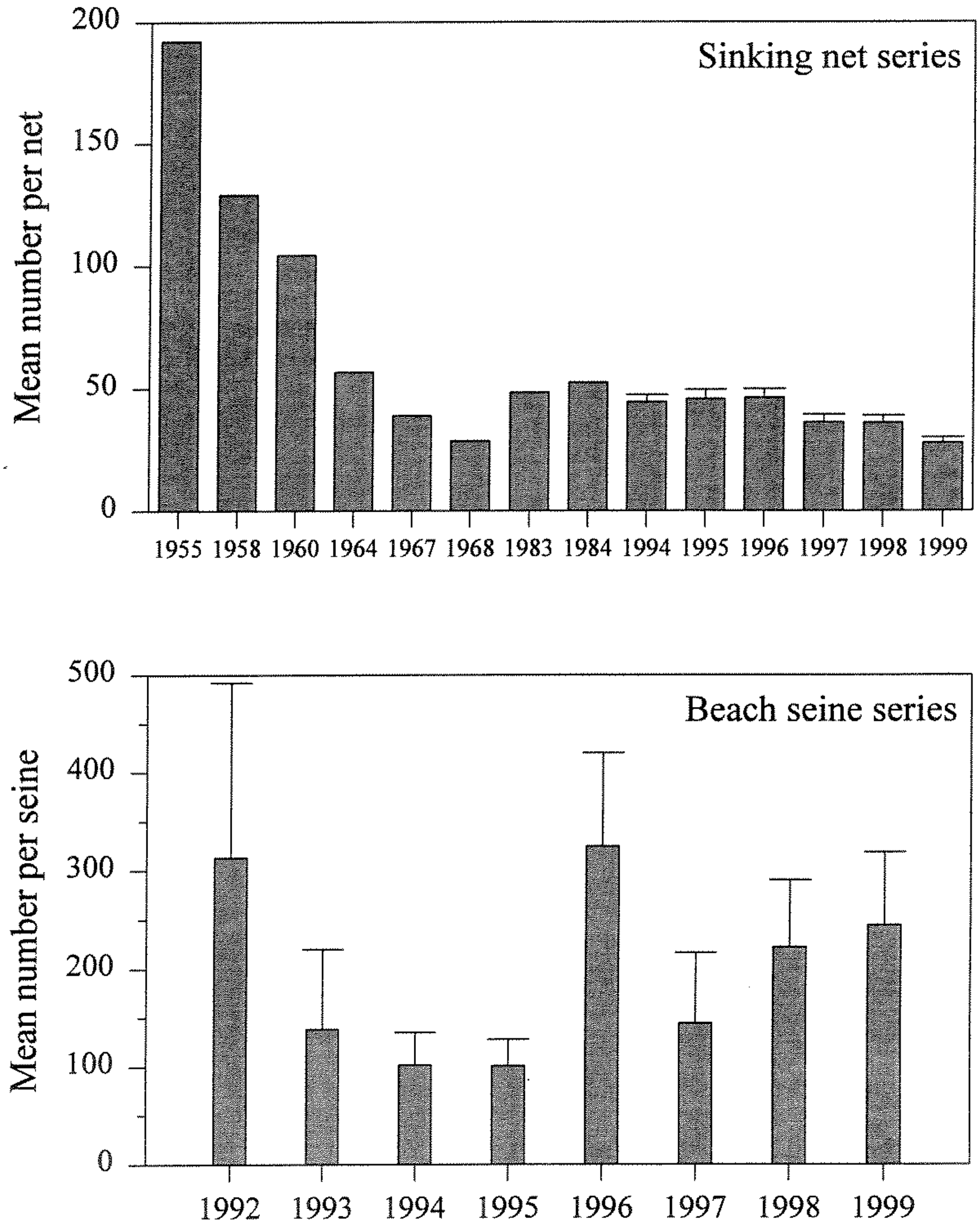


Figure 8. Trends of white sucker catch rates in standardized sampling series, Canyon Ferry Reservoir, Montana. Sinking net series catch rates include all white suckers sampled. Beach seine series catch rates summarize catches of age-0 white suckers. Vertical lines represent +1 standard error.

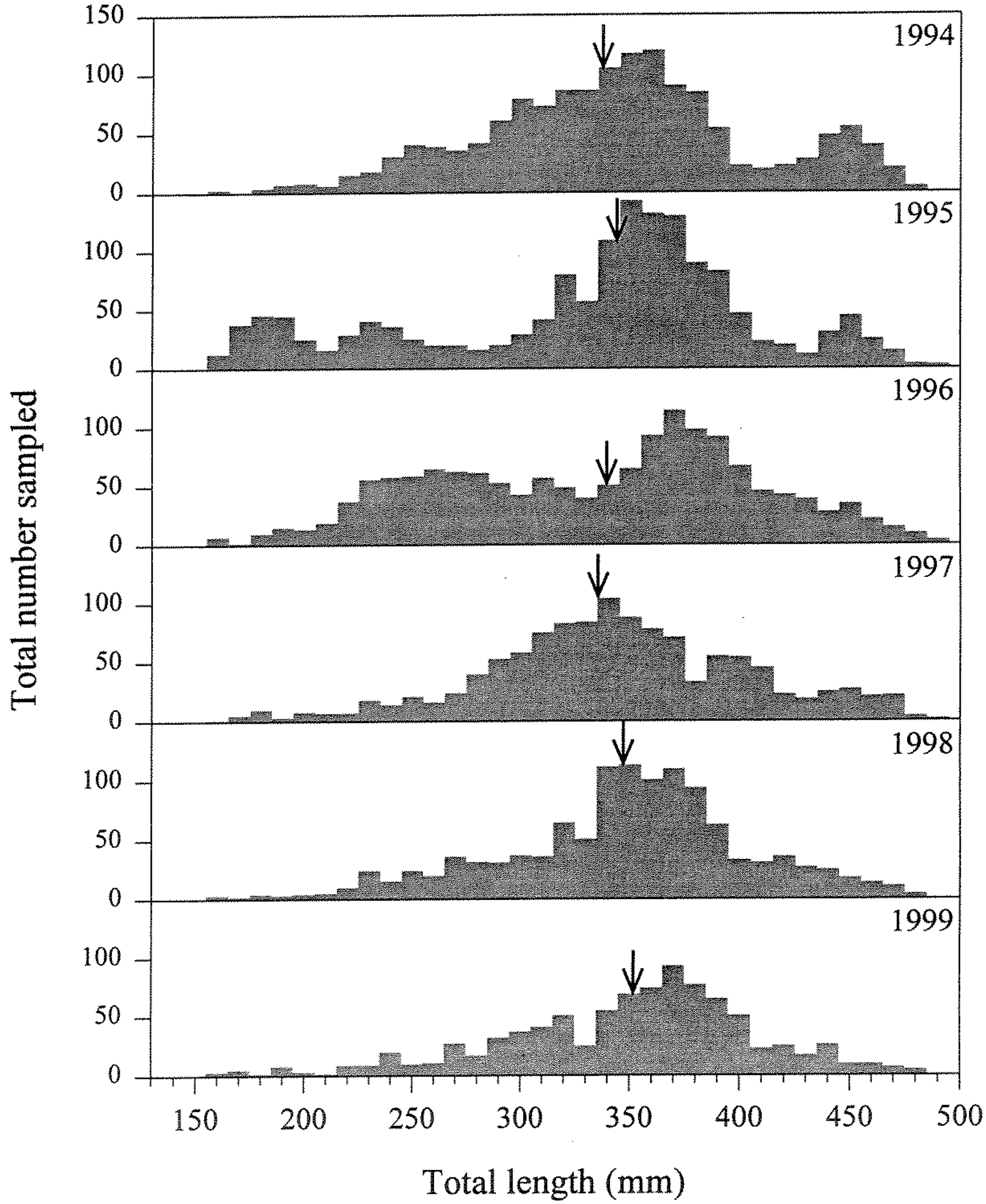


Figure 9. Length-frequency distributions (↓ median TL) of white suckers sampled in sinking gill net series, Canyon Ferry Reservoir, Montana, 1994 - 1999.

Table 9. Number sampled, median total length (TL), and range of white suckers sampled in sinking gill net series in Canyon Ferry Reservoir, Montana, 1994 - 1999.

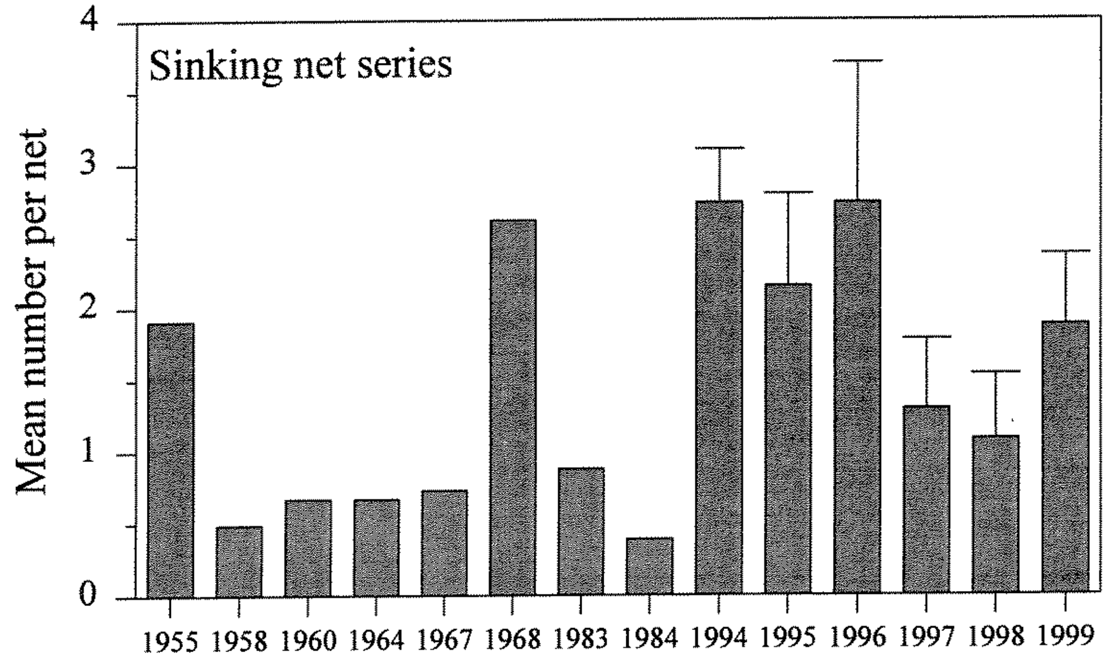
Year	Number sampled	Median TL (mm)	Range (mm)
1994	1,471	338	155 - 490
1995	1,512	343	150 - 500
1996	1,531	340	155 - 488
1997	1,198	335	160 - 487
1998	1,194	349	160 - 480
1999	919	353	155 - 477

in the netting completed in the spring of 1994, averaging 13.9 (SE = 1.02) white suckers per net. There was a decline in white sucker catch rates in the non-standardized netting in autumn 1995 relative to autumn 1994 (Figure 5).

Annual production of age-0 suckers spp. from 1994 to 1999 was relatively consistent and comparable to previous data (Figure 8). Mean CPUE rates of age-0 sucker spp. ranged from 100.9 (SE = 27.11) per seine haul in 1995 to 325.0 (SE = 94.97) in 1996. This catch rate is the highest recorded for age-0 sucker spp. in the beach seine data set (Table 4).

Rainbow Trout

Rainbow trout catch rates were stable in the sinking net series during this study, but generally higher than historic catches (Figure 10). Mean CPUE rates ranged from 1.1 (SE = 0.45) rainbow trout per net in 1998 to 2.7 (SE = 0.37) in 1994 and 2.7 (SE = 0.97) per net in 1996 (Table 2). Mean catch rates of rainbow trout in the floating net series were similar each year of the study, except in autumn 1994 (Figure 10). Catch rates in



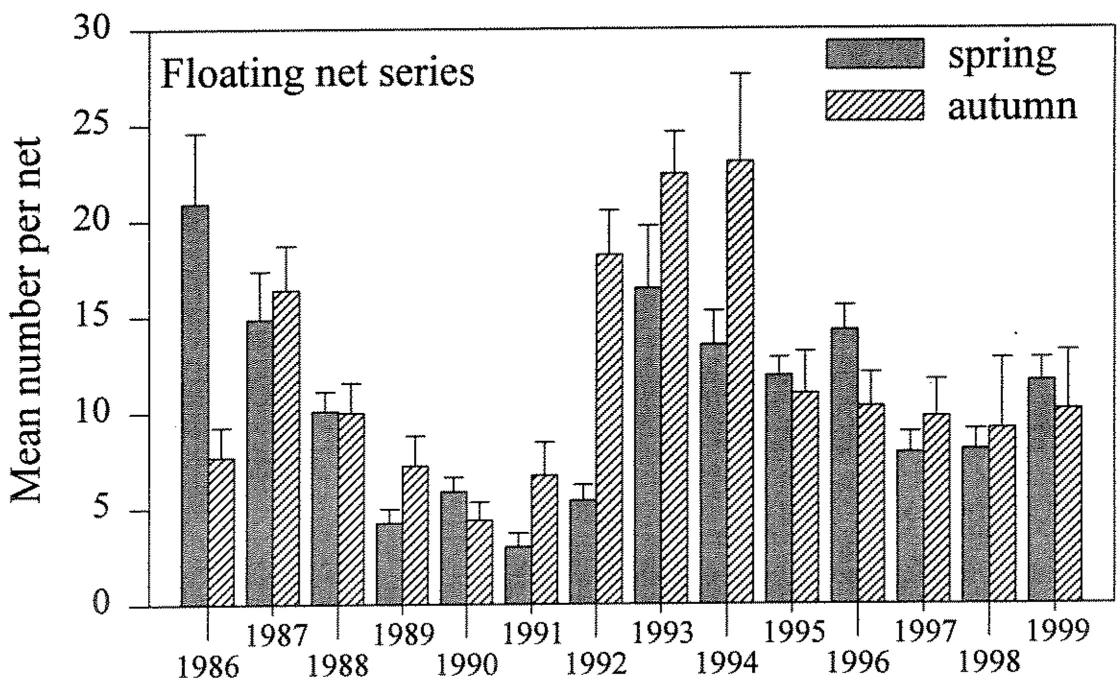


Figure 10. Trends of rainbow trout catch rates in standardized sinking and floating net series, Canyon Ferry Reservoir, Montana. Vertical lines represent +1 standard error.

autumn 1994 were the highest ever observed in this netting series, averaging 23.1 (SE = 4.54) rainbow trout per net (Table 3). Rainbow trout were the primary species sampled in the floating net series, accounting for between 48% and 93% of all fish sampled in these nets each year of this study (Table 3).

Brown Trout

Mean CPUE rates of brown trout in the sinking net series were much reduced during this study relative to historic data (Figure 11). Additionally, catch rates exhibited a continued declining trend in these nets from 0.8 (SE = 0.21) brown trout per net in 1994 to 0.2 (SE = 0.10) in 1999 (Table 2). This decline was mirrored in the spring component of the floating net series beginning in the early 1990s and continued through 1999 (Figure 11). Brown trout accounted for 1% or less of the total catch in the sinking net series during this study, but up to 6% of the total catch in the floating net series (Tables 2, 3).

Other Species

Other fishes sampled in the sinking net and floating net series included longnose sucker, common carp, mountain whitefish, burbot, Utah chub, and stonecat (Tables 2, 3).

Cyprinids sampled in the beach seine series were common carp, Utah chub, longnose dace, and fathead minnow. Catches of these less abundant species were combined (as "cyprinids") for analysis. Catch rates of cyprinids were low throughout the study (Figure 12); the highest mean catch rate observed was 9.1 (SE = 4.01) cyprinids per seine in 1998.

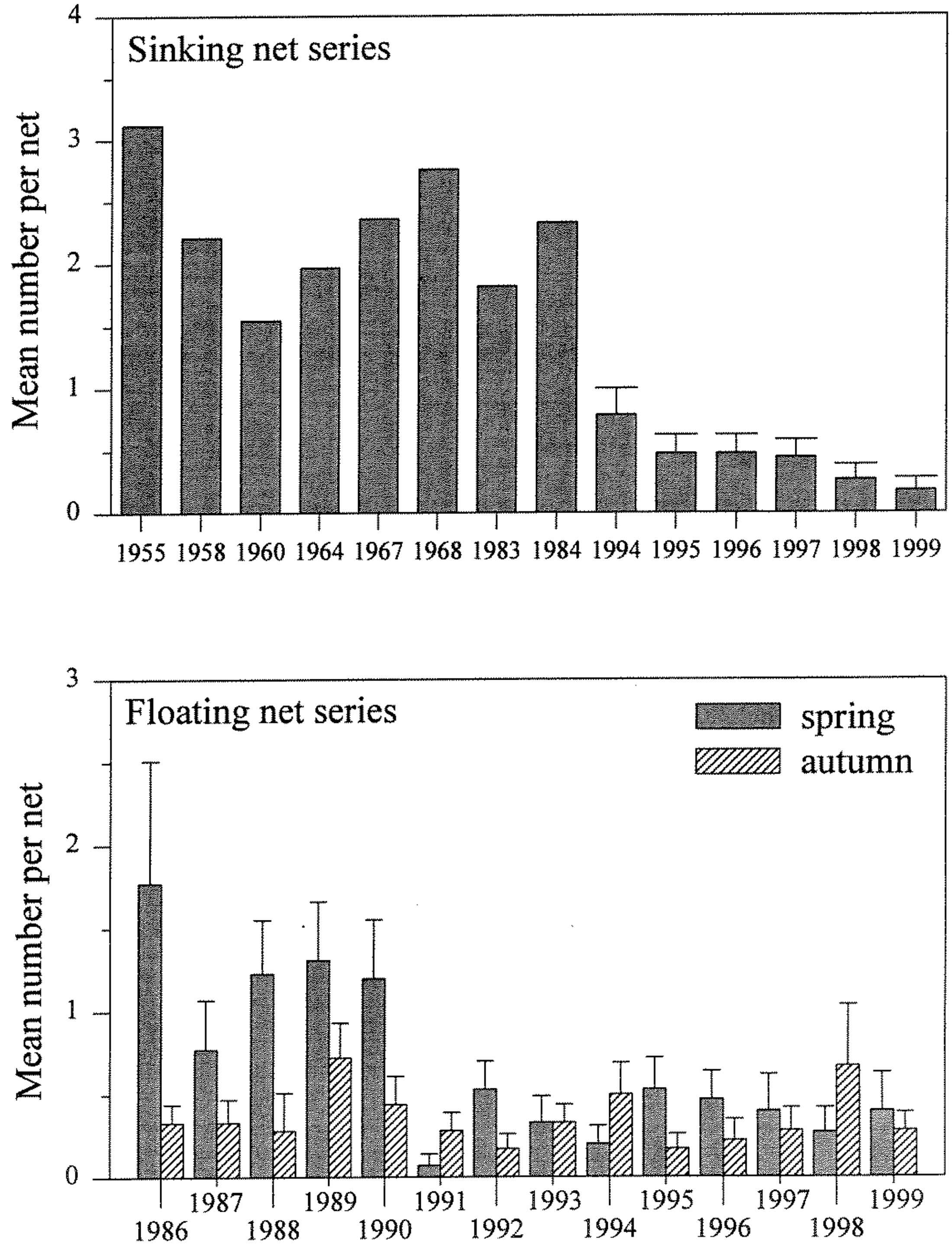


Figure 11. Trends of brown trout catch rates in standardized sinking and floating net series, Canyon Ferry Reservoir, Montana. Vertical lines represent +1 standard error.

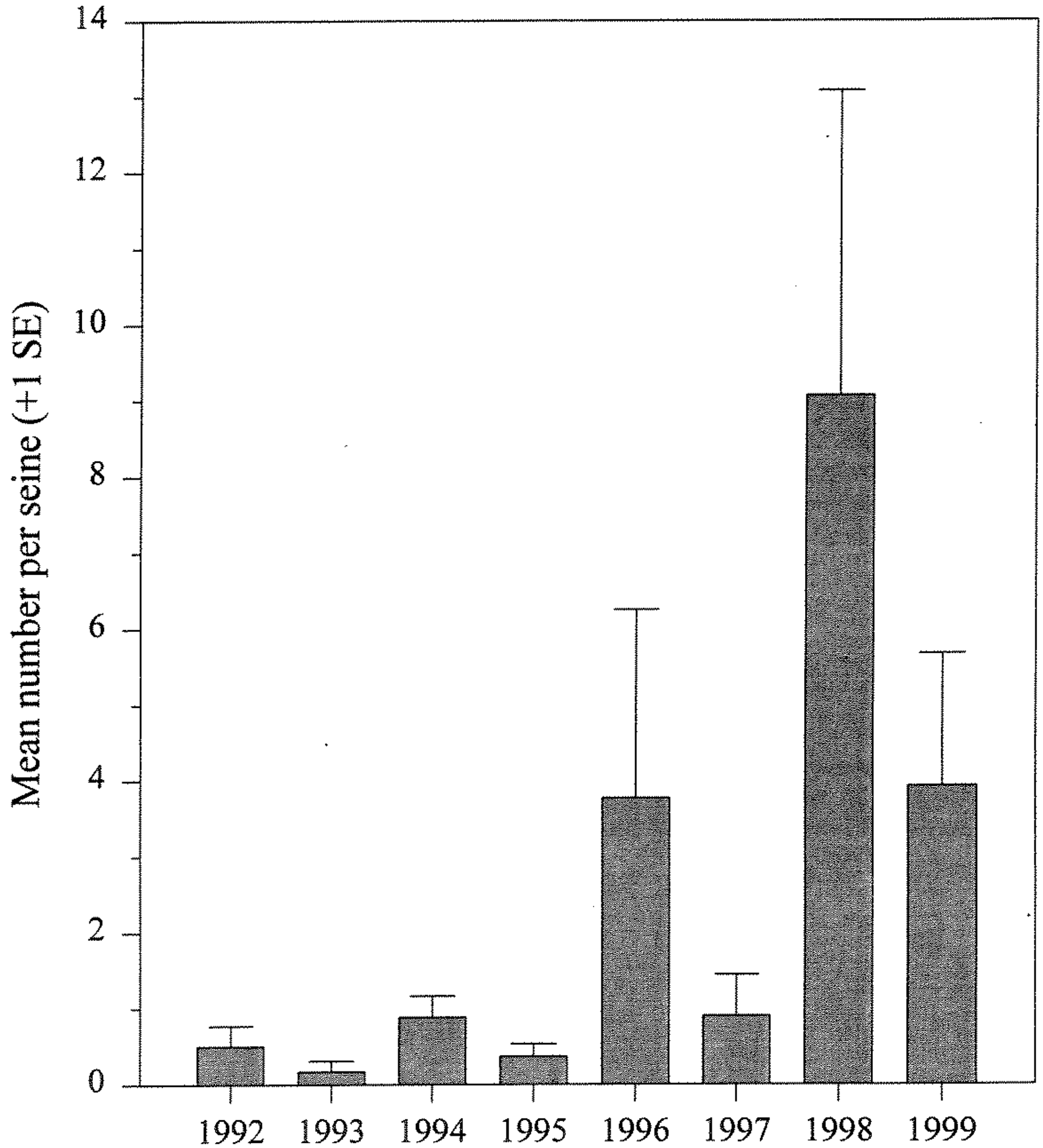


Figure 12. Mean CPUE (+1 SE) of cyprinids (common carp, Utah chubs, longnose dace, and fathead minnows) sampled in beach seine series, Canyon Ferry Reservoir, Montana, 1992 - 1999.

Several age-0 smallmouth bass were sampled in the beach seine series each year of this study except 1995: 17 were sampled in 1994, three in 1996, five in 1997, eight in 1998, and one in 1999. Age-0 smallmouth bass averaged 53 mm TL (range 30 - 77, SD = 15.4). These were the first smallmouth bass sampled in Canyon Ferry Reservoir and were the result of an illegal introduction.

A single age-0 bluegill was sampled in the beach seine series on the north end of Canyon Ferry in 1998. Bandow (1969) reported bluegill in Canyon Ferry, but this was unsubstantiated. This is the first documentation by MFWP of their presence in the reservoir. Their origin is unknown, but likely the result of an illegal introduction or invasion from the Three Forks ponds via the Missouri River.

Walleye Population Characteristics

Length and Weight Statistics

Walleye ranging from small fingerlings to very large adults were sampled each year of the study (Table 10; Figure 13). Because sampling techniques and seasonality of sampling often differed, length and weight data are not comparable among years. The largest walleye were sampled in spring 1997. Five female walleye larger than the current Montana state record (7,430 g) were sampled on the spawning area. The largest weighed 9,185 g, exceeding the state record by 1,755 g.

Lengths and weights of walleye were correlated ($P < 0.001$; Figure 14) as described by the following length-weight relationship:

$$\log_{10}W = -5.7832 + 3.3108 \log_{10}L$$

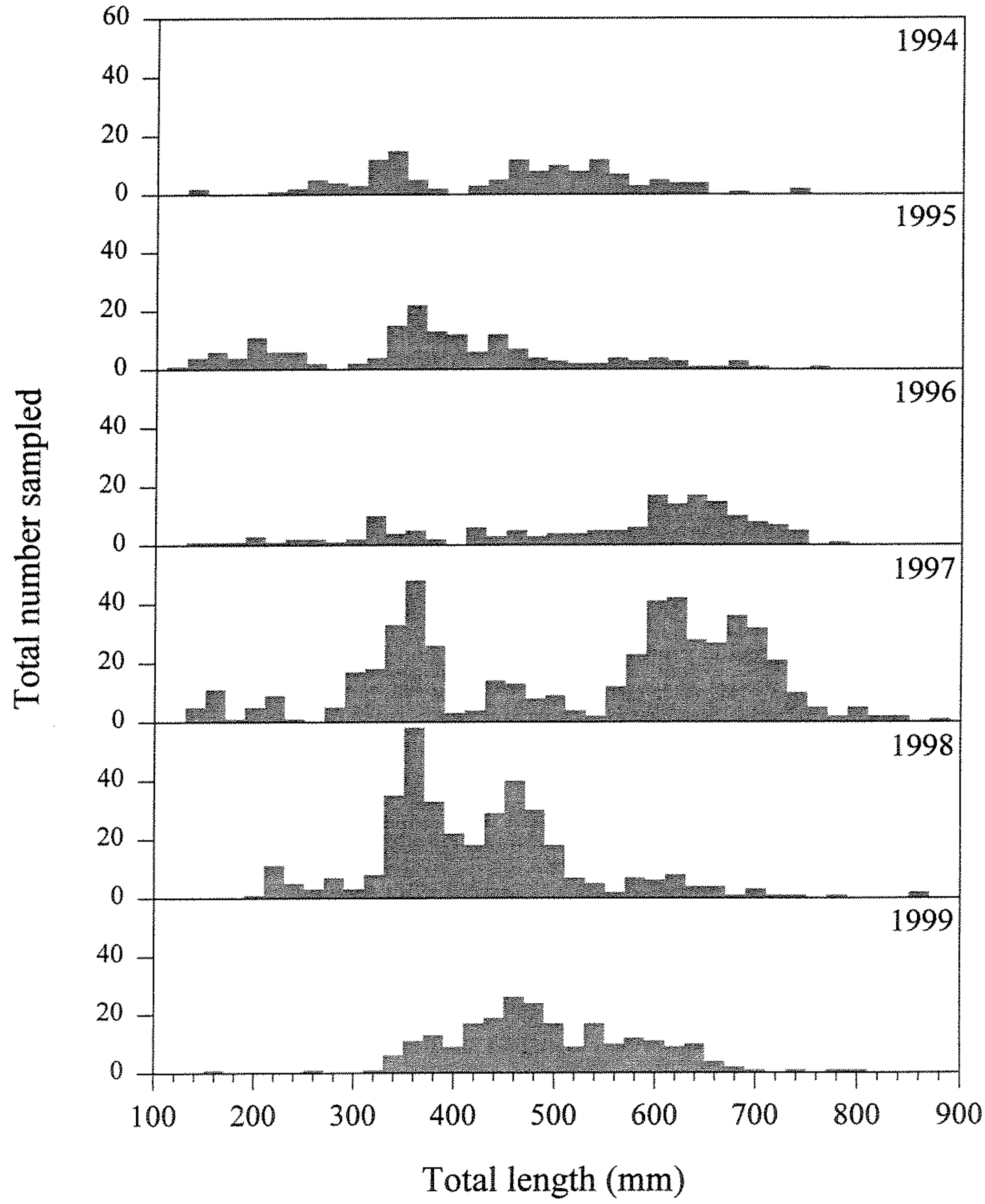


Figure 13. Length-frequency distributions of walleye sampled in Canyon Ferry Reservoir, Montana, 1994 - 1999.

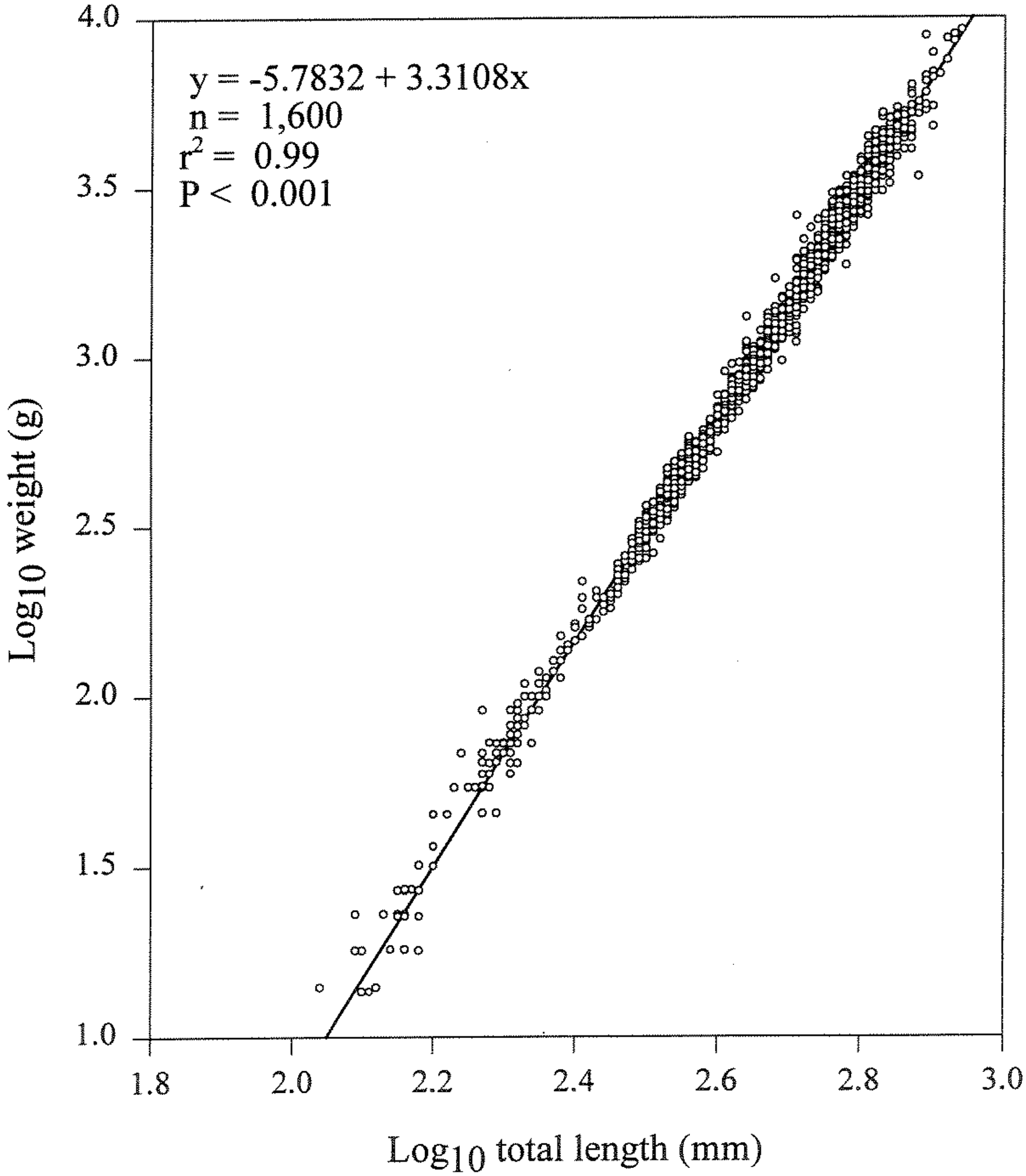


Figure 14. Total length-weight (logarithmically transformed) relationship of walleye sampled in Canyon Ferry Reservoir, Montana, 1994 - 1999.

Table 10. Number sampled, median total lengths (TL) and ranges, and median weights and ranges of walleye sampled in Canyon Ferry Reservoir, Montana, 1994 - 1999.

Year	Number sampled	Median TL (mm)	Range (mm)	Median weight (g)	Range (g)
1994	135	457	124 - 737	975	23 - 4,536
1995	165	358	109 - 757	490	14 - 5,035
1996	170	589	132 - 775	2,461	14 - 5,307
1997	525	574	127 - 866	2,359	14 - 9,185
1998	373	404	195 - 851	662	68 - 8,904
1999	233	472	160 - 800	1,111	45 - 6,636

The antilog of this equation yields:

$$W = (0.0000016)L^{3.3108}$$

A slope greater than 3.0 generally infers that as fish grow they become heavier for their length (Anderson and Neumann 1996).

Relative Stock Density

Incremental RSD values for walleye sampled during autumn 1994 and 1995 were similar across all size categories (Figure 15). A sharp increase in RSD S-Q values occurred in 1996 and 1997 with an associated decline in the proportion of RSD P-M walleye in the population. The proportion of RSD Q-P walleye remained stable through 1997. A shift in the size structure of this population resulted in 1998 when RSD S-Q walleye recruited into the RSD Q-P length group. The proportion of smaller walleye (RSD S-Q) was further reduced in 1999 as RSD Q-P and RSD P-M walleye dominated

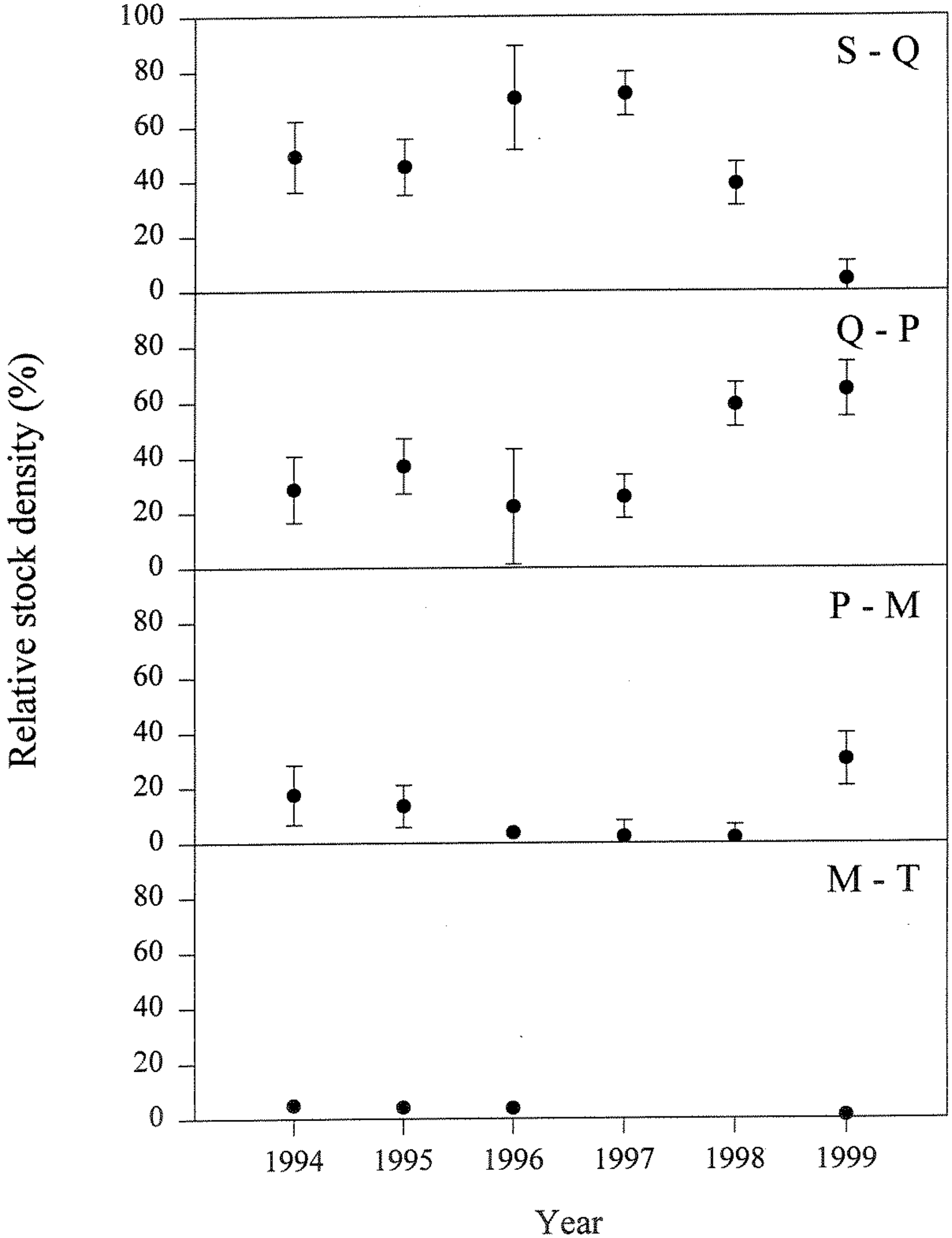


Figure 15. Incremental relative stock density values of walleye sampled in experimental-mesh gill nets, Canyon Ferry Reservoir, Montana, autumns of 1994 - 1999. Vertical lines represent 95% confidence intervals.

the population (Figure 15). Few RSD M-T and no RSD-T walleye were sampled during autumn netting efforts, indicating the relative absence of larger fish in the population.

Age Data

Walleye were accurately aged using dorsal spine cross-sections and scales. Ages I assigned compared favorably to ages determined by Paul Hamlin, MFWP, Great Falls, MT. We agreed on 26 of 30 spine samples randomly selected for aging confirmation. There was a one year disparity on all four samples that we differed on. Three of these four differences occurred with juvenile walleye. I found younger walleye (age 0 to age 3) were more easily aged with scales than spines. With the additional use of scale samples corresponding to the respective spine sections, we agreed on 28 of 30 samples compared.

A single year class (produced in 1990) dominated the walleye spawning population each year from 1994 to 1997. Age 4 was the most common age class sampled on the spawning area in 1994, representing 50% of the total walleye catch (Figure 16). Ages of adult walleye sampled during the spring 1994 spawning period ranged from 2 to 9 (n = 42). No females were sampled. Age-6 walleye dominated the catch in spring 1996, comprising 45% of the spawning population. Ages of spawning walleye in 1996 ranged from 2 to 15 (n = 108). The two age-15 individuals sampled were males. Forty percent of the age-6 walleye were females, indicating that they had recruited into the spawning population since 1994 (Figure 16). A total of 302 adult walleye were sampled in 1997, ranging from age 2 to age 16. The single age-16 male sampled was the oldest walleye observed during the study. Age-7 walleye dominated the spawning population in

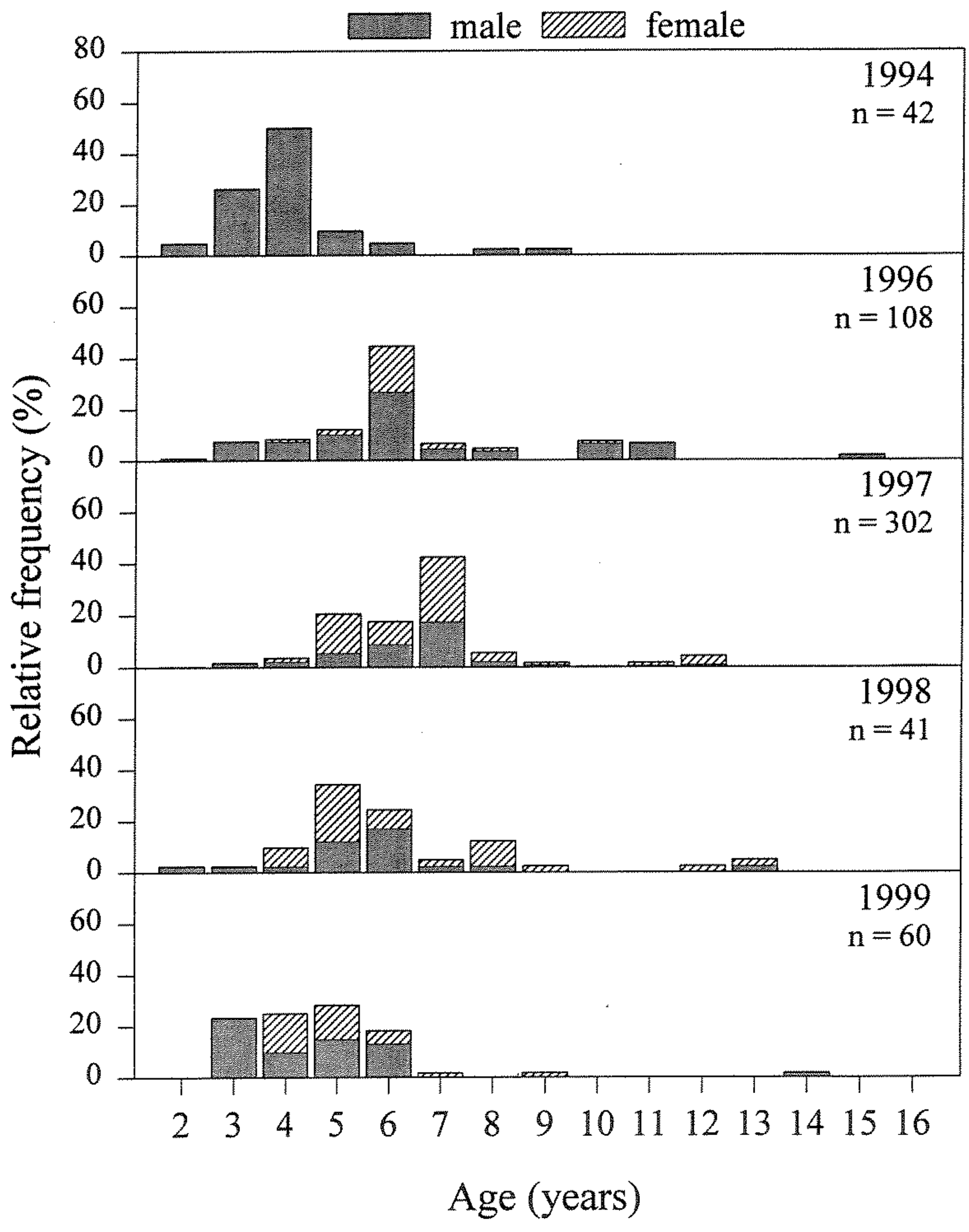


Figure 16. Relative frequency (%) of individual age-classes of walleye sampled during spring in Canyon Ferry Reservoir, Montana, 1994 and 1996 - 1999.

