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AN ASSESSMENT OF THE BIOLOGICAL EFFECTS OF POTENTIAL INTRODUCTION OF CISCO (*Coregonus artedii*) INTO TIBER RESERVOIR, MONTANA

by

David H. Bennett

and

Kristen M. Bennett

Department of Fish & Wildlife Resources
College of Forestry, Wildlife and Range Sciences
University of Idaho
Moscow, Idaho 83843

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To Whom It May Concern,

The enclosed report concerning the effects of a potential introduction of cisco (lake herring) into Tiber Reservoir was prepared by Dr. David Bennett from the University of Idaho on contract with our Department. As you may know, cisco were introduced into Fort Peck Reservoir in 1984 as forage for walleye and sauger. Cisco are now established in Fort Peck and improvements in the growth rates of predatory fishes have been observed. The apparent success of the Fort Peck introduction has sparked interest in establishing cisco in Tiber Reservoir to provide additional forage and compensate for recent declines of yellow perch, an important prey item for walleye and northern pike.

There is always some risk involved in species introductions due to the inability of scientists to accurately predict the behavior of biological systems. Introduction of naturally reproducing exotic organisms like cisco into large bodies of water are generally irreversible. Hence, the potential for unanticipated negative results must be recognized and considered carefully prior to any planned species introduction. The events that have occurred in Flathead Lake over the past decade are an example of a worst case scenario. Department efforts led to the establishment of a small shrimp (Mysis) in the lake approximately 10 years ago. The shrimp were established in hopes of improving the food supply and growth of kokanee salmon. Instead, the shrimp have been implicated in the collapse of the kokanee population, explosion of the lake trout population, and declines in bull trout; all of which were unanticipated and undesirable outcomes.

As you read the report, you will find that predicting results of fish introductions is extremely difficult because a large number of biological and environmental factors interact to regulate fish populations. There appear to be no published reports (other than on Fort Peck) concerning the effects of cisco introductions in lakes. This makes the job of predicting a probable outcome on Tiber more difficult, especially because Tiber and Fort Peck are not very similar to one another. Fort Peck is significantly more productive than Tiber and has about 2-3 times the density of zooplankton, which are the main food items for cisco and very young walleye. Also, the Fort Peck walleye population depends primarily on stocking of hatchery fish while Tiber depends entirely on natural reproduction.

The information presented in the Tiber cisco report suggests the probability of severe negative effects on other fish species is low. Chemical and physical conditions in the reservoir appear to be favorable for cisco. Zooplankton populations are low in Tiber, but are significantly higher than some lakes that support co-habiting populations of walleye and cisco. There appears to be low probability of significant dispersal of cisco to form "new" populations in upstream or downstream areas. Cisco appear to be a good choice compared to other forage species considered and they would probably improve the growth of northern pike and larger walleye if they became established in adequate numbers and mature at a relatively small body size.

However, it is impossible to predict population levels cisco would achieve in Tiber and the size at which cisco would mature. These factors have direct bearing on utilization by predators such as walleye. There is some chance that winter reservoir drawdowns would adversely affect cisco reproduction. Also, creel and fish population survey data indicate the Tiber walleye population is reasonably healthy, suggesting that forage enhancement may not be necessary at this time.

We have identified three options for addressing the cisco issue:

A) Introduce cisco into Tiber as soon as possible.
B) Do not ever introduce cisco into Tiber.
C) Defer cisco introduction until it is better justified.

Based on current knowledge and the opinions of our fisheries biologists, we recommend Option C (defer the introduction). Our data indicate a good walleye sport fishery exists in Tiber when compared to other walleye fisheries in Montana and elsewhere in North America. Recently introduced spottail shiners appear to be compensating for reduced perch numbers and seem to be providing adequate forage for walleye. Perch numbers may rebound in response to placement of spawning habitat structures and improved reservoir water level management. However, the size composition and species diversity of currently available forage fishes is relatively low and spottail numbers may decline as their population adjusts to this new environment.

We propose to closely monitor the Tiber walleye fishery by continuing annual monitoring of walleye and forage fish populations, and tracking the growth and condition of walleye. Periodic checks on angling success and size composition of the catch will also be conducted as time and manpower allow. The Department will support the recent Bureau of Reclamation request for higher minimum reservoir pool levels which could improve perch spawning success. We will continue to assist in installation of artificial perch spawning structures and monitor the dynamics of the Fort Peck Reservoir cisco population. The Department will also continue to review current scientific literature for information on walleye/cisco interactions and to identify potential new management techniques.

Our objective is to maintain flexibility and we will consider a number of factors in deciding on introduction of cisco into Tiber Reservoir. These are:

1) **Trends in walleye population size, growth, condition, and angling success.** Consistent downward trends (i.e. over a period of three or more years) in some or all of these measures may warrant action if they are determined to have been caused by inadequate forage.

2) **Status of forage fish populations.** Cisco introduction may be proposed if yellow perch numbers do not improve and densities of other forage fishes decline and remain significantly below current levels.

3) **New information.** Cisco will not be introduced if feasible new alternatives are identified or significant negative information on cisco are discovered in the interim. It is also possible cisco introduction would be recommended if there is little change in walleye or forage populations, yet further review indicates risks of adverse impacts are acceptably small relative to anticipated benefits to the reservoir fishery.

The Department would conduct environmental and public review as required by MEPA (Montana Environmental Policy Act) prior to any introduction.

We appreciate your interest in the fishery of Tiber Reservoir and encourage you to forward any comments you may have on the report or our recommendations to:

Steve Leathe, Region 4 Fisheries Manager
Montana Department of Fish, Wildlife & Parks
Box 6610
Great Falls, MT 59406 (phone 454-3441)

Thank you.

Sincerely,

Mike Aderhold

Mike Aderhold
Region 4 Supervisor

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INTRODUCTION

Tiber Reservoir, also known as Lake Elwell, is an impoundment created in 1955 by the U.S. Bureau of Reclamation on the Marias River, approximately 20 miles southwest of Chester, Montana. Tiber Reservoir is the largest water body in northcentral Montana, covering approximately 17,800 surface acres at conservation pool. Maximum depth and length are 182 feet and 25 miles, respectively. The reservoir provides flood control, irrigation, recreation, and municipal water supply to the surrounding area.

Fisheries management of Tiber Reservoir changed dramatically following impoundment. Initially, the Marias River upstream of Tiber Dam was treated with rotenone in 1954-55 to remove carp *Cyprinus carpio* and goldeye *Hiodon alosoides* from the river (Anonymous 1988). Goldeye were successfully removed but carp were not. Tiber Reservoir was then stocked with about 10 million fingerling rainbow trout *Oncorhynchus mykiss* during 1956 and 1957 and stocking continued through 1963. Trout fishing remained good until about 1959.

Cool/warmwater management was initiated in 1971 when walleye *Stizostedion vitreum* were stocked into Tiber Reservoir (Anonymous 1988). Walleye plants continued for an additional 3 years until a total of 5.1 million fry were planted. Yellow perch *Perca flavescens* and northern pike are believed to have entered Tiber Reservoir from Lake Frances, an upstream of source in 1963 and 1971, respectively.

The present sports fishery in Tiber Reservoir varies seasonally but consists of walleye, northern pike, yellow perch and rainbow trout. Walleye is the principal sport fish caught in the summer, whereas northern pike is the principal species caught in the winter. Walleye account for about 70% of the catch during the summer (Steve Leathe, Mt. Fish, Wildlife and Parks, Personal Communication). Both walleye and northern pike are large predators and their body size is related, in part, to the availability of forage. The yellow perch is a highly desirable sport and forage species but its abundance has been adversely affected recently by declining water levels that have decreased available spawning habitat. Spottail shiners *Notropis hudsonius* were introduced into Tiber Reservoir to supplement forage fish availability to predators (Hill and Gilge 1984). Spottails will spawn over gravel substrate and are less dependent upon vegetation for successful recruitment than yellow perch. Shiners are strictly oriented to the shoreline and therefore, are less available to open water predators such as walleye and northern pike. The purpose of this environmental assessment is to evaluate the need for additional forage species into Tiber Reservoir, assess the potential introduction of the cisco *Coregonus artedii* as a forage species and possible negative interactions from their introduction in Tiber Reservoir, Montana.

Specific objectives are as follows:

OBJECTIVES

1. *To review existing information on fish populations in Tiber Reservoir to determine the need for forage enhancement.*

2. *To conduct a literature review focusing on: a) cisco utilization by predators, particularly walleye; b) interactions between cisco and the dominant fish species in Tiber (walleye, northern pike, yellow perch, spottail shiner); and c) stability of cisco populations.*

3. *To evaluate potential negative effects of cisco introduction on the existing fish community in Tiber Reservoir and the Marias and Missouri River systems.*

4. *To review chemical and physical characteristics of Tiber Reservoir and compare with similar information for waters supporting healthy cisco populations to determine suitability for cisco.*

5. *To compare existing zooplankton population data from Tiber Reservoir with corresponding data (where available) from waters supporting healthy cisco populations to determine if an adequate food supply exists for cisco in Tiber Reservoir.*

6. *To evaluate results of the recent introduction of cisco in Fort Peck Reservoir, Montana and determine the applicability of such findings to Tiber Reservoir.*

7. *To consider alternative forage species for Tiber Reservoir.*

Life History of Cisco

Ciscoes are whitefishes commonly classified in the family Salmonidae, subfamily Coregoninae. Members of this subfamily are ubiquitous, morphologically variable and taxonomically difficult (Scott and Crossman 1973). Their morphological variability from system to system has contributed to difficulty in identification and misinformation about their ecology.

One species of cisco, the lake herring or tullibee (the inland form of cisco), has received much attention in the literature because of their importance as a forage and commercial species. Scott and Crossman (1973) indicated the history of whitefish and cisco fisheries in the Great Lakes is one of increasing exploitation and dwindling stocks.

Cisco (used throughout this paper) range from eastern Quebec to Hudson Bay, through the Great Lakes system and numerous inland lakes through Quebec, Ontario, Manitoba, Saskatchewan, and Alberta, north into the Northwest Territories and up to Great Bear Lake. The distribution of cisco was widely expanded by egg plants into many Minnesota lakes (Eddy and Underhill 1974).

Cisco are cold-water fish that will inhabit waters to >100 ft in depth. Summerkills are common in shallow lakes in Michigan, Wisconsin and Minnesota as a result of elevated water temperatures and low dissolved oxygen. They feed heavily on plankton, benthic organisms and will occasionally eat small fish.

Cisco spawn in late fall/early winter when water temperatures decrease to about 41^0 F. Embryos are broadcast over almost any bottom type, although most often on gravel substrate. Hatching usually occurs in April or May. Young fry generally hatch before ice-out and migrate to deeper water.

Cisco are also caught by anglers, especially in the spring, when they migrate into shore to feed (Eddy and Underhill 1974). Cisco are good fighters being caught on flies and spinners.

Walleye - Forage Fish Interactions

Walleye, being the principal sport fish in Tiber Reservoir, will be the major predator of concern in this environmental review. The amount of literature amassed on the life history and factors limiting walleye abundance is voluminous. Ebbers et al. (1988) compiled a walleye - sauger bibliography with 3116 citations. Many of these citations are related to walleye interactions with forage species. Also, nearly 30% of the papers from the Proceedings of a Coolwater Symposium (Kendall 1978) covered some aspect of the ecology and management of walleye. Colby et al. (1979) published a synopsis of biological data on walleye. Although these literature reviews are replete with technical references, subtle differences in the life cycle of walleye exist among systems. Questions always remain unanswered between predator and prey interactions in systems that may differ slightly in physico-chemical and biological habitat characteristics than those previously researched. Behavior differences of species among systems provide the unknowns in ultimately deciding upon the appropriate management decision. Even with this breadth of information a decision of whether to introduce a new species is often made without being 100% certain of the outcome. This literature review compiles information that will assist in making the decision whether or not cisco should be introduced into Tiber Reservoir.

Objective 1: Review of existing information on fish populations in Tiber Reservoir to determine the need for forage enhancement.

