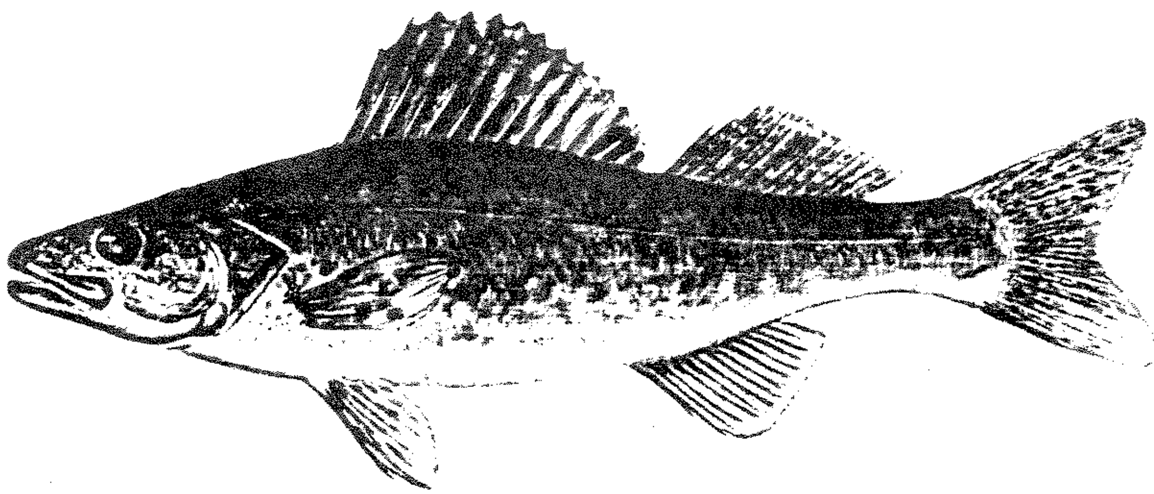
ret # 85321 F-W-2
rep #
* duplicate

ENVIRONMENTAL ASSESSMENT OF THE INTRODUCTION OF WALLEYE BEYOND THEIR CURRENT RANGE IN MONTANA

Prepared for: Montana Department of Fish, Wildlife and Parks

Prepared by: OEA Research
Helena, MT.



ENVIRONMENTAL ASSESSMENT OF THE INTRODUCTION OF WALLEYE BEYOND THEIR CURRENT RANGE IN MONTANA

Prepared for: Montana Department of Fish, Wildlife and Parks

Prepared by: OEA Research
Helena, MT.

Authors: Dr. Peter Colby
Chris Hunter

February 1989

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

EXECUTIVE SUMMARY

This environmental assessment was undertaken in response to increased demand for walleye fishing opportunites in Montana. The introduction of walleye beyond their current range in Montana to provide these fishing opportunities may affect existing valuable recreational fisheries. In order to assess the potential effects of walleye introductions beyond their current range in Montana, this report summarizes:

-walleye life history information
-walleye habitat preferences
-characteristics of walleye populations in other regions of the United States
-the status of walleye in Montana.

Walleye generally favor lakes and reservoirs larger than 250 acres that are moderately productive, provide an abundant forage base and have suitable spawning habitat. Other habitat considerations include pH 6.0-9.0, minimum dissolved oxygen greater than 6.0 ppm, mean weekly water temperature during the summer in the range 64.4-77 degrees F and a rising or stable water level during spawning and embryo development. A catch rate of 0.30 walleye/hour is considered very good in most of the United States and Canada.

Walleye introductions in Montana have met with varied success. At Nelson, Bighorn and Holter reservoirs, where creel census data is available, the walleye catch rates are comparable (.20-.27 walleye/hour) to the good walleye fisheries in other parts of the United States and Canada. The factors which appear to generally limit walleye populations in Montana waters are inadequate forage, widely fluctuating reservoir water levels, and short water retention times.

The report summarizes the results of four case history introductions of walleye. Three of the case histories involve the introduction of walleye into salmonid waters. In two of these cases, the walleye preyed heavily on salmonids. In the third, the trout never established substantial populations due to lack of suitable habitat. The fourth example describes a walleye introduction into a lake dominated by centrarchids (bass). In this case heavy predation by walleye on bass changed the fish community and resulted in a lower catch rate per hour.

The report concludes with the recommendation that an environmental assessment be completed for each proposed walleye introduction. A critical component of the environmental assessment should be the evaluation of the following questions and criteria. The first nine questions were developed by Drs. Christopher Kohler and Jon Stanley, experts in the field of introduced fish (Rosen, 1989). Criteria numbers 10-14 are specific to walleye and were developed in the course of preparing this report.

1. Is the need for the introduction valid and are there no native species available that could serve the stated need?
2. Is the exotic species (walleye) safe from over exploitation in its native range?
3. Are safeguards adequate to guard against importation of disease and parasites?
4. Would the exotic species be limited to closed systems?
5. Would the exotic species have only positive ecological impacts?
6. Would the exotic species be unable to establish a self sustaining population in the range of habitats that would be available?
7. Would the consequences of the introduction of the exotic species be beneficial to humans?
8. Does the data base indicate desirability for introduction?
9. Would the benefits of the introduction exceed the risks?
10. A trout, yellow perch or other gamefish catch rate of 0.25 or greater should preclude the introduction of walleye.
11. The proposed body of water should have abundant forage fish or the potential to support abundant forage fish.
12. The water retention time of the water body should be one year or longer.
13. If the proposed water body is a reservoir, water levels should be managed in such a way as to optimize forage fish production.
14. The water body should provide the habitat requirements for walleye as described in Table 1 of this document.

ENVIRONMENTAL ASSESSMENT OF THE INTRODUCTION OF WALLEYE BEYOND THEIR CURRENT RANGE IN MONTANA

INTRODUCTION

Fishing for walleye has become an increasingly popular pastime in Montana over the past decade. The popularity of the sport grew in the eastern part of the state and has migrated steadily west. The walleye sportsman's group Walleyes Unlimited became active in Montana in the early 1980's and grew rapidly. By virtue of its numbers and enthusiasm, Walleyes Unlimited has been successful in helping to chart the course of fisheries management in the state. Their lobbying efforts during the 1984 legislative session were in no small measure responsible for the legislature appropriating money to expand the warm water fishery program in the state.

As the popularity of walleye fishing has increased, so has interest in stocking walleye beyond their current range in Montana. The walleye is not native to Montana. However, the shallow, turbid coolwater lakes and reservoirs of eastern Montana have often provided habitat suitable for walleye introductions. There is growing interest in planting walleye in lakes and reservoirs in the central and western portions of the state that have always been regarded as trout waters.

Given the excellent trout fisheries in western Montana waters, the Department has taken a cautious approach to introducing an effective predator into these systems. The potential exists for walleye to negatively affect existing trout, yellow perch and kokanee fisheries through predation. This potential has resulted in fish and game agencies in other western states taking a firm stand for no introductions of walleye into salmonid waters. For example, the state of Idaho conducted a study similar to this one in 1982.

On the basis of this study and other information Idaho has discouraged the introduction of walleye into salmonid waters.

The purpose of this document is to attempt to determine what the effects of walleye introductions into new waters would be on fish populations currently residing in those waters and to weigh those effects against the potential benefits provided by the walleye fishery. To accomplish this the document discusses four major topics.

The first topic concerns the habitat requirements and preferences of walleye. This discussion provides background information useful in understanding subsequent sections. The information contained in this section will be useful to MDFWP in determining lakes that have potential for walleye introductions. It also provides information on habitat preference differences between walleye and trout that are useful in assessing the potential effects of walleye introductions on trout populations

This is followed by a description of the walleye fisheries of the midwestern sections of the United States and Canada, where walleye are native and the best walleye fisheries are generally considered to occur. The purpose of this section is document the highest potential of walleye fisheries and the special management considerations associated with these fisheries.

The walleye fisheries that currently exist in Montana are reviewed to give the reader an idea of the type of fishery that might be expected to develop in Montana waters stocked with walleye. It also describes the approach taken in Montana to date toward stocking coolwater reservoirs in general and walleye specifically.

The fourth major topic considered is interactions between introduced walleye and existing fisheries. Examples of interactions between these fish in several reservoirs and lakes are described.

The document concludes with a description of a general approach that the MDFWP could use in determining the appropriateness of stocking walleye in any particular lake. The authors urge caution in making further introductions of walleye, particularly in salmonid waters, due to the lack of empirical information on walleye-salmonid interactions.

This report was prepared by independent consultants Dr. Peter Colby and Mr. Chris Hunter. Dr. Colby is widely regarded as a foremost authority on walleye. Dr. Colby organized The 1977 Percid International Symposium held at Quetico Centre, Ontario. He is senior author of the Food and Agriculture Organization of the United Nations Synopsis of Biological Data on the Walleye. Dr. Colby has published widely on the suject of walleye biology.

Mr. Hunter received his Masters degree in zoology/limnology from the University of Montana in 1974. He has been employed as an aquatic biologist by OEA Research since 1981 and has worked on a variety of investigations during that time. The resumes of Dr. Colby and Mr. Hunter are appended to this report.

WALLEYE ECOLOGY

The purpose of this section of the report is to describe the habitat requirements of walleye. This information will be useful to MDFWP in determining waters that are best suited for walleye introductions. The walleye utilizes different habitats at different stages of its life cycle. In addition, the walleye is a migratory fish and uses different habitats at various times of the year. In order to manage a walleye fishery effectively, it is important to understand the habitat requirements of the fish throughout it's life cycle as well as the seasonal cycle.