1997, accounting for 42% of the walleye sampled. Younger year classes of walleye were more prevalent in the spawning population in 1998 and 1999. More than 50% of the walleye sampled in spring 1998 were either age 5 or age 6 (Figure 16). Spawning walleye sampled during 1998 ranged from age 2 to age 13 (n = 41). Younger walleye dominated the spawning population in 1999. Individuals age 3 to age 5 accounted for more than 75% of the walleye sampled (n = 60). An age-14 male was the oldest walleye sampled in spring 1999.

Female walleye generally spawned for the first time at age 5, and males at age 2 or 3 (Figure 16). A small (< 2%) number of females spawned at age 4 in 1996 and 1997. A greater proportion of females spawned at age 4 in 1998 (7%) and 1999 (15%), but this may be an artifact of the small sample sizes.

Age-1 and age-2 walleye dominated the autumn net catches each year through 1998 (Figure 17). Combined relative strengths of these age classes ranged from 95% of all walleye sampled in both 1997 and 1998 to 66% in 1995. In 1999 sampling, age-1 walleye were nearly absent. Net catches were dominated by age-2 and age-3 individuals. Walleye ages ranged from 0 to 9 in the autumn sampling. Although older walleye were never commonly sampled in these nets, individuals older than age 3 were nearly absent in the 1997 and 1998 sampling (Figure 17). Because age-0 walleye were not fully recruited into the experimental-mesh nets by autumn, these data do not accurately reflect their relative abundance.

Walleye produced in 1990 formed the dominant year class of the spawning population, accounting for 37% of the 553 walleye sampled in the spring during this

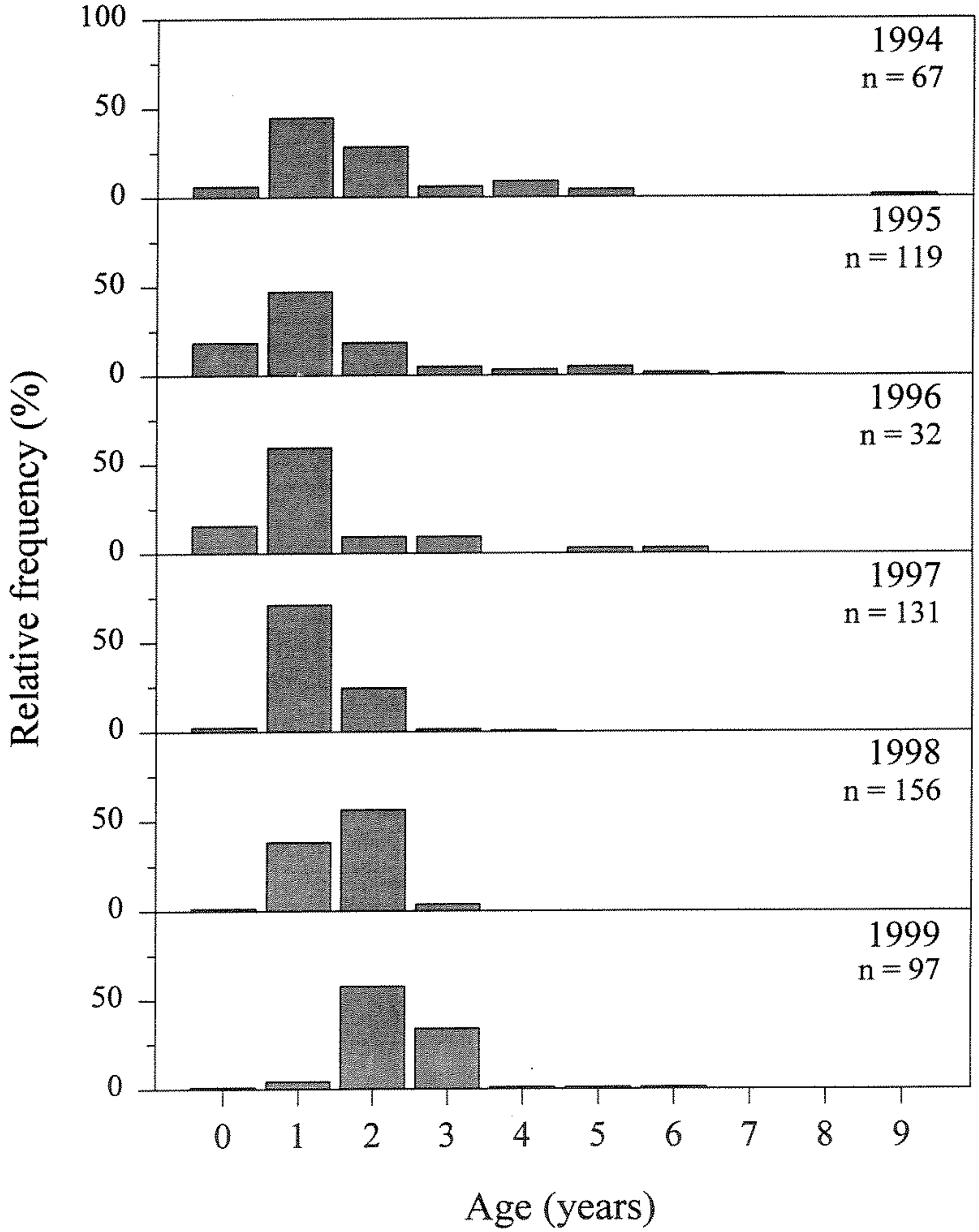


Figure 17. Relative frequency (%) of individual age classes of walleye sampled during autumn in Canyon Ferry Reservoir, Montana, 1994 - 1999.

study (Figure 18). Walleye from the 1995 to 1998 year classes were not fully recruited into the spawning population by 1999 and are not accurately represented in these data.

The strongest year class evident in the autumn netting was produced in 1996, representing 36% of all walleye sampled (Figure 18). The dominant year class (1990) in the spawning population was not prominent in the autumn sampling. Pre-1996 data indicated steadily increasing recruitment since the late 1980s (Figure 18).

Growth Rates

Back-calculation of lengths at age was possible using walleye dorsal spine sections because spine radius was linearly related ($r^2 = 0.88$, $P < 0.001$) to total length of walleye (Figure 19). Total lengths at age I determined for study walleye were similar among individual sample years (Tables 11 - 13). Back-calculated lengths at age did not differ significantly among sampling years except for age-2 data. Lengths calculated for age-2 walleye sampled in 1995 were significantly less than those calculated for walleye sampled in 1994 and 1996 (Tukey; $P < 0.05$). Overall mean back-calculated lengths at age for Canyon Ferry walleye age 1 through age 11 indicated they continued to grow throughout their lives (Table 14; Figure 20).

Walleye sampled in this study exhibited fastest growth in their second and third years. Annual growth increments, as determined from the grand mean of back-calculated lengths at age, were 93 mm in their second (between age 1 and age 2) growing season and 98 mm in their third (between age 2 and age 3). Growth rates decreased as walleye aged (Table 14; Figure 21).

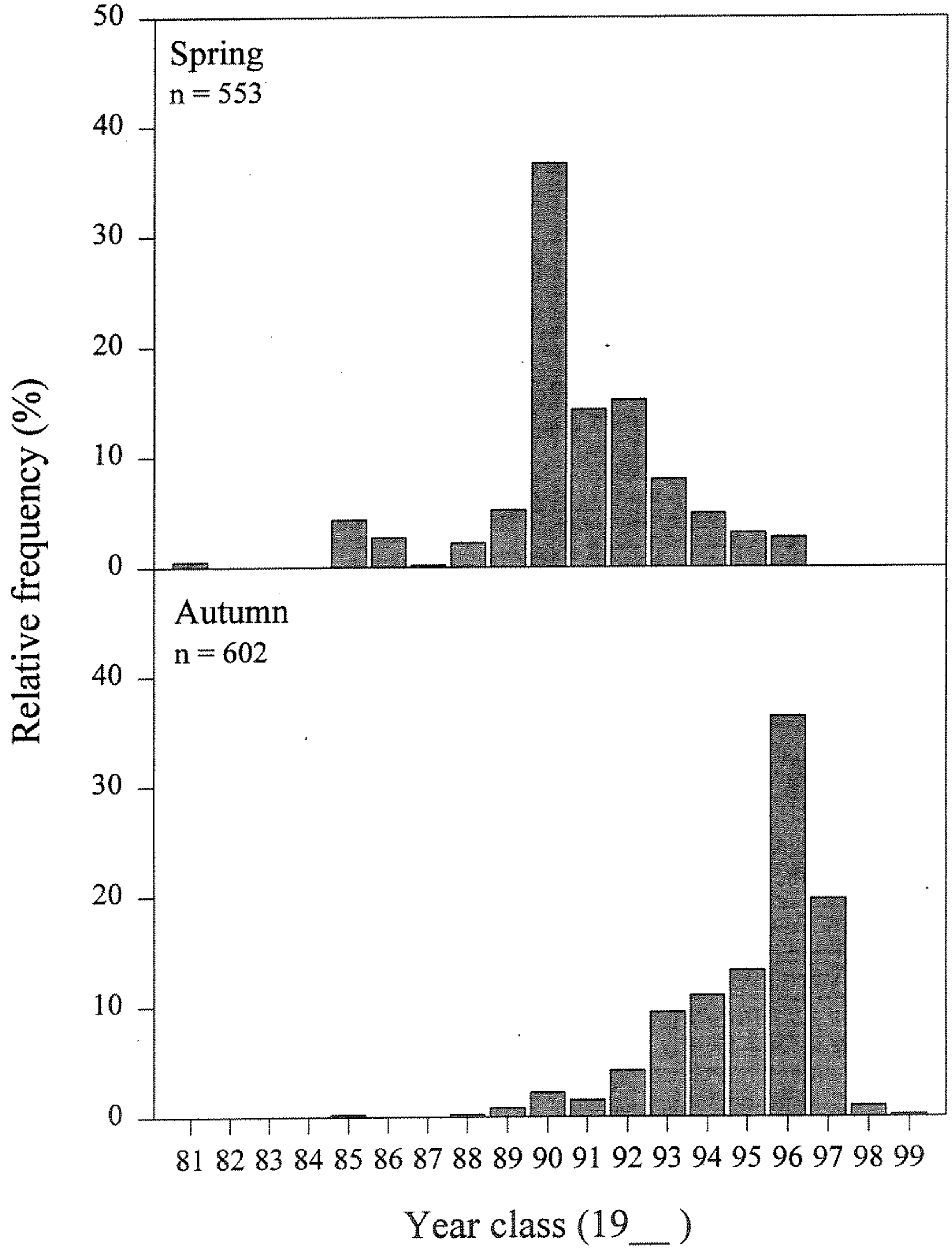


Figure 18. Relative frequency (%) of year classes of walleye sampled during spring and autumn in Canyon Ferry Reservoir, Montana, 1994 - 1999.

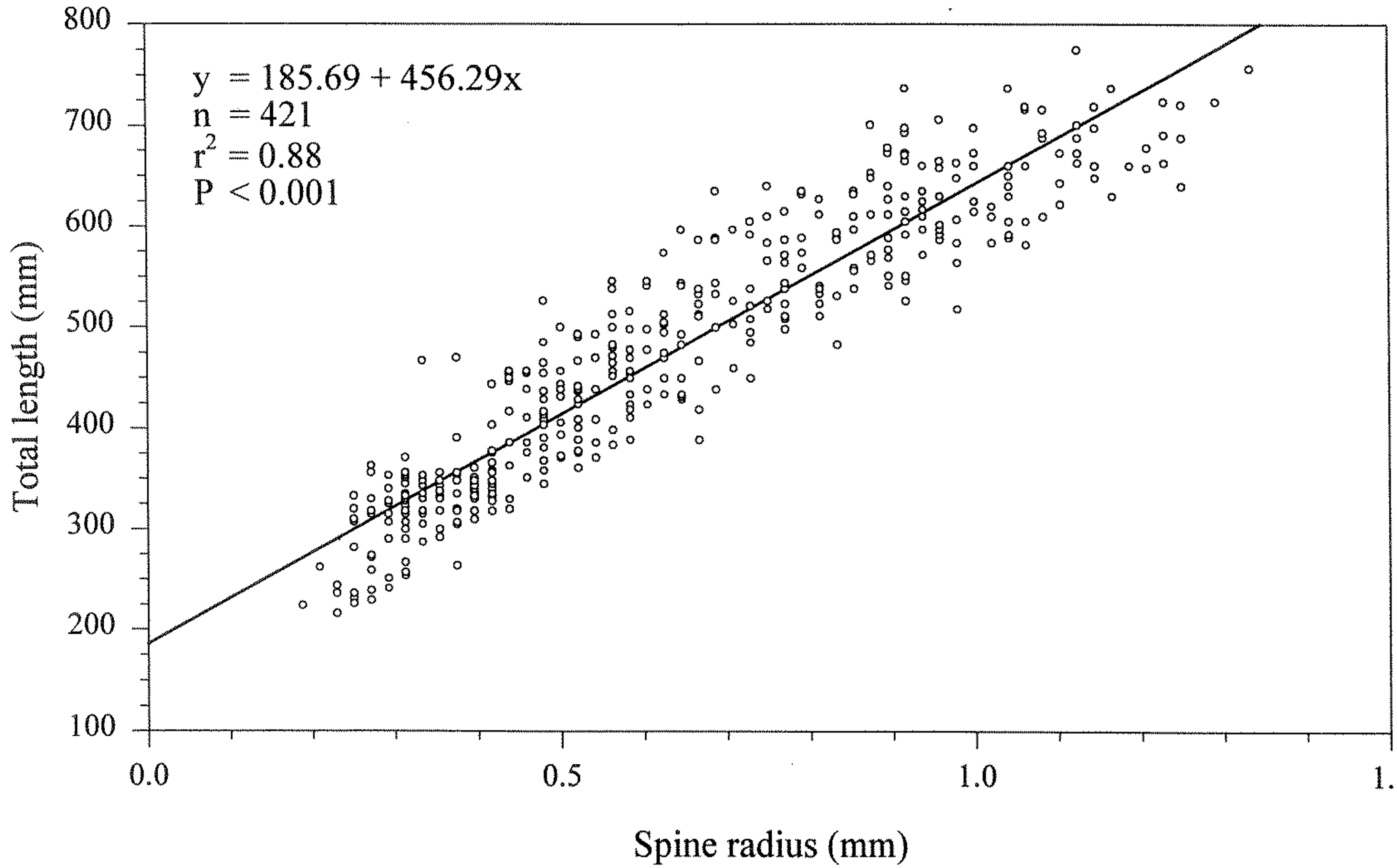


Figure 19. Relationship between radii of spine cross-sections and total lengths of walleye sampled in Canyon Ferry Reservoir, Montana, 1994 - 1996.

Table 11. Back-calculated total length (mm) at age ± 1 SD for walleye sampled during 1994 in Canyon Ferry Reservoir, Montana. Ranges are presented below lengths and number (n) is given for each year-class.

Year class	n	Length at capture	Back-calculated total length at annulus ± SD 1	2	3	4	5	6	7	8	9
1993	35	306 ± 31 236-353	225 ± 19 188-257								
1992	31	418 ± 59 315-500	276 ± 25 212-332	345 ± 25 293-407							
1991	20	477 ± 33 424-538	293 ± 24 249-349	377 ± 29 319-427	449 ± 25 393-493						
1990	33	546 ± 39 485-635	277 ± 24 236-321	370 ± 29 292-422	471 ± 28 397-514	527 ± 25 462-587					
1989	7	577 ± 49 508-635	260 ± 17 238-289	337 ± 25 294-376	429 ± 26 397-474	510 ± 27 471-550	559 ± 37 508-615				
1988	2	612 ± 21 597-627	277 ± 6 273-281	365 ± 8 359-370	441 ± 25 423-459	529 ± 2 528-531	586 ± 12 577-595	612 ± 21 597-627			
1986	1	673	284	414	494	563	613	643	663	673	
1985	1	737	283	371	438	538	582	626	670	704	737
Weighted mean			264 ± 33	361 ± 31	458 ± 30	525 ± 26	571 ± 34	623 ± 19	667 ± 5	688 ± 22	737
Range			188-349	292-427	393-514	462-587	508-615	597-643	663-670	673-704	
n			130	95	64	44	11	4	2	2	1

Table 12. Back-calculated total length (mm) at age ± 1 SD for walleye sampled during 1995 in Canyon Ferry Reservoir, Montana. Ranges are presented below lengths and number (n) is given for each year class.

Year			Back-calculated total length at annulus ± SD									
class	n	Length at capture	1	2	3	4	5	6	7	8	9	10
1994	66	344 ± 45	267 ± 26									
		216-404	212-321									
1993	32	406 ± 49	251 ± 20	342 ± 28								
		305-470	215-299	284-394								
1992	13	500 ± 47	266 ± 28	333 ± 32	443 ± 38							
		429-572	228-329	291-390	374-511							
1991	8	564 ± 43	295 ± 24	380 ± 21	451 ± 17	532 ± 18						
		503-612	264-325	347-405	428-477	503-555						
1990	7	598 ± 45	273 ± 24	360 ± 28	458 ± 19	515 ± 19	569 ± 27					
		546-665	237-310	323-392	426-482	494-553	538-614					
1989	3	663 ± 10	259 ± 29	341 ± 13	424 ± 9	514 ± 20	575 ± 24	632 ± 18				
		653-673	237-292	330-356	413-430	497-536	552-600	617-653				
1988	1	688	286	370	454	510	576	613	660			
1985	1	757	249	331	431	521	585	630	675	703	721	739
Weighted mean			265 ± 26	347 ± 30	446 ± 28	522 ± 18	572 ± 23	628 ± 15	668 ± 11	703	721	739
Range			212-329	284-405	374-511	494-555	538-614	613-653	660-675			
n			131	65	33	20	12	5	2	1	1	1

Table 13. Back-calculated total length (mm) at age ± 1 SD for walleye sampled during 1996 in Canyon Ferry Reservoir, Montana. Ranges are presented below lengths and number (n) is given for each year class.

Year class	n	Length at capture	Back-calculated total length at annulus ± SD 1	2	3	4	5	6	7	8	9	10	11
1995	24	308 ± 38	243 ± 22										
		224-361	203-277										
1994	11	404 ± 49	280 ± 24	360 ± 23									
		318-465	231-313	318-400									
1993	11	450 ± 32	252 ± 18	357 ±17	432 ± 16								
		406-498	225-274	331-379	406-450								
1992	11	517 ± 42	270 ± 36	343 ± 38	452 ± 44	517 ± 42							
		419-587	215-336	273-427	362-519	419-587							
1991	15	573 ± 35	276 ± 24	369 ± 34	449 ± 38	522 ± 36	571 ± 39						
		511-630	231-313	294-418	375-505	448-582	484-630						
1990	56	622 ± 37	271 ± 28	367 ± 35	475 ± 35	535 ± 32	585 ± 32	621 ± 36					
		518-698	205-349	281-442	382-540	446-612	495-656	518-698					
1989	9	659 ± 36	266 ± 32	351 ± 26	450 ± 41	528 ± 51	587 ± 47	628 ± 38	657 ± 35				
		587-701	227-313	319-387	382-519	442-598	510-655	556-678	587-701				
1988	4	674 ± 17	273 ± 34	364 ± 45	473 ± 46	563 ± 32	606 ± 22	630 ± 20	652 ± 18	674 ± 17			
		660-698	234-314	316-414	426-513	527-595	581-636	609-657	636-677	660-698			
1986	10	693 ± 30	261 ± 31	354 ± 23	428 ± 36	489 ± 42	555 ± 32	596 ± 33	630 ± 34	654 ± 31	675 ± 30	693 ± 30	
		640-737	224-318	310-384	373-494	427-545	498-610	534-649	570-678	600-698	620-717	640-737	

Table 13. Continued.

Year class	n	Length at capture	Back-calculated total length at annulus ± SD 1	2	3	4	5	6	7	8	9	10	11
1985	7	715 ± 38	283 ± 19	355 ± 31	437 ± 41	499 ± 56	546 ± 59	588 ± 60	626 ± 53	655 ± 45	679 ± 42	699 ± 42	715 ± 38
		665-775 256-309	312-398	354-472	386-546	428-606	470-659	534-701	586-722	618-743	639-764	665-775	
Weighted mean			266 ± 29	361 ± 32	458 ± 39	526 ± 40	578 ± 38	617 ± 39	640 ± 39	658 ± 34	676 ± 34	696 ± 34	715 ± 38
Range			203-349	273-442	354-540	386-612	428-656	470-698	534-701	586-722	618-743	639-764	665-775
n			158	134	123	112	101	86	30	21	17	17	7

Table 14. Weighted and grand mean of back-calculated total length (mm) at age ± 1 SD for walleye sampled in Canyon Ferry Reservoir, Montana, 1994 - 1996. Ranges are presented below lengths and number (n) is given for each year class.

Year sampled	Back-calculated total length at annulus ± SD 1	2	3	4	5	6	7	8	9	10	11
1994											
Weighted mean	264 ± 33	361 ± 31	458 ± 30	525 ± 26	571 ± 34	623 ± 19	667 ± 5	688 ± 22	737		
Range	188-349	292-427	393-514	462-587	508-615	597-643	663-670	673-704			
n	130	95	64	44	11	4	2	2	1		
1995											
Weighted mean	265 ± 26	347 ± 30	446 ± 28	522 ± 18	572 ± 23	628 ± 15	668 ± 11	703	721	739	
Range	212-329	284-405	374-511	494-555	538-614	613-653	660-675				
n	131	65	33	20	12	5	2	1	1	1	
1996											
Weighted mean	266 ± 29	361 ± 32	458 ± 39	526 ± 40	578 ± 38	617 ± 39	640 ± 39	658 ± 34	676 ± 34	696 ± 34	715 ± 38
Range	203-349	273-442	354-540	386-612	428-656	470-698	534-701	586-722	618-743	639-764	665-775
n	158	134	123	112	101	86	30	21	17	17	7
Total											
Grand mean	265 ± 29	358 ± 32	456 ± 35	525 ± 35	577 ± 37	618 ± 38	643 ± 37	663 ± 34	682 ± 36	698 ± 35	715 ± 38
Range	188-349	273-442	354-540	226-386	428-656	470-698	534-701	586-722	618-743	639-764	665-775
n	419	294	220	176	124	95	34	24	19	18	7
Growth increment		93	98	69	52	41	25	20	19	16	17

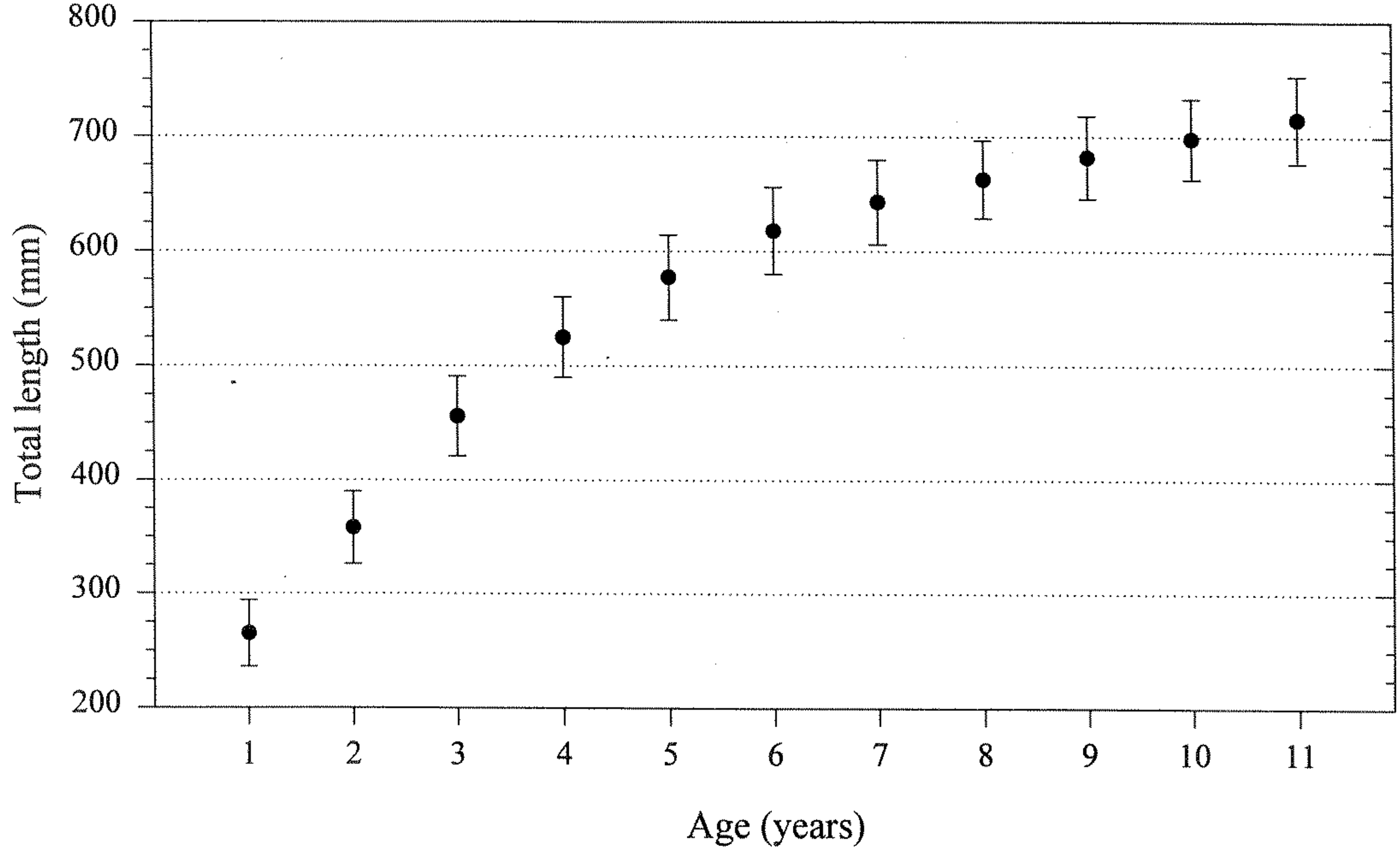


Figure 20. Mean back-calculated lengths at age of walleye sampled in Canyon Ferry Reservoir, Montana, 1994 - 1996. Vertical lines represent ±1 standard deviation.

Initial growth patterns for the three 1981 year-class walleye sampled were much different than those determined for the 1985 through 1995 year classes (Table 15). The second year (age 1 to 2) growth increments for the 1981 year-class walleye were less than one-half of the mean growth observed for the other walleye sampled during this study. These walleye did eventually attain growth rates similar to or higher than the younger year classes—one in its second growing season and the other two in their third (Figure 21).

Relative Weight

Mean W_r of walleye sampled in autumn netting were near or above 100% across all length groups. Generally, W_r increased with increasing RSD length groups (Figure 22). There were significant differences in mean W_r for S-Q walleye (ANOVA; $P < 0.001$), Q-P walleye (ANOVA; $P = 0.002$), and P-M walleye (ANOVA; $P = 0.023$) among years.

W_r of S-Q walleye sampled in 1997 (mean = 95, SD = 6.1) was the lowest observed during autumn sampling and was significantly lower than those observed for S-Q walleye all other years except 1999 (Tukey; $P < 0.05$). In 1994, W_r of Q-P walleye (mean = 109, SD = 10.8) was significantly higher than Q-P walleye in 1997 and 1998 (Tukey; $P < 0.05$). W_r of P-M walleye sampled in 1995 (mean = 113, SD = 13.7) was significantly higher than P-M walleye in 1999 (Tukey; $P < 0.05$). I did not include 1997 and 1998 P-M data in the statistical comparisons because of small sample sizes (n = 3 both years). There was no significant difference in mean W_r of M-T walleye sampled in

Table 15. Back-calculated total length (mm) at age ± 1 SD for 1981 year-class walleye sampled in Canyon Ferry Reservoir, Montana, in 1996 (n = 2) and 1997 (n = 1). Ranges are presented below lengths.

Year class	n	Length at capture	Back-calculated total length at annulus ± SD 1	2	3	4	5	6	7	8	9	10
1981	3	720 ± 4 716-724	224 ± 7 218-232	264 ± 3 262-268	323 ± 31 304-358	412 ± 40 369-449	475 ± 47 422-512	528 ± 38 484-551	572 ± 23 546-592	602 ± 11 591-613	627 ± 6 621-634	649 ± 8 639-654

11	12	13	14	15	16
664 ± 7 658-671	680 ± 8 675-688	695 ± 11 685-706	707 ± 11 695-715	717 ± 10 706-724	716

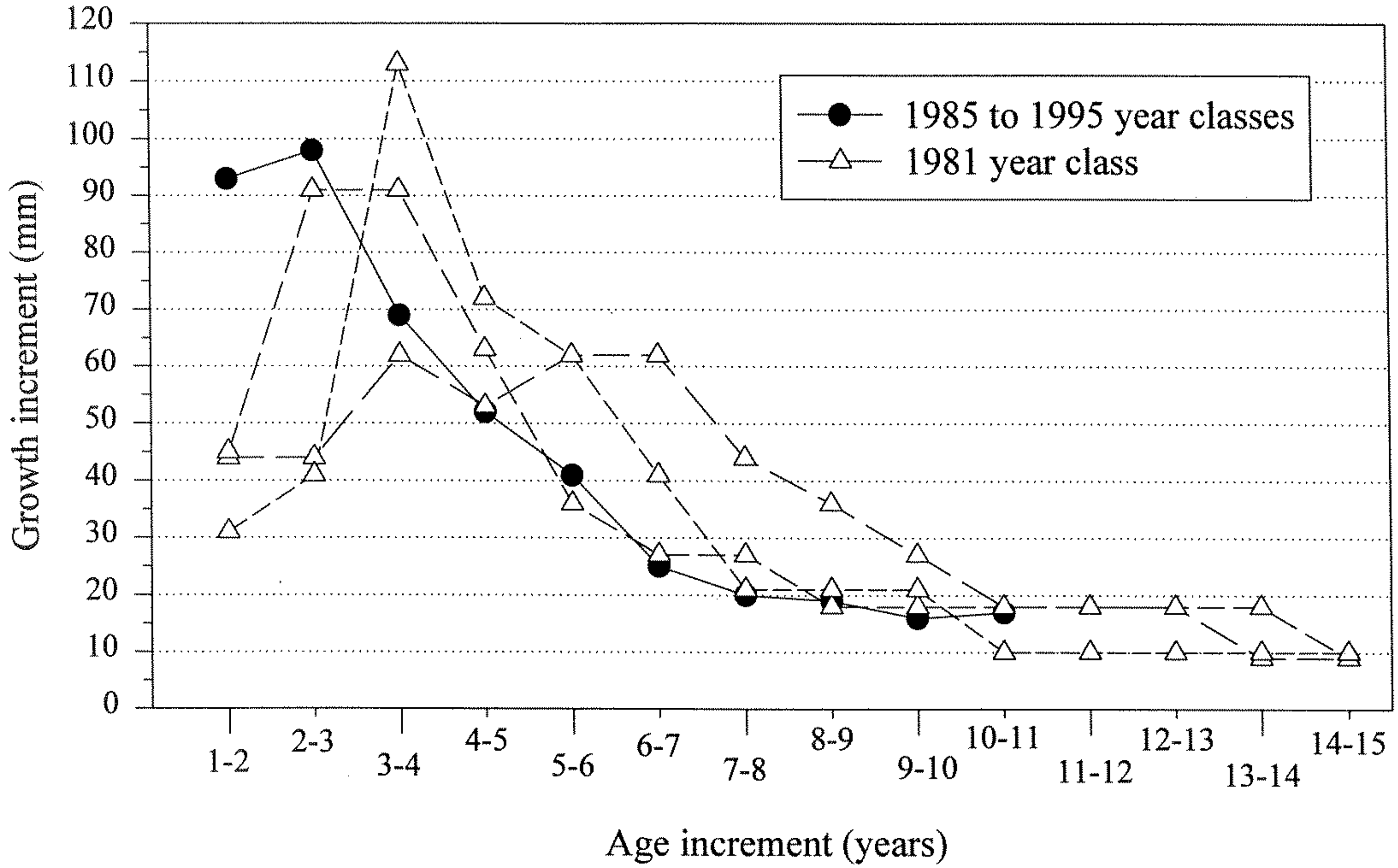


Figure 21. Mean age-specific growth increments for walleye representing the 1985 to 1995 year classes and for three individuals from the 1981 year class sampled in Canyon Ferry Reservoir, Montana.

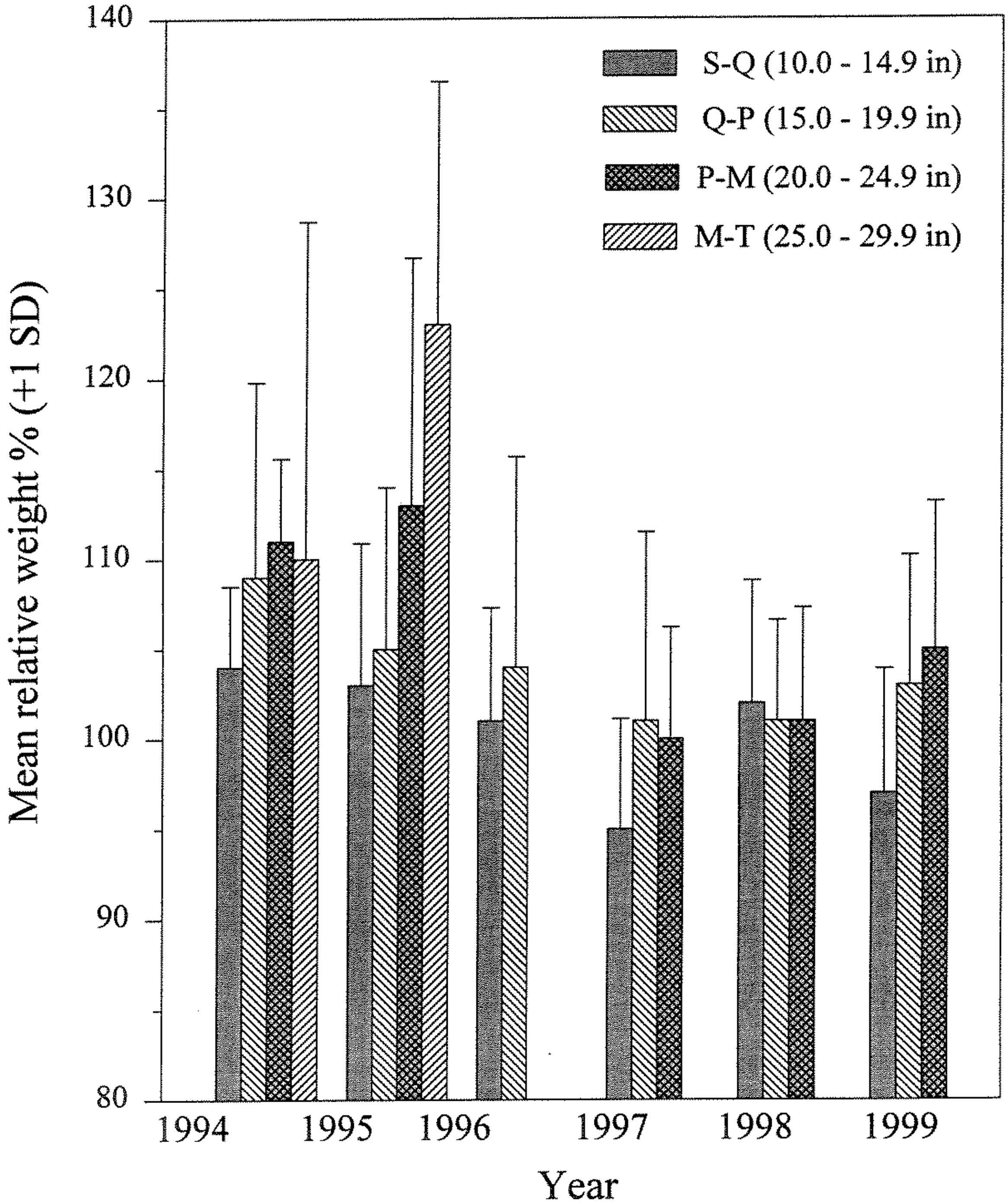


Figure 22. Mean relative weights (+1 SD) for relative stock density length groups of walleye sampled in experimental-mesh gill nets in autumns of 1994 - 1999 in Canyon Ferry Reservoir, Montana.

1994 and 1995 (ANOVA; P = 0.337), the only two years this length group was represented in autumn netting. In 1995, M-T walleye exhibited the highest W_r observed in autumn sampling (mean = 123, SD = 13.5; Figure 22).

Food Habits

Suckers were present in nearly 60% of the walleye stomachs examined in 1994 (n = 66) and accounted for over 60% of their total diet by weight and 50% by number. Yellow perch were of secondary importance, occurring in 23% of the stomachs examined and contributing about 20% of total diet by weight and number. Rainbow trout accounted for about 10% of diet by weight, 5% by number, and occurred in 5% of the stomachs examined (Figure 23). Walleye stomachs examined in 1995 exhibited similar proportions of the major prey items as was observed in 1994, except rainbow trout were essentially absent (0.9% frequency of occurrence, 0.3% by weight; Figure 24).

The number of walleye stomachs that contained yellow perch increased in 1996 (50.9% frequency of occurrence) relative to 1994 and 1995. There was a corresponding decrease in the occurrence of suckers (Figure 24). The relative number of yellow perch consumed by walleye increased to over 40% of all prey items in 1996, but accounted for only 14% of diet by weight. Suckers were the dominant prey item by weight (Figure 25). Rainbow trout accounted for about 25% of the diet by weight in 1996. However, gill netting specifically targeting walleye was completed in late May and early June. Fifteen walleye were sampled in this special netting. Of the 13 walleye that contained food items, rainbow trout were found in five.