Results of the 1991 creel census conducted in Tiber Reservoir strongly indicated that walleye was the principal sport fish (Montana Department of Fish, Wildlife and Parks, Great Falls, unpublished data). Catch rates in Tiber Reservoir were 0.34 walleye/hour from April 7, 1991 to November 1, 1991, about five times higher than catch rates for northern pike during the same period. Also, these catch rates are considerably higher than those for walleye (0.223 walleye/hour) during 1990 in Fort Peck Reservoir, Montana (Wiedenheft 1991). Tagged walleye in Tiber Reservoir have apparently exhibited good survival as 18.4% of walleye tagged in 1988 cumulatively returned to the creel through 1990. Size of walleye in fall experimental gill nets has fluctuated with the highest percentage of fish >20 inches found in 1988 (Figure 1). A high percentage of walleye >20 inches also occurred from 1978-1981. The incidence of walleye >16.0-19.9 inches attained a low in 1988 and 1989 but increased in 1990 and 1991. The comparatively high catch rates, apparently high return of tagged walleye

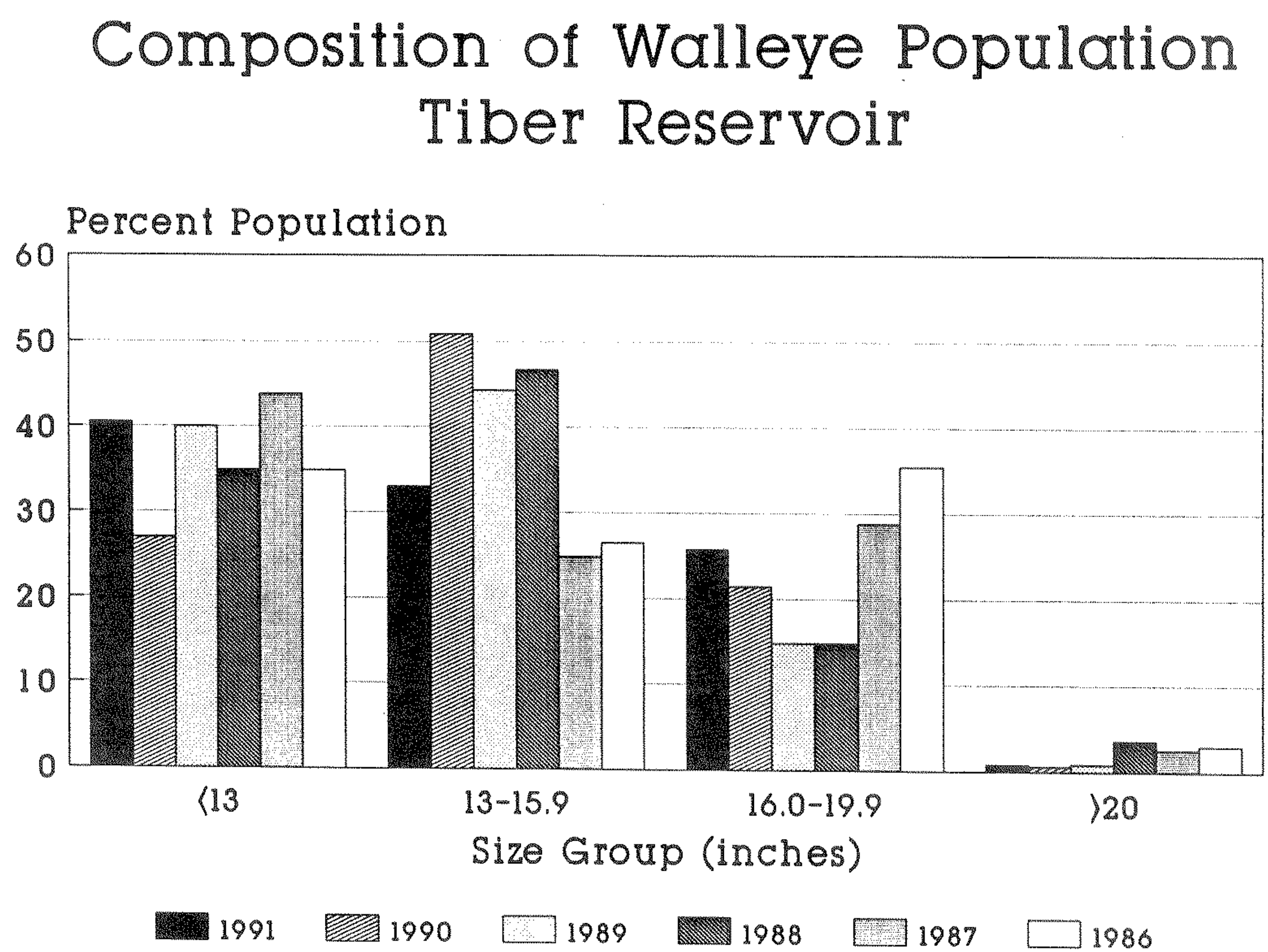


Figure 1. Comparison of changes in the size composition of the walleye population in Tiber Reservoir from 1986 to 1991.

and high incidence of large walleye suggest the present fishery is quite healthy.

Other indicators of good health of the walleye population associated with forage availability in Tiber Reservoir are the average length and relative weights of walleye. From 1973 to 1977, mean size of walleye sampled in experimental netting increased to a maximum of 18 inches. The average size decreased to slightly larger than 13 inches from 1977 to 1982 and then increased to approximately 14 inches from 1983 to 1991 (Figure 2). Growth increments, especially for walleye ages 1-2 from Tiber Reservoir, are better than those from Fort Peck Reservoir (Figure 3). Also, walleye in Tiber Reservoir are generally heavier than walleye from other Montana reservoirs (Figure 4). The relatively constant average length of 14 inches within the last 5 years and relatively high average weights by length group are two other indicators that forage availability may be currently adequate for walleye in Tiber Reservoir. Other data, especially forage fish abundance, however, suggest that forage enhancement is necessary.

Although Hill et al. (1990) reported that walleye and northern pike were primarily utilizing yellow perch for forage in Tiber Reservoir, yellow perch abundance has been declining (Figure 5). Continued decline of yellow perch abundance in Tiber Reservoir could adversely affect walleye and northern pike abundance, growth, condition, and ultimately average and maximum size. Number of yellow perch/seine haul in 1991 was about 10% of that in 1986 and about 15% of that from 1987 and 1988.

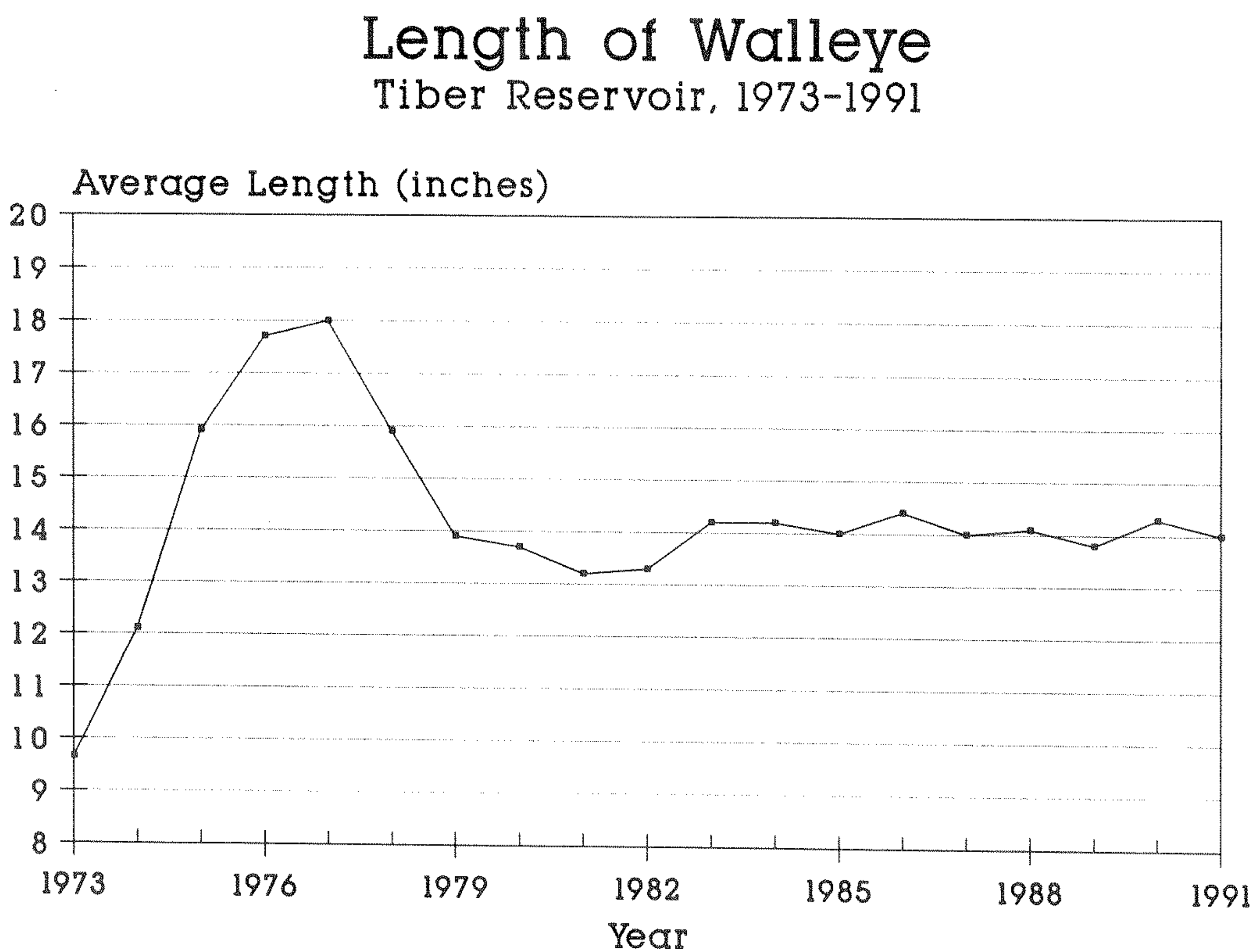


Figure 2. Changes in average length of walleye sampled by gill nets from Tiber Reservoir from 1973 to 1989 (Hill et al. 1990).

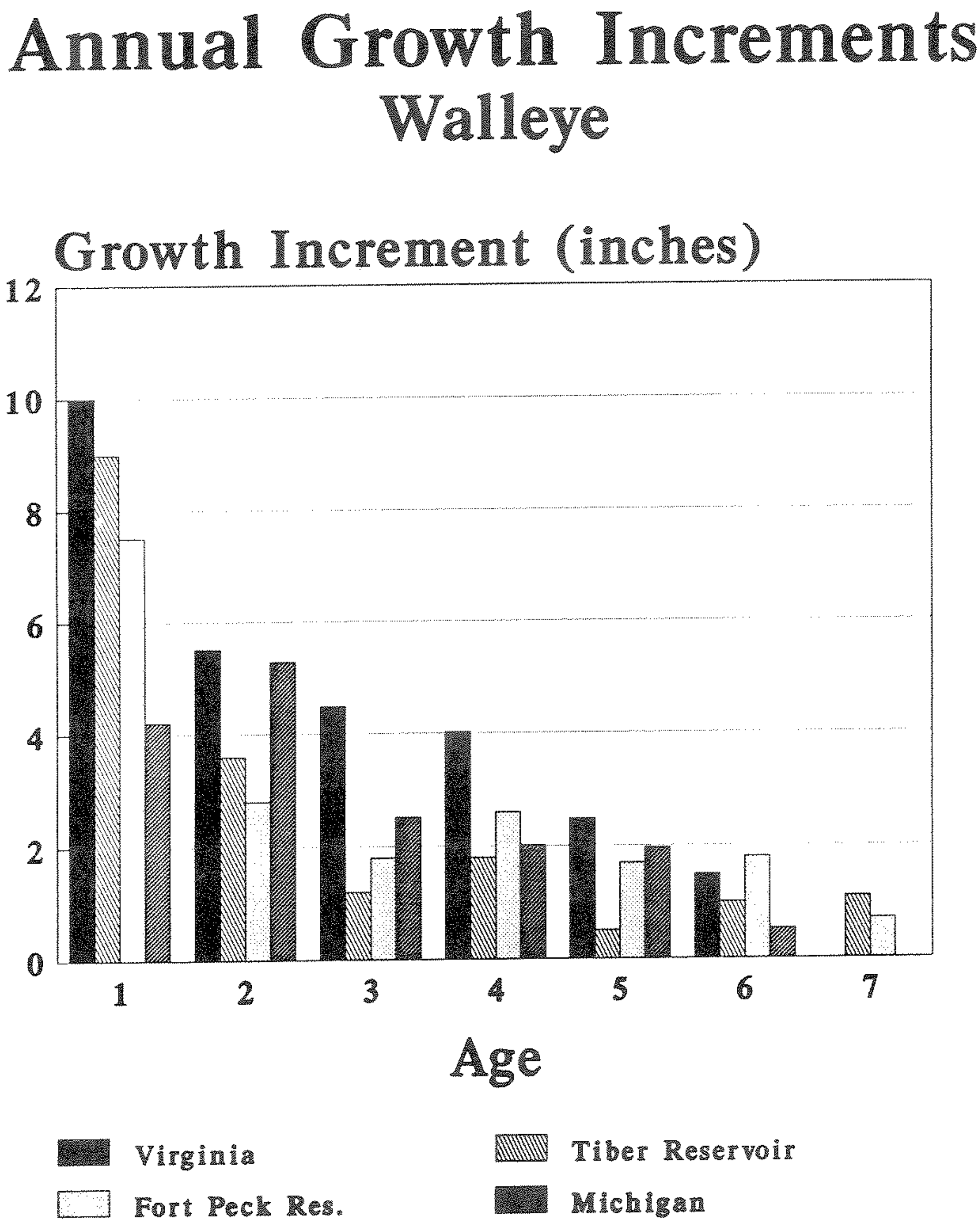


Figure 3. Growth increments of walleye from Tiber Reservoir (Montana Fish, Wildlife and Parks, Unpublished data), Fort Peck Reservoir (Wiedenheft 1991) compared with those from Michigan (Eschmeyer 1950) and Virginia (Roseberry 1951).