The section begins with a general discussion of walleye life history and habitat requirements. More detailed information regarding reproduction, behavior, forage, growth, mortality, physical habitat requirements and interactions with other species are presented in subsequent paragraphs.

Generalized Life History

The age and size of walleye at maturity vary with water temperature and probably food availability as well. For example, female walleye mature from 2-3 years of age in Texas to 9-10 years in the Northwest Territorities of Canada (Colby and Nespzy, 1981). Late maturity is usually associated with colder waters and there is a tendency for late maturing walleyes to have a longer life span than early maturers. Walleye older than 20 years of age are not uncommon in the northern part of their range. The relationships between food, energy and growth, age to maturity and longevity probably apply to differences in elevation as it does to latitude.

Walleye spawn in the spring, normally shortly after lake ice-off, at water temperatures at 44.6-48.2°F (Colby et al., 1979). Spawning has been known to occur over a range of 42.0-52.0°F. Walleye spawning usually occurs in relatively shallow (less than 3 feet) water in the lake or reservoir or in tributary streams. Walleye are broadcast spawners. Preferred spawning substrate appears to consist of gravel and rubble although they have been observed spawning over a wide range of substrate types.

The fertilized eggs drop into crevices in the gravel/rubble substrate and are protected from predators as they develop. Larval walleye begin to feed at about the time the yolk sac is fully absorbed. This occurs at about 0.35 inches total length of the fish. Principal food items at this stage of growth are zooplankton and aquatic insects.

Walleye young-of-the-year begin to develop adult coloration when they reach a length of about 1.4 inches. The optimum temperature for growth of the juvenile fish is 71-72 degrees F. During early adolescence, walleyes change feeding habits from a predominately insect-crustacean diet to one composed almost entirely of fish. This food preference is maintained throughout the remainder of the fish's life.

Generalized Habitat Preferences

The walleye is a large, piscivorous member of the family Percidae that does best in large, shallow, moderately turbid mesotrophic lakes and large, deep turbid rivers such as the Missouri, Mississippi, and St. Lawrence that provide abundant spawning areas and forage fish. The natural range of the walleye extends from the Mackenzie and Peace rivers of Canada south to Alabama and from the Dakotas and Texas east to the Atlantic Coast. The species is not native to Montana and there is no reliable information regarding the time and place of the first introduction of walleye into Montana (Brown, 1971).

As adults, walleye are highly migratory fish. With the onset of spring the sexually mature adults move from their over-wintering areas to their spawning grounds. The spawning grounds may be located along the rocky shores and shoals of the lake in which the walleye reside, or they may be found in upstream mainstem and tributary rivers. Following spawning the walleye move to their summer feeding grounds. These are generally located in the shallow, littoral portions of the lakes in which the walleye reside. As the suface waters of the lake begin to warm the walleye may move into deeper, cooler waters for the balance of the summer. During this time they will either feed on forage fish that have also sought the refuge of cooler waters, or they will move into the littoral zone during the evening and feed until dawn. They will then move back into the deeper waters for the day.

As the lake begins to cool with the onset of autumn, the walleye again move back into the littoral zone. Feeding continues but begins to taper off as the fish's metabolism slows down in response to cooler water temperatures. There is very little information regarding the winter habitat selection of adult walleye. It is generally assumed that they seek deeper waters for over-wintering.

Walleye are generally most abundant in moderate to large (greater than 250 acres) lakes or river systems characterized by cool temperatures, shallow to moderate depths, extensive littoral areas, moderate turbidities (secchi disc depths of 3-10 feet), extensive areas of clean rocky substrate and mesotrophic conditions. However smaller lakes may contain natural populations. This is especially true if they form part of a large contiguous system. Walleye are also found in oligotrophic, clear water lakes (usually dominated by salmonids) if they are sufficiently large and deep and have extensive littoral areas. Similarly, walleye are found in some eutrophic lakes (usually dominated by centrarchids). Kitchell et al., (1977) suggested that the littoral and sublittoral habitats occupied by walleye in lakes are the equivalent of extensions of suitable riverine habitat into the lake environment.

Walleye are tolerant of a wide range of environmental conditions. Walleye tolerate wide ranges in temperature (0-86°F), dissolved oxygen concentration (down to 2 ppm in lab experiments), pH (6.0-9.0) and up to 1500 ppm dissolved solids. They will also accept a wide range of turbidity, but they avoid high levels of illumination. Ryder

(1977) reviewed much of the literature on abiotic factors controlling temporal and spatial dimensions of walleye feeding and reproduction. He concluded that light is principal among these. Kerr and Ryder (1977) also suggest that a critical limiting factor for walleye populations is light intensity.

Specific Aspects of Walleye Ecology

Reproduction

The water temperture regime and the quality and quantity of suitable substrate are major factors affecting walleye reproductive success (Colby et al., 1979). Walleye spawn in spring during periods of rapid warming soon after ice breakup. Spawning is usually initiated at water temperatures of 44.6-48.2°F but has been observed to occur over a range of 42-52°F.

Preferred spawning habitats are shallow shoreline areas, shoals, riffles and dam faces with rock substrate and good water circulation from wave action or currents. Walleye do spawn successfully over vegetation. Reported spawning depths range from as shallow as 4 inches up to 3.3 feet. Walleye spawn over a variety of bottom types in streams and lakes although a rubble-gravel substrate is assumed to be best (McMahon et al., 1984). Johnson (1961) observed walleye eggs on several bottom types in Lake Winnibigoshish, Minnesota, and found survival poorest on the soft mud detritus bottom, intermediate on fine sand bottom, and best on gravel-rubble bottom.

Walleye are broadcast spawners, the eggs are adhesive for some hours after spawning. If deposited on rocky bottoms, they may adhere to the rocks for a short time, but ultimately drop into the cracks and crevices where they may be protected from predators.

The rate of development of the embryo varies directly with the temperature during incubation. The walleye embryo has the lowest temperature tolerance of all percids. The embryo can develop in waters having temperatures ranging from 40-66.5°F. Incubation periods ranging from 4 days at 75.0°F to 33 days at 40°F have been reported. The rate of development is also affected by oxygen concentrations. In laboratory experiments it has been shown that eggs held at a lower oxygen concentration required longer to hatch.

There are other abiotic factors which may affect the mortality of walleye eggs. Eggs spawned in shallow marshes often are left stranded above the water level during times of low water. The same may be true of eggs laid at elevation in a reservoir.

Behavior

The preference of walleye for moderately turbid waters or waters colored by humic acids is directly related to their avoidance of high levels of illumination. Both of these traits are attributable to the structure of the retina of their eye. The walleye retina contains a large amount of light reflecting pigment which makes them very sensitive to light. Consequently, the walleye is very negatively phototactic. At the same time, walleye appear to prefer water depths of 3-50 feet for resting and feeding. In order to live at these depths with eyes that are extremely sensitive to light requires the mitigating effects of turbidity or color to reduce light intensity.

The walleye's sensitivity to light dictates to a large extent its feeding behavior. Periods of peak walleye feeding occur at water transparencies of approximately 3-6 ft. secchi disk depths. There is a great decrease in feeding activity at less than 3 ft. or greater than 16 ft. secchi disk depths. Walleye will often move into the shallow waters to feed as light falls in the evening. Feeding is usually heaviest at dusk and dawn as light intensities are most favorable at these times. However, walleye have been observed to feed thoughout the day in very turbid lakes. This provides further evidence of the relationship between feeding and light intensity.

During the day, adult walleye generally are found under cover in moderately shallow waters (less than 50 ft.). The walleye seem to prefer a clean, hard substrate where they will spend the day resting in contact with the bottom. Cover in the form of aquatic vegetation, boulders, etc. is often utilized. There is conflicting evidence as to whether the walleye move inshore to feed during the evening or if they remain at the same depths that they utilize for resting during the day. Carlander and Cleary (1949) observed that walleye in Lake of the Woods, Minnesota and Clear Lake, Iowa moved into shallow water at night to feed. They suggested this movement was initiated by diminishing light intensities. In a radio telemetry study of walleye movement in Lake Bemedji, Minnesota, Holt et al., (1977) found no diel pattern of on-shore, off-shore movement. Instead, they found the test walleye moved chiefly parallel to the shore at depths ranging from 5-16 ft.. The behavior of walleye in a particular lake probably depends upon the situation in that body of water. For instance, if the lake water is relatively clear, or if water temperatures are high, this could result in the walleye moving to deeper water during the day. In this case, they would certainly move in-shore with declining light and temperatures in the evening to feed. If, on the other hand, the temperature and turbidity allowed the fish to stay in the shallow, littoral areas during the day there would be no reason for the fish to move offshore during the day and inshore to feed in the evening.

Forage

Prey species for walleye change with life stage and season. Walleye fry are pelagic and feed on plankton from the time shortly after hatching until they reach a length in the range of 0.9-1.3 inches. At this size, the fry move inshore and begin to feed on aquatic insects and small fish.

Adult and juvenile walleye are largely piscivorous, feeding on a great variety of prey fishes. In many lakes invertebrates form a large part of the diet of walleye in late spring and early summer. Ritchie and Colby (1988) found that young of the year walleye were more abundant in even-numbered years. This was related to the much greater emergence of *Hexagenia* mayflies in even numbered years. The authors hypothesized that the greater abundance of mayfies in even numbered years buffered the young walleye against predation and cannibalism.