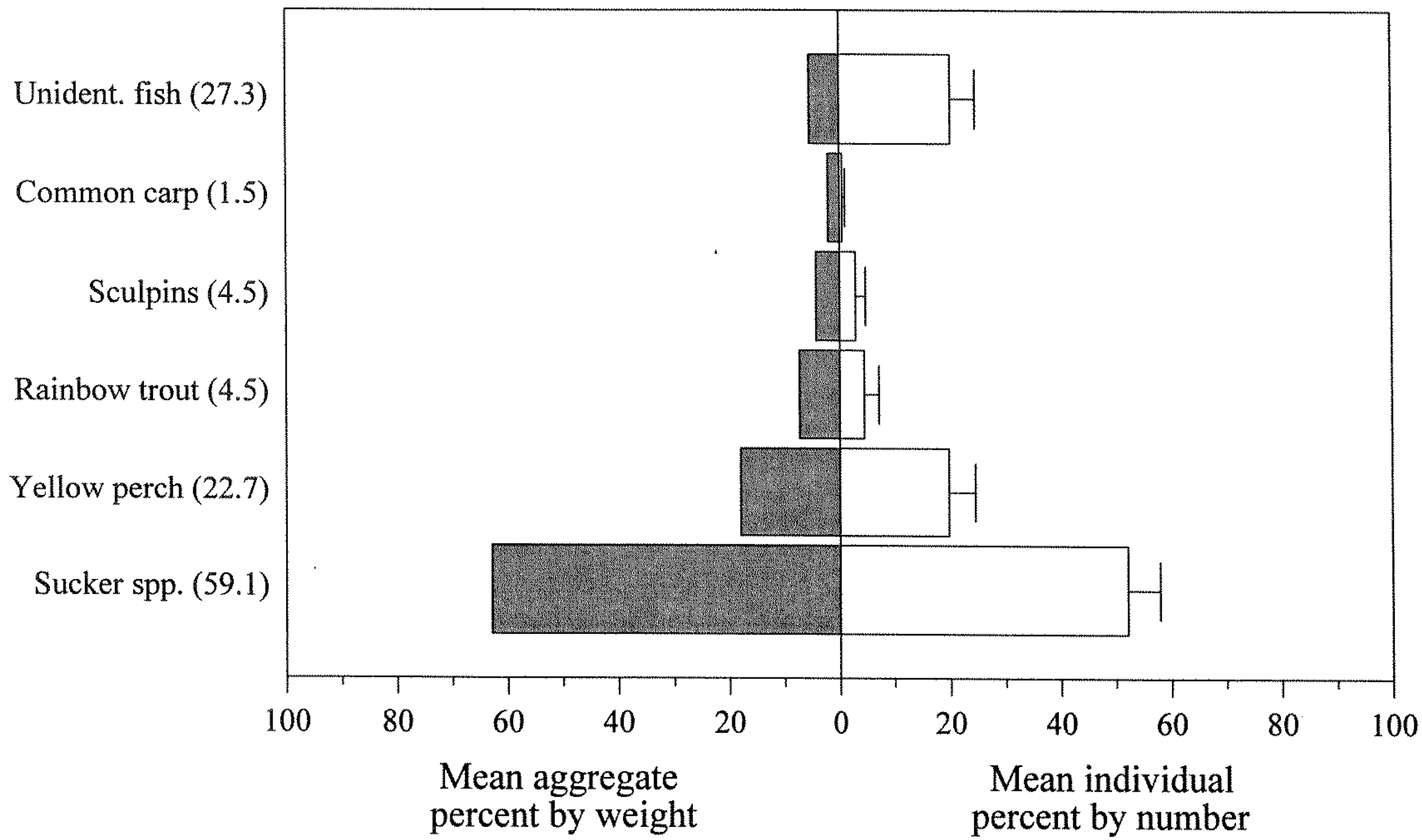


Figure 23. Mean aggregate percent by weight and mean (+1 SE) individual percent by number of food items in walleye stomachs (n = 66) collected during 1994 from Canyon Ferry Reservoir, Montana. Percentages in parentheses represent frequency of occurrence for individual prey items.

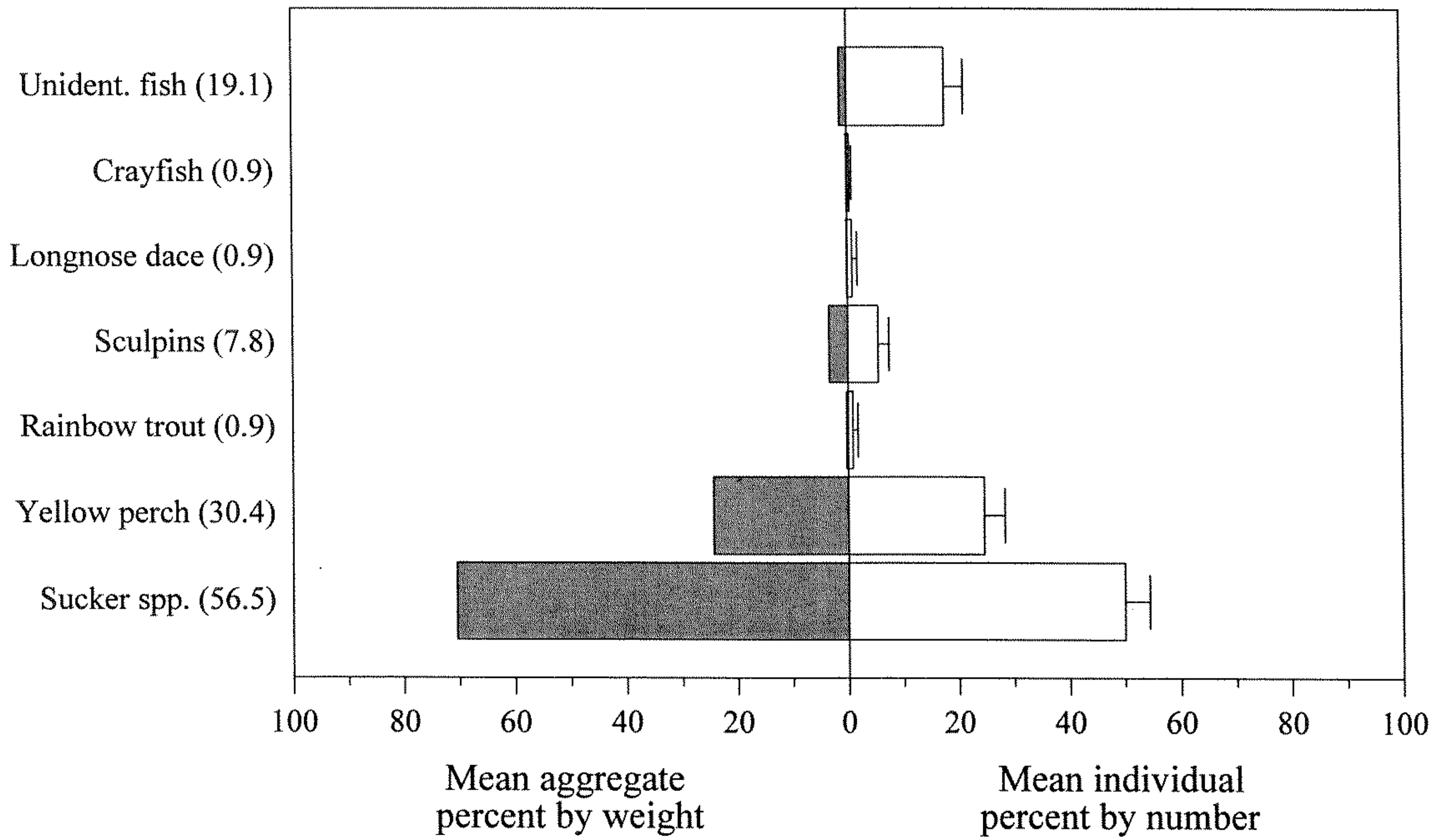


Figure 24. Mean aggregate percent by weight and mean (+1 SE) individual percent by number of food items in walleye stomachs (n = 115) collected during 1995 from Canyon Ferry Reservoir, Montana. Percentages in parentheses represent frequency of occurrence for individual prey items.

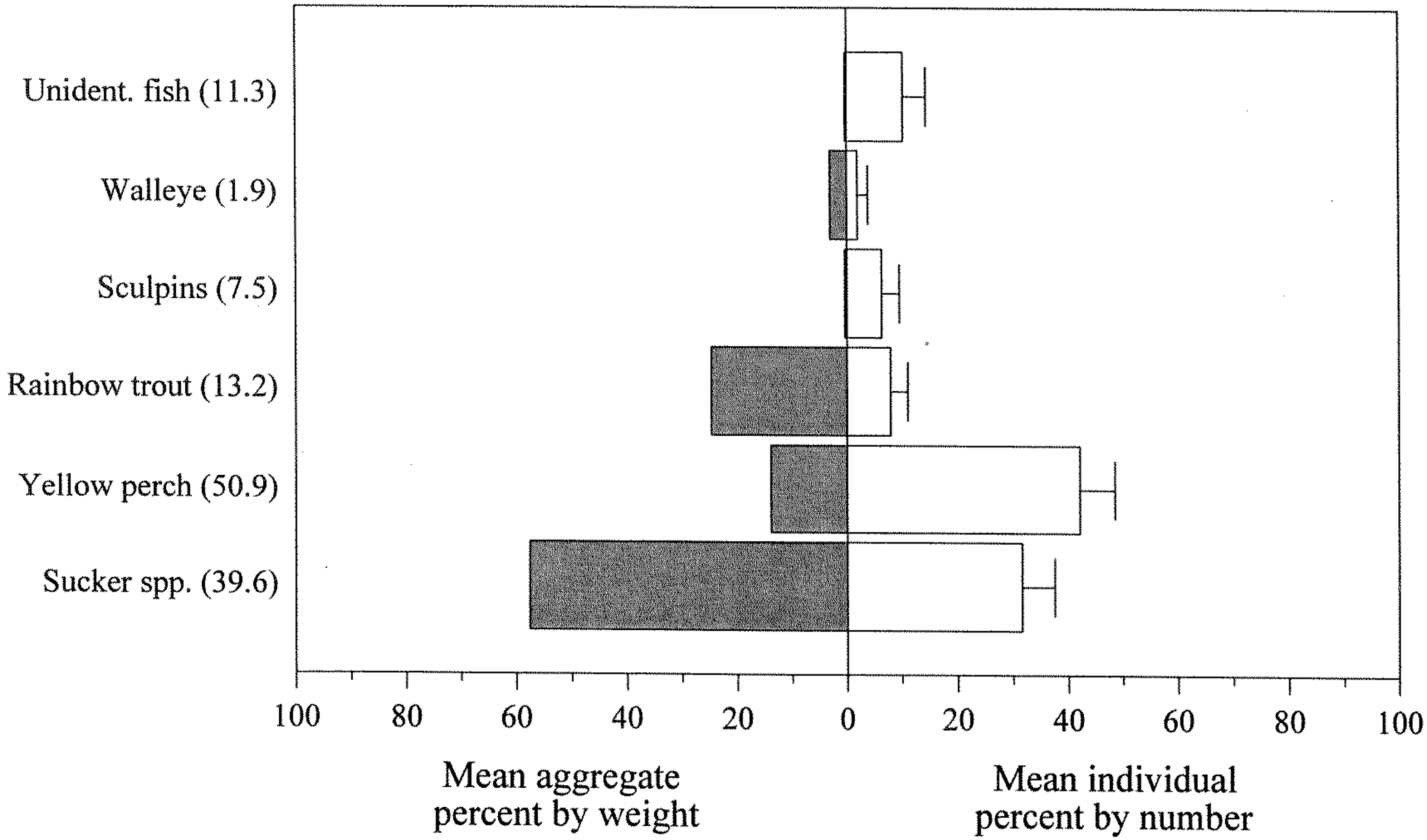


Figure 25. Mean aggregate percent by weight and mean (+1 SE) individual percent by number of food items in walleye stomachs (n = 53) collected during 1996 from Canyon Ferry Reservoir, Montana. Percentages in parentheses represent frequency of occurrence for individual prey items.

The shift in the importance of yellow perch as walleye forage that began in 1996 was clearly evidenced in their 1997, 1998, and 1999 food habits (Figures 26 - 28). Yellow perch was the predominant prey item found in walleye stomachs during this time period. Concurrently, the occurrence and relative importance of suckers as prey declined (Figure 29). Rainbow trout were the second most important prey item (by weight) of walleye in 1997 and 1998, but were absent in walleye stomachs in 1999 (Figures 26 - 28). Mottled sculpins, walleye, burbot, common carp, Utah chubs, longnose dace, crayfish, invertebrates (diptera larvae), and unidentified fish were other prey items less commonly observed in walleye stomachs. Vegetation and pebbles were categorized as 'other'.

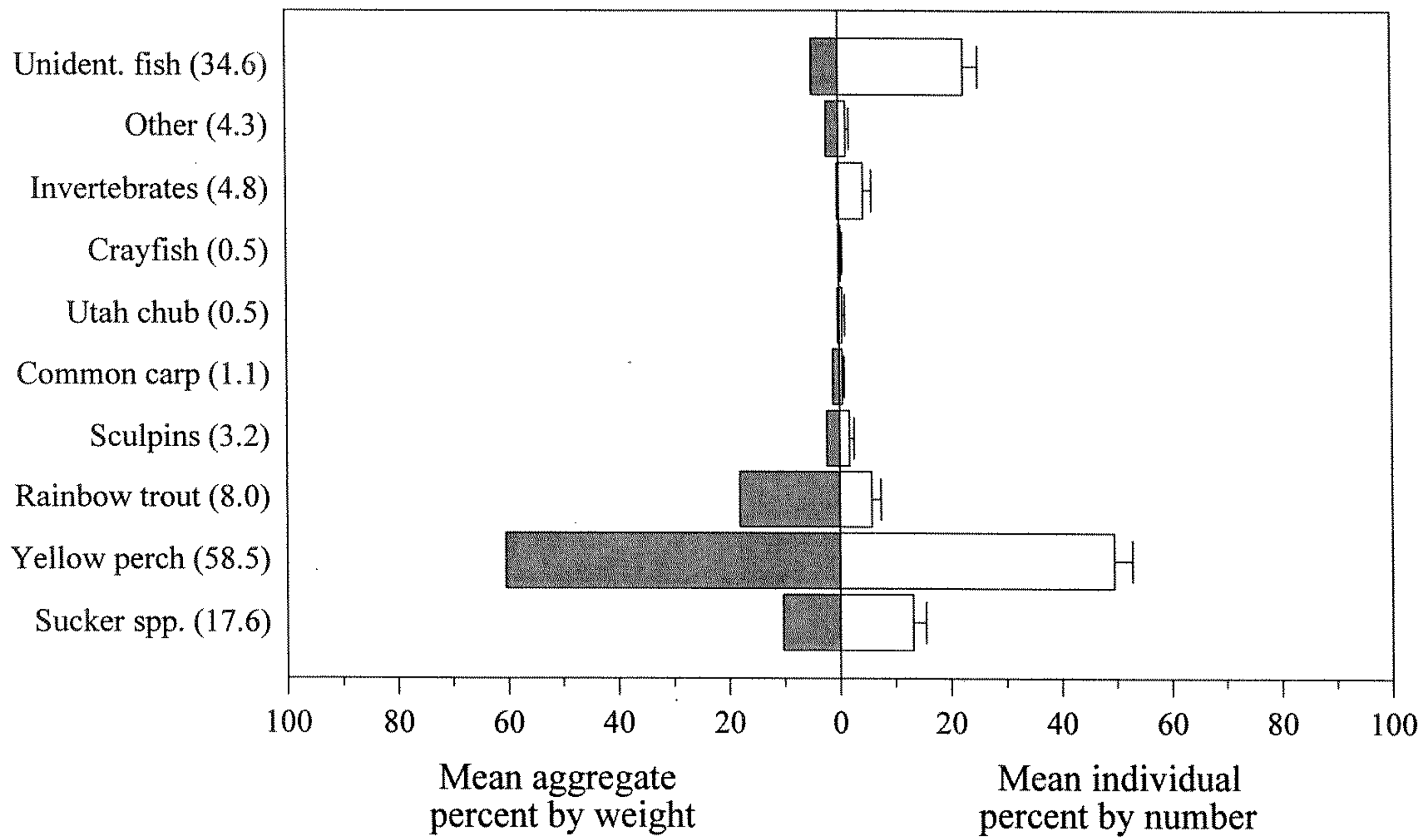


Figure 26. Mean aggregate percent by weight and mean (+1 SE) individual percent by number of food items in walleye stomachs (n = 188) collected during 1997 from Canyon Ferry Reservoir, Montana. Percentages in parentheses represent frequency of occurrence for individual prey items.

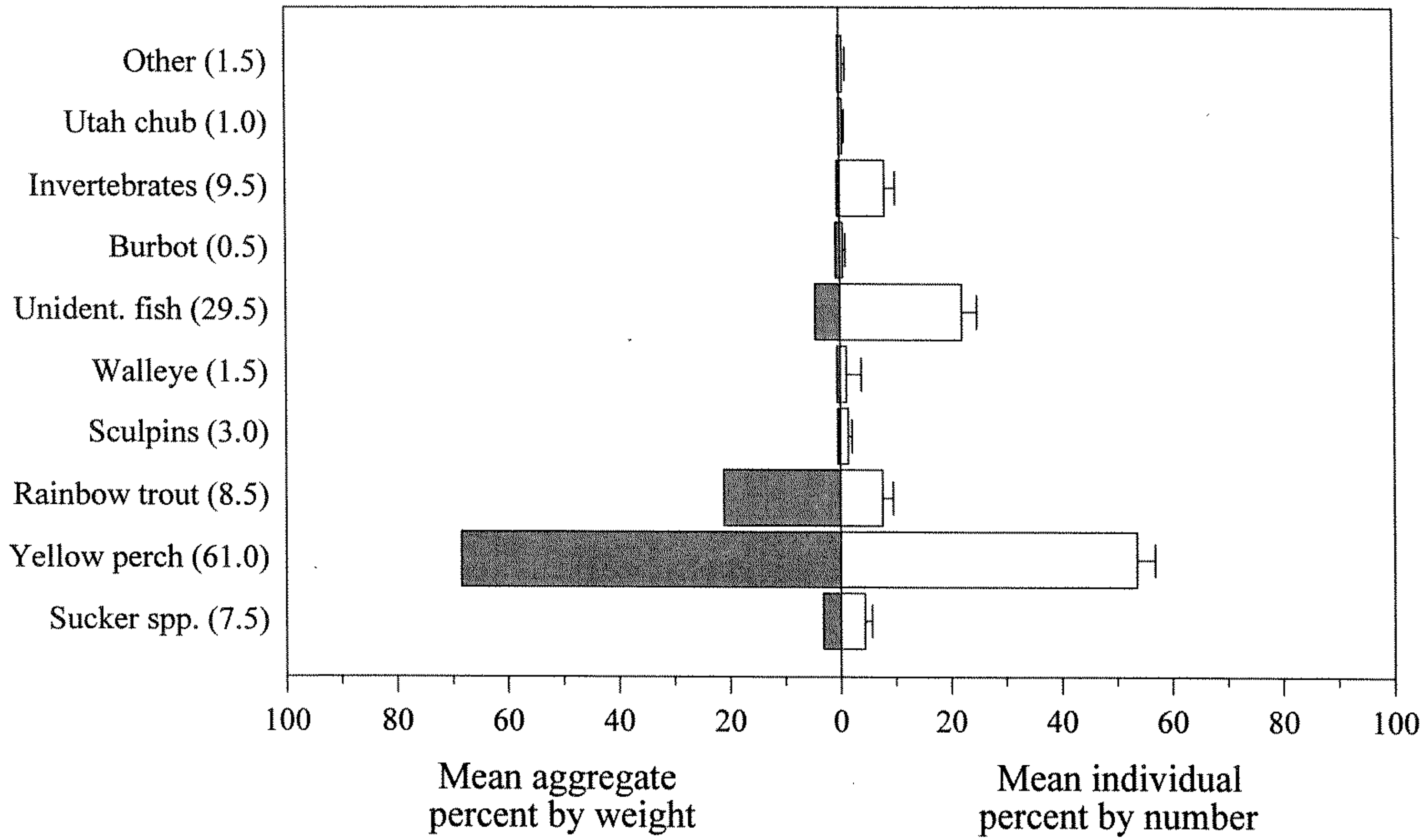


Figure 27. Mean aggregate percent by weight and mean (+1 SE) individual percent by number of food items in walleye stomachs (n = 200) collected during 1998 from Canyon Ferry Reservoir, Montana. Percentages in parentheses represent frequency of occurrence for individual prey items.

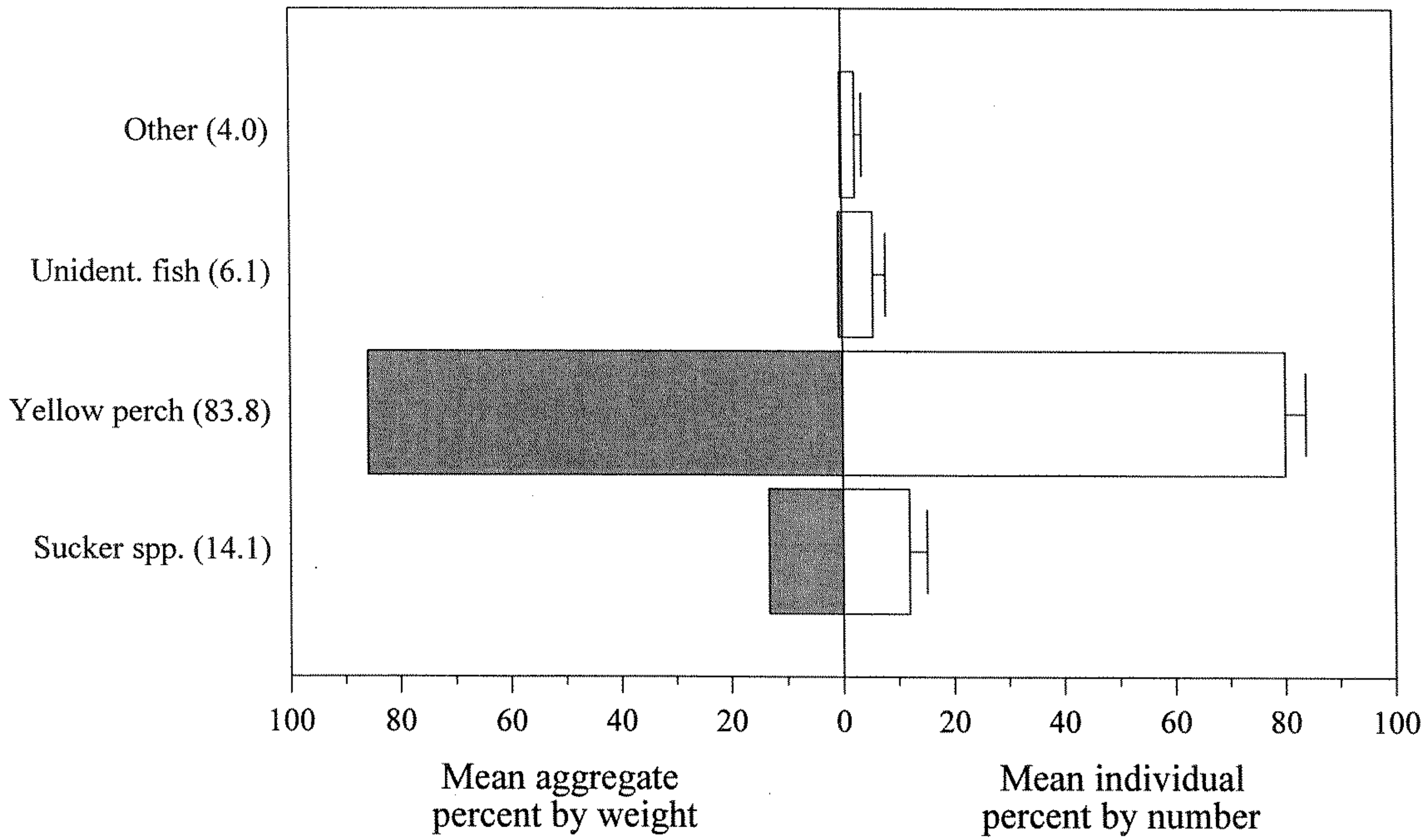


Figure 28. Mean aggregate percent by weight and mean (+1 SE) individual percent by number of food items in walleye stomachs (n = 99) collected during 1999 from Canyon Ferry Reservoir, Montana. Percentages in parentheses represent frequency of occurrence for individual prey items.

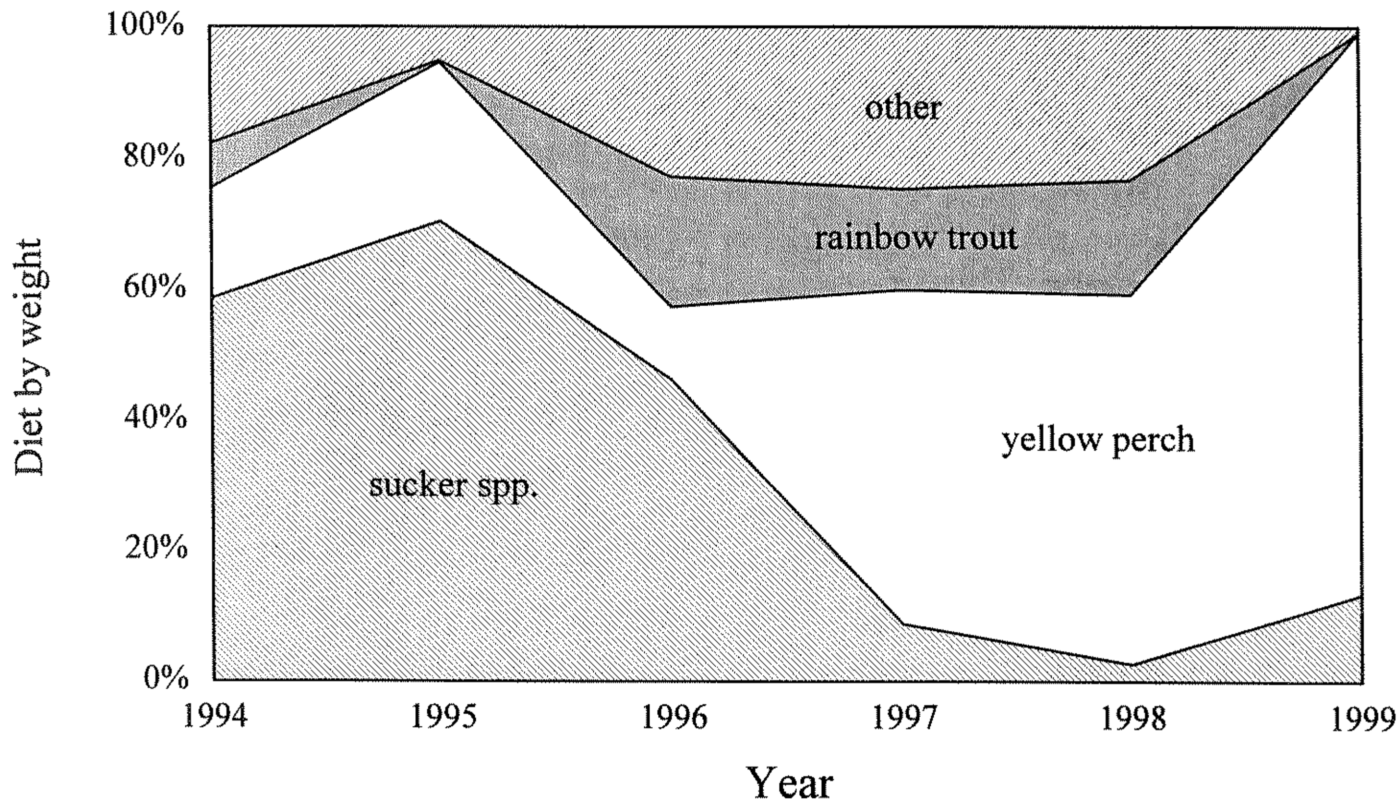


Figure 29. Relative contribution by weight of sucker spp., yellow perch, rainbow trout, and other items to diet of walleye in Canyon Ferry Reservoir, Montana, 1994 - 1999.

DISCUSSION

In 1994, at the onset of this research, the status of walleye in Canyon Ferry Reservoir was unknown. The rapid development of this population during this study has been remarkable. Walleye are now firmly established and commonly sampled in all standardized netting surveys completed in the reservoir. Additionally, in 1996 walleye became a component of the reservoir's recreational fishery when they were first documented in MFWP's creel census efforts. This is notable because summer and winter angler creel surveys have been conducted annually on Canyon Ferry since 1986. MFWP completed nearly 28,000 angler interviews on the reservoir prior to 1996; not a single walleye was ever reported (Lere 1992; MFWP, unpublished data).

The sampling of walleye in each of MFWP's standardized netting series during this study clearly indicated they are a recent addition to the Canyon Ferry fish assemblage. The strongest evidence of this was their first appearance in the sinking net series in 1994. This netting series provides excellent historical fish trend data, dating back to when the reservoir first filled in 1955. Initially, I was suspicious of the effectiveness of this series in sampling walleye. Certain net sites were located in profundal areas of the reservoir at depths greater (> 15 m) than those generally preferred by walleye (Colby et al. 1979). The relatively few walleye observed in this netting series during the first three years of this study heightened those suspicions (Figure 3). However, other sampling I completed during those years confirmed the relatively low abundance of walleye in the reservoir at that time. Intensive gill netting I completed in autumns of 1994 and 1995 specifically targeted walleye. Nets were set in areas used by telemeterized walleye and were my best effort at sampling them. Both years, gill net CPUE rates averaged one walleye per net (Figure 5).

The walleye population in Holter Reservoir has been described as low density (Colby and Hunter 1989). Standardized sinking gill net catches historically averaged about three walleye per net (Lere 1992; Skaar and Humphrey 1995). Comparing Holter's net catch rates with those I observed in the sinking net series (< 0.5 walleye per net) during the first three years of this study characterized the low abundance of walleye in Canyon Ferry at that time. The relatively few individuals observed in nets in 1994, 1995, and 1996 confirmed the sensitivity of this netting series in sampling walleye when they were not very abundant. It is likely walleye would have been observed in the sinking net series prior to this study if they were present in the reservoir.

Age and growth of Canyon Ferry walleye provided insight into the development of this population. However, the accuracy of techniques used to analyze these data dictate their value in describing these characteristics. The use of dorsal spine cross-sections to age walleye has been well supported in other studies (Carnevale 1977; Campbell and Babaluk 1979; Belanger and Hogler 1982; Erickson 1983; Marwitz and Hubert 1995) and was validated by Schram (1989). I found spine cross-sections easy to read, particularly on older fish. Marwitz and Hubert (1995) recommended against the use of scales to age walleye because of indistinct annuli. Carnevale (1977) and Erickson (1983) reported the ease of aging younger, fast growing walleye with scales. Scales I viewed from younger (< age-4) walleye exhibited distinct annuli and were easily aged.

Consequently, I used scales in the later years of the study to age younger walleye because of their ease of preparation. Ages I determined for walleye using dorsal spines and scales were consistent with those of an independent reader, thus confirming the precision of ages I assigned during this study. Francis (1990) encouraged the use of appropriate back-calculation techniques and emphasized their validation based on comparisons of individual fish. I used the Whitney-Carlander (1956) "body proportional" back-calculation technique as revised in Francis' (1990) critical review. However, validation of this method for individual Canyon Ferry walleye was beyond the scope of this study. This is a limitation of my study, as the use of dorsal spine cross-sections to back-calculate lengths at age has not been validated in the scientific literature. However, the strongly correlated, statistically significant ($r^2 = 0.88$; $P < 0.001$) spine radius to total length relationship I determined for Canyon Ferry walleye supported the use of spine cross-sections to back-calculate lengths at age and growth rates. Back-calculated lengths at age that I determined were similar to lengths at capture of walleye sampled in the spring near time of annulus formation in late May / early June. This study substantiates the use of dorsal spine cross-sections to determine age, back-calculated lengths at age, and growth rates of walleye.

The age structure of walleye sampled in the sinking net and walleye netting series indicated this population is young and developing rapidly. Beginning in 1997, walleye catches in both netting series were dominated by a strong year class produced in 1996. A similarly strong year class produced in 1997 appeared in the nets in 1998. The combination of these two year classes resulted in sharp increases in the number of walleye sampled in these nets relative to what was observed during the earlier years of the study (Figures 3, 4). Few older-aged (> age-4) walleye were sampled in either of these netting series, indicating their relative absence in the population (Figure 4).

The production of strong year classes in 1996 and 1997 was precipitated by the full recruitment of the 1990 year class into the walleye spawning population. This year class dominated the spawning population throughout the study, accounting for nearly one-third of all adult walleye sampled during the spawning period (Figure 18). During this study, male walleye sexually matured by age 3 and females by age 5. Thus, it was not until 1995 that the majority of the females from the strong 1990 year class spawned for the first time.

Further evidence of the relative youth of this population was the absence of older walleye in the spawning population during the early years of this study. Walleye are a long-lived species. Individuals as old as 28 years have been reported (Colby and Nepszy 1981), but maximum ages of walleye are typically 12 to 15 years in the northern limits of their range (Colby et al. 1979). Generally, fast growing walleye populations that mature at younger ages do not live as long as slower growing populations (Hackney and Holbrook 1978; Colby et al. 1979). Marwitz (1994) documented walleye as old as 16 years in Seminoe Reservoir, Wyoming. Similarly, walleye up to 16 years of age have been observed in Holter Reservoir (T. Humphrey, MFWP, personal communication). The oldest individual I sampled from the spawning population during 1994 was age 9, thus produced in 1985. In subsequent years of the study, 1985 was the oldest year class consistently represented in the Canyon Ferry population. This was evidenced by the large number of adults sampled during the 1996 (n = 108) and 1997 (n = 302) spawning seasons. Individuals from the 1985 year class continued to be represented in the spawning population in 1999 at age 14 (Figure 16). This suggests that Canyon Ferry walleye will likely be as long-lived as walleye in other western waters.

The oldest walleye sampled during this study were of suspect origin. Three 1981 year-class walleye exhibited very different growth patterns relative to the consistent growth observed in the younger members of the population. Their initial growth was much reduced, but then rapidly increased in subsequent years to levels similar to or higher than those determined for the 1985 to 1995 year classes (Figure 21). Whereas the uniform growth exhibited by the 1985 to 1995 year classes indicated they were produced in Canyon Ferry, the unusual growth patterns of the 1981 year class suggested they were not. This is based on the assumption that changes in environmental conditions did not result in reduced growth. Reservoir elevations in 1981 did not vary much from elevations observed during this study (USBOR 2000). Water and air temperature data was not available for 1981, but likely did not differ enough to cause such reduced initial growth. Thus, the 1981 year-class walleye possibly were introduced into the reservoir as juveniles, then flourished in their new environment. Although speculative based on only three fish, other findings of this study also indicated this population was in a developing stage in the early 1980s. Age data indicated there was a gap in year class representation from 1982 to 1984. Of the 1,601 walleye sampled during this study, none were produced during those years. Established populations typically exhibit annual recruitment. The absence of those year classes indicated that walleye recruitment did not occur in the reservoir until the introduced juvenile walleye matured sexually.

Growth rates I determined for Canyon Ferry walleye were among the highest observed in North American stocks. Back-calculated mean total lengths at age were similar to walleye in southern reservoirs and exceeded those of other western waters (by 38% at age one to 2% by age seven; Figure 30). Kitchell et al. (1977) and Colby et al. (1979) identified water temperature and prey availability as the two most important factors regulating walleye growth. Intuitively one would presume walleye growth to be considerably higher in the warmer, southern waters of their range relative to Montana. Ney (1978) and Colby et al. (1979) suggested that length of growing season influences walleye growth rates. The south end of Canyon Ferry provides a unique growing environment for walleye. Its shallow depth, turbidity, and river inflows result in warmer water temperatures earlier in the year relative to other portions of the reservoir. The physiological optimum temperature for walleye growth is 22.6 C (Craig 1987). Kelso (1972) reported that walleye growth rates were highest at temperatures of 20 to 24 C. Water temperatures in the south end of Canyon Ferry generally were within that range from mid May through August. This warm water habitat provided post-spawn walleye with an excellent growing environment and longer grower season relative to what was available in other portions of the reservoir (Chapter 3).

The exceptional growth exhibited by Canyon Ferry walleye has been observed in other newly expanding walleye populations. Initial periods of high growth were reported in developing walleye populations in the North Platte River reservoirs in Wyoming

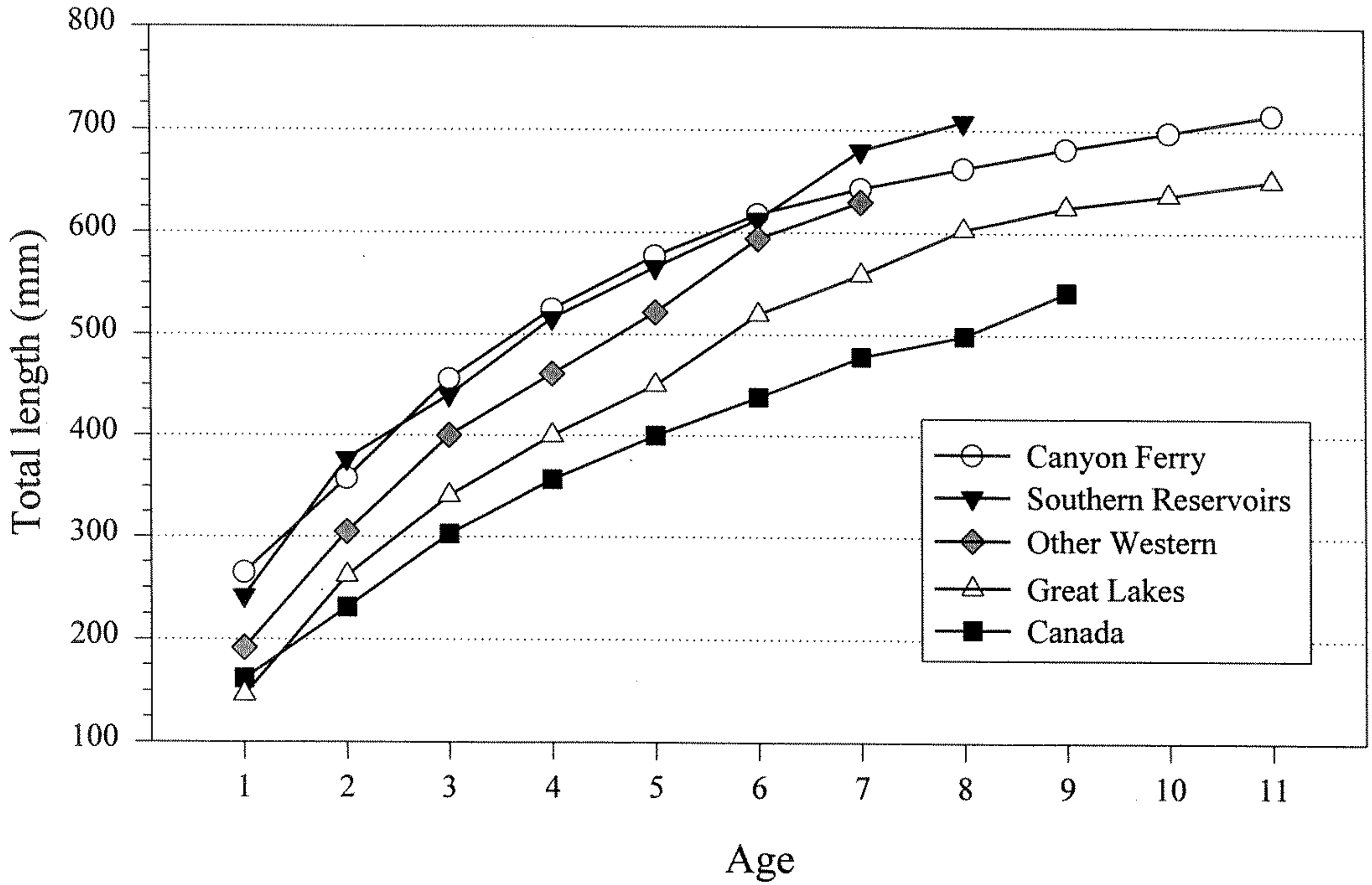


Figure 30. Back-calculated total lengths at age of walleye from Canyon Ferry Reservoir, Montana, compared to other North American walleye stocks (Carlander 1997).

(McMillan 1984; Marwitz 1994), Norris Reservoir in Tennessee (Eschmeyer and Jones 1941; Stroud 1949), and several southeastern reservoirs (Hackney and Holbrock 1978). Nelson and Walburg (1977) noted that walleye growth declined markedly in Lake Francis Case and Lake Oahe after rapid population expansion following the early years of impoundment. The high growth observed in these populations was attributed to their introduction into previously unexploited environments with abundant forage. Subsequently, growth declined as these populations expanded and forage became limiting. McMahon (1992) described this phenomenon as a 'boom and bust' phase. Growth rates I determined for Canyon Ferry walleye did not show any decline. However, these data should be considered pre-expansion or 'boom' phase data, as they described the population during the first three years of the study before walleye numbers increased sharply.

The exceptional growth of Canyon Ferry walleye was substantiated by their W_r. Positive correlations between W_r and growth have been reported for largemouth bass (Wege and Anderson 1978), northern pike (Willis 1989), and yellow perch (Willis et al. 1991). In contrast, Liao et al. (1995) could not relate W_r and growth in pumpkinseed *Lepomis gibbosus* nor golden shiner *Notemigonus crysoleucas*. Mean W_r of Canyon Ferry walleye sampled in autumn were near or above 100 for each RSD length group during all years of the study (Figure 22). Anderson and Neuman (1996) suggested that a mean W_r of 100 over several size groups within a population may reflect ecological and physiological optimality. However, Murphy et al. (1990) argued that because of the difficulty in defining a single optimum for any species, W_s should only be considered a benchmark for comparisons of populations.

There are no length associated biases with the W_s equation developed for walleye (Murphy et al. 1990). Thus, mean W_r trends across RSD length groups may provide insight into the ecological factors affecting specific sizes of fish within a population (Wege and Anderson 1978; Murphy et al. 1990, 1991). The value of W_r as a reliable predictor of prey abundance and availability has been demonstrated by numerous studies (Wege and Anderson 1978; Liao et al. 1995; Marwitz and Hubert 1997; Porath and Peters 1997). W_r trends of Canyon Ferry walleye may have indicated changes in prey availability. Generally, mean W_r increased with increasing RSD length groups, suggesting that suitable prey became more available as walleyes increased in length. In contrast, the decrease in mean W_r of Q-P and P-M walleye in the later years of the study indicated prey may have become less available or suitable for those size groups. This may have resulted from density dependent processes associated with the strong 1996 and 1997 year classes. S-Q walleye exhibited the lowest mean W_r and the greatest year-to-year fluctuation of all length groups. Smaller-sized walleye are obligated to prey on age 0 or juvenile fish because of gape limitations (Craig 1987; Madenjian 1991). Porath and Peters (1997) suggested year class strength of prey species may be easily monitored by following W_r of smaller walleye. Applied to Canyon Ferry, W_r of S-Q walleye may have indicated poor yellow perch and sucker recruitment in 1997 and 1999.