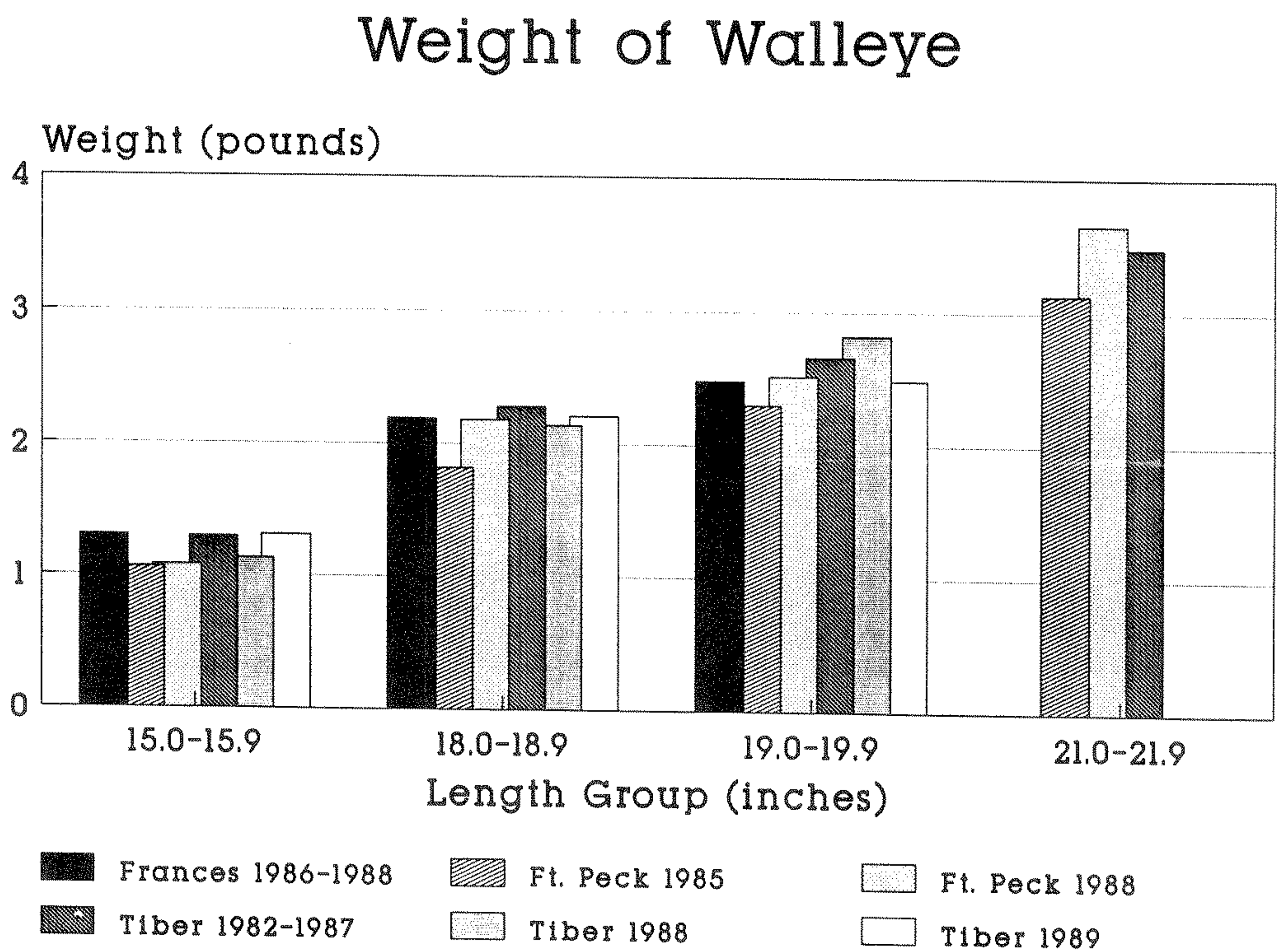


Figure 4. Comparison of mean weight by length group of walleye among three reservoirs in Montana (Unpublished data, Montana Fish, Wildlife and Parks, Great Falls).

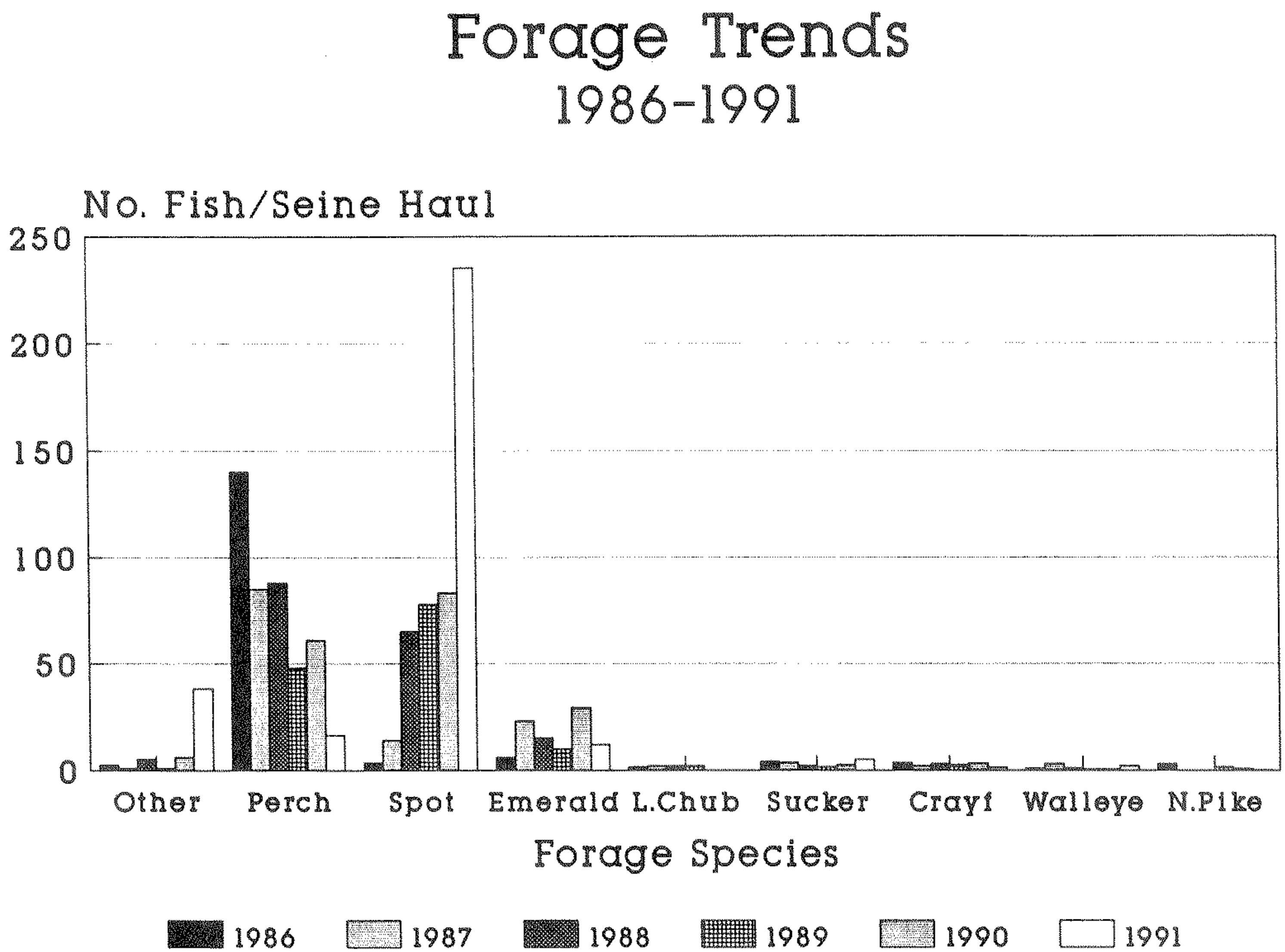


Figure 5. Trends in forage abundance from 1986-1991 in Tiber Reservoir (Hill et al. 1990; unpublished data from 1991, Montana Fish, Wildife and Parks, Great Falls).

Emerald shiner *Notropis atherinoides* abundance has fluctuated since 1986 and declined from a high in 1990. Abundance of spottails, however, increased by about 600% in 1991 from 1988-1990. Other species that could provide forage to walleye and northern pike, such as lake chub *Couesius plumbeus* and suckers *Catostomus* spp., also have been comparatively low since 1986.

In addition to prey abundance, prey size and behavioral distribution also contribute to producing a good walleye population. Parsons (1971) reported that walleye are a size selective predator. Colby et al. (1987) indicated that predators select a wide range of size of prey, although the maximum and average size of prey consumed increases with predator size. A large or intermediate sized prey item is currently lacking in Tiber Reservoir. Low numbers of yellow perch seem to limit the availability of prey for larger walleye. Substantial decreases in annual growth increments after age 2 (Figure 3) suggest that the abundance of larger prey in Tiber Reservoir may be adversely affecting growth of larger walleye. The most stable walleye fishery in Tiber Reservoir would undoubtedly be provided by a diverse forage base (Baughman 1990). An ideal forage species is one that does not get too large for the majority of the predators, has similar thermal preferences as the predator and does not attain excessively high forage density. Cisco appear to satisfy most of these requirements for walleye in Tiber Reservoir.

In spite of the low forage abundance, the present data weakly suggest the need for additional forage. The comparatively high incidence of large walleye in the catch, their relatively heavy average weights and relatively constant mean length provide limited support that additional forage in Tiber Reservoir is not necessary at the present time. However, the decrease in perch abundance and low abundance of other potential prey species used as forage suggest close monitoring of forage abundance is crucial. The quality of the walleye and northern pike fishery probably would be severely sacrificed, if yellow perch abundance declines further. Also, additional predation on weak year-classes of yellow perch could create a predator trap (Peterman and Gatto 1978), similar to what has occurred in Priest Lake, Idaho, between kokanee *O. nerka* and lake trout *Salvelinus namaycush* (Rieman and Lukens 1979). A predator trap could have highly negative affects on the predator crops and ultimately, the ability to establish prey fish in Tiber Reservoir. Present efforts to enhance in-water spawning habitat for yellow perch could be expanded although probably the best solution might be to negotiate for more stable water levels during the spawning season to flood shoreline vegetation which should result in stronger year-classes of yellow perch.

Objective 2: Literature review on cisco utilization by predators, particularly walleye, interactions between cisco and the dominant fish species in Tiber (walleye, northern pike, yellow perch, spottail shiner) and stability of cisco populations.