Invertebrate food is gradually replaced by a diet consisting mainly of fish later in the summer. This probably occurs because most of the immature insect forms have metamorphosed into adults and young-of-the-year prey fish are pelagic and readily available. Swenson (1977) suggested that the predominance of nocturnal feeding and relatively high percentages of age 0 yellow perch, rainbow smelt and *Notropis* sp. in their daily meals, showed that walleye in several Minnesota lakes utilize pelagic prey.

In many lakes in the northern and central regions of walleye distribution, young-of-the-year yellow perch, when available, seem to be the predominant walleye prey fish. Kelso and Ward (1977) report that behavior differences in these two percids offer protection to juvenile and adult perch. As discussed above, walleye feed actively from dusk to dawn. Conversely, older perch are inactive at night and apparently rest on the bottom until dawn. Age 0 perch are active at night near the surface and vulnerable to walleye predation.

In addition to yellow perch other important forage species include emerald shiners, trout-perch, nine-spine sticklebacks, suckers, cyprinids, white perch, alewives, rainbow smelt, lake herring and centrarchids. Trout have not been reported in the scientific literature as an important walleye forage species. It is assumed this is so because these two species do not usually occur together in large numbers.

Presently, in the Great Lakes, specifically western Lake Erie, Saginaw Bay, Lake Huron, and Green Bay Wisconsin, walleye seem to prefer alewives, rainbow smelt and shiners to yellow perch. Ryder and Kerr (1978) ranked yellow perch, *Coregonus sp.* and ninespine stickleback as the top forage items most frequently occurring in walleye stomachs from four lakes. Colby et al. (1987) report on the importance of coregonids in the diet of larger walleye. This is an important point because it demonstrates that walleye occupy thermal regimes with young coregonids whose thermal preferences are similar to those of trout.

Parsons (1971) determined that young-of-the-year and yearling walleye in Lake Erie exhibit a size preference for forage fishes consumed. Johnson et al (1988) report that for age 0 predator longer than 1.9 inches, mean prey length was about 30% of predator length. As walleye increase in length, the mean and range in length preference of forage species increases. If several forage species are available at preferred lengths, less than 45% of the walleye length, walleye tend to feed on the most abundant species. Because yellow perch stay within the preferred forage size range for a longer period than do other, faster growing forage fishes, they are often the primary food of walleye.

Arnold (1960) found yellow perch to be the preferred forage species in Utah Lake, Utah when other forage species of similar size (Utah chub, European carp) were more numerous. Similarly, Priegel (1962a, 1962c), in a study on Lake Winnebago, found emerald shiners to be preferred over the more numerous fresh water drum. These findings may be related to size preference. Olson (1963) found that the walleye of Many Point Lake strictly avoided white suckers even though they were numerous in the lake.

Growth

Absolute growth rates of adult walleye vary rather markedly from one body of water to another even among those in proximity. In general, the growth rate of walleye is fastest in the more southern regions of their range and slower in the more northern regions. Optimum water temperatures for growth of adults are 68-75 degrees F. Food availability appears to be the main factor governing the condition of adults. Condition factors tend to be low in areas where forage is scarce and high in areas where forage is abundant. An inverse relationship between walleye population density and growth has been documented by a number of authors.

The effects of forage abundance and population density are usually interrelated. Low walleye density means adequate food for all members of the population whereas a high density usually results in a scarcity of forage. Excellent forage abundance has been cited as a chief reason for good growth in a number of lakes. This factor not only influences adult growth, but is seen to directly affect recruitment. Forney (1977) has observed the production of strong year classes of walleye in years when growth of older walleye was rapid.

Walleye populations in the northern reaches of their distribution are usually associated with substantial populations of northern pike, yellow perch and white suckers. They are often sympatric components in a salmonid-dominated community. Walleye must compete for forage with such piscivorous fish as northern pike, yellow perch, sauger and smallmouth bass, of which northern pike is probably the most important competitor.

In Wilson Lake, Minnesota, Johnson (1977) demonstrated that walleye standing crops of a relatively simple fish community could be increased by as much as one-third by white sucker removal. White suckers were competing not only with walleye, but with the important walleye prey species (yellow perch, minnows and darters) as well. Approximately 85% of the adult white sucker were removed. During a seven year post-removal study, yellow perch abundance increased as a result of decreased white sucker competition. This benefited the adult walleye population in providing a more abundant and desirable food source. Similar results were obtained when about 90% of the white suckers were removed from Big Bear Lake, Michigan. (Colby et al., 1987). These authors suggest that at least 80% of the white suckers need to be removed for this technique to be effective.

Mortality

Scott and Crossman (1973) regarded spawning by other species over walleye eggs as an important factor in limiting walleye populations. Anthony and Jorgensen (1977) found that increasing numbers of white sucker in Lake Nipissing, Ontario, which use some walleye spawning sites after the walleye have spawned, may have interfered with development of walleye eggs and thereby adversely affected reproduction of the population.

Early studies revealed that fishes such as yellow perch, carp, suckers and minnows may feed on walleye eggs. A number of fish species feed on walleye fry. These include yellow perch, white bass, yellow bass, smallmouth bass, rainbow smelt, sauger, bullheads, burbot, and probably most significantly northern pike. However, cannibalism has been found to be a decisive factor in the determination of walleye year class strength when larval yellow perch were scarce (Forney 1976). The reader will recall the hypothesis of Ritchie and Colby (1988) that the even year abundance of *Hexagenia* mayflies buffered the young of the year against cannibalism.

Walleye fry may have to compete with other planktivorous fishes, such as they do with fry of freshwater drum for such microcrustaceans as *Cyclops* and *Leptodora*. Johnson (1969) believed that competition for food, as a factor limiting survival in Lake Winnibigoshish and Cutfoot Sioux Lake, occurs mostly in the first 60 days of life when the young walleye are feeding mostly on plankton and insects. McMillan indicated (pers. comm.) that zooplankton abundance was one of the critical factors influencing the success of a walleye year class in reservoirs of the North Platte River.

The walleye is a general predator and usually a top carnivore in the community. Thus predation is probably not an important source of mortality amoung adults.

Habitat Suitable for Walleye

McMahon et al., (1984) present a habitat suitability model that can be used to predict the habitat suitability of a given water body for walleye. Table 1. summarizes the variables that are included in the model and the values that are selected as repesenting optimum walleye habitat for predictive purposes.

Table 1. Habitat variables and their associated optimum values for walleye habitat suitability (from the Habitat Suitability Index Model of McMahon et al., 1984).

Variable	Optimum Value
Transparency	3-10 ft. secchi disk depths
Relative abundance of small forage fishes during spring and summer	High abundance of forage fish
Percent of water body with cover	Areas with sparse cover are assumed to be less suitable. Too much vegetation is assumed to reduce habitat suitability by reducing foraging ability (Swenson, 1977)

Table 1. Habitat variables and their associated optimum values for walleye habitat suitability (from the Habitat Suitability Index Model of McMahon et al., 1984) continued.

Variable	Optimum Value
pH	6.0-9.0
Minimum dissolved oxygen above thermocline in summer	Greater than 4.5 ppm
Minimum dissolved oxygen during summer-fall along shallow shoreline areas (fry)	Greater than 5.0 ppm
Minimum dissolved oxygen in spawning areas during spring (embryo)	Greater than 6.0 ppm
Mean weekly water temperature above thermocline during summer	64.4-77°F
Mean weekly water temperature in shallow shoreline areas during late spring-early summer (fry)	64.4-73.4°F
Mean weekly water temperature during spawning in spring (embryo)	51.8-64.4°F
Spawning habitat index*	Greater than 40
Water level during spawning and embryo development	Rising or normal and stable
Trophic status of lake or lake section.	Mesotrophic

*Spawning habitat index is calculated by multiplying the proportion of the water body composed of riffle or littoral areas greater than 1 ft. and less than 5 ft. deep by the substrate index where the substrate index is defined by the following equation = 2(% gravel-rubble 1-6 in. in diameter) + (% boulders-bedrock) + 0.5(% sand) + 0.5(% dense vegetation) + 0(% silt-detritus).

Species Interactions

Species interactions are, to a large extent, controlled by the habitat preferences of the species of interest. If the species have dissimilar habitat preferences, they will interact very little. Kitchell et al (1977) present a hypothesis that they feel allows for good identification of percid habitat in lakes. The hypothesis states that the habitats of *Perca* spp. and *Stizostedion* spp. in lakes are the equivalent of riverine extensions into the lacustrine environment. Where the area of habitat equivalence is large, as in shallow lakes, so are the percid populations. Where the area is small in relation to total lake area, as in large deep lakes, percids represent a lesser component of the total system.

Figure 1 broadly summarizes the Kitchell et al (1977) view of percid habitat as it compares to salmonid and centrarchid habitat preferences. Figure 2 is a graphic representation of these habitat preferences. The graphic representation requires and deserves some study. Walleye are limited to the sublittoral during periods of high light intensity and/or thermal stratification, but are released to forage throughout both the littoral and sublittoral during the diel light cycle. Walleye tend to orient toward the benthic portions of the water column, but the profundal portion of the lake is not their preferred habitat.