Suckers and yellow perch were the predominant prey of Canyon Ferry walleye. Certain studies have demonstrated species-specific prey selection by walleye irrespective of abundance (Davis 1975; Wolfort and Bur 1992; Bolding et al. 1998). Hartman and Margraf (1992) found walleye diets in western Lake Erie reflected prey fish abundances, whereas Knight et al. (1984) determined it was a combination of both prey preference and abundance that defined walleye diet. McMahon (1992) predicted that suckers and yellow perch would provide most of the forage base for walleye in Canyon Ferry based on their relative abundances in gill net catches. Canyon Ferry does not support a diverse prey fish assemblage; walleye were obligated to feed on the most abundant prey species available at suitable lengths rather than exhibit species-specific prey selectivity (Colby et al. 1979).

The combined contribution by weight of suckers and yellow perch to diets of walleye was relatively consistent throughout the study. However, there was a complete shift in the individual contribution of each of these prey fish from 1994 to 1999. Suckers were the dominant prey item initially, but by 1999 walleye were feeding almost exclusively on yellow perch (Figure 29). Although I did not analyze size of yellow perch consumed by walleye, a qualitative assessment indicated that most were age 0. Relative abundances of age-0 suckers and yellow perch in beach seine sampling did not reflect these changes in diet. Griswold and Bjornn (1989) found beach seining to be an effective technique for monitoring year-class strength of yellow perch in Cascade Reservoir, Idaho. Thus far, Canyon Ferry data has not demonstrated a correlation between seine CPUE and year class strength of yellow perch.

The cause of the shift in walleye diet was not apparent until 1999 when a strong cohort of small perch first appeared in the sinking net series (Figure 7). Lengths-at-age of Canyon Ferry perch reported by Bandow (1969) and Lere (1992) indicated this cohort was age 3 and produced in 1996. Food habits of walleye in 1996 indicated that the production of this year class initiated the prey shift. Perch were the dominant prey item by number in walleye diets that year, but only accounted for about 15% of their diet by weight (Figure 25). This indicated that walleye were feeding on smaller-sized perch, likely age 0.

Food habits and W_r of walleye suggested that substantial yellow perch production occurred in at least one of the later years of the study. The length of prey consumed by walleye averages 28% of their body length (Parsons 1971; Nielsen 1980). Assuming this average is valid for Canyon Ferry walleye, by 1998 perch produced in 1996 were too large to be effectively preyed on by most walleye in the population. However, the condition of S-Q and Q-P walleye remained excellent (as evidenced by W_r values) in 1998 and perch continued to be the dominant food item in their diets. This indicated that adequate numbers of perch were produced subsequent to 1996, although beach seine catches did not reflect any changes in abundances.

These findings suggest that detailed walleye diet analysis coupled with W_r data might provide an indirect method of assessing production of prey fishes as an alternative to beach seining. This assessment would require a more comprehensive diet analysis than what I completed during this study. Quantifying seasonal type and size of prey selected by individual walleye length groups and their associated W_r might help define relative year class strength of individual prey species.

Historic data indicated that the majority of the white sucker biomass in Canyon Ferry was tied up in large, long-lived adults. The relatively few smaller, prey-sized individuals in this 'top heavy' population precluded its potential to provide a sustainable forage base for walleye. The recent declining trend of white suckers in the sinking net series suggested that walleye predation may already be affecting this population. This decline was most evident in the smaller size groups. Walleye predation may be cropping the smaller individuals, thus limiting their recruitment into the larger size groups. Similar declines in white sucker populations were observed in other Montana reservoirs following the introduction of walleye. Walleye were introduced into Cooney Reservoir in 1984 to control an abundant white sucker population. Venditti (1994) found that by 1990 walleye predation eliminated recruitment of entire year classes of white suckers. He projected that white suckers might be entirely eliminated from the reservoir by the late 1990s. Currently, white suckers still persist in the reservoir in low numbers, presumably maintained by adults emigrating from tributary streams (M. Vaughn, MFWP, personal communication). In Tiber Reservoir, white suckers accounted for up to 85% of fish sampled in netting surveys before walleye were introduced in 1971. Net catches of white suckers have been variable since walleye were introduced, but demonstrated a declining trend (Colby and Hunter 1989). In gill net sampling completed in 1996, white suckers accounted for just 17% of the catch. Only larger individuals were sampled, ranging in size from 373 to 505 mm TL (Hill et al. 1997).

Rainbow trout were the third most common prey of walleye, though much less prevalent than yellow perch and suckers. However, this data was somewhat biased. Most walleye diet samples were collected in July, August, and September when standardized sampling was completed. Rainbow trout are probably most vulnerable to predation at time of stocking, which typically occurs in May at Canyon Ferry. McMillan (1984) reported that most of the rainbow trout planted in Seminoe Reservoir, Wyoming, were consumed by walleye within weeks of stocking. Netting I completed in 1996 during the stocking period indicated that walleye preyed on recently planted rainbow trout; five of the 13 stomachs with food items contained rainbow trout. Although some level of rainbow trout predation was certainly occurring, it was not intense enough to negatively affect the population. Standardized gill net catches and angler catch rates of rainbow trout remained consistent throughout this study.

The light predation pressure on rainbow trout can be partly attributed to the relatively small number of large walleye in the population. Rainbow trout are stocked into Canyon Ferry as yearlings; most were too large to be effectively preyed on by the younger year classes of walleye that dominated the population. However, significant walleye predation will likely occur in the next few years as the 1996 and 1997 year classes attain sizes that can efficiently use these hatchery plants. This predation pressure will be exacerbated by the continued stocking of rainbow trout in May. This is the post-spawn period for Canyon Ferry walleye, a time when food demands are very high and age-0 prey fish are not yet available to provide an abundant alternative forage base (Kelso 1973).

The paucity of other prey items in the diets of walleye was indicative of the limited forage base available in Canyon Ferry. This lack of diversity is characteristic of western reservoirs, which typically start with simple endemic species assemblages pre-impoundment (Wydoski and Bennett 1981). It is likely some of these other species (e.g., mottled sculpin, longnose dace, and crayfish) will become more important prey items for walleye if yellow perch, suckers, and rainbow trout become less available. Their sustainability is doubtful; beach seine and gill net catches indicated that none of these species are very abundant, nor are they very fecund based on their life history. The value of these other species as forage has not been widely reported in the literature. McMillan (1984) reported walleye preyed on carp and crayfish in Seminoe Reservoir, Wyoming, after other forage was no longer available. The carp population in Canyon Ferry is primarily composed of large, long-lived individuals and likely will not be of much value as alternative forage for walleye.

The results of this study supported several of McMahon's (1992) conclusions in his risk assessment evaluating the potential introduction of walleye into Canyon Ferry Reservoir. Walleye have developed into a self-sustaining population with demonstrated high reproductive potential. A relatively small number of adult walleye produced strong year classes in 1996 and 1997. Gill net catches of those adults averaged about one walleye per net in 1994 and 1995. The resulting 1996 and 1997 year classes averaged over 10 walleye per net in the walleye netting series in 1998. This net CPUE was higher than those observed in most other established walleye fisheries in Montana (MFWP 2000). The development of the Canyon Ferry walleye population had entered the 'boom' phase predicted by McMahon (1992). The existing potential for much greater population expansion may be realized in the immediate future, after the female component of the 1996 and 1997 year classes is fully recruited into the spawning population beginning in 2001 and 2002.

Walleye food habits I described during this study agreed with McMahon's (1992) predictions on forage availability and use by walleye in Canyon Ferry. Suckers, yellow perch, and rainbow trout provided the bulk of the walleye diet. Heavy walleye predation of suckers was short-lived; a population decline and shift in size distribution was already evident. Excellent production of yellow perch in the later years of the study provided an abundant forage base for walleye and likely helped buffer predation of stocked rainbow trout. The long-term sustainability of yellow perch as a stable prey base for walleye is unlikely. Historic net catches and data collected during this study indicated wide fluctuations in perch recruitment. It is probable that variable yellow perch recruitment will continue in the future. Future declines in available yellow perch and the increasing sizes of the 1996 and 1997 year classes of walleye will likely lead to increased predation pressure on rainbow trout in the next several years.

Lastly, McMahon (1992) predicted that substantial downstream movement of walleye could be expected from Canyon Ferry into Hauser and Holter reservoirs during high water years. Record high discharges coupled with the strong year classes of walleye in Canyon Ferry resulted in large numbers of walleye being flushed into both Hauser and Holter reservoirs in 1997. Although both reservoirs historically supported low level walleye populations, angler catch rates and gill net catches of walleye have increased to record levels since 1997 (S. Dalbey, MFWP, personal communication).

In 1998, MFWP initiated the development of a fisheries management plan to address the system-wide effects of the expanding Canyon Ferry walleye population. This ten-year (2000 - 2009) plan incorporated the entire reservoir / river complex. The principal objective adopted in the plan was to manage the system as a "high quality, cost-effective, multi-species fishery with high levels of angler satisfaction" (MFWP 2000). This plan formally recognized walleye as a permanent component of the Canyon Ferry Reservoir fisheries community. Findings of this study will provide a benchmark for the continued monitoring of the expansion of the Canyon Ferry walleye population and any changes in existing fisheries.

Management Recommendations

The maintenance of an adequate forage base for walleye is likely to be the greatest challenge in managing for a multi-species fishery in Canyon Ferry. An eventual forage depletion seems certain given the variable recruitment of yellow perch and the high reproductive potential exhibited by this walleye population. A growing contingent of walleye anglers and political pressure will preclude MFWP from not considering potential forage fish introductions to restore a declining walleye fishery. I recommend that MFWP take proactive measures to address this issue. An environmental assessment should be prepared evaluating the potential introduction of various forage fishes into Canyon Ferry. This will encourage open communication about this issue and provide a solid foundation in which to address it in the future. Concurrently, greater emphasis should be directed towards understanding yellow perch population dynamics. Little is currently known about the reservoir's yellow perch population outside of age and growth data and general trend information. When environmental conditions are right, perch can be tremendously productive and support a sizeable walleye population, as demonstrated in the later years of this study. A better understanding of yellow perch population dynamics would be invaluable in developing possible management strategies to provide more consistent perch recruitment. Because of their importance as both a sport and forage fish, MFWP should prioritize funding for a graduate research project studying yellow perch population dynamics in Canyon Ferry Reservoir.

Substantial walleye predation of rainbow trout could occur beginning in 2000. The 1996 and 1997 year classes of walleye are attaining sizes that can effectively prey on the yearling rainbow trout currently being stocked into Canyon Ferry. Wyoming Game and Fish Department recently completed a comprehensive study on the North Platte River reservoirs evaluating which rainbow trout stocking variables (e.g., strain, season of stocking, size at stocking) maximized angler catch in the presence of walleye (Mavrakis and Yule 1998; Yule et al. 2000). The Wyoming study found that autumn plants of rainbow trout provided a substantially higher return to the creel than spring plants. It was believed that the availability of alternative walleye forage in autumn and the added growth of rainbow trout during winter reduced their vulnerability to predation (Yule et al. 2000). Because of the similarities between the North Platte reservoirs and the upper Missouri River reservoirs, it is reasonable to assume that the results of this study have applicability to Canyon Ferry. MFWP hatchery personnel should evaluate the logistics of autumn plants of rainbow trout and determine the feasibility of experimenting with small lots of these plants in the near future. Single and double tetracycline marks could be used to differentiate between the two stocking seasons to facilitate evaluation.

Lastly and most importantly, historic data and data collected during this study provide the baseline for this to be one of the best documented case histories on the effects of a walleye introduction on salmonid fisheries in a reservoir / river system. The continued comprehensive monitoring of the development and expansion of this walleye population and the resulting system-wide effects should be a top priority for MFWP. The recreational value of these fisheries and the level of public interest warrants the commitment of a full-time biologist to this project. This will ensure that the current level of attention dedicated to the management of this changing fishery is maintained, and that data needs are met to implement the newly adopted management plan.

LITERATURE CITED

Anderson, R. O., and R. M. Neumann. 1996. Length, weight, and associated structural indices. Pages 447-481 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Bandow, F. L. 1969. Observations on the life history of the yellow perch and fish population trends in Canyon Ferry Reservoir, Montana. Master's thesis. Montana State University, Bozeman.

Beamish, R. J., and G. A. McFarlane. 1987. Current trends in age determination methodology. Pages (15-42) *in* R. C. Summerfelt and G. E. Hall, editors. Age and growth of fish. Iowa State University Press, Ames, Iowa.

Belanger, S. E., and S. R. Hogler. 1982. Comparison of five ageing methodologies applied to walleye (*Stizostedion vitreum vitreum*) in Burt Lake, Michigan. Journal of Great Lakes Research 8:666-671.

Bolding, B., S. A. Bonar, and M. Divens. 1998. Walleye diet in a shallow impoundment; relative importance of pumpkinseed sunfish and yellow perch. Journal of Freshwater Ecology 13:9-14.

Bowen, S. B. 1983. Quantitative description of the diet. Pages 325-336 *in* L. A. Nielsen and D. L. Johnson, editors. Fisheries techniques. American Fisheries Society, Bethesda, Maryland.

Campbell, J. S., and J. A. Babaluk. 1979. Age determination of walleye, *Stizostedion vitreum vitreum* (Mitchill), based on the examination of eight different structures. Canadian Fisheries and Marine Service Technical Report 849.

Carlander, K. D. 1997. Handbook of freshwater fishery biology. Volume III. Life history data on ichthyopercid and percid fishes of the United States and Canada. Iowa State University Press, Ames.

Carnevale, M. A. 1977. Age and growth of walleye, *Stizostedion vitreum vitreum* (Mitchill), from Seminoe Reservoir, Wyoming. Master's thesis, University of Wyoming, Laramie.

Colby, P. J., R. E. McNichol, and R. A. Ryder. 1979. Synopsis of biological data on the walleye *Stizostedion v. vitreum* (Mitchill 1818). Food and Agriculture Organization (FAO) Fish. Synop. 119. Rome, Italy.

Colby, P. J., and S. J. Nepszy. 1981. Variation among stocks of walleye (*Stizostedion vitreum vitreum*): management implications. Canadian Journal of Fisheries and Aquatic Sciences 38(12):1814-1831.

Colby, P., and C. Hunter. 1989. Environmental assessment of the introduction of walleye beyond their current range in Montana. Montana Fish, Wildlife and Parks, Helena.

Craig, J. F. 1987. The biology of perch and related fish. Timber Press, Portland, Oregon.

Davis, R. 1975. Food habits of walleye, *Stizostedion vitreum vitreum* (Mitchill) in a southern Minnesota lake. Minnesota Division of Natural Resources, Division of Fish and Wildlife. Job completion report F-26-R, Minnesota.

Erickson, C. M. 1983. Age determination of Manitoban walleyes using otoliths, dorsal spines, and scales. North American Journal of Fisheries Management 3:176-181.

Eschmeyer, P. H., and A. M. Jones. 1941. The growth of game fishes in Norris Reservoir during the first five years of impoundment. Transactions of the North American Wildlife Conference 6:222-240.

Francis, R. I. C. C. 1990. Back-calculation of fish length: a critical review. Journal of Fish Biology 36:883-902.

Frost, C., and five authors. 1996. Draft partial key to fishes of the Columbia and lower Snake rivers, based on diagnostic bones. U. S. Geological Survey, Columbia River Research Laboratory, Cook, Washington.

Gablehouse, D. W., Jr. 1984. A length-categorization system to assess fish stocks. North American Journal of Fisheries Management 4:273-285.

Griswold, R. G., and T. C. Bjornn. 1989. Development of indices of yellow perch abundance in Cascade Reservoir, Idaho. Idaho Department of Fish and Game. Job completion report F-71-R-12, III-6, Boise.

Gustafson, K. A. 1988. Approximating confidence intervals for indices of fish population size structure. North America Journal of Fisheries Management 8:139-141.

Hackney, P. A., and J. A. Holbrook II. 1978. Sauger, walleye, and yellow perch in the southeastern United States. Pages 74-81 *in* R. L. Kendall, editor. Selected Coolwater Fishes of North America. American Fisheries Society, Bethesda, Maryland.

Hartman, K. J., and F. J. Margraf. 1992. Effects of prey and predator abundances on prey consumption and growth of walleyes in western Lake Erie. Transactions of the American Fisheries Society 121:245-260.

Hill, W. J., A. Tews, P. D. Hamlin, and D. Teuscher. 1997. Northcentral Montana warm and coolwater ecosystems. Montana Fish, Wildlife and Parks. Job progress report F-78-R-3, Helena.

Horn, M. J., and J. Boehmke. 1998. The limnology of Canyon Ferry Reservoir, Montana. Technical Memorandum No. 8220-98-17. Bureau of Reclamation, U.S. Department of the Interior. Denver, Colorado.

Hyslop, E. J. 1980. Stomach contents analysis - a review of methods and their application. Journal of Fish Biology 17:411-429.

Jearld, A., Jr. 983. Age determination. Pages 301-324 *in* L.A. Nielsen and D.L. Johnson, editors. Fisheries techniques. American Fisheries Society, Bethesda, Maryland.

Kelso, J. R. M. 1972. Conversion, maintenance, and assimilation for walleye (*Stizostedion vitreum vitreum*), as affected by size, diet, and temperature. Journal of Fisheries Research Board of Canada 29(8):1181-1192.

Kelso, J. R. M. 1973. Seasonal energy changes in walleye and their diet in West Blue Lake, Manitoba. Transactions of the American Fisheries Society 102:363-368.

Kitchell, J. F., D. J. Stewart, and D. Weininger. 1977. Applications of a bioenergetics model to yellow perch (*Perca flavescens*) and walleye (*Stizostedion vitreum vitreum*). Journal of Fisheries Research Board of Canada 34:1922-1935.

Knight, R. L., F. J. Margraf, and R. F. Carline. 1984. Piscivory by walleyes and yellow perch in western Lake Erie. Transactions of the American Fisheries Society 113:677-693.

Lere, M. 1990. Statewide fisheries investigations, survey and inventory of coldwater lakes, mid-Missouri reservoirs study. Montana Fish, Wildlife and Parks. Job progress report F-46-R-3, II-f, Helena.

Lere, M. 1991. Statewide fisheries investigations, survey and inventory of coldwater lakes, Canyon Ferry, Hauser, Holter reservoirs study. Montana Fish, Wildlife and Parks. Job progress report F-46-R-4, II-f, Helena.

Lere, M. 1992. Statewide fisheries investigations, survey and inventory of coldwater lakes, Canyon Ferry, Hauser, Holter reservoirs study. Montana Fish, Wildlife and Parks. Job progress report F-46-R-5, II-f, Helena.

Liao, H., C. L. Pierce, D. H. Wahl, J. B. Rasmussen, and W. C. Leggett. 1995. Relative weight (W_r) as a field assessment tool: relationships with growth, prey, biomass, and enviromental conditions. Transactions of the American Fisheries Society 124:387-400.

Mackay, W. C., G. R. Ash, and H. J. Norris, eds. 1990. Fish ageing methods for Alberta.R.L. and L. Enviromental Services Ltd. in association with Alberta Fish and Wildlife Division and the University of Alberta, Edmonton, Canada.

Madenjian, C. P. 1991. Limits to growth of young-of-the-year walleye (*Stizostedion vitreum vitreum*): an individual-based model perspective. Canadian Journal of Fisheries and Aquatic Sciences 48:1492-1499.

Marwitz, T. D. 1994. Walleye fisheries in the North Platte River drainage in Wyoming. Master's thesis, University of Wyoming, Laramie.

Marwitz, T. D., and W. A. Hubert. 1995. Precision of age estimates of Wyoming walleyes from different calcified structures. Prairie Naturalist 27(1):41-49.

Marwitz, T. D., and W. A. Hubert. 1997. Trends in relative weight of walleye stocks in Wyoming reservoirs. North American Journal of Fisheries Management 17:44-53.

Mavrakis, P. H., and D. L. Yule. 1998. North Platte comprehensive fisheries study: creel survey and stocking evaluation, 1995 - 1996. Wyoming Game and Fish Department, Cheyenne.

McMahon, T.E. 1992. Potential impacts of the introduction of walleye to the fishery of Canyon Ferry Reservoir and adjacent waters. Montana Fish, Wildlife and Parks, Helena.

McMahon, T. E., and D. H. Bennett. 1996. Walleye and northern pike: boost or bane to northwest fisheries? Fisheries 21(8):6-13.

McMillan, J. 1984. Evaluation and enhancement of the trout and walleye fisheries in the North Platte River system of Wyoming with emphasis on Seminoe Reservoir. Wyoming Game and Fish Department Report. Laramie.

McMillan, J. 1991. Introduction of walleyes into the North Platte River Reservoir System, *in* video proceedings of the walleye-trout interaction workshop. Montana Fish, Wildlife and Parks, March 2, 1991. Helena.

Montana Fish, Wildlife and Parks. 1997. Montana statewide angling pressure 1997. Helena.

Montana Fish, Wildlife and Parks. 2000. Upper Missouri River reservoir fisheries management plan 2000-2009. Helena.

Murphy, B. R., M. L. Brown, and T. A. Springer. 1990. Evaluation of the relative weight (*Wr*) index, with new applications to the walleye. North American Journal of Fisheries Management 10:85-97.

Murphy, B. R., D. W. Willis, and T. A. Springer. 1991. The relative weight index in fisheries management: status and needs. Fisheries 16(2):30-38.

Ney, J. J. 1978. A synoptic review of yellow perch and walleye biology. Pages 1-12 *in* R. L. Kendall, editor. Selected coolwater fishes of North America. American Fisheries Society, Bethesda, Maryland.

Nelson, W. R., and C. H. Walburg. 1977. Population dynamics of yellow perch (*Perca flavescens*), sauger (*Stizostedion canadense*), and walleye (*S. vitreum vitreum*) in four main stem Missouri River reservoirs. Journal of Fisheries Research Board of Canada 34:1748-1763.

Nielsen, L. A. 1980. Effects of walleye *Stizostedion vitreum vitreum* predation on juvenile mortality and recruitment of yellow perch *Perca flavescens* in Oneida Lake, New York. Canadian Journal of Fisheries and Aquatic Sciences 37:11-19.

Nigro, T. 1991. Walleye / salmonid interactions in the Columbia River System, *in* video proceedings of the walleye - trout interaction workshop. Montana Fish, Wildlife and Parks, March 2, 1991. Helena.

Parsons, J. W. 1971. Selective food preferences of walleyes of the 1959 year class in Lake Erie. Transactions of the American Fisheies Society 110:474-485.

Porath, M. T., and E. J. Peters. 1997. Use of walleye relative weights (W_r) to assess prey availability. North American Journal of Fisheries Management 17:628-637.

Priscu, J. C. 1987. Environmental factors regulating the dynamics of blue-green algal blooms in Canyon Ferry Reservoir, Montana. Report No. 159. Montana State University, Water Resources Center, Bozeman.

Rada, R. G. 1974. An investigation of the trophic status of Canyon Ferry Reservoir, Montana. Ph.D. Dissertation. Montana State University, Bozeman.

Rada, R. G., and J. C. Wright. 1979. Factors affecting nitrogen and phosphorus levels in Canyon Ferry Reservoir, Montana, and its effluent waters. Northwest Science 53:213-220.

Rehwinkel, B. J. 1986. Southwest Montana fisheries investigations, inventory and survey of the waters of the Jefferson and Madison drainages. Montana Fish, Wildlife and Parks. Job progress report F-9-R-34, I-d, Helena.

Schram, S. T. 1989. Validating dorsal spine readings of walleye age. Fish Management Report 138. Wisconsin Department of Natural Resources, Madison.

Skaar, D., and T. Humphrey. 1995. Statewide fisheries investigations, survey and inventory of coldwater lakes, Hauser and Holter reservoirs study. Montana Fish, Wildlife and Parks. Job progress report F-46-R-5, II-f, Helena.

SPSS Inc. 1999. SPSS for Windows. SPSS Incorporated, Chicago, Illinois.

Stroud, R. H. 1949. Growth of Norris Reservoir walleye during the first twelve years of impoundment. Journal of Wildlife Management 13:157-177.

United States Bureau of Reclamation (USBOR). 2000. Hydromet Data System. (http://www.gp.usbr.gov/www/hydromet.htm)

Venditti, D. A. 1994. Diet overlap and habitat utilization of rainbow trout and juvenile walleye in Cooney Reservoir, Montana. Master's thesis, Montana State University, Bozeman.

Wege, G. J., and R. O. Anderson. 1978. Relative weight (*Wr*): a new index of condition for largemouth bass. Pages 79-91 *in* G. Novinger and J. Dillard, editors. New approaches to the management of small impoundments. American Fisheries Society, North Central Division, Special Publications 5, Bethesda, Maryland.

Whitney, R. R., and K. D. Carlander. 1956. Interpretation of body-scale regression for computing body length of fish. Journal of Wildlife Management 20:21-27.

Willis, D. W. 1989. Proposed standard length-weight equation for northern pike. North American Journal of Fisheries Management. 9:203-208.

Willis, D. W., C. S. Guy, and B. R. Murphy. 1991. Development and evaluation of a standard weight (W_s) equation for yellow perch. North American Journal of Fisheries Management. 9:203-208.

Willis, D. W., B. R. Murphy, and C. S. Guy. 1993. Stock density indices: development, use, and limitations. Reviews in Fisheries Science 1(3):203-222.

Wolfert, D. R. and M. T. Bur. 1992. Selection of prey by walleyes in the Ohio water of the central basin of Lake Erie, 1985 - 987. U. S. Fish and Wildlife Service. Resource Publication 182.

Wright, J. C. 1958. The limnology of Canyon Ferry Reservoir, I. Phytoplankton-zooplankton relationships in the euphotic zone during September and October 1956. Limnology and Oceanography 3:150-159.

Wright, J. C. 1980. The population dynamics and production of *Daphnia* in Canyon Ferry Reservoir, Montana. Limnology and Oceanography 10:583-590.

Wydoski, R. S., and D. H. Bennett. 1981. Forage species in lakes and reservoirs of the western United States. Transactions of the American Fisheries Society 110:764-771.

Yule, D.L., R. A. Whaley, P. H. Mavrakis, D. D. Miller, and S. A. Flickinger. 2000. Use of strain, season of stocking, and size at stocking to improve fisheries for rainbow trout in reservoirs with walleyes. North American Journal of Fisheries Management 20:10-18.

Zar, J. H. 1984. Biostatistical Analysis, 2nd Edition. Prentice-Hall, Englewood, New Jersey.

CHAPTER 3

SEASONAL MOVEMENT AND HABITAT USE OF ADULT WALLEYE IN CANYON FERRY RESERVOIR, MONTANA

INTRODUCTION

The advancement of underwater biotelemetry techniques has provided researchers with a useful tool for monitoring movements and habitat use of a variety of free-ranging aquatic organisms (Winter 1996). Behavioral patterns, seasonal distributions, movements, and habitat use of walleye *Stizostedion vitreum* have been widely studied using ultrasonic telemetry (Kelso 1976; Pitlo 1978; Summers 1979; McConville and Fossum 1981; Heidinger and Tetzlaff 1989; Prophet et al. 1989; Parks and Kraai 1991; Binkley 1996; Williams 1997; DiStefano and Hiebert 2000).

There was no pre-existing information on the newly developing walleye *Stizostedion vitreum* population in Canyon Ferry Reservoir. Prior to 1994, Montana Fish, Wildlife and Parks (MFWP) personnel had sampled just 21 individuals in the reservoir. I used ultrasonic telemetry to gain a basic understanding of seasonal distribution and habitat use of adult walleye in Canyon Ferry. This information was essential for MFWP to develop effective sampling techniques for monitoring different segments of this population. Understanding the seasonal distribution of walleye was critical for implementing population control or eradication measures as mandated in the reservoir's fisheries management plan (MFWP 1992). Special effort was directed at identifying walleye spawning areas. Walleye exhibit fidelity to specific spawning sites (Olson et al. 1978; Colby et al. 1979; Craig 1987). The identification of these spawning areas was critical if MFWP was to effectively remove adult walleye from Canyon Ferry. Specific objectives of this study were to: 1) monitor seasonal distribution and movement of adult walleye; 2) gain an understanding of general habitat preferences; and 3) identify walleye spawning areas.

STUDY AREA

Canyon Ferry is the largest and uppermost impoundment of a three reservoir chain including Hauser and Holter reservoirs on the upper Missouri River (Figure 31). Impounded in 1954, it is located in Lewis & Clark and Broadwater counties in southwest Montana. The upper end of the reservoir is located about 40 km downstream of the origin of the Missouri River at the confluence of the Jefferson, Gallatin, and Madison rivers near Three Forks, Montana. Canyon Ferry Dam is located on the north end of the reservoir and is about 23 km east of Helena, Montana. The United States Bureau of Reclamation (BOR) operates Canyon Ferry as a water storage reservoir and regulates water levels for flood control, irrigation, municipal water supply, power production, and recreation. Because it is a storage reservoir, it controls the flow regime of the two lower, run-of-the-river reservoirs (Hauser and Holter) and the Missouri River below Holter Dam.

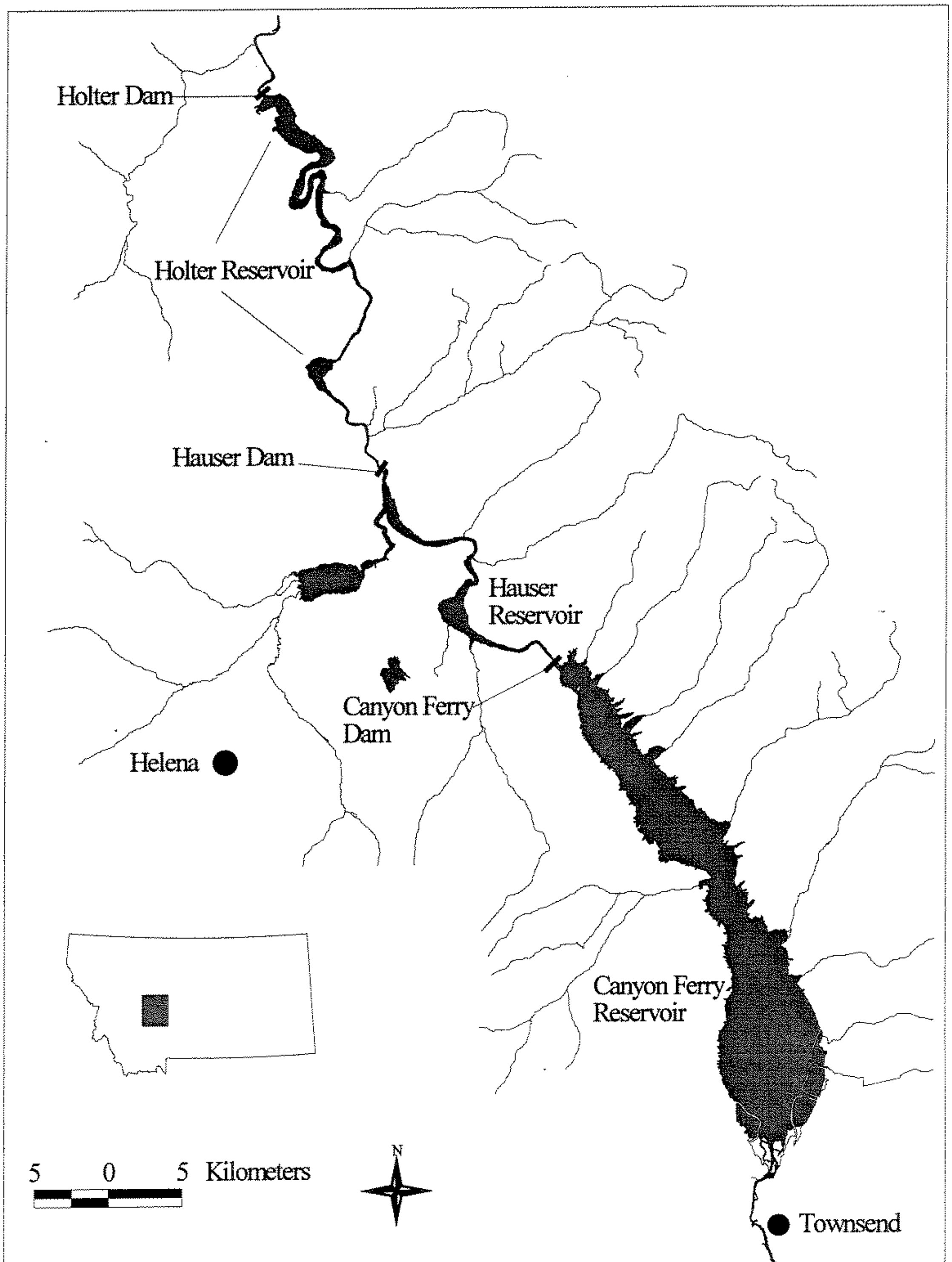


Figure 31. Map of Canyon Ferry Reservoir, Montana, showing downstream Hauser and Holter reservoirs and associated dams.

Canyon Ferry has an elevation at full-pool of 1158 m, surface area of 14,238 ha, and storage capacity of 2.53×10^9 m^3. The reservoir is 40.2 km long and has a maximum width of 7.2 km (Rada and Wright 1979). Canyon Ferry's total shore length is about 122 km and has a shoreline development factor of 2.9 (Rada 1974). It has mean and maximum depths of 17.8 m and 50.1 m, respectively. The annual drawdown is about 3.6 m and hydraulic retention averages about 135 days, but can range from 50 to 200 days depending on the flow regime and reservoir elevation (Priscu 1987). Canyon Ferry is a productive reservoir and has been classified as slightly eutrophic (Rada and Wright 1979) to hyper-eutrophic (Horn and Boehmke 1998) based on chlorophyll *a* and total phosphorus values.

The reservoir's north and south ends contrast markedly. The broad, southern (upper) portion of Canyon Ferry is characterized by relatively shallow (< 15 m), uniform depths with gently sloping shorelines and few bays. Strong wind events are common on this end of the reservoir, particularly during spring and autumn. The shoreline substrate is mostly small cobble with localized areas of sand and mud; off-shore substrate is predominately mud and silt deposited from the Missouri River. The north (lower) end of Canyon Ferry is much narrower and deeper. It has numerous small bays with steeply sloping, rocky shorelines, particularly off the points of bays. There are also several rocky islands on the north half of the reservoir, some of which are submerged when the reservoir is at full-pool. Generally, there is greater habitat complexity on the north end of the reservoir compared to the southern half.

Canyon Ferry Reservoir fills rapidly during spring run-off in late May and June, reaches its maximum storage in July, then gradually is drawn down to minimum storage levels by the following spring. The Missouri River provides nearly all water input into the reservoir except for a few small perennial tributaries (Duck, Confederate, Beaver, and Magpie creeks) that contribute only minimal inflow. Most water discharge at the dam occurs through three 4.1-m diameter power penstocks at a depth of 28 m. Additional water is released at a depth of 33 m into a pump intake to supply the Helena Valley Regulating Reservoir with irrigation and municipal water. During spring run-off when discharge exceeds the capacity of the power penstocks, excess water is released through four radial gates at the surface and through four 2.1-m diameter river outlets at a depth of 44 m.

The upper end of Canyon Ferry does not stratify because of shallow depths, strong wind activity, and the influence of the Missouri River. The mid and lower portions of the reservoir develop a weak thermocline during the summer, generally at a depth of 12 to 25 m (Horn and Boehmke 1998). It is a dimictic reservoir, turning over in early to mid-October and again in the spring at ice-out. Canyon Ferry is typically ice covered from mid-December through March. The shallower, upper end of the reservoir is the first area to ice-up and is the first portion of the reservoir to become ice-free in the spring, in part because of the warmer water inflows from the Missouri River.

METHODS

Walleye Sampling

Experimental-mesh sinking gill nets were set specifically targeting adult walleye to implant with ultrasonic transmitters (model CHP-87-M, Sonotronics Inc., Tucson, Arizona) during the spring of 1994 and autumns of 1994 and 1995 (Chapter 2). Care was taken to implant only healthy individuals that experienced minimal stress in the nets. Generally, this involved larger fish that were only "tooth caught" in the smaller mesh sizes of the nets.

Surgical Procedure

Live-captured adult walleye were placed in a surgical trough with their ventral side oriented upward. The trough was designed with an incline such that the gills of the fish could be completely submerged in the reservoir water while keeping the incision area dry. A black towel was used to shield the eyes of the walleye from sunlight during surgery, and fish were bathed frequently with a wet sponge to prevent their skin from drying (Summerfelt and Smith 1990). Restraining straps secured through the mouth, anterior to the anal fin, and around the caudal peduncle immobilized the fish. No anaesthetic was used and fish were generally docile.

A 3 to 4 cm incision was made into the median ventral body cavity with a #10 Sterisharps® round-blade scalpel immediately posterior to the pectoral fin girdle. The ultrasonic transmitters were sterilized in Betadine® solution, rinsed in saline solution, and dried prior to insertion into the peritoneal cavity. A 3/8-inch circle cutting edge needle and Surgilou® 3-0 silicone treated nonabsorbable sutures were used to close the incision following insertion of the transmitter. Typically, 5 to 7 sutures containing two triple surgeon's knots separated by a single overhand knot were required to close the incision (M. Faler, Wind River Ranger District, USFS, personal communication). The incision area was swabbed generously with Betadine® solution after closure and the fish was held until it regained equilibrium. Duration of surgery was 10 to 15 minutes.

Instrumented Walleye

Ultrasonic telemetry has proven to be superior to radio telemetry in lakes and reservoirs, where a combination of high conductivity and depth can result in attenuation of radio signals (Stasko and Pincock 1977). Thirty-eight adult walleye were implanted with ultrasonic transmitters during the study: 12 in spring 1994, 12 in autumn 1994, one in June 1995, and 13 in autumn 1995 (Table 16). Efforts were made to instrument a similar proportion of males and females. No female walleye were implanted with transmitters in spring 1994 because none were sampled then (Chapter 2). The limited number of adults live-captured during autumn 1994 and 1995 sampling precluded the opportunity to selectively implant individuals; 4 of the 12 walleye implanted in autumn 1994 and 5 of the 13 walleye implanted in autumn 1995 were females. Ages of telemeterized walleye ranged from 2 to 9 (Table 16).

Long term (i.e., located a minimum 15 times) telemetry data were collected from 28 of the 38 walleye implanted. Of the 10 walleye that I did not collect long term information, four (8-8-A, 2-7-6, 4-4-7, 2-3-2-7) died immediately (< 2 weeks) following surgery, two (3-6-6, 4-5-6) experienced delayed (> 6 months) mortality, and four (3-3-9, 3-5-7, 3-7-5, 2-2-3-7) remain unaccounted for.

Table 16. Date implanted, total length (mm), weight (g), sex, age, and transmitter code of telemeterized walleye in Canyon Ferry Reservoir, Montana.

Date	Total length	Weight	Sex	Age	Transmitter
04-14-94	737	4,536	M	9	8-8
04-28-94	544	1,601	M	4	2-4-9
04-28-94	538	1,615	M	4	2-5-8
04-29-94	597	2,250	M	6	2-6-7
04-29-94	541	1,656	M	4	2-7-6
04-30-94	526	1,606	M	4	2-8-5
04-30-94	627	2,676	M	6	2-9-4
04-30-94	526	1,701	M	4	3-3-9
05-01-94	533	1,601	M	4	3-4-8
05-01-94	566	2,159	M	5	3-5-7
05-01-94	538	1,787	M	4	3-6-6
05-01-94	615	2,948	M	5	3-7-5
10-18-94	610	2,858	F	4	3-8-4
10-18-94	538	1,792	M	3	4-4-7
10-20-94	610	2,858	M	5	4-5-6
10-21-94	605	2,563	M	4	4-6-5
11-03-94	500	1,374	M	2	5-5-5
11-03-94	483	1,361	M	2	2-2-4-6
11-09-94	490	1,383	M	2	2-2-5-5
11-10-94	627	3,311	F	4	9-7
11-10-94	635	3,447	F	4	2-2-2-8
11-10-94	513	1,669	M	3	2-2-3-7
11-11-94	538	1,987	M	3	2-2-6-4
11-11-94	635	3,515	F	5	2-2-7-3
05-25-95	653	3,493	F	6	2-3-2-7
10-20-95	632	3,856	F	5	2-3-3-6
10-20-95	617	2,631	M	5	2-3-4-5
10-24-95	572	2,223	M	3	2-3-5-4
10-24-95	673	4,627	F	6	8-8 (A)
10-25-95	665	3,674	F	5	2-3-6-3
10-26-95	597	2,631	M	4	2-4-2-6
11-09-95	584	3,084	F	4	2-4-3-5
11-14-95	533	1,706	M	3	2-4-4-4
11-16-95	541	1,823	M	3	2-4-5-3
11-16-95	561	1,796	M	5	2-5-2-5
11-16-95	589	2,359	M	4	2-5-3-4
11-18-95	566	2,381	M	5	2-5-4-3
11-18-95	612	3,175	F	4	2-6-3-3

Locating Telemeterized Walleye

The ultrasonic transmitters used in this study were self-identifying in that individual tags emitted a unique aural code (i.e., transmitter 3-4-8 denoted by three beeps, pause, four beeps, pause, eight beeps, pause, repeat), allowing for the identification of individual walleye. Telemeterized walleye were located weekly during ice-free months (April through December) using a 6-m inboard jet boat fitted with a side-mounted retractable Sonotronics hydrophone (model DH-2) coupled with a Sonotronics digital receiver (model USR-5W). Canyon Ferry Reservoir was systematically searched for telemeterized fish by moving the boat parallel to the shoreline and methodically listening for signals. Range of transmitters was influenced by environmental conditions (e.g., wave action, thermal stratification, algal blooms), and dictated distance between listening stops. Upon detection of a signal, successive triangulations enabled me to get in close proximity to the instrumented fish. A precise location was determined when the signal intensity was similar in all directions the hydrophone was rotated (Prophet et al. 1989; Parks and Kraii 1991).