Population Stability

Several investigators have reported substantial fluctuations in the abundance of exploited populations of cisco in the Great Lakes (Scott 1951; Smith 1956). Hile (1936) reported similar fluctuations in abundance but to a lesser magnitude in smaller inland lakes. Clady (1967) found that the catch/hour for cisco in gill nets dropped from 6.3 to 0.17 over a 7 year period in Birch Lake, Michigan. Recruitment was nonexistent in one year which accounted for the low abundance although the cisco population recovered numerically. However, the age structure changed during the 25 year analysis. Hoff and Serns (1983) reported substantial reductions in mean lengths and weights at age of cisco in Pallette Lake, Wisconsin from 1946-1980 after reduced harvests. Selgeby (1982) reported that over-fishing in American waters of Lake Superior from 1936-1962 caused a collapse in the cisco population and, although a residual population remained, recovery did not occur.

Predation on cisco larvae can have deleterious effects on recruitment and stability. Loftus and Hulsman (1986) indicated that predation by rainbow smelt *Osmerus mordax* was impairing recruitment of whitefishes including cisco in Twelve Mile Lake, Ontario. Although smelt were established several years before recruitment was impacted, the combination of fishing pressure and predation are believed to have caused recruitment failures of cisco. Stewart et al. (1981) found that increased abundance of smelt and alewife in Lake Michigan resulted in decreased abundance of cisco. Eaton and Kardos (1972) reported that ciscoes were the principal prey species for both walleye and lake trout in the 1920's although rainbow smelt and alewife became primary prey species in the 1970's. Selgeby et al. (1978) reported that smelt predation on juvenile cisco in one region of Lake Superior accounted for decreased abundance of cisco although in another region, predation was nonexistent. Their conclusion was that predation by smelt on cisco larvae was not the major factor controlling or suppressing the cisco stocks in either region.

Other studies have attributed instability of cisco populations to human related activities. Rudstam (1984) compared the abundance of cisco in three Wisconsin lakes from the late 1920's and early 1930's with those in 1981 and 1982. In the 1930's, year-class strength was variable but not synchronized among lakes (Hile 1936). Hile (1936) concluded that year-class strength depended more on local conditions (i.e. spawning habitat, system productivity, etc.) than on weather, a conclusion later supported by Rudstam (1984). Differences in density between the 1920's and 30's and the early 1980's, based on a comparison of catch/effort data, were related to the establishment or increased abundance of predatory fishes including walleye and muskellunge *Esox masquinongy*. Cohen et al. (1987) reported that widest fluctuations in the abundance of cisco in Lake Superior were more related to commercial fishing than predators. Henderson and Fry (1987), using correlation analysis, found significant negative correlations ($P<0.05$) between cisco and yellow perch and cisco and white sucker *Catostomus commersoni* during 1949-1964 and 1964-1984, respectively. They also indicated that yield per recruit was related to lake levels and not to abundance of other species. Henderson et al. (1983) attributed the decrease in yellow perch to be more habitat related than to the abundance of other species including cisco.

Rudstam (1984) found that there is no evidence that non-exploited populations of cisco have a more stable population structure than exploited populations. Rudstam (1984) believed that intraspecific competition was one possible explanation for variations in year-class strength as both adults and juveniles feed on zooplankton. However, zooplankton were not investigated further to assess whether they were limiting or not, which is one essential component of competition.

Most of the evidence for cisco population collapse, however, is based on overfishing. For example, Selgeby (1982) indicated collapse of the cisco fishery in Wisconsin was almost unquestionably caused by over-exploitation as catch was higher than the productive capacity of stock. Christie (1972) indicated that deepwater ciscoes *Coregonus* spp. were progressively eliminated by over-fishing in Lake Ontario.

In summary, based on available information, the population abundance of cisco has fluctuated. Causes of fluctuations have been related to harvest and/or predation and intraspecific competition. Non-exploited populations also experience fluctuations in abundance but to a lesser extent. If cisco were introduced into Tiber Reservoir, the literature suggests that their population abundance would probably fluctuate from interspecific and intraspecific interactions.

Species Interactions

Anderson and Smith (1971) reported that commercial landings of cisco decreased significantly in Lake Superior from 1954 to 1966. Competition for food at the adult and larval stages with rainbow smelt was considered responsible for the decreased abundance of cisco.

Water temperature strongly influenced the seasonal distribution of perch and cisco. Engel and Magnuson (1976) reported that yellow perch were abundant inshore throughout the year in Pallette Lake, Wisconsin, whereas cisco were captured inshore only in spring and fall, and primarily at night. In spring, cisco congregated near the bottom shortly after ice-out in April, whereas in May, cisco were widely distributed from surface to bottom. In the summer, cisco became progressively concentrated in the lower metalimnion and upper hypolimnion. In the fall, cisco again became widely distributed from surface to bottom. Yellow perch were generally caught in the upper 19 feet (6m) of the water column in the spring, summer and fall. The vertical distribution of perch followed the rise in surface temperatures during the summer to its maximum of 74.3 and 74.5^0 F (23.5 and 23.7C). Cisco were distributed in cooler water as water temperatures at their median depth of capture never exceeded 54^0 F (12C). At no time, however, were the two species totally isolated from each other. Overlap between perch and cisco in the pelagic region in summer was restricted although spatial segregation disappeared at other times of the year. Further interaction was reduced by perch using the pelagic region during the day and cisco at night. Rudstam and Magnuson (1985) did not observe effects of interspecific segregation between yellow perch and cisco in their vertical distributions beyond that expected from differences in preferred temperatures. Segregation of yellow perch and cisco seemed to be more related to habitat than interspecific interactions.

Although cisco populations have fluctuated, they have also accounted for fluctuations in abundance of other species. Colby et al. (1987) reported reduced abundance of yellow perch following the introduction of cisco into Lake Opeongo, Ontario. Interspecific interactions with cisco reduced perch populations that were important food items of young lake trout. In several interior lakes in central Ontario, lake trout growth was reduced in lakes associated with higher abundance of cisco. Martin and Fry (1972) speculated that cisco may have adversely affected the abundance of other fishes in Lake Opeongo by preying directly on eggs or fry. Declines in perch and insect fauna may have been a result of this predation. Regardless, declines in the perch population also occurred with an increase in the cisco population. In other systems, Rudstam (1984) failed to find a difference in relative yellow perch numbers in several northeastern Wisconsin lakes from the late 1920's to 1981 due to the presence of cisco.

In summary, cisco interactions either directly or indirectly have resulted in fluctuations of abundance with other fishes. Fluctuations in cisco abundance have been more system and species specific than universally among systems. Competition between yellow perch and cisco seem to be more related to habitat conditions than interspecific interactions. If cisco were established in Tiber Reservoir, spatial segregation would probably occur and interactions with yellow perch would probably be minimal.

Utilization of Cisco by Predators

Evidence of the utilization of cisco as forage has been variable among systems. Johnson (1971) indicated that ciscoes *Coregonus* spp. were deep-water species associated with burbot *Lota lota* and lake trout. Cisco were important forage for predator species in Black Lake, northern Saskatchewan, especially burbot and lake trout. Scott and Crossman (1973) indicated that cisco are an important food item for lake trout but of lesser importance for northern pike, walleye, and yellow perch. Johnson (1971) reported that walleye utilization of cisco was low in Black Lake in northern Saskatchewan. Black Lake is a deep (max. 192 ft) lake which may have accounted for the 1% consumption (by volume); suckers and lake chubs were the principal food items of walleyes. Spatial segregation was suspected to account for the low utilization of cisco as most walleye were caught in <32 ft of water, whereas most cisco were sampled in water >96 ft deep. Walleye were considered shallow-water species associated with northern pike. However, Colby (1990) believed that cisco can be an important forage fish for good walleye growth in colder waters like Tiber Reservoir.

The cisco has been considered an important prey species for northern pike and walleye in coolwater fish communities (Ryder and Kerr 1978; Colby et al. 1979). Rawson (1956) reported that cisco were the principal food item of walleye in Lac La Ronge, Saskatchewan. Jacobson (1991) reported that the presence of cisco, in part, were significantly related to the number of trophy northern pike in Minnesota waters. Also in Minnesota, Schupp (1991) indicated that high abundance of small cisco and yellow perch were associated with increased size of northern pike. Hile (1936) suggested that walleye was a significant predator on cisco in northeastern lakes in Wisconsin. Dobie (1966) found that small cisco were eaten by walleyes in Lake Vermillion, Minnesota, but cisco were not ordinarily available to walleye when feeding inshore. When water temperatures cooled, cisco migrated into the shallows but still composed <25% of the food of walleye. Some cisco were consumed in a cool summer when water temperatures were mostly below 70^0 F, but cisco still comprised a small part of the diet of walleye. Dobie (1966) concluded that cisco are not closely associated with walleye to be a significant forage fish for walleye in Lake Vermillion; cisco were neither important in Lake Vermillion as a predator on young walleye nor as forage for adult walleye. Johnson (1969) found that young-of-the-year (YOY) perch were the most important forage fish for all ages of walleye, including YOY walleye in several northern Minnesota lakes. Cisco were abundant in the lakes and their inshore distribution overlapped that of walleye in mid-summer although they were not eaten by walleye.

Predator utilization in some systems has been high and predator "quality" has improved as a result of cisco introductions. For example, Martin and Fry (1972) reported that cisco introduced into Lake Opeongo resulted in faster growing and more fecund lake trout which were in better body condition. Matuszek et al. (1990) examined long-term changes in lake trout in Lake Opeongo. Faster growth rates of lake trout were not maintained as a result of the cisco introduction because of intraspecific competition although maximum sustainable yield increased nearly three fold. Growth rates of the non-piscivorous ages-1 and 2 lake trout actually decreased because of increased survival of younger ages of lake trout and decreased abundance of insects as a result of interspecific competition with cisco. Similarly, Anderson (1990) indicated that cisco may have adversely affected lake trout by reducing their growth rates and subjecting them to additional years of mortality before they recruit to the fishery. Changes in growth rates of lake trout are of less concern in Tiber Reservoir because lake trout are a minor species.

Evidence for adverse interactions of cisco affecting recruitment of walleye seem highly limited and almost system specific. Chen (1990) found no evidence that cisco prey on walleye fry in Lake Diefenbaker, Saskatchewan. Derksen (1990) believed that cisco would not adversely affect walleye in Tiber Reservoir based on his broad experiences in Manitoba contingent upon an adequate zooplankton crop for cisco.

Anderson (1990) reported that Minnesota has numerous examples of lakes that have good walleye recruitment with cisco present, although they have not studied effects of introduction of cisco on recruitment of a pre-existing walleye population. Coevolution of walleye and cisco probably has minimized adverse interactions. However, Klingbiel (1990) suggested that cisco may have an adverse effect on walleye reproduction in Tiber Reservoir as walleye reproduction is low in numerous Wisconsin lakes where cisco are abundant although data are not available to corroborate his hypothesis. Schneider (1990) believed that cisco should improve growth of walleye and northern pike in Tiber Reservoir although cisco may prey on some walleye fry.

The growth rate of cisco ultimately controls how long they will be available as prey for walleye. Colby et al. (1987), based on available literature, indicated that 5.1 inches (fork length) was the upper size limit for cisco that walleye could consume. When they applied this 5.1 inch maximum to data from various Ontario lakes, they found that cisco would be available as prey for 0.3-4.3 years. In Lac des Mille Lacs, Ontario, yellow perch were numerically the most important food item in the diet of small and intermediate sized walleye, whereas 13.8-15.7 inch walleye consumed mainly cisco. Limited cisco vulnerability to walleye was attributed to the high rapid growth rates by cisco (Colby et al. 1987).

In Fort Peck Reservoir, Montana, cisco were purposely introduced as forage for walleye and other fish predators. Walleye fed extensively on cisco during 1990 (Wiedenheft 1991). Stomachs of walleye sampled during the Governor's Cup fishing tournament indicated that cisco was the dominant food item (Bill Wiedenheft, Montana Department of Fish, Wildlife and Parks, unpublished data). Mullins (1991) reported that cisco was the most common prey species consumed by walleye in Fort Peck in 1990. Mullins reported that growth rates, condition factors and average weights in Fort Peck have increased in walleye, northern pike, sauger *S. canadense*, and lake trout as a result of the introduction of cisco.

In summary, the literature indicates that cisco can be an important forage species for several predator species that occur in Tiber Reservoir. Cisco are consumed intensively by walleye in coolwater systems but less in coldwater systems where other species contribute to walleye food items. Rapid growth of cisco can make them less available to predation.

Objective 3: Negative effects of cisco introduction on the existing fish community in Tiber Reservoir and the Marias and Missouri River systems.