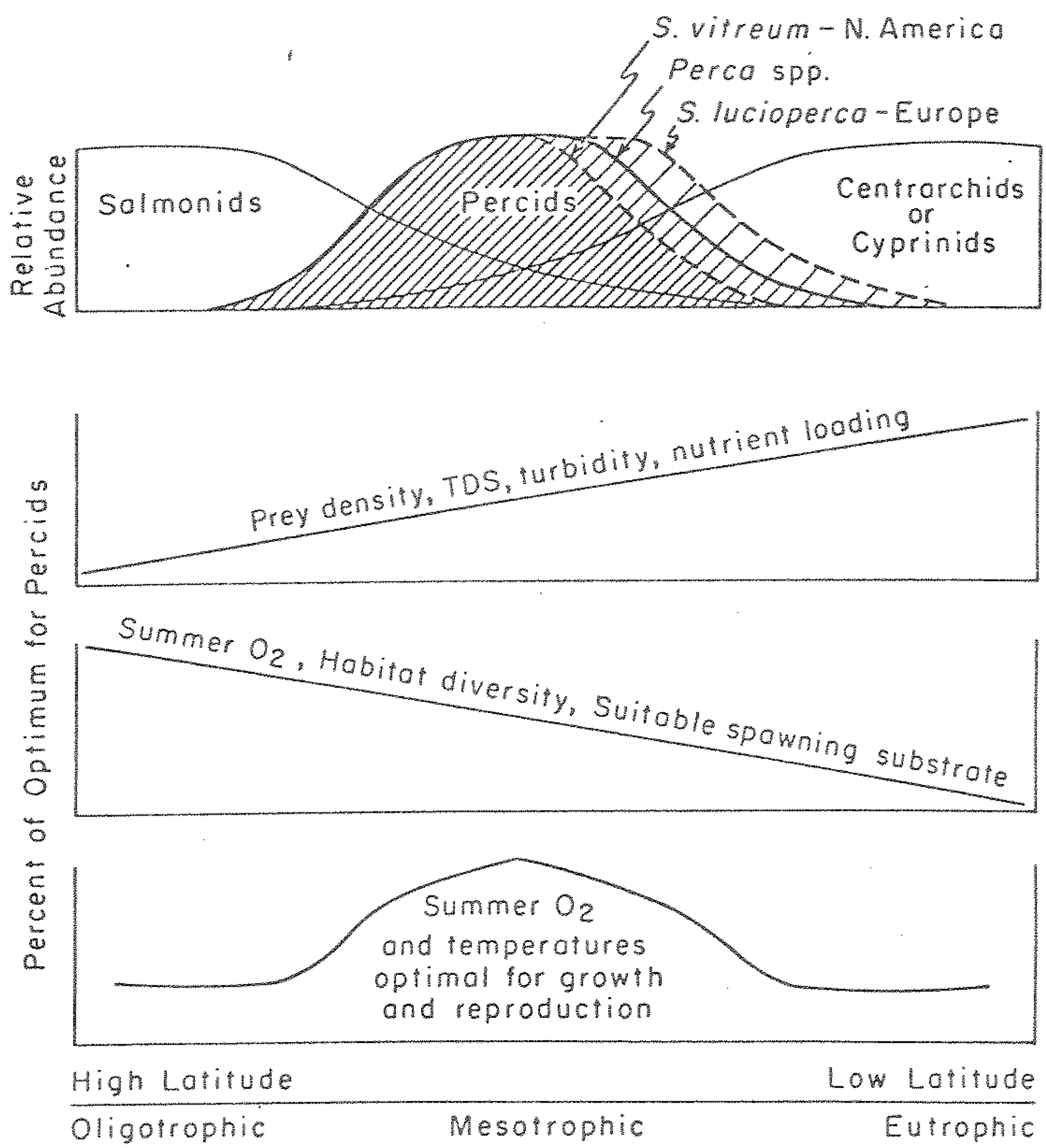
By contrast, optimal lacustrine habitat for salmonids is characterized by clear, cold deep lakes that are typically oligotrophic. Salmonids feed on plankton in the open water areas of the lake. The salmonids require colder water and higher dissolved oxygen levels than do the walleye. Adult rainbow trout select the warmest waters available to them up to about 62°F and avoid permanent residence where temperatures are above 64.4°F (Raleigh et al. 1984). In the McMahon et al., (1984) model of walleye habitat, 64.4°F is at the low end of suitable summer time temperatures for walleye. Christie and Regier (1988) report the optimal temperature ranges for lake trout (*Salvelinus namaycush*) and walleye to be 46-54°F and 61-72°F respectively. As a result, salmonids dominate percids in systems of low productivity and low mean temperature conditions. Centrarchids dominate percids in more productive, warmwater environments (Kitchell et al, 1977). Percids should be the dominant fish in the intermediate coolwater environments.

Maclean and Magnuson in their 1977 work on species interactions in percid communities discuss the importance of temperature in resource partitioning. They contend that habitat segregation of percids from salmonids and centrarchids on the basis of temperature is most nearly complete when temperate zone lakes are thermally stratified in summer. By midsummer thermally stratified lakes have a broad range of temperatures containing not only those preferred by temperate zone coolwater fish such as perch and walleye, but also temperatures preferred by warmwater fish such as centrarchids and coldwater species like salmonids.

The potential for interaction between salmonids and percids in these lakes occurs during the early spring and late fall when the lakes become isothermal. During this time there is no segregation by temperature since the entire lake is the same temperature. Maclean and Magnuson (1977) maintain that during this period of interaction between species, salmonids should have the advantage over percids and centrarchids because at this time of year temperatures are optimum only for salmonids.

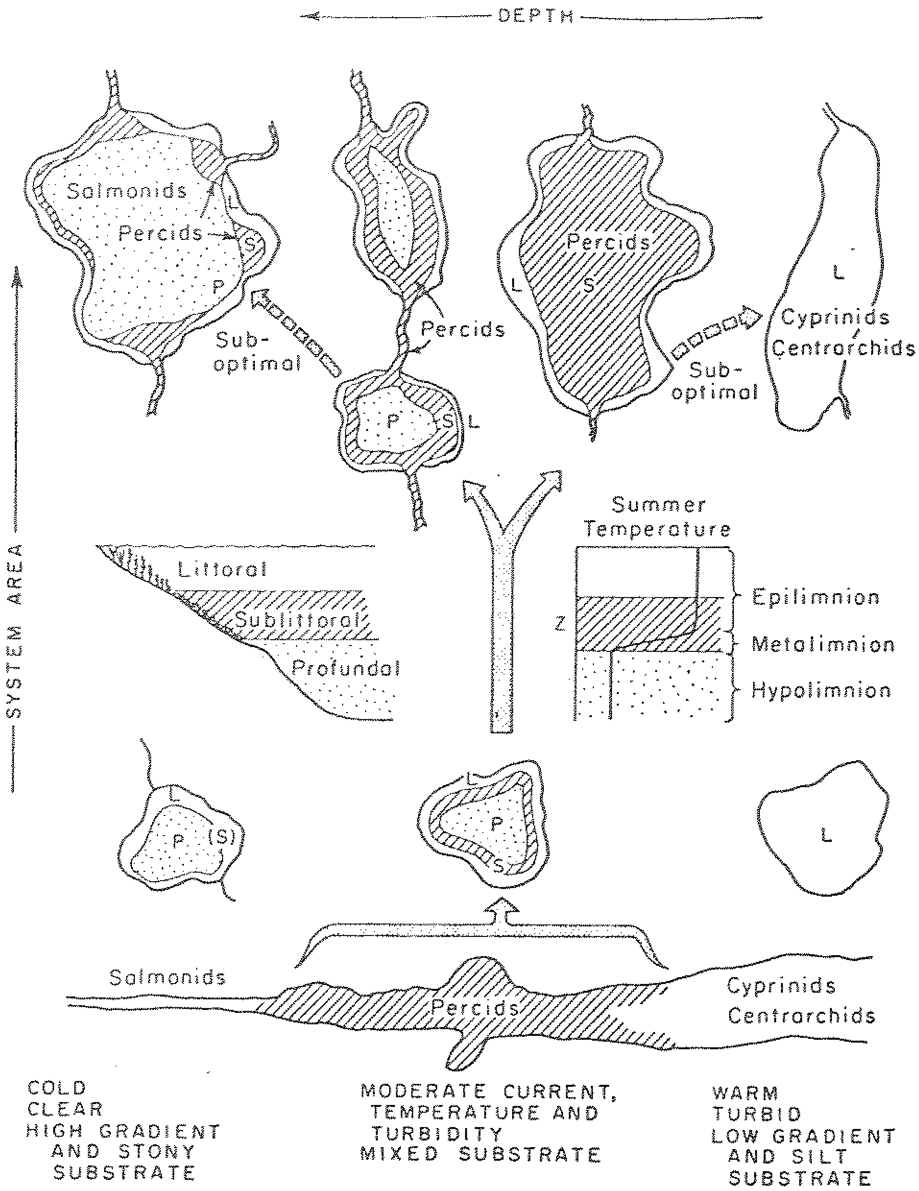
During the winter the salmonids, percids and centrarchids are not expected to segregate by temperature since all apparently prefer the warmest water available. However, potential interactions are probably reduced in intensity because metabolic processes and food demands are low.

Figure 1.



Relation of optimum condition for the percid fishes *Perca* spp. and *Stizosedion* spp. to geographic gradients and tropic status of the ecosystem. From Kitchell et al., (1977).

Figure 2.



Graphic representation of the river hypothesis of Kitchell et al., (1977). Optimum habitat for percid fishes is defined by the littoral (L) and sublittoral (S) environmental equivalents to riverine conditions. Habitat boundaries are broadly defined in plan view as function of lake depth (z) and surface area. Midsummer temperature profiles define the lower depth limit of the habitat as that of the lower boundary depth of the thermocline and upper limit of the profundal (P) zone. The upper boundary of the sublittoral corresponds to the compensation depth of light. From Kitchell et al., (1977).