Winter locations were collected monthly through the ice when conditions permitted. An ice auger was used to drill holes for lowering the hydrophone below the ice surface. Similar triangulation methods were used as during the ice-free tracking sessions, except less precise locations were collected because of the time constraints of drilling numerous holes.

UTM coordinates were recorded at individual location sites with a Trimble Scout global positioning system. Date, time, and a behavioral observation on whether the fish was actively moving or sedentary were noted. Independent habitat variables recorded at each location site were water depth to the nearest 0.5 m, surface and bottom water temperatures (C), and secchi disk depth to the nearest 0.25 m.

Data Analysis

Movement rates, aggregation (distance between all located individuals) values, and distance from dam were determined from UTM coordinates recorded at location sites of instrumented walleye. Distance measurements used in these analyses were calculated using the following formula (White and Garrott 1990):

$$\text{distance} = \sqrt{(x_{i+1} - x_i)^2 + (y_{i+1} - y_i)^2}$$

where x_i and y_i represent the first and x_{i+1} and y_{i+1} the second pair of northing and easting coordinates, respectively. Weekly movement rates were determined by calculating an overall mean distance moved by all instrumented walleye from their previous locations. Weekly aggregation values were determined by calculating an overall mean for the distances between each individual instrumented walleye located. Mean weekly movement and aggregation distances were averaged for individual two-week periods to derive an overall mean value. Safety considerations precluded the collection of comprehensive winter data. Thus, I was only able to calculate movement rates from April through November. Mean movement rates were determined for all seasons except winter; mean aggregation values were determined for all seasons.

Water and secchi disk depths recorded at location sites of instrumented walleye were summarized seasonally. Seasonal mean values were compared within years to help understand habitat preferences of telemeterized walleye. Relative number of locations at specific water and secchi disk depths were contrasted within seasons among the different years.

One-way analysis of variance (ANOVA) was used to test for significant differences among two-week mean movement and aggregation values within individual years. Significance was determined at $P < 0.05$. When significant differences were detected, Tukey's multiple comparison test was used to discern which means were different (Zar 1984).

The GLM univariate procedure (multi-factor ANOVA) was used to test for significant interaction between season and year effects in movement, aggregation, water depth, and secchi disk depth analyses. If the interaction was not significant ($P > 0.05$), an overall mean was determined for each season and statistically compared. When the interaction and season effect were significant, one-way analysis of variance (ANOVA) was used to test for significant differences among seasonal values within a year. Significance was determined at $P < 0.05$. When significant differences were detected, Tukey's multiple comparison test was used to discern which means were different (Zar 1984). All statistical analyses were performed with SPSS for Windows (1999).

Telemetry locations were projected into Montana State Plane coordinates and plotted seasonally with ArcView (version 3.0A) software. Seasonal maps were examined for temporal and spatial patterns.

RESULTS

Relocation Data

Instrumented walleye were located 972 times from April 1994 through September 1996. Nearly half (43%) of all relocations occurred during summer (8 May - 15 August). Spring (1 April - 7 May) and autumn (16 August - 30 November) locations accounted for 20% and 24% of total relocations, respectively (Table 17). The spring season represented a more intensive effort to locate telemeterized walleye because of the short duration of the spring spawning period relative to the autumn season (5 weeks vs. 14 weeks). The lowest number of relocations (13%) was collected during the winter (01 December - 31 March).

Number of relocations varied seasonally among years (Table 17). Slightly more than half of all relocations in 1994 and 1996 were recorded during the summer season. Data was more evenly distributed between all seasons for 1995. Relatively few relocations were collected during the winter in 1994 and 1996.

Table 17. Seasonal distribution of telemetry relocations of walleye in Canyon Ferry Reservoir, Montana, for individual study years and total. Numbers in parentheses represent percentage of relocations by season for individual years and for total.

		Season			
Year	Total relocations	Spring 01 Apr-07 May	Summer 08 May-15 Aug	Autumn 16 Aug-30 Nov	Winter 01 Dec-31 Mar
1994	256	26 (10)	138 (54)	85 (33)	7 (3)
1995	443	99 (22)	139 (31)	109 (25)	96 (22)
1996	273	71 (26)	140 (51)	39 (14)	23 (9)
Total	972	196 (20)	417 (43)	233 (24)	126 (13)

Sixteen of the instrumented walleye I collected long-term data from were ultimately recaptured in gill net sets specifically targeting walleye (Chapter 2). Fourteen of these were captured in netting completed on the spawning area and either died or were transported into Hauser or Holter reservoirs (Chapter 4). The other two walleye were sampled during autumn: walleye 8-8 was killed in a gill net in 1994, and walleye 2-5-8 was live-captured in a gill net in autumn 1995 and fitted with a new transmitter (2-5-2-5).

Seasonal Distributions and Movements

Telemeterized walleye used the entire reservoir annually (Figure 32). Seasonal distribution and movement patterns were consistent each year of the study (Figure 33). Generally, instrumented walleye were located on the south end of the reservoir during spring and summer, then migrated to the northern portion of the reservoir in autumn. This annual migration cycle was completed when study walleye returned to the south end of the reservoir by the following spring to spawn.

Telemeterized walleye exhibited fidelity to a single spawning area in the southeast corner of the reservoir in 1995 and 1996 (Figure 34). This spawning area was the only location that spawning walleye were sampled (Chapter 4). Male walleye were the first to arrive on the spawning ground, typically moving to the south end of the reservoir in early December before ice formation or later following ice-up (Figure 37). Female walleye generally migrated to the spawning area after ice-out in late March or early April.

Post spawning, telemeterized walleye moved off the spawning area and out into the shallow (< 4 m) water to the north of the waterfowl pond dikes on the south end of the

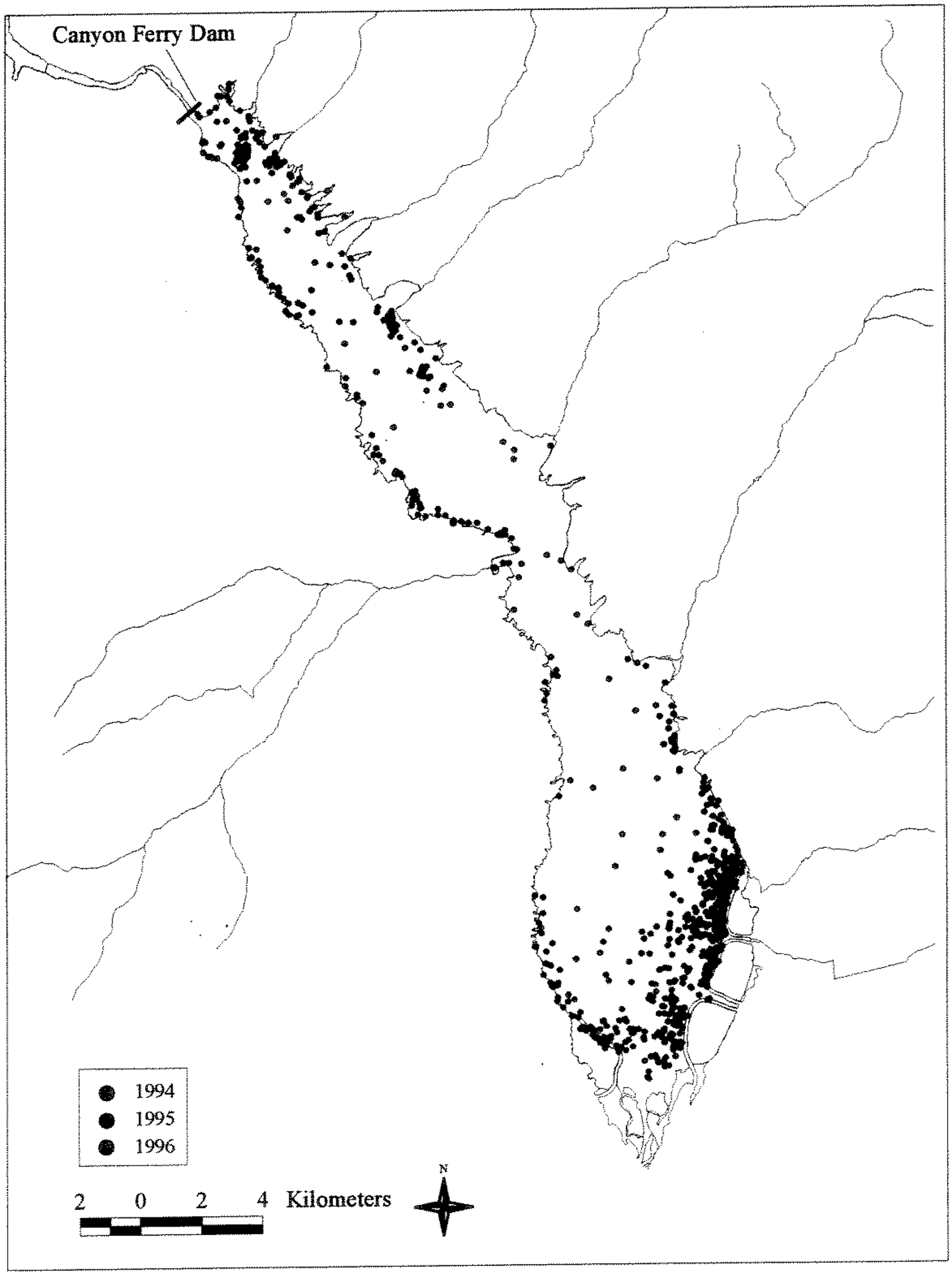


Figure 32. Location of telemeterized walleye in Canyon Ferry Reservoir, Montana, during 1994 (n = 256), 1995 (n = 443), and 1996 (n = 273).

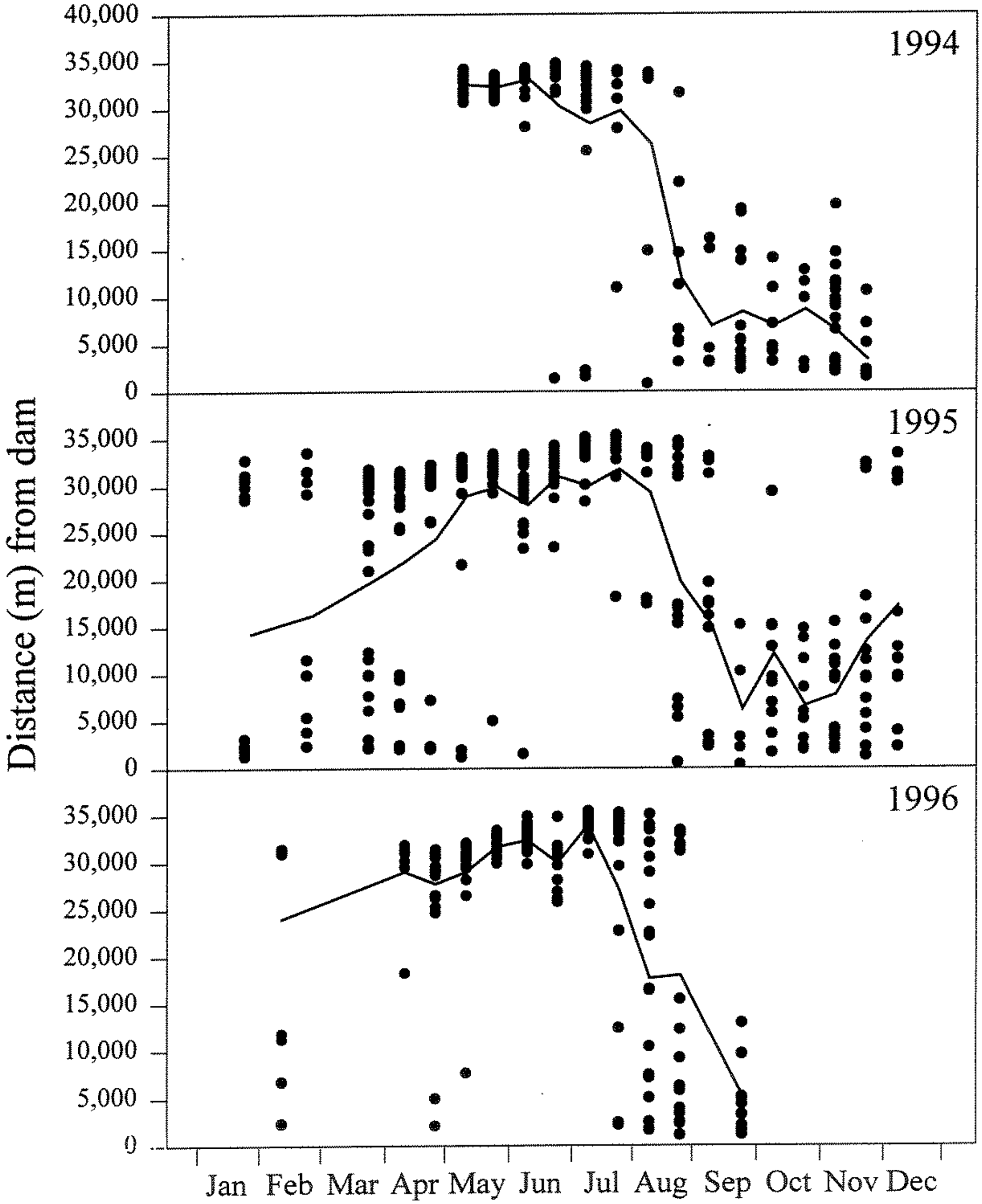


Figure 33. Distance (m) from dam of individual relocation points of telemeterized walleye in Canyon Ferry Reservoir, Montana, 1994 - 1996. Solid line represents mean of distances from the dam.

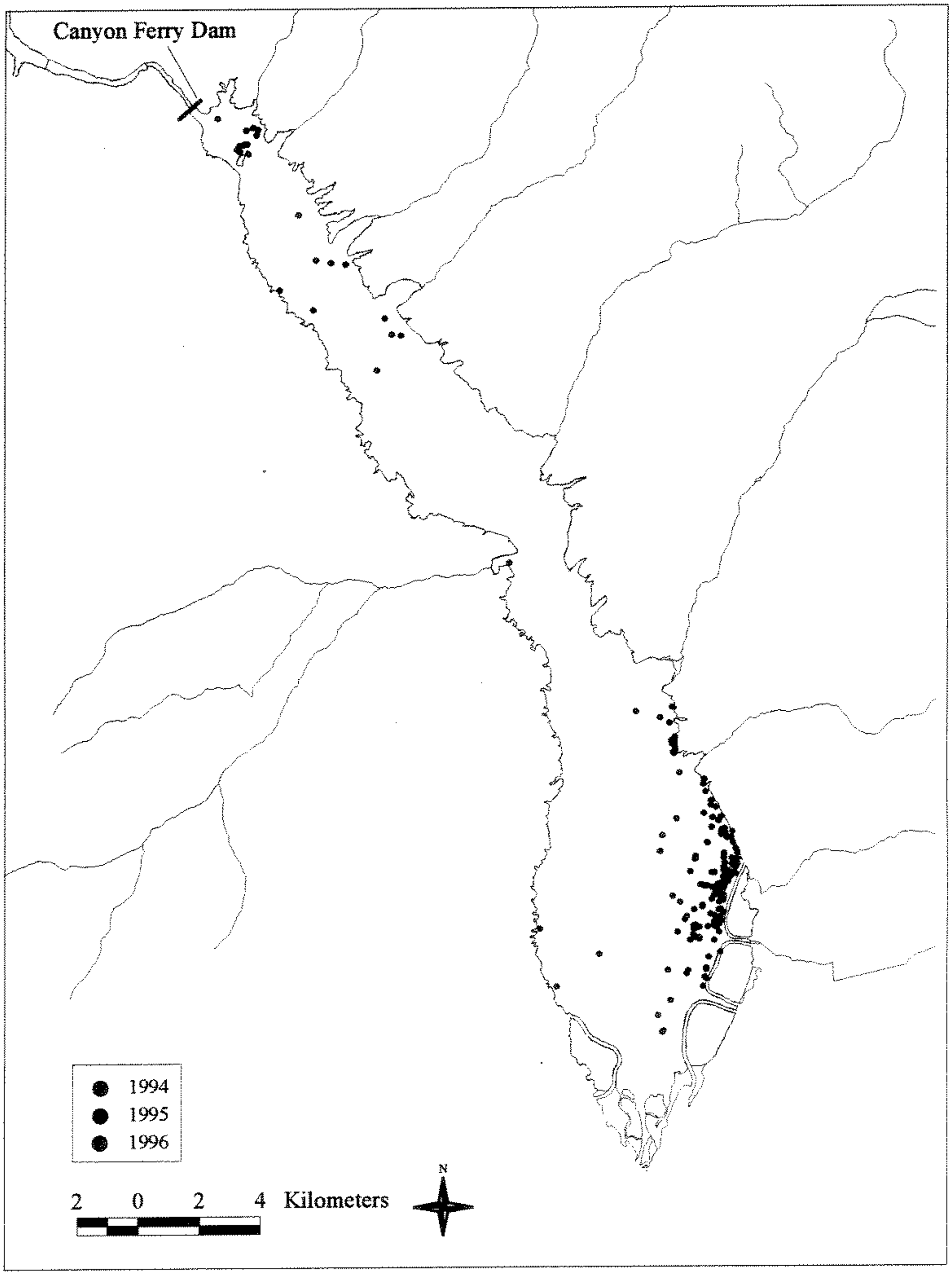


Figure 34. Location of telemeterized walleye in Canyon Ferry Reservoir, Montana, during spring 1994 (n = 26), 1995 (n = 99), and 1996 (n = 71).

reservoir (Figure 35). There was a general east to west movement of instrumented walleye as summer progressed. Walleye were typically distributed from the mouth of the Missouri River westward to the southwest corner of the reservoir by early to mid August (Figure 35).

There was directed movement to the north end of the reservoir by all instrumented walleye by mid September each year of the study (Figure 36). This south to north migration was completed in one to three weeks and typically began in August. No telemeterized walleye remained on the south end of the reservoir the entire year, nor were mid-reservoir habitats used much. Instrumented walleye remained on the north end of the reservoir for varying periods of time before migrating back to the south end prior to the spawning period. This annual north to south (lower to upper reservoir) movement pattern was exhibited by all telemeterized walleye.

Certain individual walleye exhibited movements that were unique compared to the established patterns of other instrumented walleye. Walleye 2-6-7 migrated to the north end of the reservoir in June 1994 and 1995 and remained there through autumn. Walleye 3-4-8 used two mid-reservoir bays in late summer and autumn 1994 and 1995 before migrating to the north end in late October. This was the only instrumented walleye to occupy mid-reservoir habitats for extended periods of time. In 1995, walleye 2-2-4-6 did not migrate to the south end of the reservoir until mid May, about a month later than other instrumented walleye. Walleye 2-5-2-5 showed similar delayed movements in spring 1996.

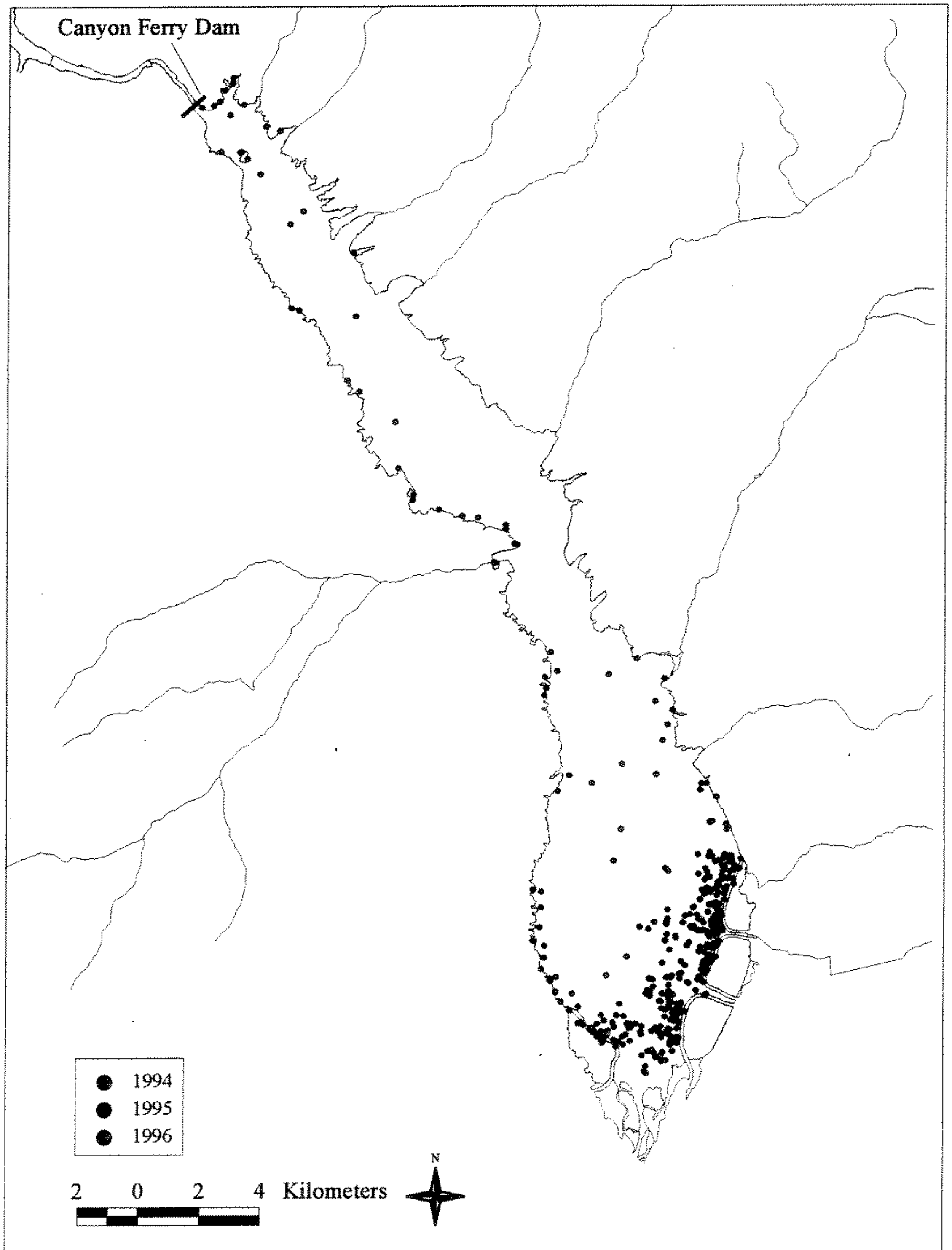


Figure 35. Location of telemeterized walleye in Canyon Ferry Reservoir, Montana, during summer 1994 (n = 138), 1995 (n = 139), and 1996 (n = 140).

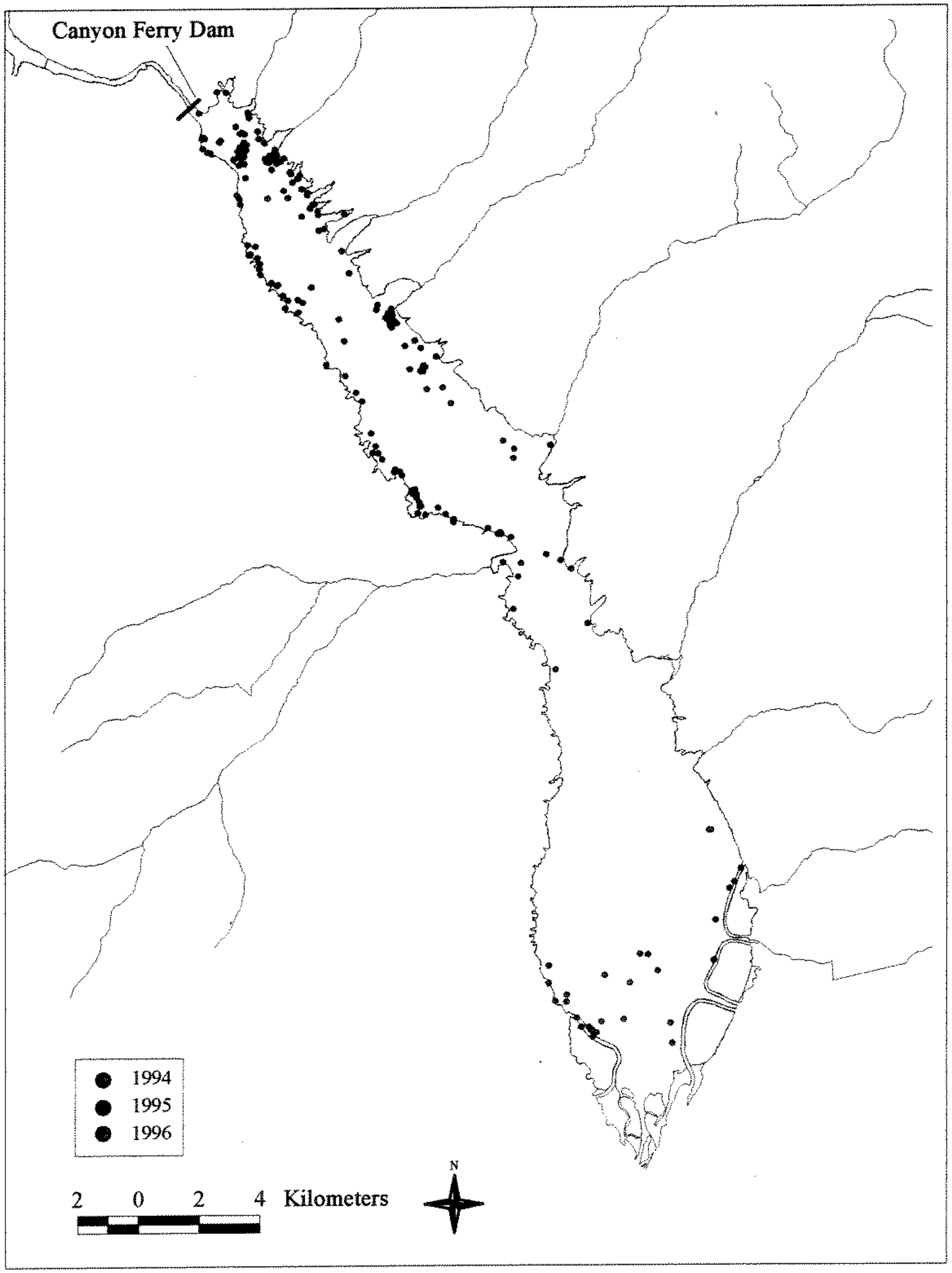


Figure 36. Location of telemeterized walleye in Canyon Ferry Reservoir, Montana, during autumn 1994 (n = 85), 1995 (n = 109), and 1996 (n = 39).

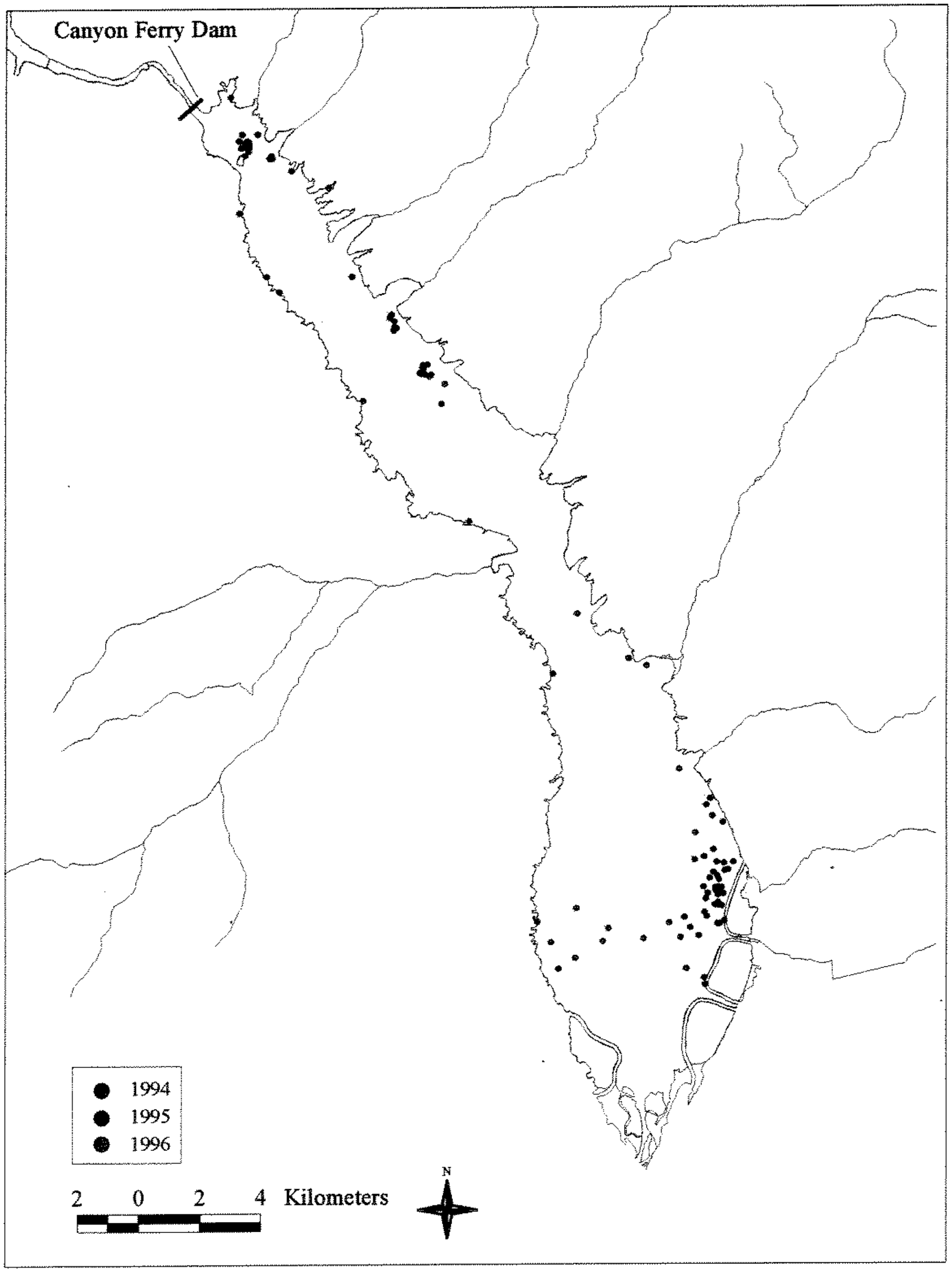


Figure 37. Location of telemeterized walleye in Canyon Ferry Reservoir, Montana, during winter 1994 (n = 7), 1995 (n = 96), and 1996 (n = 23).

Movement Rates

Telemeterized walleye exhibited the greatest movement in late August and September when they migrated from the south end of the reservoir to the north end (Figure 38). This movement was observed each year of the study. A secondary movement peak occurred in late November 1995 when several telemeterized walleye migrated back to the south end of the reservoir from the north end. The least amount of movement occurred during the spring and summer months when instrumented walleye were on the south end of the reservoir (Figure 38).

The highest mean movement rate (m/week) was observed in late August 1994 (mean = 14,833; SE = 5,017). This period exhibited the only significant change in movement from the previous two-week period for all three years of the study (Figure 38). However, there were significant differences in mean movement rates among individual two-week periods in 1994 (ANOVA; $P = 0.001$) and 1996 (ANOVA; $P < 0.001$). In 1994, the mean movement rate in late August was significantly higher than for all other periods except the early September period (Tukey; $P < 0.05$). Similarly, during 1996, mean movement rate of walleye in early September was significantly higher than the mean movement rates observed for the late April through early July period (Tukey; $P < 0.05$). There were no significant differences among mean movement rates of walleye for individual two-week periods in 1995 (ANOVA; $P = 0.072$).

The interaction of year and season effects on movement rates was not significant (multi-factor ANOVA; $P = 0.453$). Thus, overall mean movement rates for individual years and seasons were statistically compared. Annual movement rates did not differ

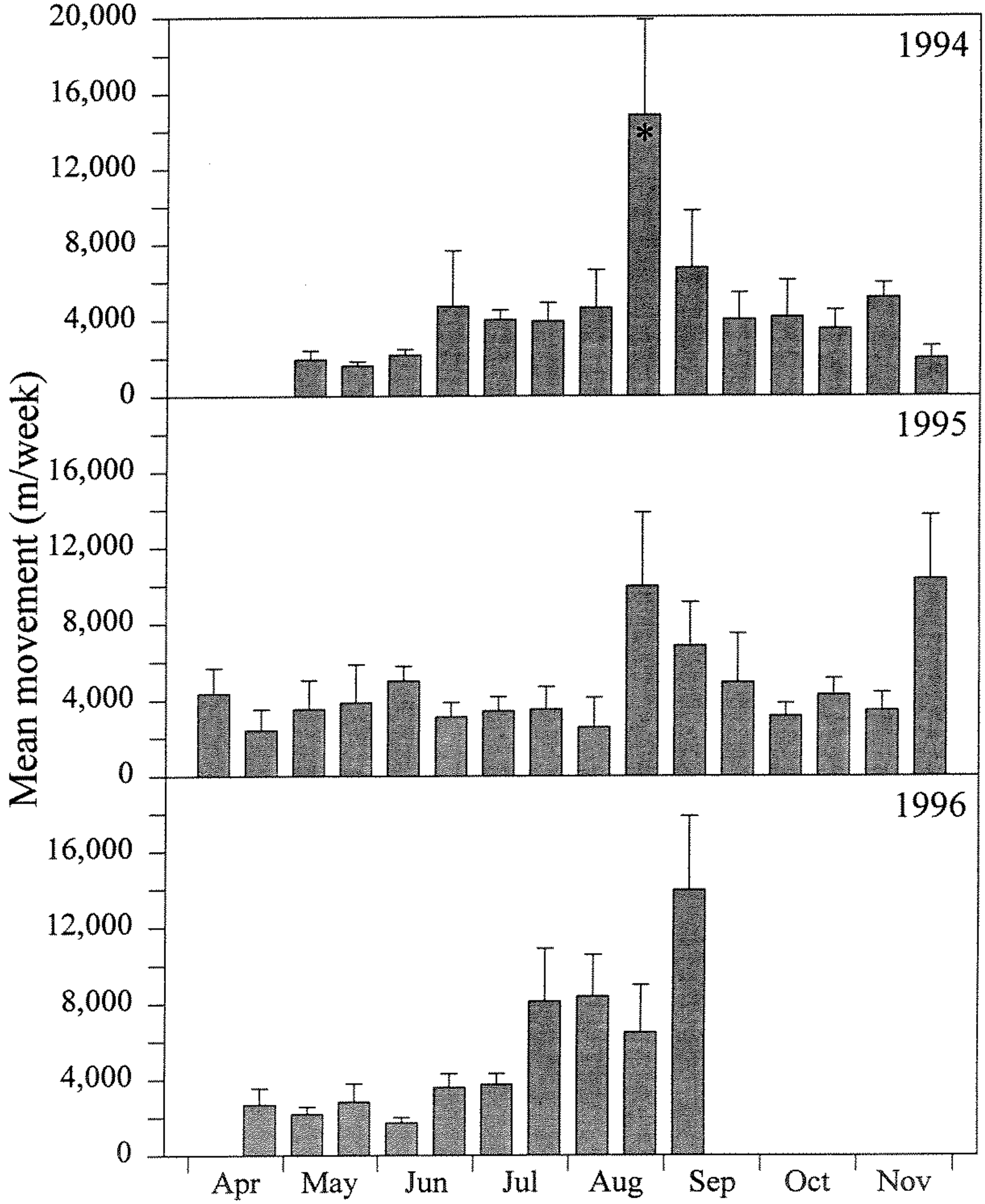


Figure 38. Mean movement (+1 SE) of telemeterized walleye from April through November in Canyon Ferry Reservoir, Montana, 1994 - 1996. Asterisks denote a significant change in mean movement from previous two week period for individual years (Tukey; $P < 0.05$).

significantly among years (multi-factor ANOVA; P = 0.387); seasonal movement rates differed significantly (multi-factor ANOVA; P = 0.001). Walleye movement in autumn (mean = 5,899; SE = 684) was significantly higher (Tukey; P < 0.05) than in spring (mean = 3,066; SE = 500) and summer (mean = 3,969; SE = 357). There was no significant difference between spring and summer movement rates (Tukey; P > 0.05).

Aggregation Analyses

Weekly mean distances (m) among individual telemeterized walleye (i.e., aggregation) were highest in August / early September and in late November / early December through late March. The lowest aggregation values were observed from early April through early July, and from late September through early November (Figure 39).

The highest biweekly aggregation value for study walleye was observed during the second two weeks of August 1996 (mean = 16,521; SE = 1,121) and the lowest the second two weeks of May 1996 (mean = 1,295; SE = 80). Significant differences among mean weekly aggregation values were detected within each year (ANOVA; P < 0.001 in 1994; P< 0.001 in 1995; P < 0.001 in 1996). Significant changes in mean aggregation values from the previous two-week period occurred numerous times during the study (Figure 39). There did not appear to be a pattern in those changes among years.

Year and season effects on aggregation values were significant (multi-factor ANOVA; P < 0.001, P < 0.001, respectively), as was their interaction (multi-factor ANOVA; P < 0.001). Significant differences were not detected between seasonal aggregation values in 1994 (ANOVA; P = 0.823). Mean aggregation values for

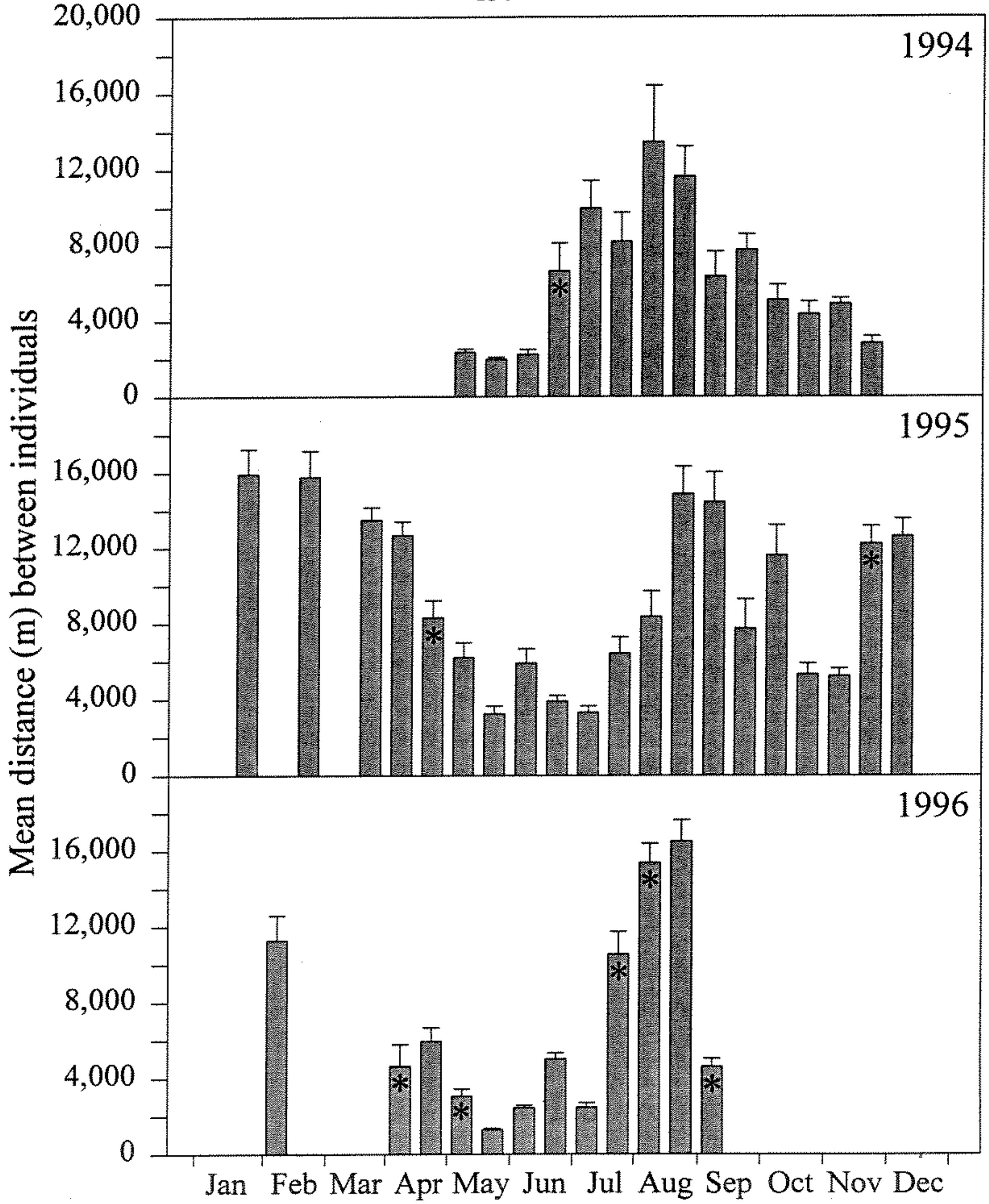


Figure 39. Mean distances (+1 SE) between individual telemeterized walleye in Canyon Ferry Reservoir, Montana, 1994 - 1996. Asterisks denote a significant change from previous two week period for individual years (Tukey; $P < 0.05$).

individual seasons differed significantly in 1995 and 1996 (Table 18). Walleye were significantly more aggregated in summer than all other seasons in 1995; conversely, walleye were significantly less aggregated (i.e., more dispersed) in winter than all other seasons (Tukey; $P < 0.05$).