The potential for negative effects on the existing fish and other communities exists with any introduction especially into more nutrient poor systems (Li and Moyle 1981). Theoretically, potential negative effects exist in Tiber Reservoir and in the Marias and Missouri River systems with the introduction of cisco. Only limited information exists on cisco habitation in riverine systems (Dymond 1933). Although cisco have a diverse food base, plankton are commonly associated food items. Plankton abundance is generally low in moving waters and the high turbidity in the Marias River, upstream of Tiber Reservoir (Stober 1963), adversely affects plankton abundance. The Marias River, is a relatively small, shallow river and the potential for permanent establishment of cisco is probably minimal. In addition to the turbidity, the Marias River has a sedimented bottom which is not highly productive for suitable cisco food production. Also, being predominantly a lacustrine species, cisco are not known to inhabit turbid waters. Water temperatures in the Marias River in late spring, summer and early fall probably exceed the preferred temperature of cisco. Engel and Magnuson (1976) reported that cisco were distributed in waters $<54^0$ F. Stober (1963) reported a maximum water temperature of 84^0 F in 1961 in the Marias River upstream of Tiber Reservoir. Mean maximum temperature from June 5 to September 20, 1961 averaged 71^0 F, considerably higher than the reported preferred temperature ($<54^0$ F) of cisco. Therefore, long-term cisco habitation in the Marias River upstream of Tiber Reservoir is probably unlikely.

Hypolimnetic releases downstream of Tiber Dam, provide suitable temperatures in the tailwater to support salmonid and coregonid fishes. However, based on Stober's (1963) research from 1961, temperatures increase substantially into the 70's and 80's^0 F in June, July and August about 5-10 miles downstream of the dam. Therefore, thermal conditions appear more suitable for cisco in the tailwater of Tiber Dam than upstream but quickly become excessively warm during the summer. Again, food habits and various adaptations suggest that cisco are predominantly a lacustrine species and are unlikely to permanently reside in the Marias River downstream of Tiber Dam.

Cisco currently have the opportunity to migrate upstream in the Missouri River from Fort Peck Reservoir, which makes concern for potential habitation in the Missouri River downstream of Tiber Reservoir of lesser significance. No cisco were collected during a survey on the Missouri River from Morony Dam to Fort Benton (Binkley et al. 1991), although 1992 fish collections by Montana Fish, Wildlife and Parks personnel in this same section revealed cisco were present (Steve Leathe, Montana Fish, Wildlife and Parks, Personal Communication). Wiedenheft indicated that cisco have been found in the Missouri River about 50 mile upstream from Fort Peck Reservoir (Montana Fish, Wildlife and Parks, Personal Communication). Also, cisco have been stocked as forage for salmonids into Lake Oahe, South Dakota, the second mainstem Missouri River impoundment downstream of Fort Peck Reservoir, because cisco would eventually migrate there (Gary Marrone, South Dakota Game, Fish & Parks, Personal Communication).

The published literature is not clear but suggests that cisco generally would not inhabit large rivers for prolonged periods. Scott and Crossman (1973) indicated that cisco were basically a plankton feeder in keeping with its pelagic habit although others (Brown and Moffett 1942; Dobie 1966; Janssen 1978) have indicated opportunistic feeding. Colby and Brooke (1970) indicated that when incubating cisco embryos were rolled by high flow rates, the incidence of abnormalities was high which suggests that cisco may not spawn in a riverine system. Bernatchez and Dodson (1985) compared energy requirements of cisco and other salmonids. Energy requirements of cisco were considerably higher than those for rainbow, brook *Salvelinus fontinalis* and lake trout for a given swimming speed which suggests that survival in a riverine system would be energetically inefficient. Also, more than 50% of the cisco tested to fatigue died within 48 hours following the tests. However, Dymond (1933) reported that cisco may occur in large rivers in the Hudson Bay region and further west.

In summary, based on bioenergetics and reproductive requirements, cisco probably would not permanently inhabit the riverine sections of the Marias and Missouri rivers although temporary habitation will occur. The presence of cisco in the Missouri River should alleviate most of the concern for cisco migrations upstream and/or downstream, if they were stocked into Tiber Reservoir.

Objective 4: Chemical and physical characteristics of Tiber Reservoir compared to waters supporting healthy cisco populations.

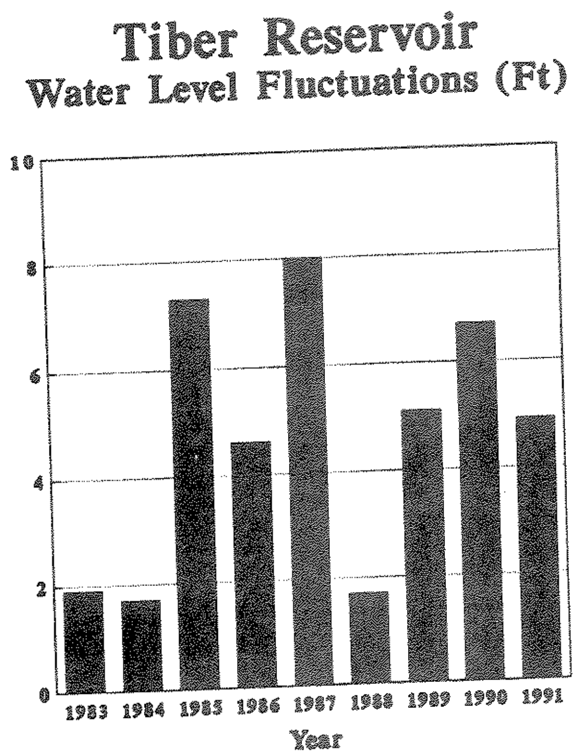
Chemical and physical habitat characteristics greatly influence the abundance and distribution of cisco in lacustrine systems. Smith (1972) indicated that cisco are generally associated with deep, cold lakes although cisco survive in Oneida Lake, New York, where temperatures exceed 75^{o}F at 6 feet and >68^{o}F in the deeper (>28 feet) areas of the lake for extended periods during the summer. Dissolved oxygen concentrations of <3 PPM have occurred in Oneida Lake at depths >28 feet during periods of weak circulation. Die-offs occur there each summer, primarily in age-2 and older cisco. Colby and Brooke (1969) reported a cisco die-off associated with low dissolved oxygen in Halfmoon Lake, Michigan. The "cisco layer", defined by water temperatures <68^{o}F and >3 PPM, completely disappeared in the lake by early August. They reported an ultimate upper lethal temperature of 75 to 79^{o}F (24-26C) for young and adult ciscoes. Frey (1955) indicated that the physiological limits for cisco were <68^{o}F and >3 mg/l. Edsall and Colby (1970) determined the upper lethal temperature of young cisco at 78.8^{o}F.

Water quality characteristics of Tiber Reservoir are similar to numerous other systems that successfully support cisco in the northcentral United States and Canada. Stober (1963) reported that water surface temperatures near Tiber Dam reached a high temperature at the surface of near 70^{o}F in 1960 and 1961 and decreased to the mid-40's and 50's^{o}F at and below the thermocline near 50 feet. Based on these temperatures, and the temperature preference data for cisco (Engel and Magnuson 1976), thermal conditions in Tiber Reservoir would be highly suitable for cisco.

Water temperature and dissolved oxygen can also have deleterious affects on embryo incubation. Brooke and Colby (1980) found that the percent normal fry hatched during incubation decreased at oxygen levels <4 mg/l. Colby and Brooke (1970) found that the optimum temperature for incubation of cisco was 35.6-46.4^{o}F whereas, water temperatures at 50^{o}F resulted in abnormalities. Based on available dissolved oxygen and water temperature data for Tiber Reservoir, incubation success of cisco would not be adversely affected.

Other physical habitat features such as water level fluctuations can affect cisco production. Gaboury and Patalas (1984) reported that weak year-classes of cisco were produced during years with a marked winter or spring drawdown and conversely, strong year-classes were produced during years with little drawdown. They found an inverse relationship between fall to spring drawdown and year-class strength of cisco. Drawdowns adversely affected the spawning success of cisco by dewatering spawning areas and desiccating embryos. A marked overwinter drawdown of 7.2 ft reduced cisco hatching success apparently by dewatering the spawning areas and desiccating the embryos. Pritchard (1931) found that cisco spawned in November and December in 7-10 ft of water in the bay of Quinte, Lake Ontario. Hatching occurred in late April and early May. John and Hasler (1956) found that cisco spawned at depths between 6 and 16 feet at night in Lake Mendota, Wisconsin. However, Dryer and Beil (1964) reported cisco spawning at 120 feet and deeper where embryos drifted to the bottom after release. Brown and Moffett (1942) reported cisco spawned in mid-December in Swains Lake, Michigan coinciding with the formation of a thin layer of surface ice, the same time when Tiber Reservoir has experienced decreasing water levels.

Water level fluctuations in Tiber Reservoir could adversely affect cisco recruitment. Water levels in Tiber Reservoir in 1990 increased from November to December from 2983 to 2986 ft (Anonymous 1990), about 3 ft followed by declining water levels of about 5 ft to 2981 ft elevation in February, March and April (Figure 6). However, these fluctuations



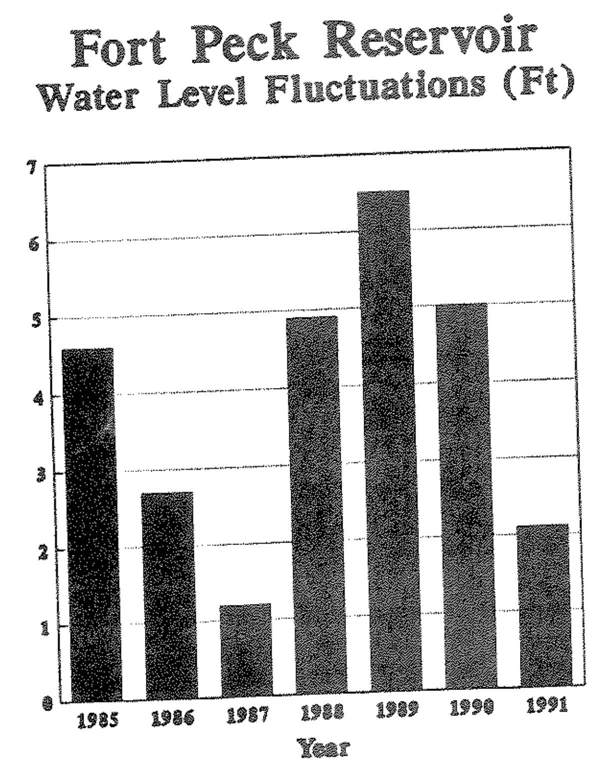


Figure 6. Water levels recorded at Tiber Dam, Marias River, near Chester, Montana and at Fort Peck Reservoir.

are similar to those in Fort Peck Reservoir that is currently supporting a self-sustaining cisco population. Water level fluctuations in Tiber Reservoir are similar to those Gaboury and Patalas (1984) considered in Cross Lake, Manitoba to adversely affect spawning success of cisco. Colby (1990) believed that the physical habitat in Tiber Reservoir would be suitable for cisco although the water level fluctuations might prevent them from becoming overly abundant. Based on the timing of cisco spawning presented by Brown and Moffett (1942) and Pritchard (1931), water level fluctuations in Tiber Reservoir could reduce cisco spawning success.

In summary, the physical and chemical habitat characteristics in Tiber Reservoir are generally suitable for cisco although decreasing water levels throughout the incubation period could adversely affect their recruitment. This interpretation is largely supported by the literature although similar fluctuations in Fort Peck Reservoir have not apparently impacted cisco recruitment to date.

Objective 5: Comparison of zooplankton data from Tiber Reservoir with waters supporting healthy cisco populations.