The role of temperature in potential species interactions is different in lakes that do not thermally stratify. In these cases, there is little opportunity to segregate on the basis of temperature because the temperature range at any given time is narrow. This is also true for many reservoirs with short water retention times. In these situations water is not in the reservoir for a long enough period of time to stratify. Assuming that predation and competition are the most intense when the temperature is within the optimal range of two species, this would occur in spring and fall for walleye and salmonids in non-stratifying lakes (Maclean and Magnuson 1977).

Johnson et al., (1977) attempted to relate the morphological characteristics of Ontario lakes to the fish communities inhabiting them. They observed that walleye did not occur in many lakes containing lake trout (*Salvelinus namaycush)* and pike or lake trout, with pike and bass even though these lakes were in the same geographic region in which a large number of walleye and pike community lakes occurred. They concluded that the lakes which did not contain walleye were smaller and of lower productivity, as evidenced by their morpho-edaphic index (MEI of Ryder 1965), than did the lakes containing walleye. The confounding factor in this analysis was that walleye were found in association with lake trout in large lakes having low productivity.

The authors concluded that larger lakes with low overall MEI can have bays with MEI comparable to small, high MEI lakes. These bays could serve as habitat for walleye within the larger lake ecosystem. Johnson et al ., (1977) found that only 169 of the 839 lakes with lake trout also had walleye. These often seemed to be the larger lakes. A large oligotrophic lake is more likely to have mesotrophic environments (bays) of sufficient size to support percids than a small oligotrophic lake.

WALLEYE FISHERIES OF THE UPPER MISSOURI AND MISSISSIPPI RIVERS SYSTEMS

The purpose of this section is to describe walleye fisheries found in those portions of Canada and the United States known for their quality walleye fisheries. A review of the information regarding catch rates, yields, seasons and seasonality and special management considerations of these walleye fisheries will provide the MDFWP and Montana walleye anglers an idea of what they might expect from a high quality walleye fishery.

Fishing Regulations

Many states have a year-round open angling season for walleye. Those states and Canadian provinces that do not have year-round angling usually close the angling season for 1-3 months in the spring to allow the adult fish to spawn unmolested.

Minimum size limits are often placed on walleye fisheries in an attempt to maximize yield. These restrictions range from 12 to 15 inches. A minimum size limit set to maximize the yield from a walleye fishery is based on the assumption that rates of growth and natural mortality do not change after the length limit is imposed. However, when some sizes of walleye are protected in the fishery, the changes in population density can alter rates of growth and natural mortality. If there is a high natural reproduction combined with a slow growth rate, a high density of undersized fish can result (Brousseau and Armstrong, 1987).

Schneider (1978) states that the application of size limits can give the manager flexibility to manage for alternative goals such as recreational values on stock sizes. For example, Schneider (1978) has predicted that for the average Michigan sports fishery, increasing the minimum limit from 13 to 15 inches will have the following effects: 1) have no significant effect on yield; 2) increase walleye egg production by 20-30 percent; 3) increase total number of walleye caught (legal plus sub-legal) and the biomass of the population by 15-20 percent; and 4) cause a similar decrease in the numbers of legal sized walleyes taken home.

Brousseau and Armstrong (1987) caution that minimum size limits should not be used as a broad management technique, since the rates of growth and natural mortality for walleye may vary considerably from one population to another. These authors suggest that minimum size limits be lake-specific and only applied if the walleye population exhibits the following characteristics: low reproduction; good growth, especially of small fish; low natural mortality; and high angling mortality.

Catch limits generally range between six and ten walleyes per day, but may be as low as five (Michigan, Iowa) or as high as 15 (Mississippi, Alabama).

Diurnal and Seasonal Changes in Fishing Success

Generally speaking, angling success is greatest at dawn and dusk (Zimmerman, 1966; Cheshire, 1968; Anderson, 1971) when light conditions for feeding are optimum. Walleye are very sensitive to light. They will move into deeper waters during the day to avoid bright sunshine. Walleye then move back into the littoral zone to feed at low light levels. Feeding takes place all night, but appears to be particularly heavy at dawn and dusk.

Fishing success is usually greater during the first month of the fishing season in the spring and then tapers off as the summer progresses (Lux and Smith, 1960; Wesloh, 1961, Leach, 1964; Rice, 1964; Payne, 1964; Zimmerman, 1965; Armstrong, 1967;

Gregory and Powell, 1969; Johnson and Johnson, 1971). This same phenomenon has been observed in several Montana reservoirs. It is generally believed that walleye move into the deeper water as summer progresses to avoid high water temperatures encountered in the littoral zone.

Sport Fishing Catch Rates and Yield

Sport fishing catch rates are usually stated as the number or weight of walleye caught per person or rod hour (where more than one fishing rod is permitted). However, the data used are often the number of hours fished for all species, not just for walleye. In such cases, comparisons of catch rates from one lake to another may be biased. The catch rates reported may appear unreasonably low to an experienced walleye angler. The reader must understand that these rates are seasonal averages, they include data from the good spring months as well as the slower summer months, and they are based on the success of all anglers interviewed.

Walleye catch rates at Caribou Lake, Minnesota, (based on number of hours fished for walleye only) over three years ranged from 0.18-0.32 (Micklus, 1959). Catch per unit effort (C.U.E.) values computed in the same manner for two Ontario waters were reported as 0.14 to 0.31 over three summers for the Mississagi River (Payne, 1965) and 0.33 for Polly Lake (Ryder, 1968).

Savanne Lake, Ontario was a relatively unexploited lake since its closure to the public in 1969. A walleye catch rate (based on the number of hours fished for all species) for 1977-1982 when the lake was first lightly fished ranged from 0.51 to 1.05 walleye per man hour (Colby, 1984)

Hiner (1943) stated that a walleye C.U.E. (based on the number of hours fished for all species) of 0.32 was average for Minnesota lakes. In general, a good fishery exists when walleyes are caught at a rate of 0.3 walleyes per hour fished for all species (Colby et al., 1979).

A yield of 3.0 lbs-acre-year was considered by Olson and Wesloh (1962) to be characteristic of walleye production in many of Minnesota's natural walleye waters. Schneider (1969) citing Groebner (1960) and Johnson (1964), stated that a good walleye lake should yield 1.9-4.0 lbs-ac-yr.

Adams and Olver (1977), studying long-term commercial yields from 70 northern Ontario lakes, determined that few of these lakes were capable of sustaining percid (essentially walleye) yields greater than 1.34 lbs-ac-yr. They further stated that a sustainable percid yield of 0.9-1.1 lbs-ac-yr, or about one-third of the total yield, is probably a reasonable expectation for many moderately to intensively fished lakes in the region studied. Some lakes will be able to sustain higher or lower yields, depending upon their yield potentials.

Special Management Considerations

Reservoir Water Retention Time

The residence time of water in a reservoir can have a bearing on walleye populations. Water remains in a reservoir with a high retention time longer than it does in a reservoir with a low retention time. Data from Ohio (Johnson et al., 1988) and Kansas (Willis and Stephen, 1988) indicate that water retention time is related to walleye harvest. Johnson et al., (1988) hypothesize that this is due to large numbers of walleye, particularly juveniles, being lost downstream from reservoirs with low retention times. Walleye appear to be very sususceptible to downstream movement due to reservoir surface discharges (McMillan, per comm.). Willis and Stephen (1987) found that walleye density and stocking success in Kansas reserviors were directly relatd to retention time and state that walleye stocking is not justified in reservoirs with retention times of less than 1 year. Johnson et al., (1988) state that Ohio impoundments supporting the best walleye harvests generally have retention times greater than about 0.7 years.

Retention time is also important because it can affect thermal stratification of a reservoir. If a reservoir does not thermally stratify, this can increase interactions between coolwater species (walleye) and coldwater species (trout).

Control of Water Levels

Klingbiel (1969) noted that in the United States most state agencies attempt to maintain stable or slightly rising water levels in reservoirs during spawning and incubation. However, stable levels have not proved to be necessary at other times during the year. Groen and Schroeder (1978) state that in certain Kansas reservoirs where water level management consists of a two-part cycle, walleye populations have actually been improved. Raising the water level in spring to improve spawning and nursery conditions, followed by a mid-summer drawdown for revegetation, improved the forage base and water quality for walleyes.

Erickson (1972) observed that onstream impoundments which produced the best walleye populations were characterized by slow water level fluctuations. The manner in which water levels are managed can have serious consequences particularly for walleye young-of-the-year which are very susceptible to being lost through the dam during periods of rapid water drawdown.

Control of predation and competition

Rough fish removal programs have often been attempted in hopes of increasing walleye populations by reducing competition. Two examples of white sucker removal were provided in the section on Growth (pg. 12). Ricker and Gottshalk (1941) reported that following the removal of rough fish from Bass Lake, Indiana, gamefish populations, including walleye, showed a large increase. In contrast, removal of 34 percent of the adult sucker population in Many Point Lake, Minnesota, was not considered successful in reducing interspecific competition between sucker and walleye. Similarly, 12 years of intensive fresh water drum removal on Lake Winnebago, Wisconsin, resulted in only a small increase in walleye numbers (Priegel, 1971). In these later two examples, less than 80% of the rough fish population was removed. The Michigan Department of Natural Resources rule of thumb is that at least 80% of a white sucker population must be removed to be effective. This rule may hold true for other rough fish species as well.