Table 18. Seasonal[a] summary of mean (standard error) weekly aggregation distances (m) of telemeterized walleye in Canyon Ferry Reservoir, Montana, 1994 - 1996. Statistical comparison of seasonal aggregation values within years was completed using ANOVA (denoted by P values). Seasonal values with similar letters did not differ significantly within years (Tukey; $P > 0.05$).

	spring	summer	autumn	winter	P
1994	insufficient data	[a]5,540 (453)	[a]5,457 (264)	no data	0.823
1995	[b]9,530 (477)	[a]4,444 (263)	[b]10,013 (456)	[c]14,348 (557)	<0.001
1996	[a]4,329 (359)	[b]6,306 (351)	insufficient data	[c]12,054 (769)	<0.001

[a] Seasons: spring - 01 April through 07 May; summer - 08 May through 15 August; autumn - 16 August through 30 November; winter - 01 December through 31 March.

Spring and autumn aggregation values did not differ significantly in 1995 (Tukey; $P > 0.05$). Mean aggregation values differed significantly across all seasons in 1996 (Tukey; $P < 0.05$). Mean aggregation values were generally highest (i.e., walleye were more dispersed) in winter and lowest in summer (Table 18). Study walleye were least aggregated in winter 1995 (mean = 14,348; SE = 557) and most aggregated in spring 1996 (mean = 4,329; SE = 359).

Habitat Preferences

Telemeterized walleye used shallower, more turbid habitats in spring and summer relative to autumn and winter (Figures 40 - 43). The narrowest range of habitats was used during summer (Figure 41), and the greatest range during autumn (Figure 42). Mean water depth at location sites was lowest in spring 1996 (mean = 2.47; SD = 2.45) and highest in autumn 1994 (mean = 10.52; SD = 10.76). Mean secchi disk measurement at location sites was lowest in spring 1996 (mean = 0.49; SD = 0.76) and highest in winter 1996 (mean = 3.31; SD = 0.65).

Year effect on water depth was not significant (multi-factor ANOVA; $P = 0.245$); season effect and the interaction of year and season effects were significant (multi-factor ANOVA; $P < 0.001$, $P < 0.001$, respectively). Mean water depth at location sites differed significantly across all seasons within individual years except in 1995 (Table 19). Summer and autumn water depths in 1995 were the only seasons to differ significantly (Tukey; $P < 0.05$).

Year and season effects on secchi disk depths were significant (multi-factor ANOVA; $P = 0.001$, $P < 0.001$, respectively), as was their interaction (multi-factor ANOVA; $P < 0.001$). Seasonal secchi disk depths at location sites differed significantly across all seasons within individual years except in 1995 (Table 20). Mean secchi disk depth at winter location sites did not differ significantly from those at autumn nor spring sites in 1995 (Tukey; $P > 0.05$).

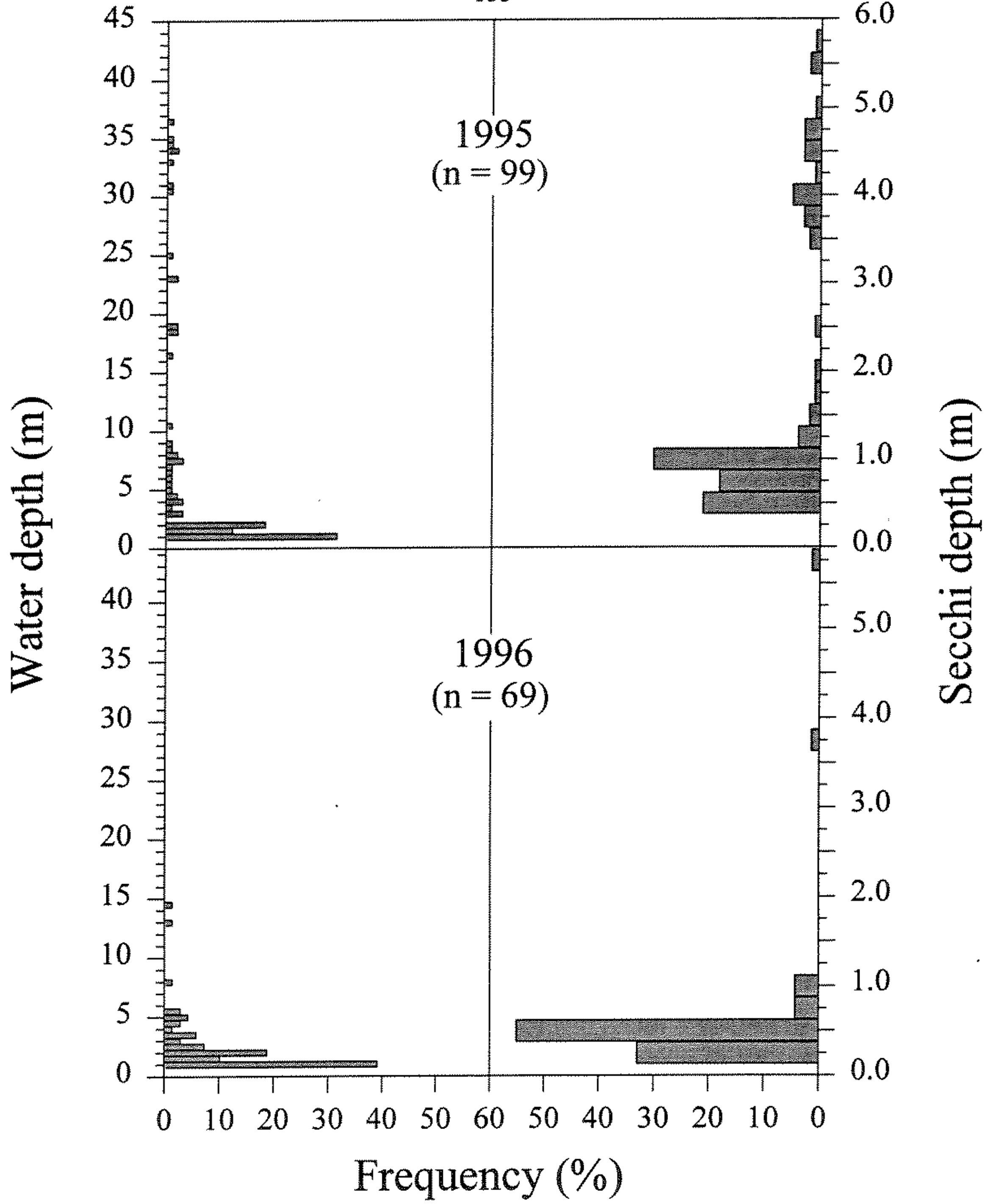


Figure 40. Relative frequency of water and secchi depths observed at relocation sites of telemeterized walleye during spring (01 April - 07 May) 1995 and 1996 in Canyon Ferry Reservoir, Montana.

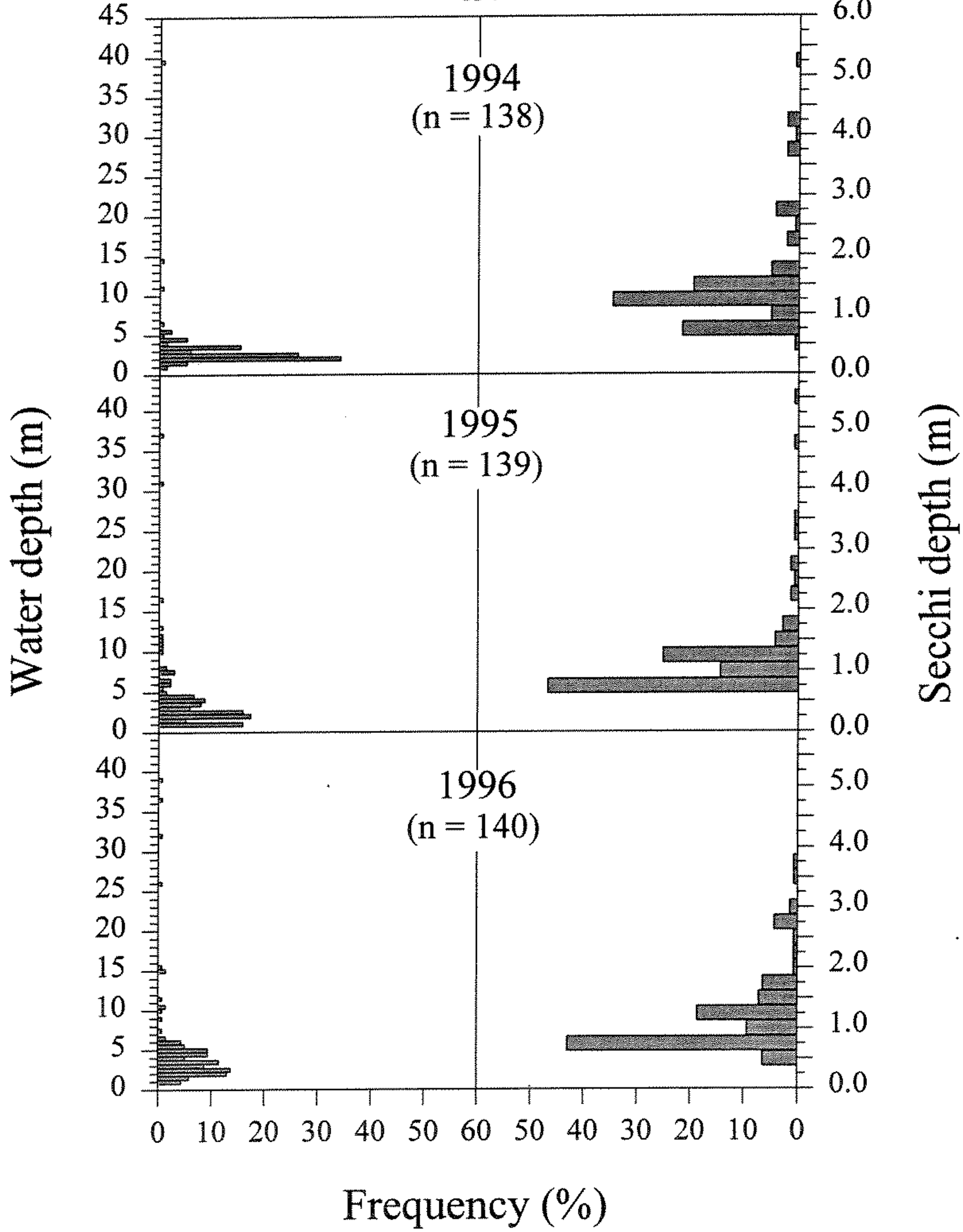


Figure 41. Relative frequency of water and secchi depths observed at relocation sites of telemeterized walleye during summer (08 May - 15 August) 1994 - 1996 in Canyon Ferry Reservoir, Montana.

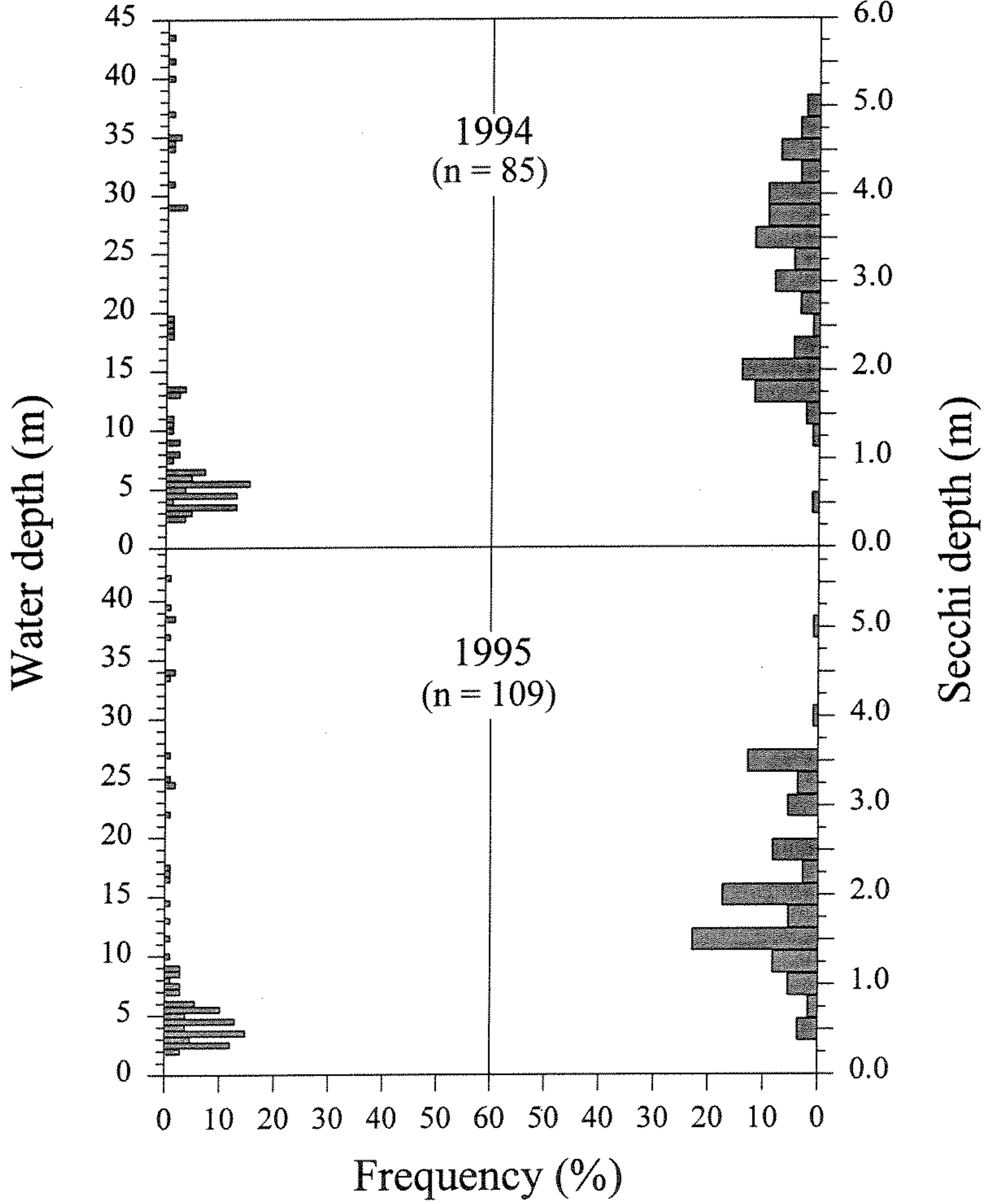


Figure 42. Relative frequency of water and secchi depths observed at relocation sites of telemeterized walleye during autumn (16 August - 30 November) 1994 and 1995 in Canyon Ferry Reservoir, Montana.

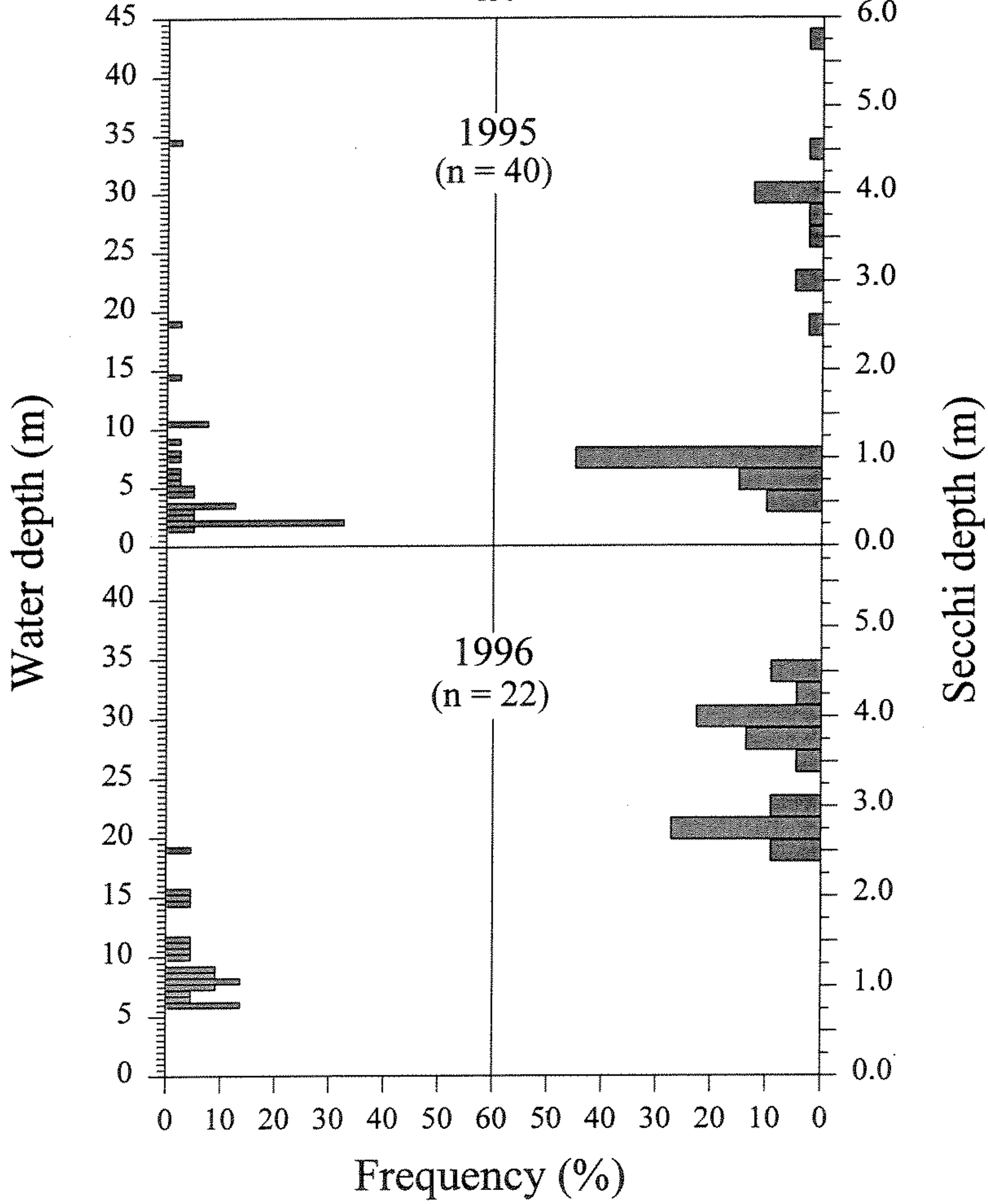


Figure 43. Relative frequency of water and secchi depths observed at relocation sites of telemeterized walleye during winter (01 December - 31 March) 1995 and 1996 in Canyon Ferry Reservoir, Montana.

Table 19. Mean (standard deviation) seasonal[a] water depths (m) observed at relocation sites of telemeterized walleye in Canyon Ferry Reservoir, Montana, 1994 - 1996. Statistical comparison of seasonal water depths within years was completed using ANOVA (denoted by P values). Seasonal values with similar letters did not differ significantly within years (Tukey; P > 0.05).

	spring	summer	autumn	winter	P
1994	insufficient data	[a]3.09 (3.49)	[b]10.52 (10.76)	no data	<0.001
1995	[a,b]6.53 (9.68)	[a]3.87 (4.52)	[b]8.52 (9.56)	[a,b]5.46 (6.09)	<0.001
1996	[a]2.47 (2.45)	[b]4.79 (5.60)	insufficient data	[c]9.66 (3.50)	<0.001

[a] Seasons: spring - 01 April through 07 May; summer - 08 May through 15 August; autumn - 16 August through 30 November; winter - 01 December through 31 March.

Table 20. Mean (standard deviation) seasonal[a] secchi disk depths (m) observed at relocation sites of telemeterized walleye in Canyon Ferry Reservoir, Montana, 1994 - 1996. Statistical comparison of seasonal secchi depths within years was completed using ANOVA (denoted by P values). Seasonal values with similar letters did not differ significantly within years (Tukey; P > 0.05).

	spring	summer	autumn	winter	P
1994	insufficient data	[a]1.11 (0.83)	[b]2.98 (1.06)	no data	<0.001
1995	[b]1.50 (1.53)	[a]0.76 (0.69)	[c]1.98 (0.92)	[b,c]1.68 (1.49)	<0.001
1996	[a]0.49 (0.76)	[b]0.80 (0.62)	insufficient data	[c]3.31 (0.65)	<0.001

[a] Seasons: spring - 01 April through 07 May; summer - 08 May through 15 August; autumn - 16 August through 30 November; winter - 01 December through 31 March.

DISCUSSION

Two basic assumptions of most telemetry studies are that instrumented individuals represented an unbiased sampling of the population, and that behavior of those individuals was not affected by the methods used (White and Garrott 1990). The extensive effort required to sample adult walleye in Canyon Ferry precluded my ability to randomly select individuals to implant with transmitters. Walleye I implanted were captured over a two year period and in different portions of the reservoir. Forney (1963) and Ferguson and Derksen (1971) reported that discrete walleye spawning stocks intermingled extensively after the spawning season. It is unlikely that separate stocks of walleye (if present) would remain spatially segregated throughout the year in Canyon Ferry. Thus, I believe my extensive sampling efforts provided an unbiased representation of adult walleye in Canyon Ferry. It should be recognized that results of this study solely reflected movements and habitat use of adult walleye and should not be extended to juveniles. Juvenile walleye may not use the same habitats or exhibit similar movement patterns as adults because of different life history requirements (Ferguson and Derksen 1971; Olson et al. 1978).

The surgical procedure and carrying of transmitters did not appear to affect most instrumented walleye. Sixteen of the 28 walleye I collected long term data from were recaptured in gill nets. All of these individuals except one exhibited normal growth, condition, and spawning behavior. Walleye 8-8 declined in condition from time of implanting in spring 1994 to capturing the following autumn. At age 9, this was the oldest walleye implanted during the study. This decline in condition may indicate older individuals are more susceptible to physiological stress resulting from the surgical procedure and transmitter implantation.

The four instrumented walleye that remain unaccounted for could be attributed to: 1) surgery related mortality, 2) angler harvest, 3) movement into an adjacent water body, or 4) transmitter malfunction. All four of these walleye were actively moving and appeared otherwise healthy at the time they disappeared. I collected location data from each of them for a minimum of a month following their release. I tracked walleye 2-2-3-7 for five months and observed it migrate from the north end of the reservoir to the south end before losing it. Possibly, these walleye may have died and I was unable to detect the signal from their transmitters. Other walleye that died following implanting generally did not move after release and were easily located. It is possible that these fish were harvested by anglers but not reported. However, this is unlikely considering anglers did not start catching walleye in Canyon Ferry until 1996 (Chapter 2). Transmitters were labeled with reward information, which should have encouraged their return. These walleye potentially could have moved upstream into the Missouri River or downstream into Hauser or Holter reservoirs. I spent three days in 1994 and four days in 1995 attempting to locate these walleye in the 37 km section of Missouri River between Canyon Ferry and upstream Toston Dam. Range of sonic transmitters was greatly limited in running water due to background noise generated by the water current. Thus, I cannot definitively state that these walleye were not occupying this section of river. I also spent three days on Hauser Reservoir and one day on Holter Reservoir in 1994 searching for these individuals. Because of excellent tracking conditions and their relatively small size, I was confident I adequately covered these water bodies. During autumn 1994, I had lost contact with walleye 8-8 before capturing it in a gill net. Subsequent inspection of the transmitter revealed that it was not working. An evaluation by the manufacturer determined that a capacitor in the transmitter had failed. Failure of the same component is occasionally seen in the same lots of transmitters (D. Brumbaugh, Sonotronics, Inc., personal communication). Transmitters 3-3-9, 3-5-7, and 3-7-5 were all purchased in the same lot as 8-8. It is possible that defective capacitors resulted in the failure of those transmitters as well.

Telemetry proved to be a valuable tool for identifying seasonal habitat use and movements of Canyon Ferry walleye, including the identification of a single spawning site. Suitable walleye spawning habitat is widely available throughout Canyon Ferry (McMahon 1992). The return of all instrumented walleye to this one specific site each year demonstrated their fidelity to this spawning area. Fidelity, or homing, of walleye to spawning areas has been observed in other populations. Crowe (1962) reported that all walleye populations investigated in Michigan exhibited homing tendencies to specific spawning sites. Olson and Scidmore (1962) noted that walleye in Many Point Lake, Minnesota, returned to spawn at the same sites despite the availability of other spawning areas. Telemeterized walleye in Holter Reservoir, Montana, returned to the same spawning areas in consecutive years (Binkley 1996). Similar examples of walleye exhibiting fidelity to specific spawning areas have been reported by several other authors (Eschmeyer 1950; Smith et al. 1952; Forney 1963; Czajkowski 1993).

Discrete spawning stocks often develop within walleye populations. These stocks result from adaptations to local environmental factors (Hokanson 1977) and often occur within the same body of water (Crowe 1962; Forney 1963; Ryder 1968). Fidelity of Lake Winnebago, Wisconsin, walleye to specific spawning areas in both the Fox and Wolf rivers led Czajkowski (1993) to suggest they were separate stocks. Stocks are often differentiated by the type of spawning habitat used (Colby et al. 1979). Jennings et al. (1996) presented evidence that selection of spawning habitat (e.g., river or lake shoreline) may be genetically pre-determined for walleye. Heidinger and Tetzlaff (1989) reported that separate stocks of walleye in Lake Shelbyville, Illinois, exhibited preferences for both river and lake spawning habitats. Suitable walleye spawning habitat was identified in the section of Missouri River between Canyon Ferry and upstream Toston Dam (McMahon 1992). The potential existence of additional reservoir spawning stocks and separate river-spawning stocks was recognized in my study design. Limited sampling of other potential spawning areas in Canyon Ferry did not detect any additional reservoir spawning stocks (Chapter 4). Additionally, I found no evidence that walleye used the Missouri River for spawning. I did not lose contact with any of the instrumented walleye during the spawning period, which indicated they did not use the river. No walleye have been observed in limited electrofishing completed on this section of river each spring by MFWP (R. Spoon, MFWP, personal communication). Because walleye often spawn in discrete areas, a more comprehensive sampling effort would be required to definitively rule out the existence of a river-spawning stock.

Olson et al. (1978) proposed that homing of walleye to spawning areas is an adult-learned behavior which is reinforced by repeated migrations. Previously cited examples of homing were reported for long established or native walleye populations. Spawning site fidelity exhibited by Canyon Ferry walleye may provide insight into the development of this behavior. The relative youth of the Canyon Ferry population indicated that homing can be established in a short time period and by a small number of adults. Walleye were first produced in Canyon Ferry in 1985 (Chapter 2). The females of this year class would not have been fully recruited into the spawning population until 1990. Fidelity to the identified spawning area was already established by 1995, as evidenced by the return of all instrumented walleye from spring 1994. Individual movements of five female walleye (9-7, 3-8-4, 2-2-2-8, 2-4-3-5, 2-6-3-3) I implanted at age 4 in autumn provided further insight into the development of this homing behavior in Canyon Ferry. The following spring, all of these individuals exhibited directed movement to the spawning area during either pre-spawn or spawning periods. None of these walleye demonstrated what might be considered exploratory meanderings. Assuming these walleye first spawned at age 5, the movement they demonstrated likely indicated their general attraction to that portion of the reservoir and was not indicative of a repeated trip to the spawning area.

The spawning area used by Canyon Ferry walleye provided a unique environment relative to the remainder of the reservoir. Because of its shallow depth and inflows of warmer water from the Missouri River, the south end of the reservoir was the first portion to become ice-free. Prevailing west winds resulted in very turbid water conditions as wave activity transported suspended solids towards the southeast shoreline. This turbid water acted as a heat sink, particularly on calm, sunny days. I suggest that it was this rapidly warming water that attracted walleye to this portion of the reservoir during spring. Binkley (1996) reported that walleye in Holter Reservoir, Montana, moved into the upper reservoir during spring, presumably seeking the warmer water being discharged from Hauser Dam.

Olson et al. (1978) suggested that walleye fidelity to specific spawning sites may be increased by their proximity to open-water feeding areas. They defined feeding areas as "chosen locations for feeding during open-water seasons in preference to other potentially suitable sites". In Many Point Lake, Minnesota, Olson and Scidmore (1962) observed that walleye with feeding areas nearer a particular spawning site returned more frequently to spawn at that site. The proximity of the summer feeding area to the identified spawning site in Canyon Ferry may help explain the complete fidelity exhibited by walleye to this one spawning site.

Olson et al. (1978) suggested that adult walleye also home to feeding areas. This behavior is also considered to be learned. Most instrumented walleye in Canyon Ferry exhibited fidelity to the south end of the reservoir during the summer months. Their use of this portion of the reservoir provided walleye an optimal growing environment. Its shallow depth, turbidity, and river inflows resulted in warmer water temperatures earlier in the year relative to other areas of the reservoir. The physiological optimum temperature for walleye growth is 22.6 C (Craig 1987). Kelso (1972) reported that walleye growth was highest at temperatures of 20 to 24 C. Water temperatures on the south end of Canyon Ferry generally were within that range from mid May through August. This warm water habitat provided post-spawn walleye with an excellent growing environment and longer growing season relative to what was available in other portions of the reservoir. The exceptional growth exhibited by Canyon Ferry walleye (Chapter 2) reflected their efficient use of this unique reservoir environment.

The preference exhibited by walleye for the south end of the reservoir can probably be extended to forage fishes. It is likely they sought out this warmer water for rearing, although this could not be substantiated by any sampling I completed. However, the availability of an abundant forage base on this end of the reservoir was evidenced by the excellent growth and condition of Canyon Ferry walleye. This may have been further substantiated by the reduced movement exhibited by walleye during the summer. Schupp (1972) suggested that movement of walleye during the summer months was inversely related to the abundance of age-0 yellow perch. Summer movement of walleye in Canyon Ferry was significantly less than autumn movement rates.

Turbid water conditions were likely another key habitat characteristic that attracted walleye to the south end of Canyon Ferry. Light is probably the most important environmental stimulus affecting walleye behavior (Colby et al. 1979). Ryder (1977) and Binkley (1996) found that light penetration was the principle variable that regulated depth, activity, and feeding of walleye. Ryder (1977) noted that walleye avoided light intensities by either moving into deeper water, moving to a more turbid portion of the lake, or using some sort of physical shelter. Binkley (1996) reported that walleye in Holter Reservoir, Montana, maximized daytime feeding opportunities by moving into turbid plumes associated with eroding clay banks along shorelines. Pitlo (1978) observed that walleye in West Lake Okoboji, Iowa, used rooted aquatic vegetation to reduce light intensities. In turbid lakes, walleye can feed throughout the day (Ryder 1977). The highly turbid conditions on the south end of Canyon Ferry provided walleye with adequate cover from ambient light and an optimal feeding environment. Scott and Crossman (1973) noted that optimum walleye feeding occurs at water transparencies of about 1-2 m secchi disk depth. Secchi disk depths observed at the south end of Canyon Ferry were at or below that range throughout the summer.

The directed and repeated movement of instrumented walleye to the north end of the reservoir in late summer was likely a response to an environmental cue and not random wanderings. I examined several variables in an attempt to explain this phenomenon, including depth preferences, water temperature, turbidity, and forage availability. An inherent preference to overwinter in deeper water is a plausible explanation for the walleye movement observed in Canyon Ferry. Pitlo (1978) reported walleye in West Lake Okoboji, Iowa, abandoned their summer activity centers in October and moved considerable distances into deeper water during autumn and winter months. Walleye in Center Hill Reservoir, Tennessee, moved into deep channel areas of major tributaries for the autumn and winter (Ager 1976). Steadily dropping reservoir elevations throughout the summer may have triggered this movement pattern in Canyon Ferry. However, the return of several instrumented walleye to the south end of the reservoir in late autumn before ice-up and later in winter following ice development weakens this hypothesis.

Movement might be induced by water temperatures warming above the preferred range of walleye. Water temperatures recorded at walleye relocation sites on the south end of the reservoir peaked at 23 C in late July and early August. This was within the preferred temperature range of 20 to 24 C reported for walleye (Kelso 1973). Furthermore, water temperatures on the south end of the reservoir began to cool before most walleye started their migrations to the north end of the reservoir. Thus, it is unlikely autumn movement of walleye was motivated by high water temperatures.

The importance of water turbidity in dictating walleye behavior was discussed previously. It is expected that reduced turbidity could prompt walleye movement to avoid light intensities (Ryder 1977). Secchi disk depths on the south end of the reservoir did not increase greatly during the summer months in response to decreasing inflows from the Missouri River, as might be expected. The reservoir was more turbid in August when walleye began their annual migration than in July during all three years that I followed instrumented walleye.

Decreased forage availability on the south end of the reservoir may have motivated movement of instrumented walleye. A reduction in prey availability might result from predation pressure or movement of forage fishes. It is unlikely a forage depletion of such magnitude to incite large-scale movement would occur at about the same time each summer, given the variable production of walleye and yellow perch. Movement of yellow perch has not been well documented in the literature. Decreasing water temperatures may have led to the dispersal of young suckers and yellow perch from the south end of the reservoir. Movement of instrumented walleye to the north end of the reservoir may have reflected their following this prey base, or possibly their seeking out alternative forage. This is speculative as little is known about the movement and distribution of suckers and yellow perch in Canyon Ferry, particularly the juveniles of these populations.

There is no clear explanation for the annual migration to the north end of the reservoir demonstrated by Canyon Ferry walleye. It does not appear directly attributable to decreasing water turbidity or high water temperatures. The seeking of deeper, warmer water for overwintering is a reasonable hypothesis; however, there is no obvious explanation why equally suitable habitats available in the middle portion of the reservoir would not have been used by walleye. The availability of forage is also probably linked to this movement, as it is unlikely walleye would leave an area with abundant forage to migrate into a new environment without adequate food. Thus, it can be assumed there was ample forage available on the north end of the reservoir. August beach seine catches of age-0 yellow perch are generally much higher at sites on the north end of the reservoir relative to mid-reservoir sites (Table 4). This may indicate their relative availability during autumn and winter.

The highest rates of walleye movement were associated with their migration to the north end of the reservoir in early autumn. A secondary peak that occurred in late autumn 1995 was attributable to movement back south towards the spawning area by several individuals. Movement rates were reduced during spring and summer when walleye were located on the spawning site or summer feeding area on the south end of the reservoir. The highest seasonal movement was observed in autumn, when walleye were much more active and rarely relocated in the same area in consecutive tracking sessions. This increased movement was probably related to active foraging. Similar seasonal movement patterns were reported by several other studies. Pitlo (1978) found that movement declined once summer activity centers were established, but increased in autumn as walleye moved into deeper water. Walleye in Laurel River Lake, Kentucky, exhibited the greatest movement in spring, primarily because of spawning movements. After activity areas were established, walleye movement was significantly less in summer than spring and winter (Williams 1997). Ager (1976) observed the highest rates of walleye movement during winter months and the lowest during spring and summer.

Timing of high aggregation values (i.e., more dispersed) corresponded with high movement rates, and conversely, low aggregation values (i.e., less dispersed) corresponded with low movement rates. Thus, the highest aggregation values occurred during the late summer and early autumn movement to the north end of the reservoir, and in late autumn and winter when walleye were distributed between the north and south ends of the reservoir. The lowest aggregation values generally occurred during summer when most walleye were located on the south end of the reservoir. Although not discernable from the weekly or seasonal aggregation values reported, I commonly observed instrumented walleye closely 'schooled' (up to five individuals at one location) during all seasons.

Walleye were not as aggregated on the spawning area as is often described in the literature. Recognizing the disparate spawning behaviors exhibited by each sex helps explain the reason for this. Male walleye generally arrived on the spawning area at ice-out and remained there for several weeks, often closely associated with other males. They did not vacate the spawning area during the day for deeper water, as was reported by Eschmeyer (1950). This possibly indicated that spawning activity occurred during the daytime, as was reported by Ager (1976). Female walleye did not always immediately migrate from the north end of the reservoir to the spawning area at ice-out. This delayed migration was reflected in the high aggregation values observed during spring 1995 (Table 18). Upon reaching the south end of the reservoir, female walleye often remained a considerable distance (> 1 km) offshore until moving in to spawn. After spawning was completed, the females moved back off the spawning area into deeper water. Similar walleye spawning behavior was described by Eschmeyer (1950) and Forney (1963).

Ranges of water and secchi disk depths at relocation sites were greatest in autumn and winter when instrumented walleye were often pelagic on the north end of the reservoir. Walleye were regularly observed in open water areas distant from any shore. Subsequent relocations indicated they were often crossing the reservoir, although foraging may also have been associated with these movements.

Seasonal water and secchi disk depth values I reported should only be used as approximations of habitat preferences of walleye. At pelagic relocations, I was not able to determine if walleye were suspended in the water column or located near the substrate. Thus, the depths plotted indicated the water depth at that location site, but may not reflect the actual depth of the walleye from the water surface. Winter water and secchi disk depths may not be characteristic of the entire season, as they were only recorded during the ice-free periods in early December and late March. Lastly, the significant differences observed for seasonal water and secchi disk depth values among years were likely attributable to variations in environmental conditions (e.g., reservoir elevations, turbidity) rather than changes in habitat selection. Seasonal movement and distribution of instrumented walleye remained consistent throughout the study. Thus, recorded habitat parameters at relocation sites are likely more indicative of their availability rather than selectivity.

LITERATURE CITED

Ager, L. M. 1976. A biotelemetry study of the movements of the walleye in Center Hill Reservoir, Tennessee. Master's thesis, Tennessee Tech University, Cookeville.

Binkley, K. M. 1996. Habitat selection of adult walleye *(Stizostedion vitreum)* in Holter Reservoir, Montana. Master's thesis, Montana State University, Bozeman.

Colby, P. J., R. E. McNichol, and R. A. Ryder. 1979. Synopsis of biological data on the walleye *Stizostedion v. vitreum* (Mitchill 1818). Food and Agriculture Organization (FAO) Fish. Synop. 119. Rome, Italy.

Craig, J. F. 1987. The Biology of Perch and Related Fish. Timber Press, Portland, Oregon.

Crowe, W. E. 1962. Homing behavior in walleyes. Transactions of the American Fisheries Society 91:350-354.

Czajkowski, S. P. 1993. Distribution, movement, and population statistics of walleyes *Stizostedion vitreum vitreum* in the Lake Winnebago system, Wisconsin. Master's thesis, University of Wisconsin, Stevens Point.

DiStefano, R. J., and J. F. Hiebert. 2000. Distribution and movement of walleye in reservoir tailwaters during spawning season. Journal of Feshwater Ecology 15:145-155.

Eschmeyer, P. H. 1950. The life history of the walleye *Stizostedion vitreum vitreum* (Mitchill) in Michigan. Michigan Department of Conservation, Insitute for Fisheries Research Bulletin 3.

Ferguson, R. G. and A. J. Derksen. 1971. Migration of adult and juvenile walleyes (*Stizostedion vitreum vitreum*) in southern Lake Heron, Lake St. Clair, Lake Erie, and connecting waters. Journal of Fisheries Research Board of Canada 28:1133-1142.

Forney, J. L. 1963. Distance and movement of marked walleye in Oneida Lake, New York. Transactions of the American Fisheries Society 90:47-52.

Heidinger, R. C., and B. L. Tetzlaff. 1989. Movement of walleye in Illinois reservoirs. Final Report, Illinois Department of Conservation. F-56-R. Carbondale, Illinois.

Hokanson, K. E. 1977. Temperature requirements of some percids and adaptations to the seasonal temperature cycle. Journal of Fisheries Research Board of Canada 34:1524-1550.

Holt, C. S., G. D. S. Grant, G. P. Obestar, C. C. Oakes, and D. W. Bradt. 1977. Movement of walleye, *Stizostedion vitreum*, in Lake Bemidji, Minnesota as determined by radio-telemetry. Transactions of the American Fisheries Society 106(2):163-169.

Horn, M. J., and J. Boehmke. 1998. The limnology of Canyon Ferry Reservoir, Montana. Technical Memorandum No. 8220-98-17. Bureau of Reclamation, U.S. Department of the Interior. Denver, Colorado.

Jennings, M. J., J. E. Claussen, and D. P. Phillip. 1996. Evidence for heritable preferences for spawning habitat between two walleye populations. Transactions of the American Fisheries Society 125:978-982.

Kelso, J. R. M. 1972. Conversion, maintenance, and assimilation for walleye (*Stizostedion vitreum vitreum*), as affected by size, diet, and temperature. Journal of Fisheries Research Board of Canada 29(8):1181-1192.

Kelso, J. R. M. 1973. Seasonal energy changes in walleye and their diet in West Blue Lake, Manitoba. Transactions of the American Fisheries Society 102:363-368.

Kelso, J. R. M. 1976. Diel movement of walleye, *Stizostedion vitreum vitreum*, in West Blue Lake, Manitoba, as determined by ultrasonic tracking. Journal of the Fisheries Research Board of Canada 33:1167-1171.

McConville, D. R. and J. D. Fossum. 1981. Movement patterns of walleye (*Stizostedion v. vitreum*) in pool 3 of the upper Mississippi River as determined by ultrasonic telemetery. Journal of Freshwater Ecology 1:279-285.