Limited zooplankton data are available on systems with cisco and walleye although numerous studies have reported on dietary zooplankton. Engel (1976) reported that copepods (chiefly *Cyclops bicuspidatus thomasi*), dominant food items of cisco, reached peak abundance in May-June and October-November in Pallette Lake, Wisconsin. Cladocerans (primarily *Chydorus sphaericus*, *Bosmina longirostris*, and *Daphnia* spp.), the most abundant food items of cisco, peaked in abundance between June and August. Smaller zooplankton comprised 89% by number of food items eaten by cisco. Carter and Goudie (1986) found relationships between turbidity and planktivorous fish, including cisco, affected the vertical distribution of two copepods, *Limnocalanus macrurus* and *Senecella calanoides*. Densities of these copepods ranged from 0.05 to 2.0/l. Janssen (1978) compared feeding behavior of alewives and cisco and found that cisco are specialized particulate feeders and can easily feed on or near the bottom and even will take buried prey. Brown and Moffett (1942) found that in Swains Lake, Michigan, cisco consumed in descending order of abundance *Daphnia*, *Diaptomus*, some rotifers and miscellaneous items including *Corethra* larvae, and dragonfly nymphs. Janssen (1978) reported that cisco fed by a variety of methods including particulate feeding, darting, gulping, near-bottom feeding, bottom-surface feeding, and bottom subsurface feeding. He did not find cisco to be filter feeders. Although Janssen (1978) tried to feed cisco *Daphnia* at densities to 93,000/ft^2 ($10^6/m^3$), cisco never exhibited filter feeding.

He concluded that filtering was not in their feeding repertoire. Dobie (1966) reported that cisco consumed mainly microcrustaceans (45.7% by volume), insects (32.4%) and fish (0.1%). Dryer and Beil (1964) found that crustacea comprised about 83% occurrence in cisco stomachs; copepoda (71%), cladocera (36%), amphipoda (2%), mysidacea (19%), fish eggs (23%), diatoms (12%), and chlorophyta (24%) also were found. Johnson (1971) reported that plankton were the predominant food item of cisco in Black Lake, northern Saskatchewan.

Data on changes in the zooplankton community following the introduction of cisco are limited. Mullins (1991) found a shift in the zooplankton community to smaller types in Fort Peck Reservoir following the introduction of cisco. He indicated that the zooplankton density in Fort Peck Reservoir has not decreased since 1983, although the zooplankton community composition has changed. *Daphnia pulex* and *D. schodleri* were highly abundant in 1983-1985 prior to the introduction of cisco (Figure 7). These two larger cladocerans were not present during 1989 and 1990 and probably disappeared as a result of the selective grazing by cisco. These shifts in size of the zooplankton community are commonly associated with planktivory (Brooks and Dodson 1965) and have been used as an index of fish abundance and balance among fishes (Mills and Schiavone 1982).

One concern for the introduction of cisco into Tiber Reservoir is the availability of zooplankton for larval walleye. Priegel (1970) reported that walleye fry initiate feeding prior to complete absorption of the yolk sac. Initially, food was zooplankton consisting of copepods

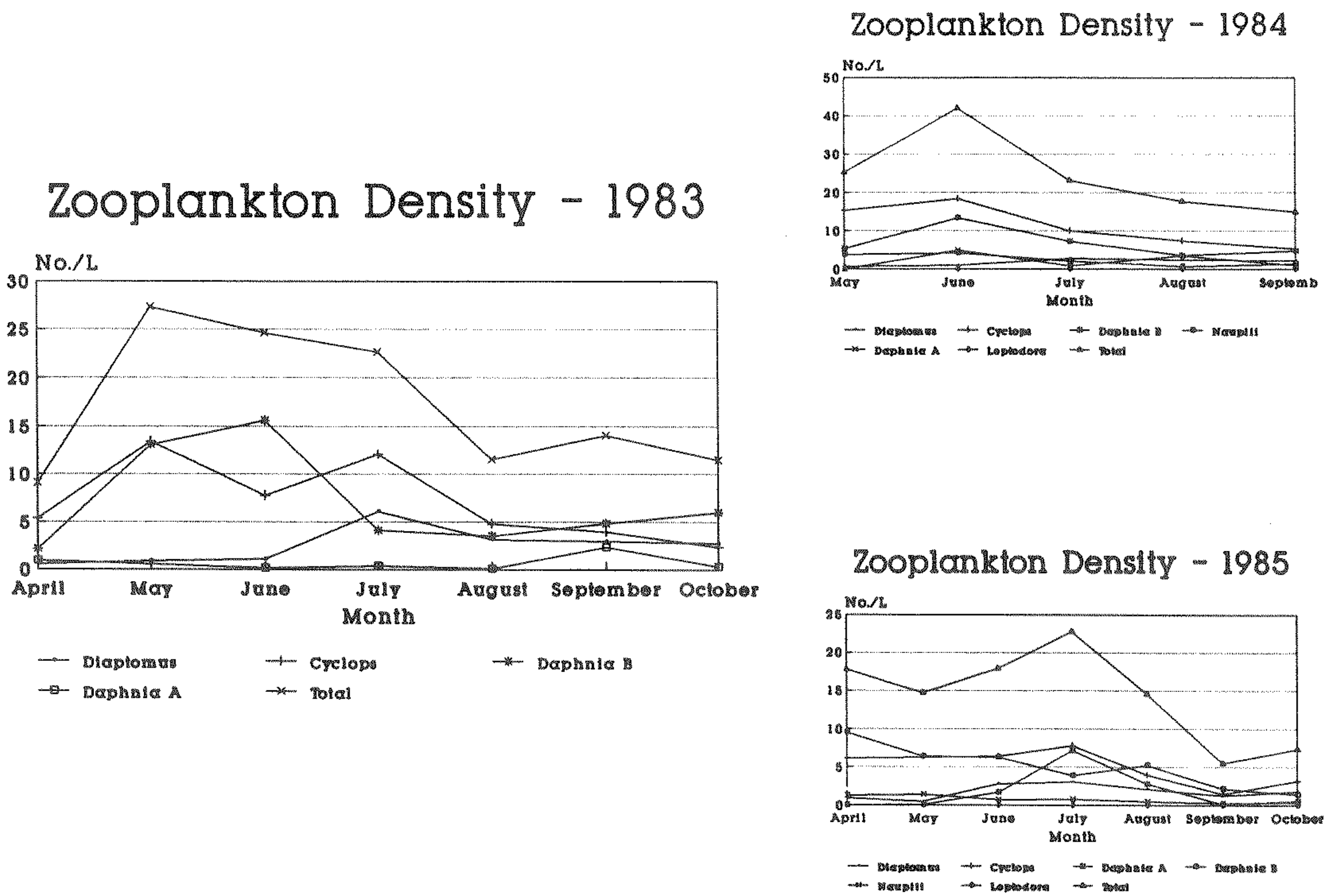


Figure 7. Zooplankton community composition and abundance prior to the establishment of cisco in Fort Peck Reservoir, Montana (Unpublished data, Montana Fish, Wildlife and Parks).

(*Diaptomus*, *Cyclops*) and cladocerans (*Leptodora*, *Daphnia*). Chironomid larvae and larval fishes (sucker and yellow perch and trout perch [*Percopsis omiscomaycus*]) also were consumed. Bulkley et al. (1976) found walleye fry first contained food at a length of 0.35 inches (9mm) even though many fry retained yolk material. Cladocera and Copepoda were the major (95%) taxa of food organisms ingested. *Diaptomus* and *Cyclops* were the principal copepods eaten. Although walleye grew to 1.25 inches (32mm) after the fourth week, few fish were eaten. Maloney and Johnson (1956) examined food habits of young-of-year walleye >1.2 inches in length and found that fish constituted about 99% of the food items. Houde (1968) found that copepods were the most common food item in the stomachs of 0.3 to 0.5 inch (7.0 - 12.0mm) walleye from Oneida Lake. Larger fry, 0.5 to 1.0 inch (13 - 24.0mm), contained copepods, cladocera, and fish. He too found that walleye fed before complete absorption of the yolk sac. Smith and Pycha (1960) reported that yellow perch were an important dietary item after walleye attained a length of 2 inches (51mm). Hohn (1966) found that diatoms were dominant food items in 0.4 inch (<9mm) walleye, whereas larger walleye consumed zooplankton and diatoms. Spykerman (1974) indicated that walleye began feeding at 0.4 inch (9mm) and Cladocera and Copepoda comprised 94.6% of the total number of food organisms consumed in Clear Lake, Iowa.

Introductions of prey fish that are more effective planktivores than predators have not always resulted in enhanced predator populations. Interspecific competition for identical food items during the larval feeding stage with predators has been implicated. For example, the introduction of threadfin shad *Dorosoma petenense* in California increased growth rates of largemouth bass *Micropterus salmoides* although interspecific competition for food had an adverse impact on bass survival and recruitment (von Geldern and Mitchell 1975). The overall effect of the shad introduction was a reduction in catch rates of largemouth bass. In Ohio, DeVries et al. (1991) showed that intense feeding on zooplankton by threadfin shad reduced survival in bluegill *Lepomis macrochirus* that contributed to poor growth on largemouth bass. They concluded that the shad could in some systems in some years negatively affect growth and recruitment of the very species they were meant to enhance.

The zooplankton community in Tiber Reservoir in 1990 was dominated by copepods although *Diaptomus*, a copepod, and *Daphnia* dominated in 1991 (Figure 8). Densities were similar between years and higher than those reported by Carter and Goudie (1986) for several Canadian lakes that have abundant cisco populations. The wide diversity of food items and feeding behavior that cisco manifest would enable them to successfully colonize Tiber Reservoir.

The potential for adverse interspecific interactions between cisco and larval walleye in Tiber Reservoir appear minimal. Johnston (In Preparation) found no relationship between survival of walleye fry and food at densities of 40-150/L in culture ponds. Therefore, the minimum density of zooplankton required by walleye fry for successful feeding is <40 zooplankters/liter. The density of zooplankton in several North American lakes that support both walleye and cisco are generally similar

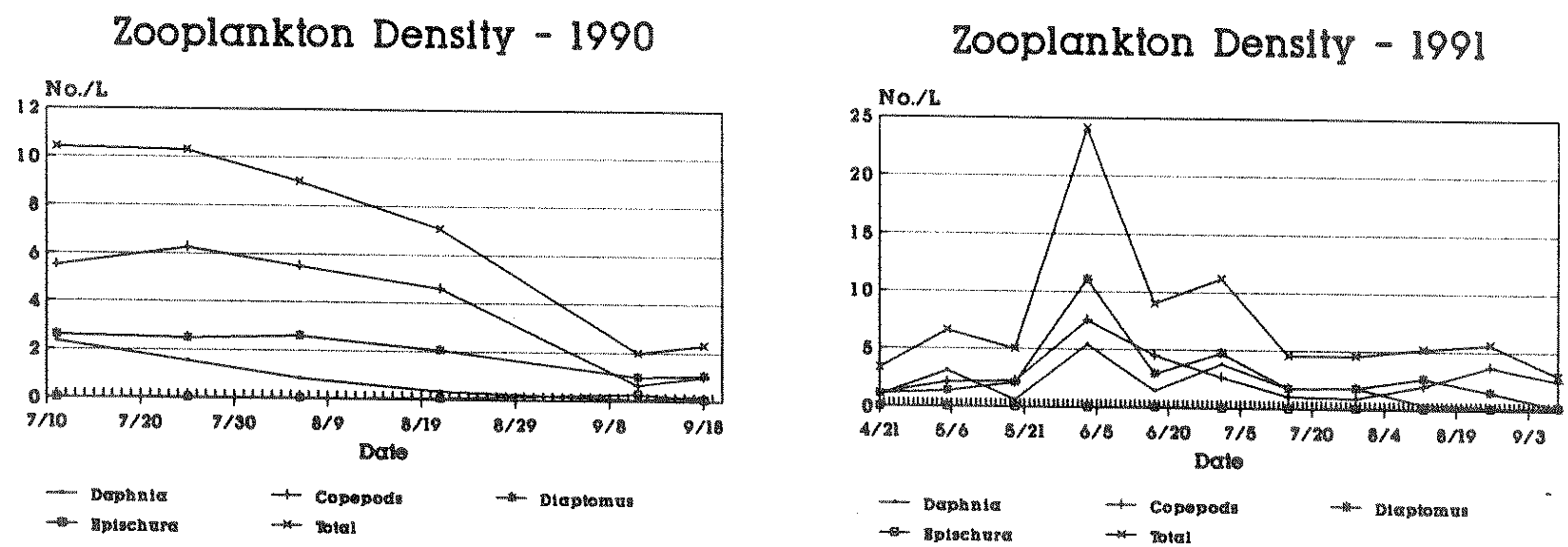


Figure 8. Zooplankton community composition and abundance in Tiber Reservoir for 1990 and 1991.

or lower than those in Tiber Reservoir. The lowest plankton density where both walleye and cisco coexist (Johnson 1975) is 1.3/L in Great Bear Lake, Northwest Territories, Canada (Patalas 1975). Rawson (1951) also reported cisco and walleye plus several other species were inhabiting Great Slave Lake, Canada where zooplankton densities averaged 2.8/L (Patalas 1975). In both of these extremely oligotrophic lake systems, walleye were found in the shallower, warmer parts of the lakes and in some small adjacent lakes. Rawson (1960) reported that cisco and walleye were found in Raindeer Lake, Saskatchewan, and Patalas (1975) reported an average plankton density of about 50/L for this lake. Also, average zooplankton density may not be the necessary metric to assess an adequate food supply for larval walleye. Since zooplankton are known to be contiguously distributed, the variance associated with zooplankton abundance may be a more meaningful metric to evaluate the adequacy of zooplankton to support both cisco and walleye (Tom Johnston, Department of Fisheries and Oceans, Winnipeg, Canada). Although the precise zooplankton density and/or variance required for walleye and cisco to coexist without adverse effects to walleye survival is not known, walleye and cisco are apparently coinhabiting systems that have lower plankton densities than are found in Tiber Reservoir. These data suggest that the zooplankton community is probably adequate to support feeding of larval walleye and cisco in Tiber Reservoir and that the potential for adverse interactions is slight.