Stocking

Continuous planting of walleye in lakes in which no natural reproduction occurs, has provided good angling returns in a number of lakes (Groebner, 1960; Schneider, 1969). More commonly, walleye fry and fingerling plantings are made to supplement naturally reproducing populations with hopes of improving the sport fishery. For most lakes which contain good reproducing populations and into which walleye have been planted, no correlation could be found between plantings and year class abundance. However, some lakes with naturally reproducing populations have shown a positive correlation between stocking and year class abundance (Colby et al., 1979). There is evidence (Schneider, 1969) that some lakes with naturally reproducing populations can be measurably improved, but only at high stocking densities.

Stocking of walleyes smaller than 3 inches in waters where established populations exist has generally met with little success (Klingbiel, 1969). An important factor influencing the success of fingerling stocking is the size relationship between stocked fingerlings and other fish present in the lake (Johnson, 1971). Not only will stocked fingerlings often compete with native fry, but if they are stocked at a size too small to utilize forage fishes, they may have to compete with a variety of species for invertebrates upon which they would be forced to feed. Fry may also become forage for adult walleye and other predators.

Introductions

Walleye introductions into natural lakes have established some reproducing populations, while introductions into reservoirs have met with varied success. For example, of 97 Ohio reservoirs stocked with walleyes, only 23 developed reproducing populations (Colby et al., 1979). Introductions into three reservoirs (Angostura, Belle Fourche, and Shadehill) in South Dakota have been very successful. The success of these introductions is attributed to the favorable light regime (due to high turbidity) and temperature regimes (Colby et al., 1979).

Introductions of walleyes into lakes with stunted panfish or perch populations in hopes of increasing the growth rate by augmenting predator pressure have met with limited success. When eleven Wisconsin lakes containing stunted panfish populations were stocked with walleye fingerlings, in only one lake was there significant survival of the stocked fish (Klingbiel, 1969).

Laarman (1978) conducted a study of the success of stocking walleye in 125 bodies of water in the upper Midwest. The author concluded that the success or failure of walleye stocking appeared to depend more on the environmental and biological condition of individual bodies of water than on the number and size of walleye that were stocked.

STATUS OF WALLEYE IN MONTANA

This portion of the document is based largely upon information found in the Montana Department of Fish, Wildlife and Parks annual reports. The data presented in these annual reports is summarized here. The information is arranged by drainage basin beginning with the Missouri River at the Montana-North Dakota border and moving upstream. The Yellowstone River drainage information is presented in like manner.

Lower Missouri River

The MDFWP conducted intensive studies of game fish in the Lower Missouri River (North Dakota border to Fort Peck dam) from 1979 through 1983. Walleye were commonly found within this reach of river , although not nearly as abundant as sauger. The average catch rate for walleye per hour of electrofishing was .36 fish/hour. The catch rate for sauger was 13.1 fish/hour. Similarly the catch rate for walleye using experimental gill nets in 1979 and 1980 was .3 fish/overnight set versus a catch rate of 1.45 fish/overnight set for sauger.

Tagging studies revealed that walleye are very mobile within this reach of river. Movement of walleye between Garrison Reservoir, and the upstream portion of this reach of river was common. An important spawning area is located in the vicinity of Fort Peck dam. Walleye migrate from Lake Sakakawea as well as the lower reach of the river, to the upper reach to spawn. One walleye travelled 350 miles over an 825 day period.

In a 1976 survey, walleye were found to be the dominant game fish in the Poplar River. Population estimates of walleye (excluding young of the year), conducted using mark and recapture techniques, yielded values of 178/mile in the East Fork and 297/mile in the main river downstream of the confluence of the East and West Forks.

The MDFWP conducted an evaluation of the fishery in the Fort Peck tailwater and dredge cut area immediately downstream of Fort Peck Dam during the early and mid 1980's. Walleye and sauger are the preferred game fish in this area. The walleye population is dependent upon the migration upstream from Garrison Reservoir, although a limited amount of spawning does occur within the study area and adult fish are caught throughout the year.

A comparison of the seasonal catch of walleye and sauger in the dredge cut area was made based upon experimental gill nets set during 1983 and 1984. The catch per net for walleye was 1.1, 0.8 and 0.4 during spring, summer and fall respectively. The catch per net for sauger was 1.5, 1.3 and 3.35 for these same sampling periods. Frazer (1986) continued his work during the 1985 field season and found similar catch rates for walleye.

Fort Peck Reservoir

Walleye have been stocked in Fort Peck Reservoir since 1951. The first stocking consisted of 878,000 fry. No additional stocking took place until 1977. By the early 1970's, an excellent walleye fishery had developed in the Big Dry Arm of the reservoir. The annual stocking which was initiated in 1977 was undertaken to maintain and expand the fishery. The fishery managers felt that natural reproduction was too erratic and insufficient to maintain a quality fishery.

Various combinations of walleye fry and fingerlings have been stocked in Fort Peck

Reservoir since 1977. An effort is currently underway to evaluate fry versus fingerling plants by stocking various areas on alternate years. Fingerling plants have produced better results to date, however, a fry plant at Bear-Duck Creek in 1982 produced good results. Walleye stocking consisted of 5.2 million fry and 15,073 fingerlings in 1986, 12 million fry with 30 thousand fingerlings in 1987 and 25 million fry with 25 thousand fingerlings in 1988.

In an attempt to provide additional forage fish for walleye, northern pike, lake trout and the chinook that were planted from 1983-1986, cisco (*Coregonus artedii*), were first introduced into Fort Peck in 1984 (Hadley, 1982). Stocking of cisco fry and fingerlings occurred in 1984, 1985 and 1986. Abundance of cisco captured in floating commercial goldeye nets indicated good survival of the 1984 and 1985 plants. A naturally reproducing population has obviated the need for further plants.

Length and weight data collected in 1985 and 1986 revealed exceptional growth for cisco. Condition factors of 1985 and 1986 age 1 cisco were in the 40's. However the naturally reproducing population has apparently reached a maximum density and condition factors have fallen significantly. 1988 age I cisco had condition factors in the 27-28 range. Both lake trout and walleye are utilizing this forage fish . The average weight of lake trout has gone from 3 pounds in 1985 to 7 pounds in 1988 (Wiedenheft, pers. comm.).

Table 2. provides a summary of the walleye catch by spring trap netting in the upper Big Dry Arm of Fort Peck Reservoir, 1974-1986. It would appear from this table that the decline in catch rate coincided with the initiation of plants of fry and fingerlings. This may be simply a coincidence. The upswing in catch rate appears to coincide with the introduction of cisco.

Table 2. Summary of the walleye catch by spring trap netting in the upper Big Dry Arm of Fort Peck Reservoir, 1974-1986.

Year	Trap Days	No. Walleye trapped	Walleye/Trap-day
1974	71	1243	17.4
1975	97	1114	11.5
1976	100	2108	21.1
1977	323	1727	5.3
1978	81	1896	23.4
1979	63	326	5.2
1980	97	535	5.5
1981	140	371	2.7
1982	89	655	7.4
1983	106	725	6.8
1984	96	579	6.0
1985	97	1202	12.4
1986	102	1448	14.2

Figure 3 illustrates the changes in the size of walleye taken by spring trap netting in the upper Big Dry Arm. This figure shows a decrease in the size of walleye taken that seems to coincide with the introduction of walleye fry and fingerlings. The rebound in sizes seems to coincide with the introduction of cisco for forage.