McMahon, T.E. 1992. Potential impacts of the introduction of walleye to the fishery of Canyon Ferry Reservoir and adjacent waters. Montana Fish, Wildlife and Parks, Helena.

Montana Fish, Wildlife and Parks. 1992. Canyon Ferry Reservoir / Missouri River fisheries management plan, January 1993 - January 1998. Helena.

Olson, D. E., and W. J. Scidmore. 1962. Homing behavior of spawning walleyes. Transactions of the American Fisheries Society 91:355-361.

Olson, D. E., D. H. Schupp, and V. Macins. 1978. A hypothesis of homing behavior of walleyes as related to observed patterns of passive and active movement. Pages 52-57 *in* R. L. Kendall, editor. Selected Coolwater Fishes of North America. American Fisheries Society, Bethesda, Maryland.

Parks, J. O., and J. E. Kraii. 1991. Behavioral characteristics of adult walleyes in Meredith Reservoir, Texas as determined by ultrasonic telemetry. Proceedings of the Annual Conference of Southeast Fish and Wildlife Agencies 45:460-469.

Pitlo, J. M. 1978. Walleye movement and behavior in West Lake Okoboji, Iowa. Master's thesis, Iowa State University, Ames.

Priscu, J. C. 1987. Environmental factors regulating the dynamics of blue-green algal blooms in Canyon Ferry Reservoir, Montana. Report No. 159. Montana State University, Water Resources Center, Bozeman.

Prophet, C. W., T. B. Brungardt, and N.K. Prophet. 1989. Diel behavior and seasonal distribution of walleye, *Stizostedion vitreum* Mitchill, in Marion Reservoir, based on ultrasonic telemetry. Journal of Freshwater Ecology 5:177-185.

Rada, R. G. 1974. An investigation of the trophic status of Canyon Ferry Reservoir, Montana. Ph.D. Dissertation. Montana State University, Bozeman.

Rada, R. G., and J. C. Wright. 1979. Factors affecting nitrogen and phosphorus levels in Canyon Ferry Reservoir, Montana, and its effluent waters. Northwest Science 53:213-220.

Ryder, R. A. 1968. Dynamics and exploitation of mature walleye (*Stizostedion vitreum vitreum*) in the Nipigon Bay region of Lake Superior. Journal of Fisheries Research Board of Canada 25:1347-1376.

Ryder, R. A. 1977. Effects of ambient light variations on behavior of yearling, subadult, and adult walleyes. Journal of Fisheries Research Board of Canada 34:1481-1491.

Schupp, D. H. 1972. The walleye fishery of Leech Lake, Minnesota. MinnesotaDepartment of Natural Resources, Fisheries Investigative Report Number 317.

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin 184.

Smith, L. L. JR., L. W. Krefting, and R. L. Butler. 1952. Movements of marked walleye *Stizostedion vitreum vitreum* (Mitchill) in the fishery of the Red Lakes, Minnesota. Transactions of the American Fisheries Society 81:179-196.

SPSS Inc. 1999. SPSS for Windows. SPSS Incorporated, Chicago, Illinois

Stasko, A. B., and D. G. Pincock. 1977. Review of underwater biotelemetry, with emphasis on ultrasonic techniques. Journal of the Fisheries Research Board of Canada 34(9):1261-1285.

Summerfelt, R. C., and L. S. Smith. 1990. Anesthesia, surgery, and related techniques. Pages 213-272 *in* C. B. Schreck and P. B. Moyle, editors. Methods for Fish Biology. Anmerican Fisheries Society, Bethesda, Maryland.

Summers, G. L. 1979. Seasonal distribution of adult walleye as determined by ultasonic telemetry in Canton Reservoir, Oklahoma. Proceedings of the Annual Conference of Southeast Fish and Wildlife Agencies 33:611-619.

White, G. C., and R. A.Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press Inc., San Diego, California.

Williams, J. D. 1997. Walleye movement, distribution, and habitat use in Laurel River Lake, Kentcuky. Kentucky Department of Fish and Wildlife Resources, Fisheries Bulletin No. 98.

Winter, J. 1996. Advances in underwater biotelemetry. Pages 555-590 *in* B. R. Murphy and D. W. Willis, editors. Fisheries Techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Zar, J. H. 1984. Biostatistical Analysis, 2nd Edition. Prentice-Hall, Englewood, New Jersey.

CHAPTER 4

THE EFFECTIVENESS OF TELEMETRY AS A TOOL IN IDENTIFYING WALLEYE SPAWNING AREAS

INTRODUCTION

Inadvertent or illegal introductions of aquatic species have challenged managers to develop effective control or removal methods to minimize risks to existing communities. A variety of means (e.g., chemical, biological, mechanical) can be considered to achieve carefully planned and predetermined objectives (Wiley and Wydoski 1993). Key to the successful implementation of these methods is that the targeted species is accessible.

Telemeterized walleye *Stizostedion vitreum* in Canyon Ferry exhibited complete fidelity to a single spawning area (Chapter 3). In order for Montana Fish, Wildlife and Parks (MFWP) to implement effective walleye population control measures, it was of paramount importance to confirm that the telemetry-identified area was the only spawning site being used by walleye. I recognized that the area identified by instrumented walleye may not signify the only spawning area in Canyon Ferry. The objective of this study was to evaluate the effectiveness of telemetry as a tool in identifying spawning areas of a relatively low density walleye population. Several different sampling techniques were used to compare abundances of adult walleye on the telemetry-identified spawning area with those of adult walleye sampled in other suitable spawning habitats not being used by instrumented walleye.

STUDY AREA

Canyon Ferry is the largest and uppermost impoundment of a three reservoir chain including Hauser and Holter reservoirs on the upper Missouri River (Figure 44). Impounded in 1954, it is located in Lewis & Clark and Broadwater counties in southwest Montana. The upper end of the reservoir is located about 40 km downstream of the origin of the Missouri River at the confluence of the Jefferson, Gallatin, and Madison rivers near Three Forks, Montana. Canyon Ferry Dam is located on the north end of the reservoir and is about 23 km east of Helena, Montana. The United States Bureau of Reclamation (BOR) operates Canyon Ferry as a water storage reservoir and regulates water levels for flood control, irrigation, municipal water supply, power production, and recreation.

Canyon Ferry has an elevation at full-pool of 1158 m, surface area of 14,238 ha, and storage capacity of 2.53×10^9 m^3. The reservoir is 40.2 km long and has a maximum width of 7.2 km (Rada and Wright 1979). Canyon Ferry's total shore length is about 122 km and has a shoreline development factor of 2.9 (Rada 1974). It has mean and maximum depths of 17.8 m and 50.1 m, respectively. The annual drawdown is about 3.6 m and hydraulic retention averages about 135 days, but can range from 50 to 200 days depending on the flow regime and reservoir elevation (Priscu 1987).

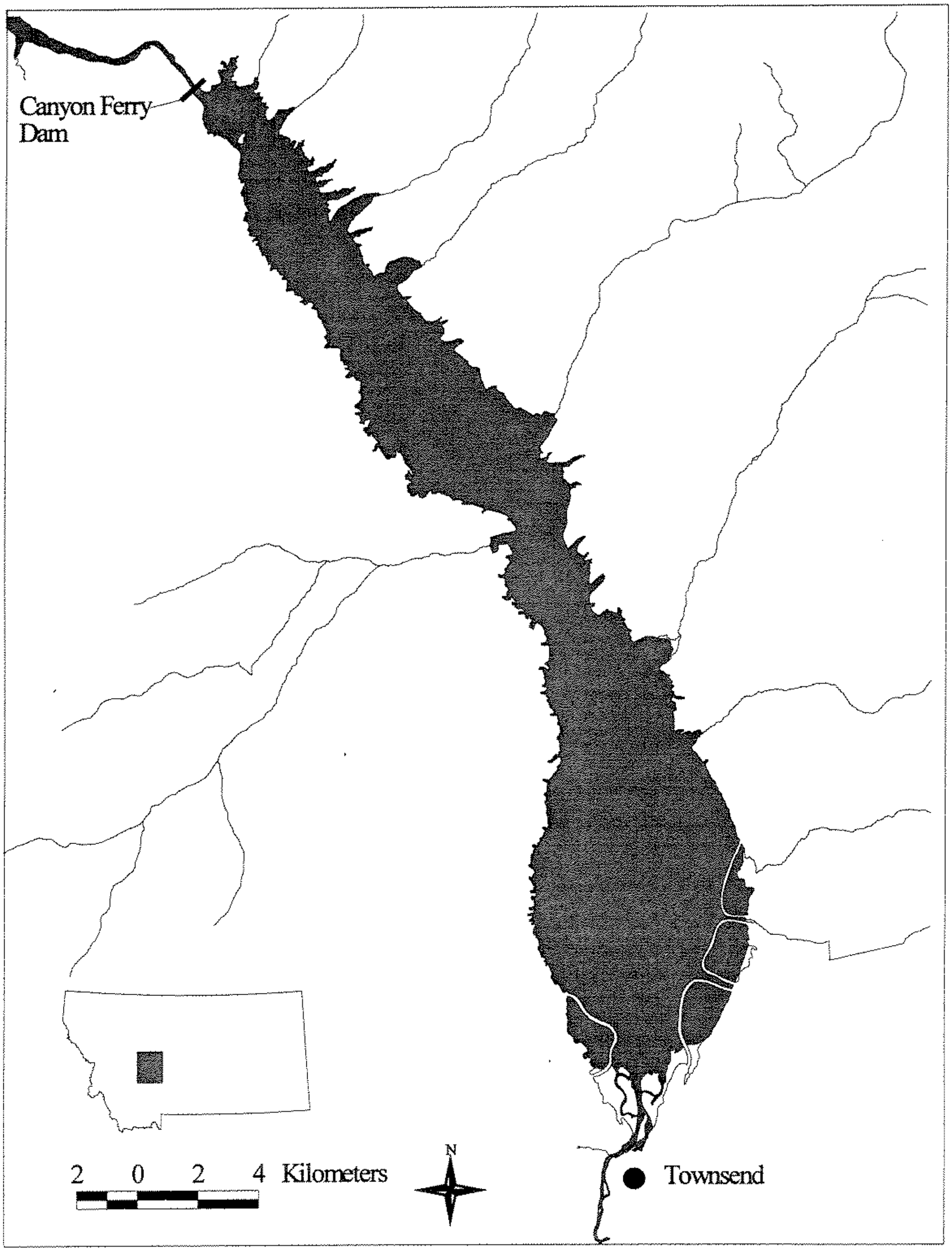


Figure 44. Map of Canyon Ferry Reservoir, Montana.

The reservoir's north and south ends contrast markedly. The broad, southern (upper) portion of Canyon Ferry is characterized by relatively shallow (< 15 m), uniform depths with gently sloping shorelines and few bays. Strong wind events are common on this end of the reservoir, particularly during spring and autumn. The shoreline substrate is mostly small cobble with localized areas of sand and mud; off-shore substrate is predominately mud and silt deposited from the Missouri River. The north (lower) end of Canyon Ferry is much narrower and deeper. It has numerous small bays with steeply sloping, rocky shorelines, particularly off the points of bays. There are also several rocky islands on the north half of the reservoir, some of which are submerged when the reservoir is at full-pool. Generally, there is greater habitat complexity on the north end of the reservoir compared to the southern half.

Canyon Ferry Reservoir fills rapidly during spring run-off in late May and June, reaches its maximum storage in July, then gradually is drawn down to minimum storage levels by the following spring. The Missouri River provides nearly all water input into the reservoir except for a few small perennial tributaries (Duck, Confederate, Beaver, and Magpie creeks) that contribute only minimal inflow.

Canyon Ferry is typically ice covered from mid-December through March. The shallower, upper end of the reservoir is the first area to ice-up and is the first portion of the reservoir to become ice-free in the spring, in part because of the warmer water inflows from the Missouri River.

METHODS

Sampling Design

Potential walleye spawning sites were stratified among the upper, middle, and lower reservoir based on springtime surface water warming patterns (Lere 1991). All potential spawning areas within these strata were identified based on preferred spawning habitat criteria including substrate, depth, contour, temperature, and water circulation (Colby et al. 1979; McMahon et al. 1984). Six potential spawning sites were randomly selected each year from the pool of identified areas within each individual stratum and sampled for adult walleye (Table 21; Figures 45 - 47).

Table 21. Randomly selected potential spawning sites sampled for adult walleye within individual strata in Canyon Ferry Reservoir, Montana, during spring 1995 and 1996. Numbers correspond with areas denoted on maps (pages 160 - 162).

	Stratum		
	upper reservoir	middle reservoir	lower reservoir
1995	1, 4, 46, 47, 49, 50	10, 37, 38, 41, 42, 43	15, 20, 26, 28, 31, 32
1996	4, 5, 47, 48, 49, 50	6, 10, 11, 40, 41, 44	16, 19, 20[a], 28[b], 22, 33, 34

[a] gill net only
[b] electrofishing only

Sampling Protocol 1995

Relative abundances of walleye at the telemetry-identified spawning site and potential spawning sites in the upper reservoir stratum were quantified using trap nets and electrofishing in 1995. Trap nets (1.8 m x 1.2 m frame with 18.3 m leads, 25 mm bar mesh) were set perpendicular to shore and fished overnight on the spawning area 22 times

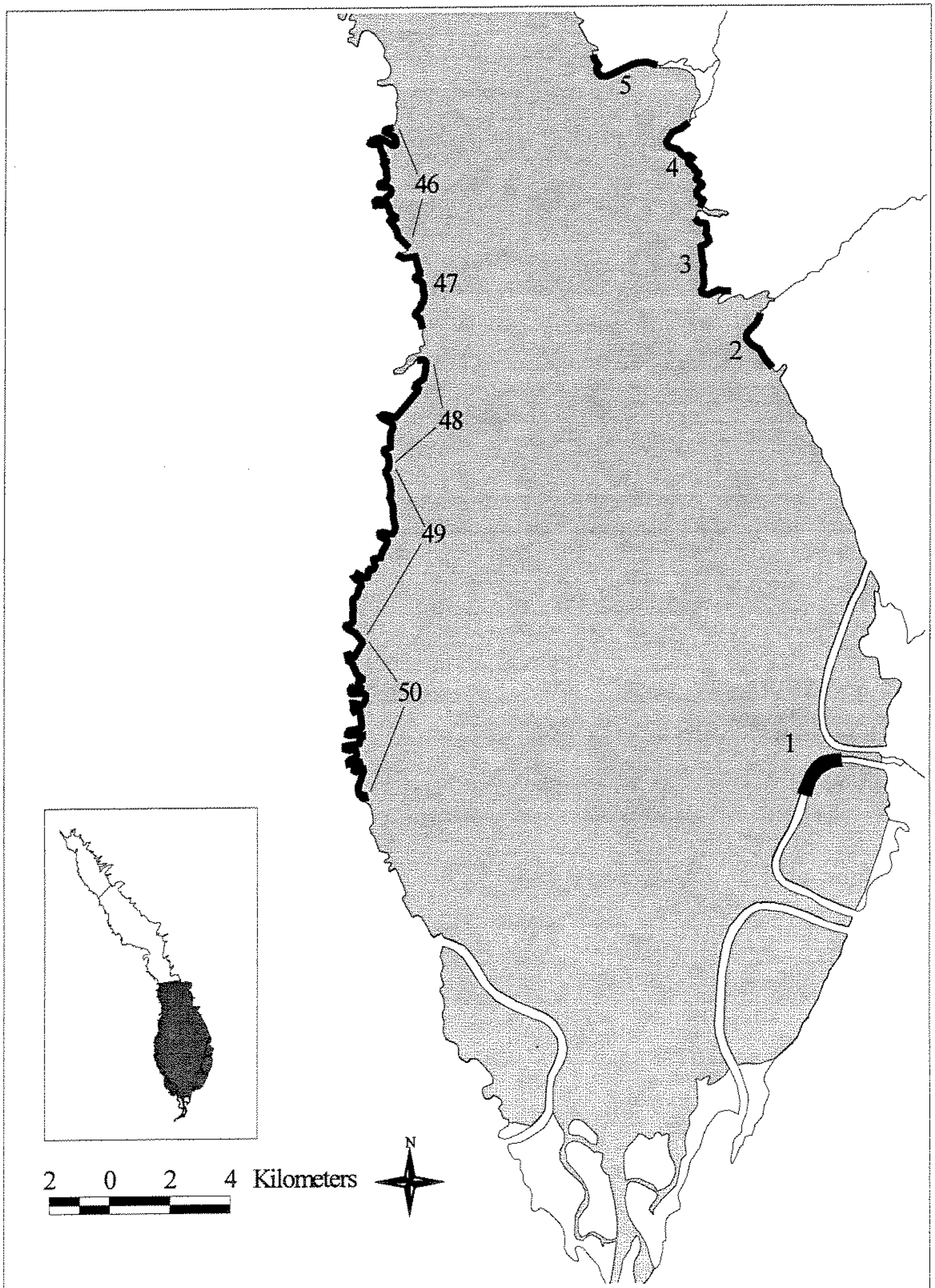


Figure 45. Potential walleye spawning sites identified in upper reservoir stratum, Canyon Ferry Reservoir, Montana.

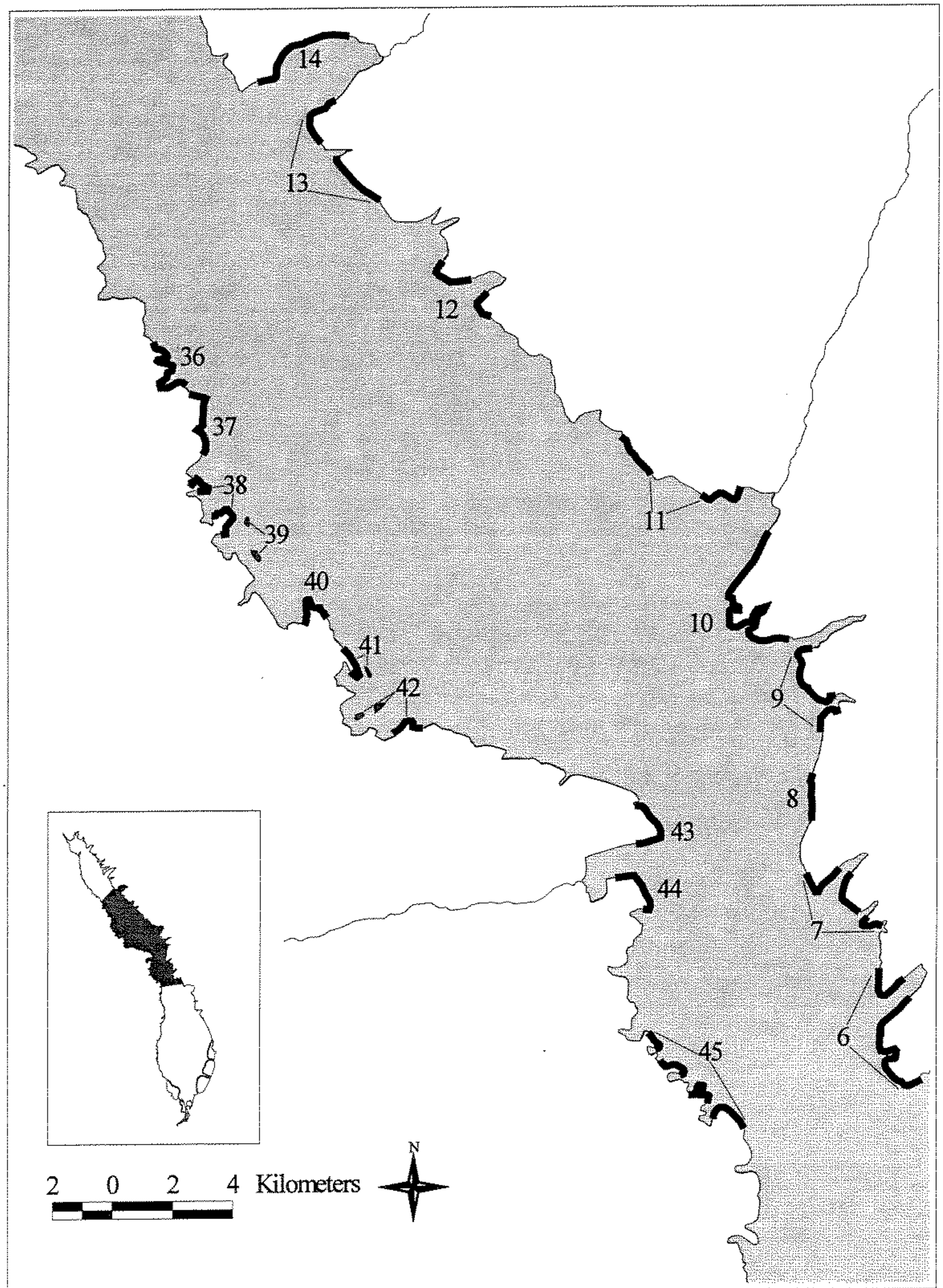


Figure 46. Potential walleye spawning sites identified in mid reservoir stratum, Canyon Ferry Reservoir, Montana.

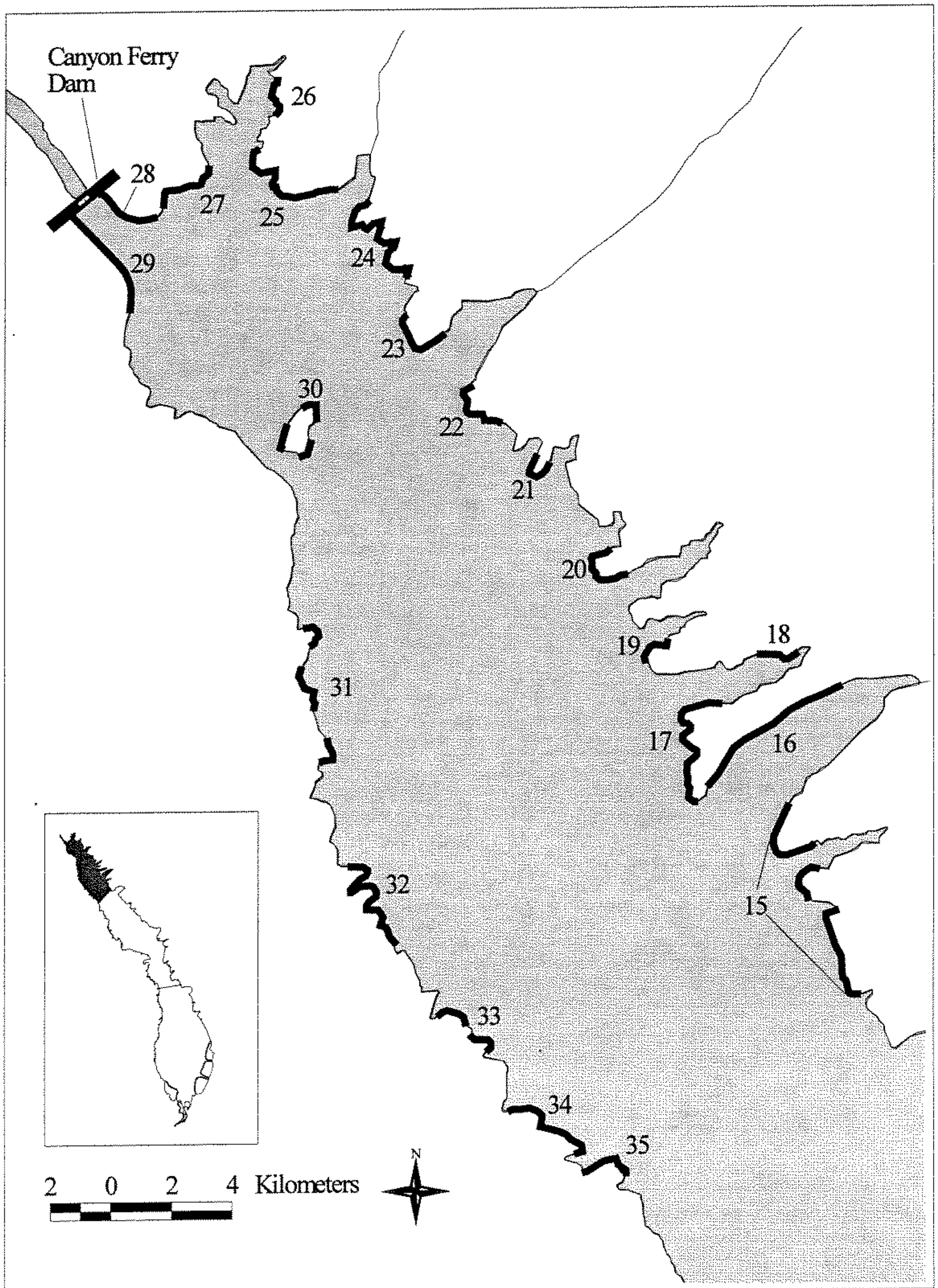


Figure 47. Potential walleye spawning sites identified in lower reservoir stratum, Canyon Ferry Reservoir, Montana.

over seven different evenings between 16 April and 02 May. Concurrently, six potential spawning sites in the upper reservoir stratum were sampled with trap nets 31 times over seven different evenings between 16 April and 02 May. Catches of walleye and other species were quantified in terms of mean number per trap net night. Middle and lower reservoir strata were not sampled with trap nets because of time constraints.

Electrofishing was conducted with a boom-suspended system mounted on a 5-m aluminum flat-bottom river boat equipped with a 90-hp Yamaha jet outboard motor. Electricity was generated by a Honda 5000 watt generator converted into pulsed direct current with a Coffelt VVP-15 electrofishing unit. Electrofishing transects were sampled during nighttime to optimally sample spawning fish (K. Binkley, R-2 Resource Consultants, personal communication). Electrofishing was completed on the telemetry-identified walleye spawning area on 26 April and 05 May. The entire spawning shoreline was electrofished both evenings. Six potential spawning sites within each of the upper, middle, and lower strata were electrofished between 26 April and 15 May. The entire shoreline at each site was sampled a minimum of one time; site number 1 in the upper stratum was electrofished twice. Time spent electrofishing at each site was recorded and catch per unit effort (CPUE) was calculated by dividing the number of walleye captured during each transect by the duration of the transect.

Sampling Protocol 1996

Horizontal sinking gill nets (30.5 m x 1.8 m with 76 mm bar mesh) and electrofishing were used to sample spawning walleye in the spring of 1996. Gill nets were set overnight 21 times on the telemetry-identified walleye spawning area over 11 different evenings between 15 April and 05 May. Potential walleye spawning sites in the upper and middle strata were sampled with gill nets only. Gill nets were set overnight 29 times on potential spawning sites over eight different evenings between 01 May and 09 May. Each individual site was sampled a minimum of two different evenings. Potential spawning site number 50 was sampled with three gill net sets; site number 5 was not sampled with gill nets because of possible conflict with anglers. Lower stratum potential walleye spawning sites were sampled one night each with gill nets and electrofishing. Gill net catches were quantified as mean number of walleye and other species captured per net night.

Nighttime electrofishing was completed on the known spawning area on 17 April and 24 April. Potential walleye spawning sites in the lower stratum were electrofished on 07 May and 16 May. The entire shoreline at each site was sampled. Because of possible conflict with shore anglers, potential walleye spawning site number 28 was only electrofished; site number 20 was substituted for gill net sampling. Time spent electrofishing at each site was recorded and catch per unit effort (CPUE) was calculated by dividing the number of walleye captured during each transect by the duration of the transect.

Walleye catch rates in trap nets and gill nets were compared in spring 1996. Trap nets were set in close proximity to gill nets on the telemetry-identified walleye spawning area 24 times over eight different evenings between 15 April and 03 May. Trap net catches of walleye were quantified as mean number per trap net night. Walleye CPUE for each technique were statistically compared (independent-samples *t*-test) to evaluate their effectiveness in sampling walleye. All statistical analyses were performed with SPSS for Windows (1999).

A Hobo™ XT thermograph was installed at the one identified spawning area in the spring of 1995 and 1996. Catch rates of walleye were compared to water temperature data to determine timing of peak walleye abundance on the spawning area.

RESULTS

Spring 1995

Trap nets

Four walleye were sampled in trap nets set on the identified spawning area (mean = 0.2, SE = 0.10), comprising 0.3% of the total catch (Table 22). White suckers *Catostomus commersoni* dominated the catch (mean = 55.9, SE = 12.33), followed by rainbow trout *Oncorhynchus mykiss* (mean = 19.4, SE = 3.28) and yellow perch *Perca flavescens* (mean = 7.9, SE = 3.80). These three species combined constituted nearly 95% of all fish sampled in trap nets set on the walleye spawning area. Other species sampled less commonly included longnose suckers *Catostomus catostomus*, mountain whitefish *Prosopium williamsoni*, burbot *Lota lota*, common carp *Cyprinus carpio*, Utah chubs *Gila atraria*, and stonecats *Noturus flavus*. Four trap nets beached by high wind events were not included in the netting summary.

Table 22. Individual catches, total and mean (SE) catch by species, and percent composition of total catch for all fish captured in trapnets set overnight on identified walleye spawning area in Canyon Ferry Reservoir, Montana, spring 1995. Asterisks denote sets not included in overall summary.

Date	Water temp (C)	Walleye	Rainbow trout	Brown trout	White sucker	Longnose sucker	Mtn. whitefish	Yellow perch	Burbot	Common carp	Utah chub	Stonecat
16 April*	9.0	0	0	0	5	0	0	0	0	1	0	0
16 April	9.0	1	25	0	77	0	1	10	0	4	0	0
21 April*	9.5	0	23	0	3	0	0	1	0	0	0	0
21 April*	8.0	0	19	0	6	0	0	2	0	0	0	0
21 April	9.0	0	33	0	39	0	0	3	0	1	0	2
21 April*	8.0	0	0	0	0	0	0	0	0	0	0	0
22 April	10.5	1	11	0	13	0	0	2	0	0	0	0
22 April	10.5	0	11	0	27	1	0	13	0	0	0	1
22 April	10.0	0	2	0	17	0	0	15	1	0	0	0
22 April	9.5	0	18	0	86	0	0	2	0	0	0	5
22 April	9.0	0	5	0	18	0	0	4	1	0	0	0
22 April	9.5	1	21	0	53	0	0	0	0	0	0	0
25 April	12.0	0	15	0	30	0	0	1	0	0	1	1
25 April	12.0	0	28	0	107	0	0	70	0	0	7	1
27 April	11.5	0	14	0	33	0	0	2	0	0	2	1
27 April	10.5	0	40	0	180	0	0	8	1	1	2	1

Table 22. Continued.

Date	Water temp (C)	Walleye	Rainbow trout	Brown trout	White sucker	Longnose sucker	Mtn. whitefish	Yellow perch	Burbot	Common carp	Utah chub	Stonecat
28 April	10.0	0	8	0	59	0	0	5	2	2	9	0
28 April	10.0	0	6	0	65	0	0	3	3	6	9	0
28 April	10.5	1	40	0	172	0	0	.2	0	2	1	5
28 April	11.0	0	5	0	17	0	0	0	0	0	2	0
02 May	10.0	0	50	0	12	0	0	2	0	1	0	3
02 May	10.0	0	17	0	1	0	0	0	0	0	0	0
Total catch:		4	349	0	1,006	1	1	142	8	17	33	20
Mean number per trap net:		0.2	19.4	0	55.9	0.1	0.1	7.9	0.4	0.9	1.8	1.1
		(0.10)	(3.28)	(0)	(12.33)	(0.06)	(0.06)	(3.80)	(0.20)	(0.39)	(0.73)	(0.39)
Percent of total catch:		0.3	22.1	0	63.6	0.1	0.1	9.0	0.5	1.1	2.1	1.3

No walleye were captured in trap nets set at potential walleye spawning sites. White suckers (mean = 52.4, SE = 12.54), rainbow trout (mean = 29.3, SE = 8.24), and yellow perch (mean = 4.2, SE = 1.15) dominated the catch, comprising 97% of all fish sampled (Table 23). Brown trout *Salmo trutta*, longnose suckers, mountain whitefish, burbot, common carp, Utah chubs, and stonecats were sampled in smaller numbers. One set was excluded from the netting summary because it was beached by high winds.

Electrofishing

Six adult walleye were sampled on the identified spawning area on 26 April, including instrumented walleye 4-6-5 (CPUE = 0.08; Table 24). One other walleye was observed that avoided capture. No walleye were sampled or observed while electrofishing on the spawning area on 05 May, nor at any of the potential spawning sites in the upper, middle, and lower strata (Table 25).

Walleye Abundance on Spawning Area

Insufficient numbers of walleye were sampled to determine when the peak spawner abundance occurred on the spawning area.

Spring 1996

Gill Nets

Walleye were readily sampled in gill nets on the identified spawning area (mean = 3.6, SE = 0.93); 13 of the 21 sets (62%) captured at least one adult walleye (Table 26). Common carp dominated the catch (mean = 14.5, SE = 2.52), comprising

Table 23. Individual catches, total and mean (SE) catches for individual species, and percent composition of total catch for all fish captured in trap nets set overnight on potential walleye spawning sites in upper Canyon Ferry Reservoir, Montana, spring 1995. Asterisk denotes set not included in overall summary.

Date	Site number	Water temp (C)	Walleye	Rainbow trout	Brown trout	White sucker	Longnose sucker	Mtn. whitefish	Yellow perch	Burbot	Common carp	Utah chub	Stonecat
16 April	1	9.5	0	33	0	13	0	1	20	1	15	0	0
16 April	1	9.5	0	25	0	14	0	1	16	0	4	0	0
16 April	47	7.0	0	1	0	13	0	0	1	0	0	0	0
16 April	47	7.0	0	1	0	33	0	0	0	0	0	0	0
21 April	46	8.5	0	28	0	319	0	0	1	0	1	0	0
21 April*	46	8.5	0	0	0	3	0	0	0	0	0	0	0
21 April	50	13.0	0	13	0	149	0	0	8	0	0	0	0
21 April	50	13.0	0	39	0	213	0	0	23	0	10	0	0
22 April	1	10.5	0	73	0	94	0	0	8	0	2	0	1
22 April	1	9.0	0	30	0	67	0	0	9	0	2	0	0
25 April	4	12.0	0	70	0	17	0	0	0	0	0	1	0
25 April	4	11.5	0	31	0	34	0	0	0	0	0	1	2
25 April	49	11.0	0	0	0	25	0	0	6	2	0	0	1
25 April	49	10.5	0	0	0	23	0	0	13	0	0	0	0
25 April	50	11.0	0	24	0	99	0	0	4	0	2	1	1
27 April	4	12.0	0	28	0	38	0	0	1	0	0	2	0

Table 23. Continued.

Date	Site number	Water temp (C)	Walleye	Rainbow trout	Brown trout	White sucker	Longnose sucker	Mtn. whitefish	Yellow perch	Burbot	Common carp	Utah chub	Stonecat
27 April	4	10.0	0	12	0	77	0	0	0	0	1	0	1
27 April	46	10.0	0	13	0	39	0	0	0	0	0	0	1
27 April	46	10.5	0	2	0	25	0	0	0	1	4	0	0
27 April	47	10.0	0	0	1	0	0	0	0	2	0	0	0
27 April	47	10.0	0	14	0	58	0	1	2	0	0	0	0
28 April	1	12.5	0	27	0	56	0	0	6	0	0	1	0
28 April	1	13.5	0	24	0	71	0	0	1	1	0	0	0
28 April	50	10.0	0	182	0	8	0	0	0	0	0	0	0
28 April	50	9.5	0	5	0	18	0	0	6	0	0	0	0
02 May	49	9.0	0	5	1	7	1	0	1	0	0	0	0
02 May	49	9.5	0	0	1	5	0	0	0	0	1	0	1
02 May	46	9.0	0	8	0	7	0	0	0	0	0	0	1
02 May	46	8.5	0	5	0	29	0	0	0	4	0	0	4
02 May	4	9.0	0	7	0	6	0	0	0	0	0	2	0
02 May	4	9.5	0	179	0	16	0	0	1	0	0	0	0
Total catch:			0	879	3	1,573	1	3	127	11	42	8	13
Mean number per trap net:			0	29.3	0.1	52.4	<0.1	0.1	4.2	0.4	1.4	0.3	0.4
			(0)	(8.24)	(0.06)	(12.54)	(0.03)	(0.06)	(1.15)	(0.16)	(0.60)	(0.11)	(0.16)
Percent of total catch:			0	33.0	0.1	59.1	0	0.1	4.8	0.4	1.6	0.3	0.5

Table 24. Sampling statistics of electrofishing completed on the identified walleye spawning area in Canyon Ferry Reservoir, Montana, spring 1995. Walleye catch rates are represented by catch-per-unit-effort (CPUE; number of walleye sampled per minute of electrofishing).

Date	Water temp (C)	Time start	Time finish	Total time (min)	Walleye sampled	CPUE
26 April	10.5	2223	2339	76.27	6	0.1
05 May	11.5	0030	0143	72.48	0	0

Table 25. Sampling statistics of electrofishing completed on randomly selected potential walleye spawning sites in Canyon Ferry Reservoir, Montana, spring 1995. Walleye catch rates are represented by catch-per-unit-effort (CPUE; number of walleye sampled per minute of electrofishing).

Date	Site number	Water temp (C)	Time start	Time finish	Total time (min)	Walleye sampled	CPUE
26 April	1	11.0	2128	2148	19.45	0	0
02 May	46	8.0	2154	2225	30.35	0	0
02 May	47	8.5	2226	2257	30.47	0	0
02 May	49	8.5	2321	0005	44.18	0	0
02 May	50	8.5	0005	0043	38.12	0	0
04 May	4	12.0	2142	2012	29.82	0	0
04 May	1	14.0	2336	2359	22.53	0	0
10 May	37	10.0	2142	2157	15.13	0	0
10 May	38	8.5	2207	2229	21.65	0	0
10 May	41	9.5	2243	2303	19.95	0	0
10 May	42	9.5	2321	2331	10.20	0	0
10 May	10	8.0	2359	0039	39.32	0	0
10 May	43	11.0	0053	0105	11.60	0	0
15 May	26	9.5	2155	2200	5.25	0	0
15 May	20	10.0	2224	2237	12.30	0	0
15 May	15	9.0	2249	2321	32.02	0	0
15 May	32	9.0	2349	0008	18.32	0	0
15 May	31	9.0	0026	0039	12.52	0	0
15 May	28	9.0	0055	0110	15.25	0	0

Table 26. Individual catches, total and mean (SE) catches for individual species, and percent composition of total catch for all fish captured in gill nets (76 mm bar mesh) set overnight on identified walleye spawning area in Canyon Ferry Reservoir, Montana, spring 1996.

Date	Water temp (C)	Walleye	Rainbow trout	Brown trout	White sucker	Common carp
15 April	8.5	4	0	0	0	12
15 April	9.0	1	1	0	0	17
16 April	10.0	9	6	0	0	15
16 April	10.0	4	4	0	0	21
19 April	9.0	9	3	0	0	2
19 April	8.5	0	2	0	0	2
23 April	12.0	10	4	0	0	12
23 April	11.5	12	7	0	0	10
24 April	10.0	2	6	0	0	8
24 April	10.0	0	6	0	0	4
29 April	11.0	12	4	0	0	29
29 April	12.0	3	4	0	0	31
30 April	8.5	0	3	0	0	1
30 April	7.0	3	5	0	0	13
02 May	8.5	0	7	0	0	1
02 May	7.5	0	7	0	0	7
03 May	10.5	0	2	0	0	39
04 May	9.0	5	10	0	0	25
04 May	8.0	0	2	0	0	31
05 May	10.0	1	10	0	0	23
05 May	10.0	0	5	0	0	2
Total catch:		75	98	0	0	305
Mean number per net:		3.6	4.7	0	0	14.5
		(0.93)	(0.58)	(0)	(0)	(2.52)
Percent of total catch:		15.7	20.5	0	0	63.8

64% of the total catch. Rainbow trout were sampled in abundances similar to walleye (mean = 4.7, SE = 0.58). No other species were captured.

No walleye were sampled in gill nets set on potential spawning sites. Common carp (mean = 9.3, SE = 1.12) and rainbow trout (mean = 5.7, SE = 0.98) dominated the catch, contributing 98% of the total catch (Table 27). The remainder of the catch consisted of equal numbers of brown trout and white suckers.

Table 27. Individual catches, total and mean (SE) catches for individual species, and percent composition of total catch for all fish captured in gill nets (76 mm bar mesh) set overnight on randomly selected potential walleye spawning sites in Canyon Ferry Reservoir, Montana, spring 1996.

Date	Site number	Water temp (C)	Walleye	Rainbow trout	Brown trout	White sucker	Common carp
01 May	50	9.0	0	9	1	0	13
01 May	50	8.5	0	24	0	0	7
03 May	49	8.5	0	3	1	0	15
04 May	4	7.5	0	11	0	0	8
04 May	47	8.0	0	3	1	0	8
04 May	48	8.0	0	4	1	0	13
04 May	49	8.0	0	4	0	0	4
05 May	4	9.0	0	2	0	0	0
05 May	47	8.0	0	1	0	0	8
05 May	48	8.0	0	0	0	0	2
05 May	50	10.0	0	13	0	0	15
07 May	6	11.5	0	2	1	0	15
07 May	10	10.0	0	4	0	0	10
07 May	11	10.0	0	4	0	0	23
07 May	40	8.0	0	3	0	0	8
07 May	41	8.5	0	0	0	0	9

Table 27. Continued.