Objective 6: Results of the introduction of cisco in Fort Peck Reservoir, Montana

Cisco were introduced into Fort Peck Reservoir in 1984 (Wiedenheft 1987) and results have been largely positive. High numbers of cisco collected in 1986 indicated that stocking and/or natural reproduction were highly successful in 1986. Wiedenheft (1988) indicated that cisco were present in walleye and northern pike stomachs in 1987. Wiedenheft (1991) reported that starting in 1987 the percent composition of walleye >3, >4, and >5 pounds has increased dramatically (Figure 9). Also, condition factors have generally increased for all size groups of walleye, especially larger walleye (>20 inches).

Mullins (1991) data corroborates information presented by Wiedenheft (1987, 1989, 1991). Mullins (1991) showed that a number of changes have occurred in the fish and zooplankton communities in Fort Peck Reservoir following the introduction of cisco. One of the key changes that has occurred in walleye from Fort Peck Reservoir is that condition factors have increased for all size classes of walleye, especially the larger size classes (Figure 9). The abundance of larger walleye has generally increased from attaining the lowest abundance in the early 1980's, prior to the introduction of cisco.

As indicated earlier, one concern is the possible adverse interaction of cisco with predator survival and recruitment (Objective 5). The abundance of juvenile walleye/seine haul in Fort Peck Reservoir has fluctuated with peaks in abundance occurring in 1982, 1985, and 1989 (Figure 10). Northern pike abundance has also fluctuated but peaks

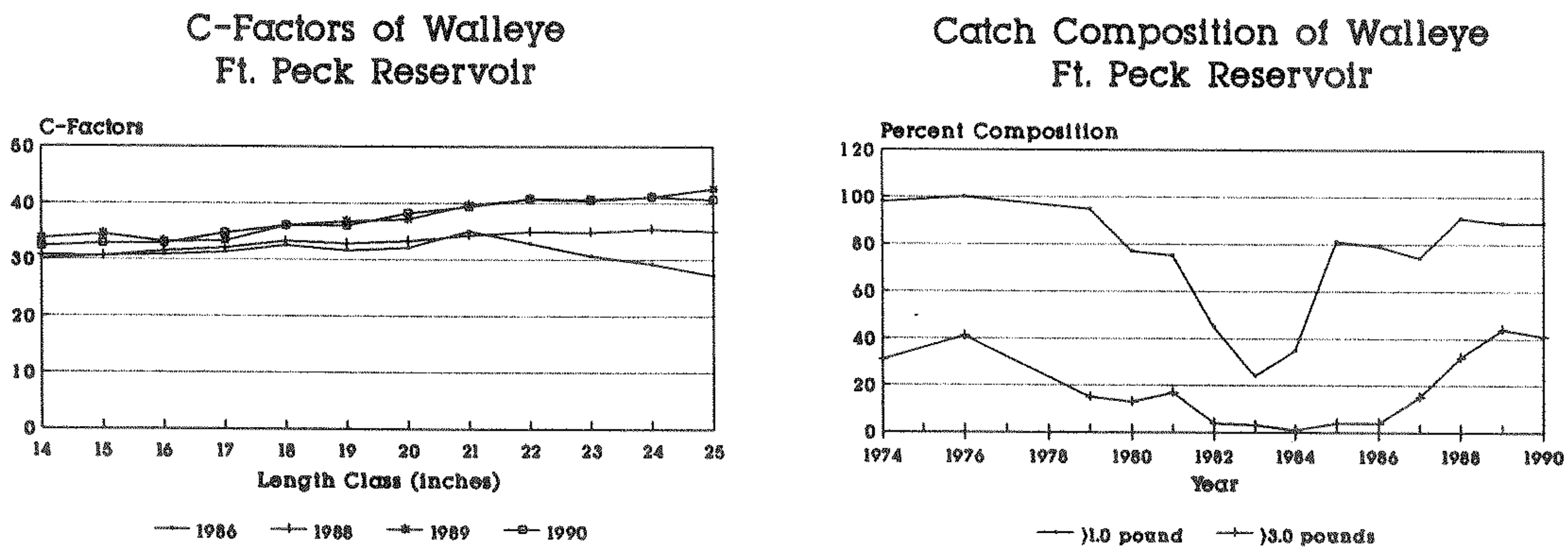


Figure 9. Changes in condition factors and catch composition of walleye through time in Fort Peck Reservoir (Wiedenheft 1991; Mullins 1991).

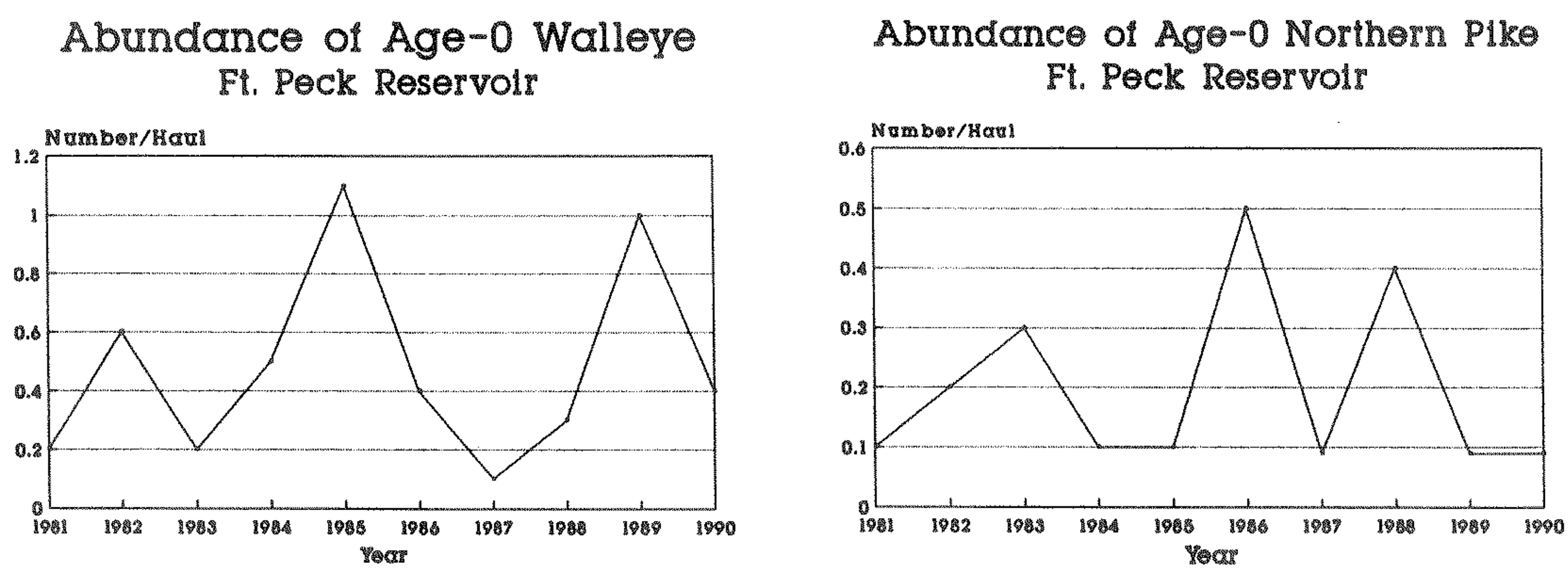


Figure 10. Changes in the abundance of young-of-year walleye and northern pike based on beach seine samples from Fort Peck Reservoir.

occurred in 1983, 1986, and 1988, years preceding or following walleye abundance (Figure 10). Although walleye fry are annually stocked into Fort Peck Reservoir, the abundance of juvenile walleye later in the year could provide an indicator of survival and year-class strength. Year-class success of walleye has frequently been determined by survival during the fry to fingerling stage (Johnson 1969; Priegel 1970), regardless of whether fry were stocked or naturally reproduced (Bulkley et al. 1976). Forney (1976) reported that cannibalism in Oneida Lake, New York, limited walleye population size. Decreased number of fingerlings was attributed to predation by older walleye. No information exists on factors limiting year-class strength in Fort Peck Reservoir. The number of walleye collected/gill net set generally remained stable or increased from 1986 through 1989 (Figure 11). No data exist that implicate an adverse cisco - walleye interaction in Fort Peck Reservoir.

Growth increments of walleye from Fort Peck are similar to those for walleye from other geographical areas. The largest increment is at age-1, is lower but relatively constant at ages-2 through 6, and then declines at age-7 (Figure 3). Growth increments of walleye in Fort Peck are either better than or intermediate to those from Michigan and Virginia.

Population characteristics of cisco has changed rapidly following their introduction into Fort Peck. Condition factors of cisco have

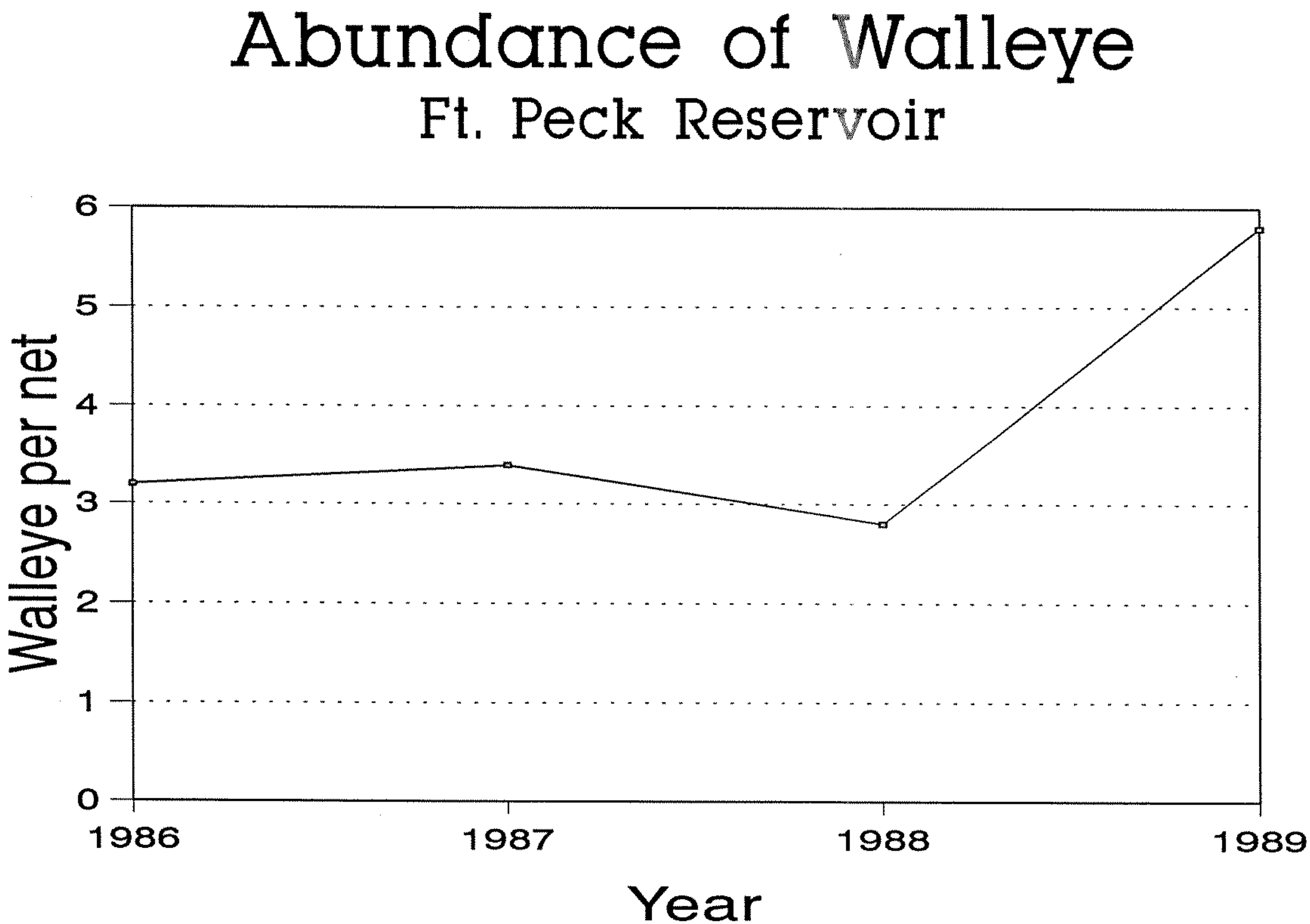


Figure 11. Abundance of walleye in Fort Peck Reservoir based on gill net samples (Wiedenheft 1991).