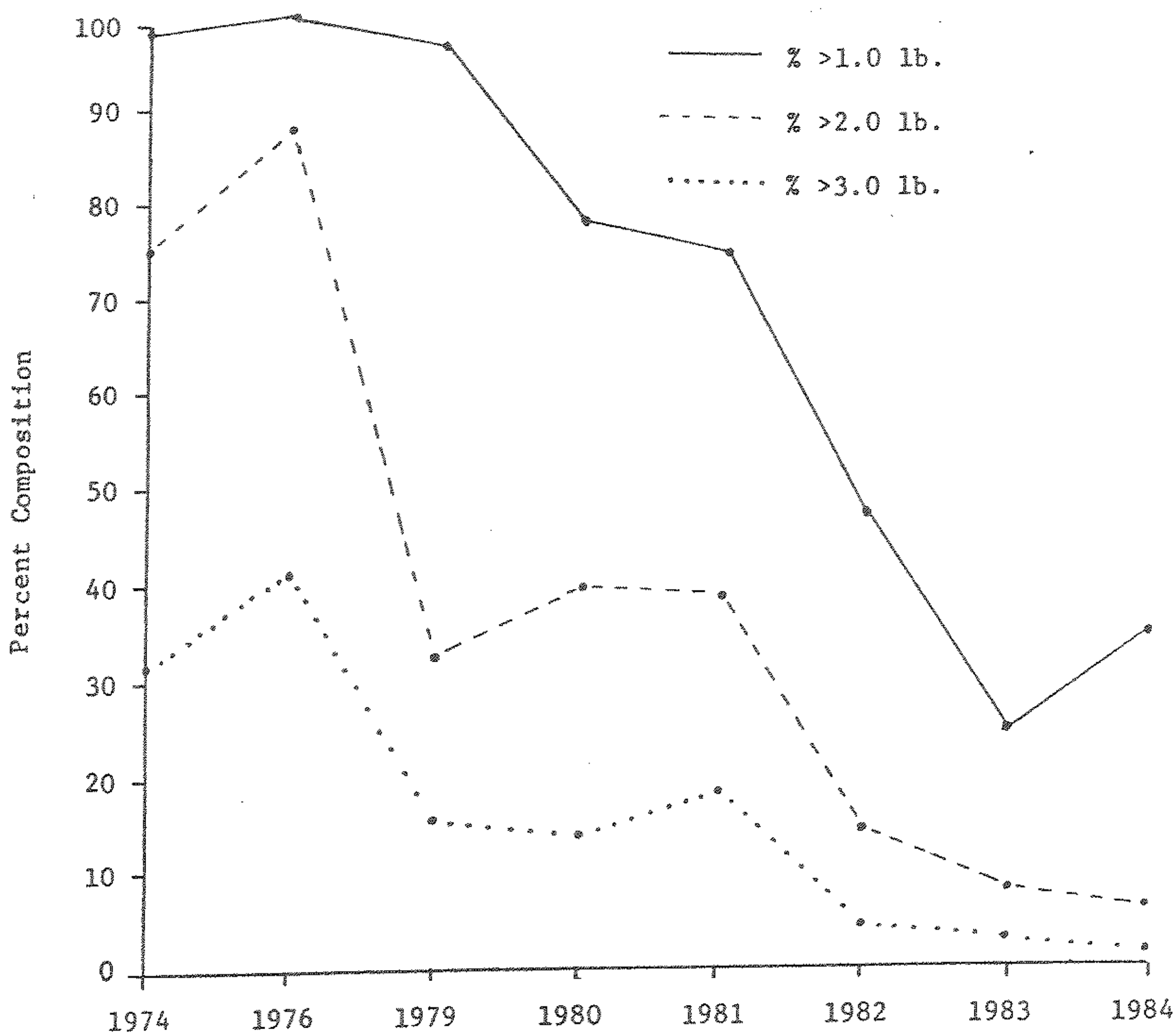


Figure 3. Changes in the size of walleye taken by spring trap netting in the upper Big Dry Arm of Fort Peck Reservoir, 1974-1984. From MDFWP, F-11-R-34.

Nelson Reservoir

Nelson Reservoir is a 4500 acre reservoir located in the Milk River drainage. The reservoir is an off-stream storage site for irrigation water. Consequently, water levels have fluctuated greatly over the last ten years. While observations indicated that the best spawning habitat is not available during dry years, this does not appear to have a definite effect on walleye reproduction. Despite very low water levels in the spring of 1978, walleye reproduction was very good.

As the result of a creel census undertaken during 1984, there is excellent mangement information for this reservoir. Table 3 summarizes the results of the 1984 creel census. The data collected indicate that the overall catch rate of walleye per hour was .27. This compares favorably with the better walleye lakes found in the the Upper Midwest. The creel census data also indicates that the walleye fishery in Nelson is seasonal. Fishing is slow in May, picks up in June and July but tails off after that for the rest of the summer and early fall.

Table 3. Results of 1984 Nelson Reservoir creel census.

Period	Total Anglers	Total Hours	Catch Rate (fish/hr)
May	546	2157	.14
June	922	5384	.31
July	947	4952	.36
August	294	974	.15
September	237	1143	.21
	2946	14610	.27

The creel census was undertaken, in part, to determine if the walleye fishery was subject to over-harvest. Fishermen harvested 27% of the adult walleye population (age III and older). Schneider (1978) considered 21% to be the typical annual exploitation rate for present day walleye fisheries in Michigan. MDFWP concluded that while the creel census provided valuable information, more data is needed to adequately address the issue of over harvest.

Wild and Scenic Missouri

Most of the walleye found in the Wild and Scenic reach of the Missouri River are probably seasonal migrants from Fort Peck Reservoir. Walleye are distributed throughout this reach of river, but they are not very abundant. Electrofishing surveys yield catch rates of only 0.3 or fewer fish/electrofishing hour.

Limited information on movement of walleye is provided by recapture studies of tagged fish. One walleye tagged near Carter Ferry on May 11, 1978 was recaptured by an angler 10 days later in Fort Peck. Walleye migrate the 186 miles from Fort Peck to within 3 miles of Morony Dam to spawn. Belt and Highwood Creeks appear to be important spawning areas. These walleye are relatively early spawners compared to other populations. Spawning begins in April and has peaked by late April in most years.

Petrolia Reservoir

Petrolia Reservoir is a 515 acre irrigation reservoir. This reservoir is subject to large annual fluctuations in water level. MDFWP annual reports from 1970-1975 indicate that the walleye population had stabilized at a low level. It was concluded that the lack of forage fish was limiting the population. Yellow perch were introduced in 1975 in an attempt to establish a perch fishery and provide forage for walleye and burbot which were planted in 1973.

Gill net surveys conducted in fall of 1977, and spring, 1978 revealed the walleye population had an unhealthy age structure. The nearly equal ratio of young fish to old fish suggested that survival of young fish was low. By 1980 it appeared that the yellow perch introduction was successful. There were signs that the perch had established a naturally reproducing population and each year more young of the year and adult fish were being captured.

In the fall of 1980 the reservoir was drained to dead storage capacity. Gill net surveys in the spring of 1981 confirmed that most of the rough fish population along with the walleye population had been flushed from the lake into the stream below. Rainbow were planted later in 1981. Northern pike were introduced in 1983.

In 1984, heavy irrigation withdrawal again drew the reservoir very low. Gill netting in the spring of 1985 showed that all fish sampled were in extremely poor condition. Walleye and northern pike were planted in the spring of 1985. By late summer the reservoir had again been drained to dead storage. In all likelihood, any fish in the reservoir were again flushed out during the draining of the reservoir.

Fresno Reservoir

Fresno Reservoir is an irrigation reservoir located on the Milk River near Havre. According to a 1975 MDFWP annual report, Fresno was historically known for its production of large rainbow trout. However, stocking of rainbow was discontinued in 1959 since a flourishing population of northern pike had developed. Walleye introductions were made from 1957-1961 resulting in a good population of this species.

Apparently, water level fluctuations were responsible for a decline in the northern pike population and rainbow trout stocking was experimentally reinstated in 1973-1974. No rainbow were taken in gill nets in August, 1974. This netting event also yielded the poorest catch on record of northern pike. The low numbers of northerns was attributed to the 34 ft. drawdown the reservoir experienced in 1973. This drawdown reduced the reservoir volume by 92% and the surface area by 72%. Interestingly, the gill net catch for walleye remained good compared to previous years, indicating that the intense drawdown did not permanently harm this population.

A proposal to install low head hydroelectric generators at Fresno Reservoir initiated a study to determine movement of walleye and northern pike through the outlet of the dam. In 1980, larval fish sampling revealed a substantial number of walleye fry passing out of the reservoir. The passage of large numbers of adult fish had been suspected in years of extensive drawdown. The adult fish enhance the tailwater fishery downstream of the dam.

1984 was an extremely low water year at Fresno, as it was at many of the irrigation reservoirs. Despite low water levels, walleye produced large numbers of young of the year fish. This phenomenon was noted in earlier years as well.

In June, 1985, 10,000 spottail shiners were planted in the reservoir in an attempt to increase the forage base for the walleye and northern pike populations. This plant was successful and, together with yellow perch and emerald shiners, they appear to be providing sufficient forage for walleye and northern pike.

The 1987 gill net take of walleye was good and average size was larger than had been found in previous netting. This work indicated that the population is 'top heavy' with 68% of the fish captured Age IV and older. The 1986 walleye year class was well represented in 1987 gill netting. This was a surprise, because walleye young-of-the-year (YOY) were not abundant in 1986 beach seining. There appears to be little correlation between the number of YOY walleye captured by summer beach seining and adult walleye year class strength. Either the beach seining has not been effective at estimating YOY year class strength or recruitment to the adult walleye population may be limited by factors other than reproductive success and first summer survival of juvenile walleye. Successful recruitment of juvenile walleye to the adult population may be related to low winter water levels.

Due to the negative effects of the wide water level fluctuations in Fresno Resevoir, a walleye stocking contingency plan has been developed. This will allow quick response stocking in the spring of those years when natural walleye reproduction is inadequate, when significant numbers of juvenile fish are swept from the reservoir with extreme drawdowns or when good walleye production in severely affected by extreme reservoir drawdowns.

Tiber Reservoirr

Tiber Reservoir is a 22,180 acre reservoir on the Marias River. The closure date of the reservoir was October, 1955. In 1971, when walleye were introduced, yellow perch was the most abundant fish in the reservoir. The majority of the walleye introduced were stocked in Willow Creek Arm which contains more littoral zone than the rest of the reservoir. This area also has the best potential for walleye spawning sites in the form of gravel and rubble.

From 1971-1974, 5.1 million walleye fry were planted in Tiber Reservoir. Natural reproduction was expected to occur in 1975. Subsequent sampling showed that the 1975 year class was somewhat weak, but natural reproduction yielded strong year classes in 1976 and 1977.

The principal forage fish for all of the piscivorous game fish (walleye, northern pike and burbot) in Tiber Reservoir is yellow perch. White sucker and spottail shiners (introduced in 1985) are the secondary forage fish species. The 1979 MDFWP annual report indicated that populations of these forage fish species had fluctuated over time but have shown a definite decreasing trend. This trend coincides with the increased pike and walleye populations during the same time period (Table 4).

Table 4. Percent of total catch in fall gill net surveys represented by yellow perch, sucker, walleye, northern pike and rainbow for the years 1960-1978.