Date	Site	Water temp (C)	Walleye	Rainbow trout	Brown trout	White sucker	Common carp
07 May	44	10.0	0	2	0	1	9
08 May	6	8.5	0	15	0	0	11
08 May	44	8.5	0	12	0	1	14
08 May	10	8.5	0	2	0	1	5
08 May	11	9.5	0	8	0	0	22
08 May	40	8.5	0	4	0	0	8
08 May	41	9.5	0	6	0	0	14
09 May	34	6.0	0	5	0	1	1
09 May	16	6.0	0	2	0	0	11
09 May	33	6.0	0	10	0	1	1
09 May	19	7.5	0	5	0	0	14
09 May	20	7.0	0	5	0	0	0
09 May	22	6.0	0	2	0	0	2
Total catch:			0	165	5	5	270
Mean number per net:			0	5.7	0.2	0.2	9.3
			(0)	(0.98)	(0.07)	(0.07)	(1.12)
Percent of total catch:			0	37.1	1.1	1.1	60.7

Electrofishing

No walleye were sampled nor observed while electrofishing the telemetry-identified spawning area on 17 April. Windy conditions precluded electrofishing the entire shoreline. Two walleye were sampled while electrofishing the spawning area on 25 April (CPUE = 0.02; Table 28). No walleye were sampled nor observed while electrofishing potential walleye spawning sites (Table 29).

Table 28. Sampling statistics of electrofishing completed on identified walleye spawning area in Canyon Ferry Reservoir, Montana, spring 1996. Walleye catch rates are represented by catch-per-unit-effort (CPUE; number of walleye sampled per minute of electrofishing).

Date	Water temp (C)	Time start	Time finish	Total time (min)	Walleye sampled	CPUE
17 April	8.0	2147	2251	63.98	0	0
25 April	7.0	2152	2326	93.58	2	0.02

Table 29. Sampling statistics of electrofishing completed on randomly selected potential walleye spawning sites in Canyon Ferry Reservoir, Montana, spring 1996. Walleye catch rates are represented by catch-per-unit-effort (CPUE; number of walleye sampled per minute of electrofishing).

Date	Site number	Water temp (C)	Time start	Time finish	Total time (min)	Walleye sampled	CPUE
07 May	33	7.0	2222	2250	27.80	0	0
07 May	34	7.0	2258	2333	34.58	0	0
07 May	16	7.0	2351	0010	18.57	0	0
07 May	28	6.5	0042	0057	15.27	0	0
16 May	19	10.5	2204	2217	13.27	0	0
16 May	22	9.5	2229	2613	26.22	0	0

Trap Nets

Nine walleye were sampled in trap nets on the identified spawning area (mean catch = 0.5, SE = 0.25); seven of the nine were sampled on 23 April (Table 30). This peak catch date agreed with that observed for the gill net sampling (Table 26). Mean CPUE of walleye in trap nets was significantly less than in gill nets (independent-samples *t*-test; P = 0.001). Walleye accounted for less than 1% of the total trap net catch (Table 30). Rainbow trout (mean = 31.4, SE = 7.01) and white suckers (mean = 24.8, SE = 5.24) dominated the total catch, constituting over 80% of all fish sampled. Other species

Table 30. Individual catches, total and mean (SE) catch by species, and percent composition of total catch for all fish captured in trap nets set overnight on identified walleye spawning area in Canyon Ferry Reservoir, Montana, spring 1996. Asterisks denote sets not included in overall summary.

Date	Water temp (C)	Walleye	Rainbow trout	Brown trout	White sucker	Longnose sucker	Mtn. whitefish	Yellow perch	Burbot	Common carp	Utah chub	Stonecat
15 April	13.0	0	31	0	82	0	0	9	4	1	2	0
15 April	11.5	0	31	0	64	0	0	2	1	5	0	1
15 April	9.0	0	33	0	55	0	2	1	0	3	1	1
15 April	9.0	0	65	1	45	0	2	16	6	8	1	5
16 April	8.0	0	102	0	29	0	0	4	3	0	0	1
16 April	7.5	0	18	0	19	1	2	9	5	8	0	1
19 April*	8.5	0	1	0	0	0	0	0	0	1	0	0
19 April*	9.0	0	0	0	0	0	0	0	0	0	0	0
19 April*	8.5	0	1	0	1	0	0	0	0	0	0	0
23 April	13.0	1	60	0	7	0	0	17	0	6	3	0
23 April	13.0	2	49	0	23	2	0	2	1	5	0	0
23 April	11.0	4	99	0	44	0	0	5	2	8	4	5
24 April*	10.0	0	11	0	0	0	0	0	0	0	0	0
24 April*	10.0	0	3	0	1	0	0	0	0	0	0	0
24 April	10.0	0	16	0	3	0	0	5	1	1	0	1
29 April	11.0	0	30	0	16	0	3	3	0	6	0	2

Table 30. Continued.

Date	Water temp (C)	Walleye	Rainbow trout	Brown trout	White sucker	Longnose sucker	Mtn. whitefish	Yellow perch	Burbot	Common carp	Utah chub	Stonecat
29 April	11.5	0	5	0	6	0	0	3	0	6	1	0
29 April	12.5	0	12	0	8	0	0	7	0	13	0	0
30 April	7.0	0	14	0	16	1	0	1	0	0	1	1
30 April	6.0	0	7	0	14	0	0	1	0	0	0	0
30 April	7.5	2	11	0	17	1	0	2	0	2	0	0
03 May	11.0	0	6	0	1	0	0	0	0	0	0	0
03 May	11.5	0	3	0	20	0	1	5	0	0	1	1
03 May	10.5	0	4	0	3	0	0	0	0	4	0	0
Total catch:		9	596	1	472	5	10	92	23	76	14	19
Mean number per trap net:		0.5	31.4	0.1	24.8	0.3	0.5	4.8	1.2	4.0	0.7	1.0
		(0.25)	(7.01)	(0.05)	(5.24)	(0.13)	(0.22)	(1.13)	(0.44)	(0.85)	(0.26)	(0.35)
Percent of total catch:		0.7	45.3	0.1	35.8	0.4	0.8	7.0	1.7	5.8	1.1	1.4

sampled less frequently included brown trout, longnose suckers, mountain whitefish, yellow perch, burbot, common carp, Utah chub, and stonecat. Five trap nets beached by high winds were not included in the netting summary.

Walleye Abundance on Spawning Area

Mean gill net catches of walleye varied greatly during the spawning period (range: 0 to 11 walleye per net). Similarly, mean surface water temperature fluctuated widely during April, and then gradually warmed in early May. Based on gill net catches, peak spawner abundance occurred on the spawning area on 23 April when surface water temperature averaged 11.0 C following a warming trend (Figure 48).

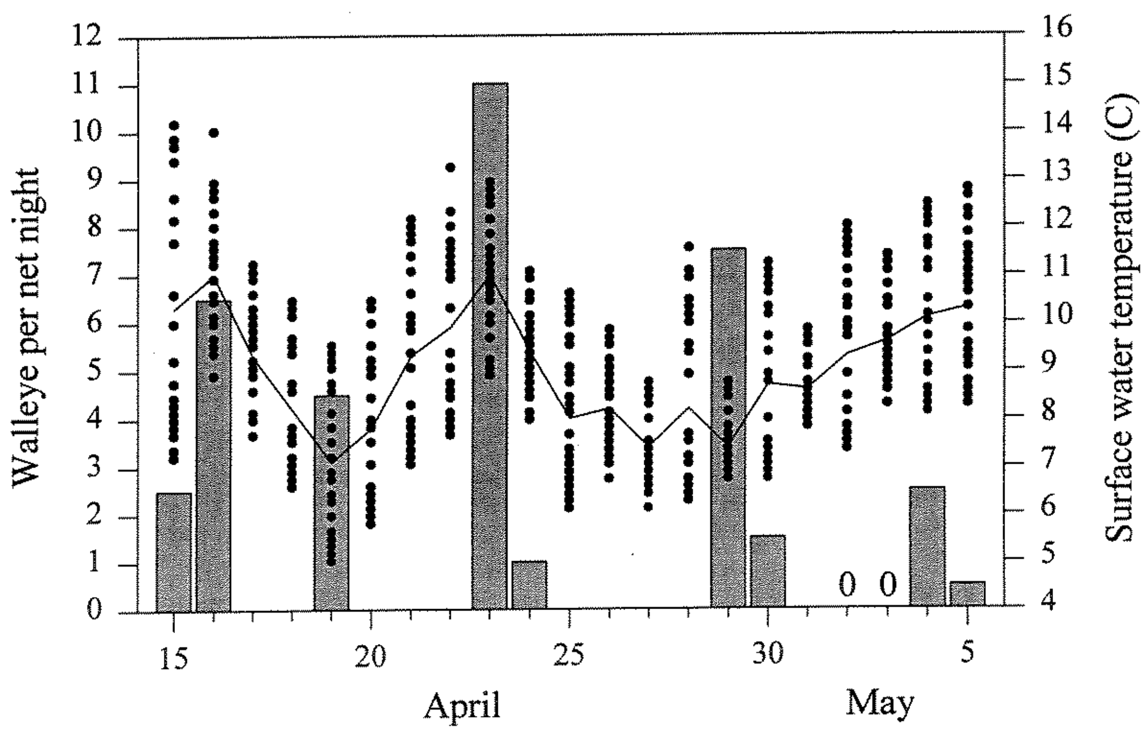


Figure 48. Mean gill net catch of walleye (vertical bars) versus surface water temperature (dots) at telemetery-identified walleye spawning area on Canyon Ferry Reservoir, Montana, spring 1996. Solid line represents mean daily surfacewater temperature.

DISCUSSION

Sampling I completed during this study suggested that the telemetry-identified spawning area was the only location used by walleye for spawning. These results are not conclusive, however. Walleye are spawning generalists. They are able to spawn at depths varying from a few centimeters to several meters (Colby et al. 1979) and use a broad range of habitats (see review in Eschmeyer 1950).

This study was limited by the number of potential spawning sites I was able to sample on the reservoir. Canyon Ferry has over 122 km of shoreline. Because walleye are able to use many different habitats for spawning, they possibly could use most of the shoreline. Thus, the 50 potential spawning sites I identified based on preferred habitat variables were not inclusive of all possible spawning areas. The validity of this study is based on the assumption that walleye were attracted to use the best spawning habitats available, which may not hold true.

Two of the sampling gears I used were not effective at capturing spawning walleye. Trap net and electrofishing catch rates of walleye were very low despite the known presence of several instrumented walleye on the spawning area. Based on these findings, it was unlikely either of these gear types was effective in sampling walleye at potential spawning sites. Electrofishing was probably even less effective at middle and lower reservoir strata sites because of clear water conditions. In water with good visibility, the approach of a boat often causes spawning walleye to vacate shoreline areas (personal observation in Holter Reservoir, Montana). The use of 76 mm bar mesh gill nets during spring 1996 proved to be effective in sampling spawning walleye. Walleye were readily caught in gill nets on the identified spawning area. Trap nets set on the spawning area in close proximity to gill nets captured significantly fewer walleye, substantiating their ineffectiveness.

Growth characteristics of Canyon Ferry walleye indirectly supported the findings of this study. Growth rates I determined for this population were very consistent. There were no significant differences evident in first-year growth of the different year classes (Chapter 2) that might have indicated the existence of different spawning stocks in Canyon Ferry. Based on surface water temperature patterns, walleye would presumably spawn three to four weeks later in the middle or lower part of the reservoir relative to the identified spawning area. Walleye produced in those areas would likely be smaller in size and demonstrate less first-year growth compared to those produced in the upper reservoir. This data suggested that walleye were not spawning in middle or lower reservoir habitats. It does not, however, rule out the possibility that other stocks may have spawned in the upper reservoir or the Missouri River upstream from Canyon Ferry.

An important benefit of this study was the evolution of an effective technique to sample a relatively low density walleye population on their spawning grounds. Trap nets and electrofishing were used to minimize the killing of non-targeted species (e.g., rainbow trout) as occurred with gill nets, but were generally ineffective. Trap nets captured very few walleye and were susceptible to being beached during high wind events. The ability to electrofish was greatly limited by safety considerations. Because the prevailing winds during springtime blew towards the spawning area, windy conditions prevented the use of this technique most evenings. The use of experimental-mesh gill nets on the spawning area during 1994 proved effective for sampling walleye, but also killed large numbers of rainbow trout (Chapter 2). Larger-sized mesh (76 mm bar mesh) gill nets used in 1996 minimized by-catch of rainbow trout but consistently captured walleye.

During spring 1997, MFWP used the results of this study to implement walleye population control measures in Canyon Ferry as mandated by the reservoir's fisheries management plan (MFWP 1992). Gill nets were set on the spawning area to remove adult walleye from the reservoir. Walleye not killed in the nets were transported and released into either Hauser or Holter reservoir. Seventy percent of the 303 walleye captured were removed and released into the downstream reservoirs. Ultimately, the control effort proved ineffective in slowing the expansion of the walleye population. However, there was evidence that the age structure of the spawning population was affected by these removal efforts. Walleye produced in 1990 dominated the spawning population from 1994 to 1997, accounting for over 40% of all spawners sampled each year (Figure 16). In spring 1998, this year class accounted for only 12% of the walleye sampled on the spawning area. There is no other apparent explanation for the large decline in this year class except for the walleye removal efforts completed in spring 1997.

The use of telemetry to locate individuals for the implementation of population control measures has not been widely reported for terrestrial nor aquatic species. Telemetry did facilitate the eradication of island populations of feral goats *Capra hircus* (Taylor and Katahira 1988; Keegan eta al. 1994). Because of their gregarious nature, telemeterized goats (called "Judas goats") led to the location of small, elusive bands, thus expediting their extermination.

The use of instrumented walleye to identify their spawning areas was analogous to the use of Judas goats. Results from this study were suggestive, but not conclusive, that telemeterized walleye did lead to the identification of the only spawning area in Canyon Ferry Reservoir. Recently, this technique has been applied in other areas. In Upper Priest Lake, Idaho, sonic telemetry was used to determine if there were identifiable lake trout *Salvelinus namaycush* spawning areas where adults could be removed from the population. Lake trout did not aggregate on a specific spawning site, which made control measures infeasible (Fredericks et al. 1999). Similar efforts were successfully applied in Yellowstone Lake, Wyoming, where illegally introduced lake trout threaten native Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri*. The use of sonic telemetry there has lead to the identification of lake trout spawning areas, which has resulted in the increased removal of significant numbers of large, predatory adults (D. Mahoney, U.S. Fish and Wildlife Service, personal communication).

LITERATURE CITED

Colby, P. J., R. E. McNichol, and R. A. Ryder. 1979. Synopsis of biological data on the walleye *Stizostedion v. vitreum* (Mitchill 1818). Food and Agriculture Organization (FAO) Fish. Synop. 119. Rome, Italy.

Eschmeyer, P. H. 1950. The life history of the walleye *Stizostedion vitreum vitreum* (Mitchill) in Michigan. Michigan Department of Conservation, Insitute for Fisheries Research Bulletin 3.

Fredericks, J., N. Horner, and E. Crawford. 1999. Population assessment and experimental control of lake trout in Upper Priest Lake, Idaho. *In* ODFW and NMFS. 1999. Management implications of co-occurring native and introduced fishes: proceedings of the workshop. October 27-28, 1998, Portland, Oregon.

Keegan, D. R., B. E. Coblentz, and C. S. Winchell. 1994. Feral goat eradication on San Clemente Island, California. Wildlife Society Bulletin 22:56-61.

Lere, M. 1991. Statewide fisheries investigations, survey and inventory of coldwater lakes, Canyon Ferry, Hauser, Holter reservoirs study. Montana Fish, Wildlife andParks. Job progress report F-46-R-4, II-f, Helena.

McMahon, T. E., J. W. Terrell, and P. C. Nelson. 1984. Habitat suitability information: walleye. U.S. Fish and Wildlife Service Report, FWS/OBS-82/10.56. Washington, D.C.

Montana Fish, Wildlife and Parks. 1992. Canyon Ferry Reservoir / Missouri River fisheries management plan, January 1993 - January 1998. Helena.

Priscu, J. C. 1987. Environmental factors regulating the dynamics of blue-green algal blooms in Canyon Ferry Reservoir, Montana. Report No. 159. Montana State University, Water Resources Center, Bozeman.

Rada, R. G. 1974. An investigation of the trophic status of Canyon Ferry Reservoir, Montana. Ph.D. Dissertation. Montana State University, Bozeman.

Rada, R. G., and J. C. Wright. 1979. Factors affecting nitrogen and phosphorus levels in Canyon Ferry Reservoir, Montana, and its effluent waters. Northwest Science 53:213-220.

Taylor, D., and L. Katahira. 1988. Radio telemetry as an aid in eradicating remnant feral goats. Wildlife Society Bulletin 16:297-299.

Wiley, R. W., and R. S. Wydoski. 1993. Management of undesirable fish species. Pages 335 - 354 *in* C. C. Kohler and W. A. Hubert, editors. Inland fisheries management in North America. American Fisheries Society, Bethesda, Maryland.

CHAPTER 5

GENERAL DISCUSSION

In just 11 years since Montana Fish, Wildlife and Parks (MFWP) personnel sampled their first walleye *Stizostedion vitreum* in Canyon Ferry Reservoir, walleye are firmly established and an important component of this popular fishery. Certain individuals have argued that walleye were present in the reservoir since impoundment occurred in 1954. Age, growth, and sampling data determined from this study indicated walleye were likely introduced into Canyon Ferry in the early 1980s, and have been reproducing in the reservoir since 1985. The production of a strong year class in 1990 precipitated the rapid development of this population in the later years of this study. Subsequent strong year classes produced in 1996 and 1997 resulted in higher standardized gill net catches of walleye in Canyon Ferry relative to those observed in other established walleye fisheries in Montana. Exponential population growth may be realized beginning in 2001, when females from the 1996 year class are fully recruited into the spawning population.

Yellow perch *Perca flavescens* and suckers *Catostomus* spp. were the primary forage of Canyon Ferry walleye. A decline in sucker abundance and shift in size distribution towards larger individuals probably resulted from walleye predation. The production of strong year classes of yellow perch in the later years of the study provided an abundant forage base for walleye and likely buffered predation of stocked rainbow trout *Oncorhynchus mykiss*. However, predation pressure on rainbow trout is likely to increase as the 1996 and 1997 year classes of walleye attain sizes in which they can efficiently prey on the stocked yearlings.

Ultrasonic telemetry revealed that Canyon Ferry walleye exhibit seasonal preferences for different parts of the reservoir. Walleye were generally located on the south end of the reservoir during summer months. The warm and turbid water conditions characteristic of that portion of the reservoir provided walleye with an optimal growing environment. During autumn, instrumented walleye occupied the north end of the reservoir. The reason for their directed and repeated annual migration to this part of the reservoir was not clearly evident, but was likely attributable to forage availability and preference for overwintering in deeper water. Telemeterized walleye exhibited complete fidelity to a single spawning area located on the southeast corner of the reservoir. Sampling of other suitable spawning habitats throughout the reservoir and growth characteristics of the population suggested that this may have been the only spawning area used by walleye in Canyon Ferry.

MFWP used the results of this study to implement population control measures by mechanically removing adult walleye from the spawning area in 1997. The subsequent production of a strong year class that spring and the likelihood of this expanding population to pioneer new spawning areas deemed these efforts futile.

Walleye numbers sharply increased in Hauser and Holter reservoirs in 1997 following record water discharge from Canyon Ferry. The system-wide increase of walleye was the impetus for MFWP to develop a new fisheries management plan for the entire reservoir / river complex. This recently adopted plan will attempt to manage the three-reservoir system as "a high quality, cost-effective, multi-species fishery with high levels of angler satisfaction" (MFWP 2000). Walleye were formally recognized as an established component of the Canyon Ferry fishery.

The sustainability of the popular rainbow trout and yellow perch fisheries in Canyon Ferry will be dependent upon limiting the expansion of the walleye population. The adoption of liberal angler harvest limits in the new management plan is an attempt to reduce the reproductive potential of the 1996 and 1997 year classes. Should the walleye population continue to expand in Canyon Ferry and negatively affect the other fisheries, the plan is adaptive in that it allows for the implementation of progressively more aggressive population control measures. These measures may include spear fishing, collection of eggs, mechanical removal of individuals, and the authorization for commercial harvest of walleye. The effectiveness of these measures in limiting a population with demonstrated high reproductive potential is questionable. To date, anglers have not been very successful in catching walleye in Canyon Ferry. Their excellent growth and condition resulting from an abundant forage base likely has reduced their catchability (Forney 1980; Straw 1994). Mechanical removal of adults proved ineffective in 1997. Future use of this technique would require a long-term commitment of personnel and resources.

Recent genetic analysis of this population brings into question its value as a potential walleye egg source. Billington (2000) reported that Canyon Ferry walleye are hybridized with sauger and recommended against using them as brood stock. The politicized nature of this issue will likely prevent the authorization of commercial fishing for walleye in the reservoir. Furthermore, size and condition of walleye at that time may diminish their value for commercial purposes.

Ultimately, natural processes such as flushing losses and variable recruitment will probably influence the expansion of this population more than adopted management actions. The continued comprehensive monitoring of this developing fishery is critical for understanding the limiting factors of this population and their potential applicability in maintaining a multi-species fishery in the reservoir complex. As the popularity of walleye fishing continues to grow in Montana and throughout the Northwest, this information will be invaluable to managers challenged with similar demands from their angler constituents.

LITERATURE CITED

Billington, N. 2000. Genetic analysis of an illegally introduced walleye population from Canyon Ferry Reservoir, Montana. Technical report of AQUAGENET to Montana Fish, Wildlife and Parks, Helena.

Forney, J. L. 1980. Evolution of a management strategy for the walleye in Oneida Lake, New York. New York Fish and Game Journal 27:105-141.

Montana Fish, Wildlife and Parks. 2000. Upper Missouri River reservoir fisheries management plan 2000-2009. Helena.

Straw, M. 1994. Advanced walleye prognostication. In Fisherman 19(6):44-50.

APPENDIX

SAMPLE SITE LOCATIONS FOR STANDARDIZED SAMPLING SERIES

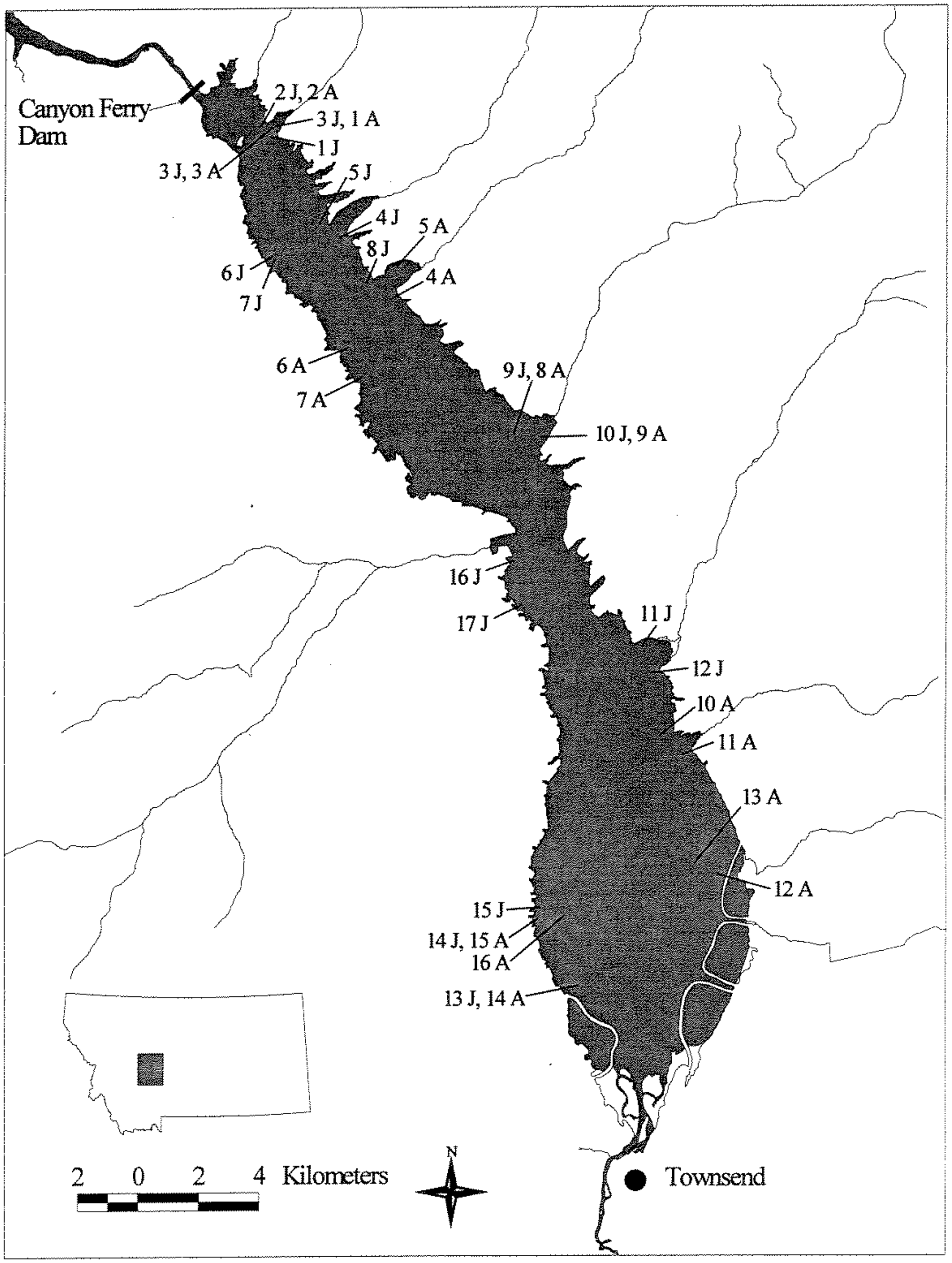


Figure 49. Net site locations for sinking net series, Canyon Ferry Reservoir, Montana. Letters 'J' and 'A' denote locations of sets in June and August, respectively.

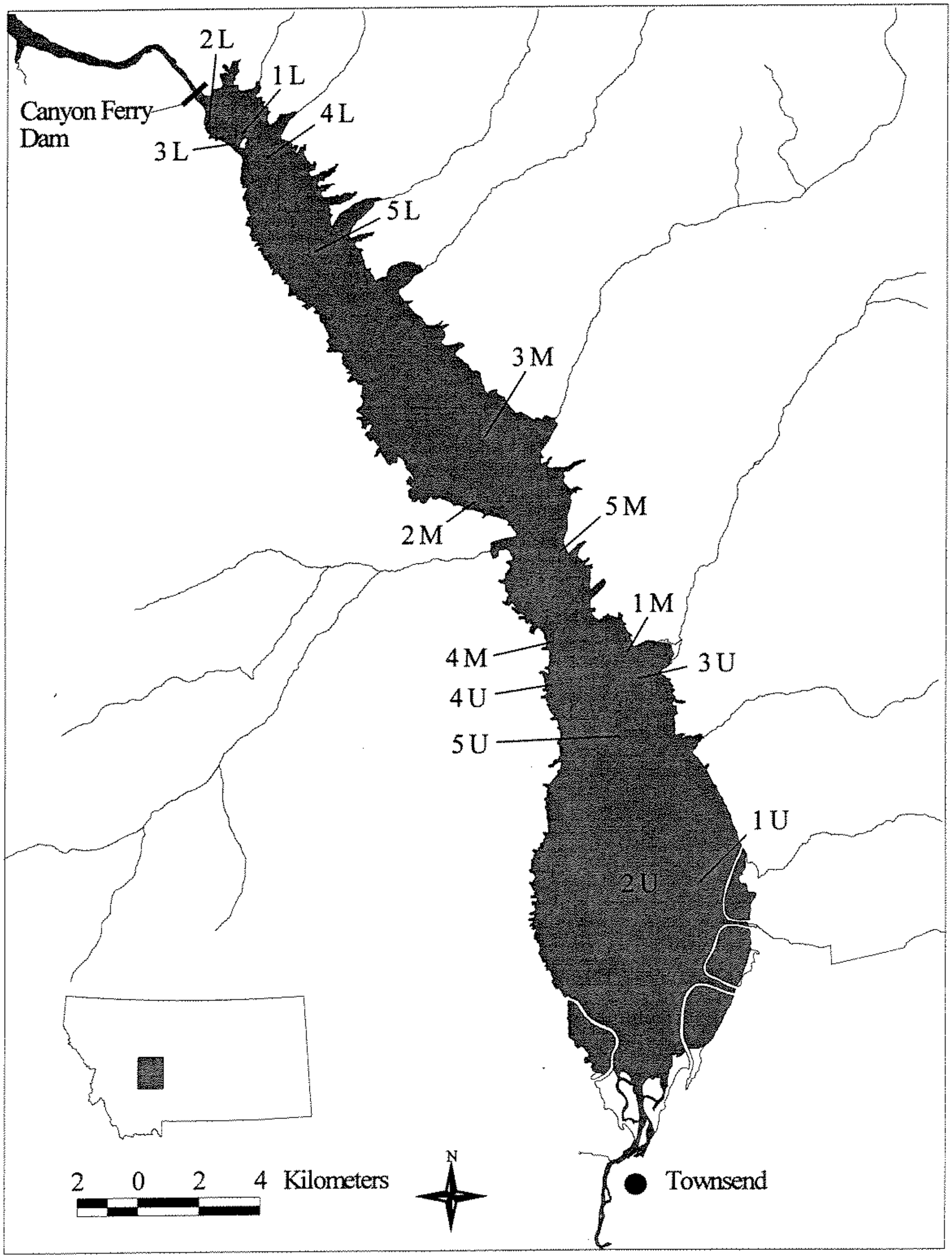


Figure 50. Spring net locations for floating net series, Canyon Ferry Reservoir, Montana. Letters 'U', 'M', and 'L' denote net locations in upper, middle, and lower portion of reservoir, respectively.

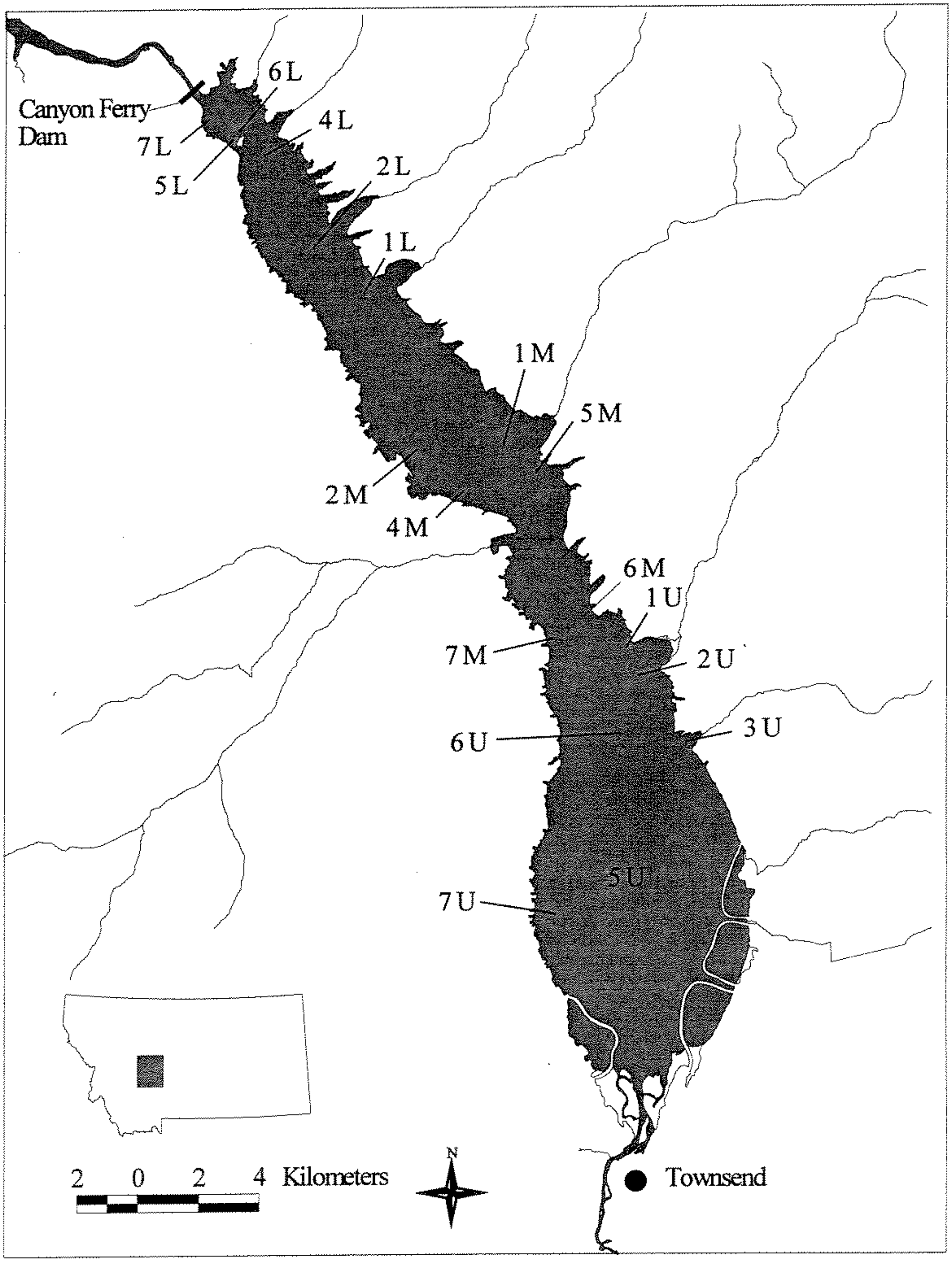


Figure 51. Autumn net locations for floating net series, Canyon Ferry Reservoir, Montana. Letters 'U', 'M', and 'L' denote net locations in upper, middle, and lower portion of reservoir, respectively.

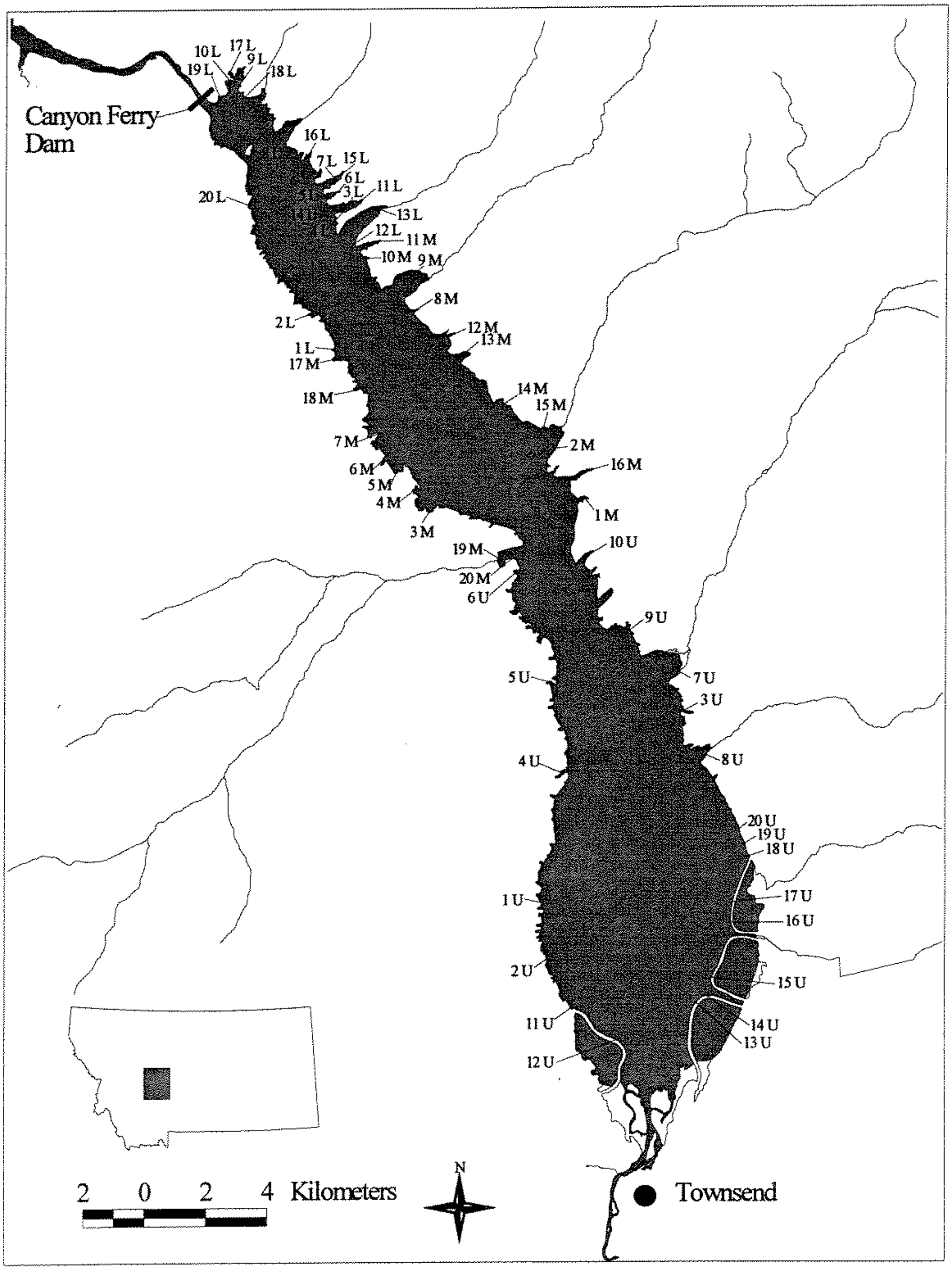


Figure 52. Sampling locations for beach seine series, Canyon Ferry Reservoir, Montana. Letters 'U', 'M', and 'L' denote seine locations in upper, middle, and lower portion of reservoir, respectively.

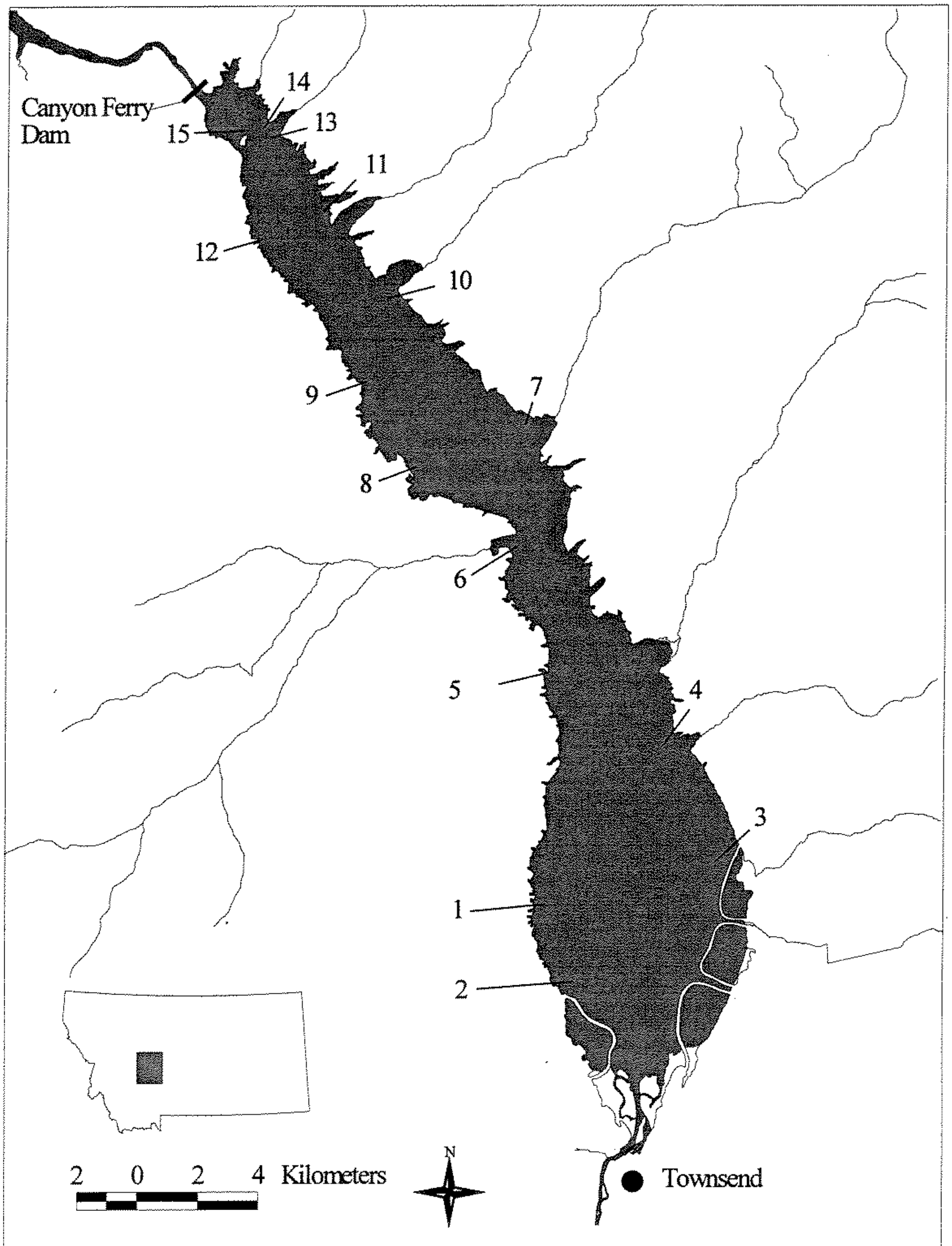


Figure 53. Net locations for walleye netting series, Canyon Ferry Reservoir, Montana.