declined in the 7 years following their introduction and now generally range from poor to average based on criteria of the Minnesota Department of Natural Resources (Carlander 1969). Wiedenheft (1991) found that the mean condition factor of cisco ranged from 0.77 to 0.98 in 1990 compared to a mean in 1985 at 1.3. Wiedenheft (1990) reported that the length of age-1 cisco declined from 12.1 to 7.9 inches and size of age-2 cisco decreased from 15.7 to 10.7 inches from 1985 and 1986 to 1989. However, a similar decline in size has been observed in Lake Opeongo, Ontario (Matuszek et al. 1990). Mullins (1991) suggested that growth rates of cisco may have stabilized in Fort Peck Reservoir as their growth was similar between 1989 and 1990. Back-calculated lengths at age for cisco in Fort Peck Reservoir were similar or slightly larger than those reported by Carlander (1969) for other cisco populations. Associated with the decline in size, fecundity has decreased in cisco from 1985 to 1990 by about 2.5 times. All of these biological changes in cisco are probably density dependent responses associated with the cisco population reaching carrying capacity. Although the cisco population is bringing about changes in the aquatic communities of Fort Peck Reservoir, none of the changes have been unexpected. These changes may have been beneficial in that reduced body size of cisco may make them more available as prey for a longer period than soon after the introduction (Mullins 1991).

To date in Fort Peck Reservoir, effects of the cisco introduction have been largely beneficial. Growth and condition of predators are good and the quality of the fishery is good. Survival of younger age classes of predators is not known but appears good. At present, reduced survival of younger age classes of predators that has occurred in other systems associated with numerous planned or unplanned introductions has not been found in Fort Peck Reservoir (Objective 5). Although the data for the first 8 years suggest that predators have benefited from the introduction of cisco in Fort Peck Reservoir, nothing is known about the effects of cisco on other fishes in the community.

Objective 7: Alternative forage species for Tiber Reservoir.

Several other species of fish could be used as alternative forage in lieu of cisco. Flathead chub *Hybopsis gracilis*, emerald shiner, golden shiner *Notemigonus crysoleucas*, alewife, goldeye, Bonneville cisco *Prosopium gemmiferum*, gizzard shad *D. cepedianum* and redside shiner *Richardsonius balteatus* are species that have successfully provided forage in waters of Montana and other neighboring states. Both emerald shiner and flathead chub already occur in Tiber Reservoir although neither are relatively abundant (Figure 5). Goldeye were originally removed from Tiber Reservoir by rotenone treatment in 1954-55 and probably would not be considered for reintroduction. Goldeye apparently afford little forage benefit to walleye based on data from Wiedenheft (1987, 1988, 1991) and Mullins (1991). Golden shiners appear to be more dependent on aquatic vegetation than yellow perch for successful reproduction (Scott and Crossman 1973). Fluctuating water levels in Tiber Reservoir would adversely affect them as have the perch. Redside shiners are not found in the Missouri River drainage and thus would also require a major introduction and range extension. Redside shiners also require vegetation to prosper; they were the most abundant species in Dworshak Reservoir, Idaho prior to water level fluctuations (Ball and Pettit 1974) but following extreme (>150ft) annual fluctuations, both aquatic vegetation and redside shiners disappeared (Tim Cochnauer, Idaho Department of Fish and Game, Personal Communication).

Gizzard shad are another potential forage species for consideration. Although gizzard shad have been generally associated with warmer waters, Wyoming has successfully used them for forage in some of their North Platte River reservoirs. Baughman (1983) reported on the success of stocking gizzard shad into Wyoming reservoirs. They were first introduced in 1978 and annually through 1982. Gizzard shad have provided excellent forage for trout and walleye. Walleye recruitment increased dramatically during the years of gizzard shad introduction. Little over-winter survival has been observed which provides a check on over-population.

Three states have attempted to introduce Bonneville cisco. Utah has tried to introduce Bonneville cisco into Flaming Gorge Reservoir, however, the introduction was not successful (Birdsey 1991). Frantz and Cordone (1967) reported that Bonneville cisco were introduced for forage into Lake Tahoe, Nevada and California. This introduction was apparently successful and Bonneville cisco are now established in the lake (Simpson and Wallace 1978). Bonneville cisco are probably more an obligate planktivore than cisco but similar concerns exist about introductions of this species. Unlike cisco (lake herring), Bonneville cisco have not coevolved with walleye and hence do not have a "performance record" in the literature of interaction with walleye.

DISEASE CONSIDERATIONS

Disease and parasite infestations must be a major consideration with any species introduction. Cisco may become heavily infested with numerous parasites. Watson and Dick (1979) reported that cisco hosted 18 species of parasites; they also found differences in parasite abundance among sections of the same lake. Of greatest concern is the larval stage of the tapeworm (plerocercoid) *Triaenophorus crassus*. The larvae form large yellow cysts on the dorsal musculature of an infested fish which are obnoxious to observe but harmless to man when the fish flesh is properly cooked (Eddy and Underhill 1974). When cisco feed on cestode-vectoring copepods, they become infected. The life cycle is completed when the intermediate host, the cisco, is eaten by a predatory species such as walleye and northern pike. Importation of subadult/adult cisco could infest Tiber Reservoir with this parasite that has not been reported there or in Fort Peck (Peterson 1990). If stocking of cisco were implemented, eggs could be safely imported without threat of infestation. However, extreme caution would be necessary not to have contaminated water or gear.

SUMMARY COMMENTS

The need for forage enhancement in Tiber Reservoir seems to be directly related to yellow perch abundance. If perch numbers were to increase as a result of habitat and/or water management, the need for an introduction of cisco is questionable. However, without adequate forage, the quality of the walleye and pike fisheries would probably decline. Based on the literature, the selection of cisco as a possible forage species to introduce into Tiber Reservoir seems to be an excellent choice. Published data indicate that under most conditions walleye utilize cisco as forage and potential negative effects on walleye are uncommon.

The current need for additional forage species to sustain the existing walleye population in Tiber Reservoir is not clearly apparent by the available data. Natural recruitment and growth of walleye in Tiber Reservoir currently appears adequate to maintain a good quality fishery. Weights of walleye <20 inches long and annual growth increments are better or similar to those from Fort Peck Reservoir where cisco were introduced as a forage fish in 1984. The literature generally supports the fact that cisco are a good forage species for lake trout, walleye, and northern pike, all predator species of interest in Tiber Reservoir.

Cisco have improved population characteristics of similar predators in Fort Peck Reservoir. The literature suggests that population changes might occur in the lake trout population as a result of possible interspecific competitive interactions between cisco and younger age classes of lake trout although lake trout is considered a minor species in Tiber Reservoir. Yield and both the size at age and condition of northern pike, lake trout and walleye, especially larger walleye, would probably increase if cisco were introduced and established an abundant population. The potential for "natural" upstream and/or downstream unwanted distribution of cisco does not seem to be significant in Tiber Reservoir. The probability of long-term cisco habitation in the Marias River, upstream and downstream of the dam, is low. Their migration into the Missouri River is a lesser concern because they have already migrated both upstream and downstream from Fort Peck Reservoir. The current and potential for more widespread distribution makes the selection of cisco a good one.

The literature cautions against any species introductions, especially those made into systems with low productivity similar to Tiber Reservoir. The potential for negative impacts from the introduction of cisco based on habitat conditions in Tiber Reservoir and available data seems low although caution for any introduction seems highly warranted. Walleye-cisco interactions have been observed in numerous states and provinces and have largely been positive. The concern for decreased survival and reduced walleye recruitment in Tiber Reservoir appear unfounded. The potential for adverse interactions between cisco and walleye larvae for a zooplankton food base appears minimal. Walleye and cisco are coexisting in numerous systems that have considerably lower plankton densities than Tiber Reservoir. Plankton data are limited for Tiber Reservoir but available data suggests that if cisco were introduced into Tiber Reservoir, the zooplankton community may change but not to the extent that the change would be detrimental to the walleye population. For example, several larger zooplankton species disappeared from Fort Peck Reservoir following establishment of cisco. Fort Peck is much larger, more fertile, and has a considerably longer retention time than Tiber Reservoir. Long retention time greatly enhances zooplankton productivity (Dr. C.M. Falter, Limnologist, University of Idaho, Moscow, Personal Communication) but the adverse effects of increased grazing on walleye survival have not been observed and probably would not be observed on Tiber Reservoir.

RECOMMENDATIONS

I recommend that the following actions be implemented on the concept of forage enhancement in Tiber Reservoir.

1. Negotiate for more favorable reservoir levels. The abundance of yellow perch and need for additional forage would probably not be an issue if suitable spawning habitat were available.
2. Promote enhancement of in-water spawning habitat for yellow perch. Fishing clubs could be encouraged to provide artificial structure to the lake to enhance available habitat. This technique has proven to be effective in the southwestern United States and is especially germane if negotiations for more stable reservoir levels were not possible.
3. Continue monitoring the abundance of forage fishes and recruitment, growth and condition of walleye and northern pike in Tiber Reservoir. Collect sufficient data annually to establish trends in the forage community and changes in the predator populations. Concurrently, the growth potential of walleye under the prevailing physical conditions in Tiber Reservoir should be evaluated using a bioenergetics model (Hewett and Johnson 1992). The model can be fit to extant physical conditions in Tiber Reservoir and the output from this evaluation would provide the growth potential of

walleye in Tiber Reservoir. Comparison of walleye growth potential with existing growth rates could provide additional information on the adequacy of the forage base in Tiber Reservoir and what could be gained if forage enhancement were conducted.

4. If monitoring data above demonstrate a decline in "health" of the predator community and the bioenergetics modelling indicates substantial gain could be accrued, stocking of cisco should be considered.

5. The literature suggests that fluctuating water levels during the probable time of cisco embryo incubation in Tiber Reservoir could adversely affect recruitment. Because of numerous similarities between the Tiber and Fort Peck Reservoir systems, the influence of water level fluctuations and other possible environmental factors that could affect cisco spawning success and recruitment should be monitored. Fort Peck Reservoir has similar timing and magnitude of water level fluctuations as those in Tiber Reservoir and probably would be the selected stock of cisco for Tiber Reservoir. Also, recent information indicates that ice cover may be correlated with year-class strength of cisco in Fort Peck Reservoir (Wiedenheft, Personal Communication). Monitoring of ice cover and abundance of cisco should continue in Fort Peck to provide additional information on the habitat suitability of Tiber Reservoir. Results from continued monitoring of cisco year-class strength and related habitat factors in Fort Peck Reservoir would be highly applicable to Tiber Reservoir.

6. If the decision to introduce cisco were made, the selection of the appropriate stock of cisco is important (Leathe 1991). Adverse interactions between cisco and walleye could be minimized by proper stock selection. Cisco are extremely variable in their habits but proper stock selection may further enhance the success of an introduction. Electrophoresis/DNA analysis and examination of stocking records may provide information on walleye in Tiber Reservoir. Walleye and cisco that have co-evolved have far greater chance of success than stocks that have not evolved together. Although stock considerations have not progressed much beyond trout and salmon in current applied fisheries management, the concept of stocks should be applied to the Tiber Reservoir management scenario to further increase the probability of a successful introduction and interaction with existing species.

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