Year	Yellow Perch	Sucker	Northern Pike	Walleye	Rainbow
1960	--	71.0	--	--	29.0
1961	--	85.0	--	--	15.0
1968	59.0	39.0	--	--	1.0
1971	78.2	16.3	--	--	2.4
1972	65.7	32.9	--	--	--
1973	17.7	64.9	0.5	9.8	4.6
1974	11.5	42.4	1.9	40.5	2.3
1975	17.6	31.4	22.9	20.4	4.9
1976	9.7	19.8	17.2	52.3	0.3
1977	8.1	16.2	7.0	66.9	0.3
1978	4.2	26.6	9.7	56.0	1.9

Preliminary observations made in 1978 also indicated that growth rates of pike and walleye were slower than in previous years, presumably related to the decreasing food supply. Scale analysis of age group I+ and II+ walleye from 1978 yielded average calculated lengths of 4.6 and 9.6 inches respectively. Corresponding lengths for these age classes for the years 1973,1974 and 1975 were 6.0, 12.2; 6.5, 12.4; and 6.4, 12.3 inches, respectively. Given this information the MDFWP began to consider stocking additional forage fish in Tiber Reservoir.

The 1980 gill netting surveys again showed slower growth rates during the first two years of life than had been the norm prior to 1979. These surveys also yielded fewer walleye than in previous years. This was attributed to the population making the change from annual stocking to natural reproduction.

The 1980 annual report also noted that June and July account for the majority of tagged fish caught by fishermen. Pike were taken throughout the year, but walleye appeared to be much harder to catch thoughout the late fall, winter, and early spring.

The 1982 annual report indicated that numbers of walleye and northern pike continued to be considerably lower compared to previous years. This was, again, attributed to the lack of forage fish. The report goes on to state that the Bureau of Reclamation, which operates the reservoir, planned to keep water levels higher in 1982 and 1983. It was hoped that higher water levels during the critical spawning period would increase yellow perch popuations as well as primary food organisms. It was believed that the overall condition of the reservoir fishery would improve with increased food production.

The water level has been operated in this fashion since 1983. The result has been increased yellow perch populations which have helped to support the walleye and northern pike populations. The MDFWP has developed operating guidelines for Tiber Reservoir that will allow for ample reproduction of both gamefish and forage fish species.

Tiber Reservoir typifies some of the problems associated with maintaining walleye populations in irrigation reservoirs in Montana. It is difficult to maintain adequate forage for these effecient predators with native forage species. This leads to the decision to introduce exotic species in order to maintain the fishery. A second, and related problem, is maintaining water levels conducive to both the game fish and the forage species (Wipperman, pers comm.)

Morony Reservoir

Morony reservoir is the most downstream of a series of 5 reservoirs on the mainstem of the Missouri at Great Falls. The reservoir covers about 327 acres, has a maximum depth of 55 feet and contains about 7,000 acre feet of water. This reservoir is a run of the river facility. As such, water exchange is quite rapid, generally occurring several times per day. This situation is very conducive to flushing fish downstream.

Despite its physical characteristics, walleye fry and fingerlings were planted in the reservoir from 1985 through 1987 in an attempt to establish a walleye fishery. In May, 1987 two experimental gill nets and two trap nets were fished in the reservoir to inventory the fish population. No walleye were taken. Another planting of fingerling walleye was planned for late summer, 1987.

Lake Francis

Lake Francis is a 5536 acre irrigation storage reservoir having a maximum depth of 45 feet. Species found in the reservoir include northern pike, yellow perch, rainbow trout, walleye, kokanee, white sucker, longnose sucker and burbot. Walleye fry were first planted in the reservoir in 1969. They first began to appear in the annual gill netting surveys in 1975. Walleye collected in the nets ranged in size from 12.8-19.2 inches.

The 1980 MDFWP annual report states that walleye have been planted periodically since 1969 with little to fair survival and little or no reproduction. In 1976, 200,000 walleye fingerlings were planted. In 1977, 1.6 million fry were planted. At that time the Department was hopeful that a self-sustaining population could be established.

The 1982 annual report indicates that walleye were reproducing successfully and providing a significant fishery, particularly during the summer months. Concern was expressed that forage fish (yellow perch) might be limited and result in poor growth rates of walleye in future years.

The walleye population reached its highest numbers during 1982-1984. Harvest by fishermen was good in 1983 and exceptional in 1984. However, the 1985 gill net surveys revealed below average growth for northern pike and walleye.

A review of the data on tag returns by fishermen indicated that over 76% of the tagged walleye taken by fishermen were caught in June and July.

Holter Reservoir

Walleye were never stocked in Holter Reservoir. The walleye found in Holter are most likely the progeny of walleye planted in Lake Helena in 1951. The plant did not take in Lake Helena and it is believed that some of the stocked fish were flushed out of Lake Helena into Holter via Hauser Reservoir. Limited gill netting data collected prior to 1986 revealed a low density, stable population of walleye in Holter Reservoir since 1969. Detailed investigations into the fisheries of Holter Reservoir, as well as the other mid-Missouri River reservoirs were conducted during the 1986 and 1987 field seasons. In addition to collecting fish population information, temperature profiles and euphotic zone depth data were obtained.

Holter Reservoir did not thermally stratify during 1986 although a very weak stratification was observed during the 1987 field season. The thermocline in Holter, although not always readily evident, ranged from 60-70 feet below the surface.

Thermal stratification of Holter and the other mid-Missouri reservoirs is probably an unusual occurrence. It could be attributed to the very low water year during 1987 and resultant longer than usual water residence times in these run of the river reservoirs.

The euphotic zone, the depth of which roughly approximates the littoral zone, averaged 6.7 feet near the dam and 8.9 feet upstream in 1986. During the 1987 season the euphotic zone depths averaged 9.4 and 13.1 feet near the dam and at the upstream station respectively.

Fish population investigations were carried out utilizing floating and sinking horizontal gill nets as well as vertical nets. The fish community composition data from the gill netting is provided in table 5.

Table 5. Fish community composition of Holter Reservoir. Data is from floating and sinking gill nets fished during spring and fall of 1986 and 1987.

	Floating Gill Nets		Sinking Gill Nets	
	1986	1987	1986	1987
Rainbow Trout	47.9%	61.8%	4.5%	1.6%
Brown Trout	0.4	1.9	0.2	0.6
Kokanee	2.5	3.7	0.4	0.1
Mt. Whitefish	2.8	0.8	1.1	1.9
Yellow Perch	0.0	10.0	22.7	45.3
Walleye	7.0	4.0	2.6	2.2
Longnose Sucker	24.3	8.5	24.6	18.6
White Sucker	14.4	8.5	43.9	29.7
Carp	0.7	0.8	0.0	0.1

It is apparent that the fish community population is dominated by rainbow trout, yellow perch and suckers. Walleye and kokanee are also important components of the community.

Stomach analysis of netted fish revealed that the walleye diet consists largely of fish (99% by volume). Fish species eaten by walleye, in decreasing order of importance, were yellow perch, rainbow trout and mountain whitefish.

In addition to the fish population data collected, an extensive creel census was conducted. Tables 6 and 7 report the species targeted by fishermen and per cent composition of the sport catch during 1986 and 1987 respectively for all three of the mid-Missouri Reservoirs.

Table 6. Species targeted by anglers fishing the mid-Missouri Reservoir Complex during 1986 and 1987.

	Canyon Ferry		Hauser		Holter	
	1986	1987	1986	1987	1986	1987
Trout	82.0%	61.0%	75.0%	36.0%	85.0%	52.0%
Kokanee	--.--	--.--	1.0	15.0	--.--	1.0
Yellow Perch	13.0	15.0	3.0	5.0	6.0	12.0
Walleye	--.--	--.--	--.--	--.--	--.--	5.0
Any Fish	3.0	17.0	7.0	31.0	5.0	24.0

Trout is clearly the species targeted by most anglers fishing the mid-Missouri reservoir complex. Yellow perch ranks second in Holter and Canyon Ferry while kokanee rate second in Hauser. Walleye are ranked third in Holter, the only one of the reservoirs containing significant numbers of walleye.

It appears from the data in the Any Fish category that either the fishermen became less fussy or there was a change in the way the census was administered between the two years. The percentage decrease in trout fishermen mirrors the per cent increase in people seeking Any Fish.

Table 7. Per cent composition of the angler catch from the mid-Missouri Reservoir Complex during 1986 and 1987.

	Canyon Ferry		Hauser		Holter	
	1986	1987	1986	1987	1986	1987
Rainbow Trout	42.6	22.9	52.9	48.6	67.5	46.3
Brown Trout	2.0	0.4	0.9	0.3	0.3	0.1
Kokanee	0.0	0.0	19.8	26.6	1.0	1.8
Yellow Perch	55.4	76.7	26.2	24.2	30.8	49.6
Walleye	0.0	0.0	0.0	0.0	0.4	2.2

This table tells the same story as Table 6. Trout and yellow perch are the most important sport fish in Holter. Walleye was caught slightly more often in Holter than are kokanee in 1987.

Table 8 reports the average (April-October) catch rates for rainbow and brown trout, kokanee, walleye and yellow perch from the mid-Missouri reserviors during 1986 and 1987. Rainbow trout and yellow perch had similar, high catch rates in 1987, followed by a walleye catch rate of 0.27. The walleye catch rate is similar to rates reported for good walleye fisheries from other parts of the country.

Table 8. The average (April-October) catch rates for rainbow and brown trout, kokanee, walleye and yellow perch, 1986 and 1987.

	Canyon Ferry		Hauser		Holter	
	1986	1987	1986	1987	1986	1987
Rainbow Trout	0.28	0.28	0.26	0.26	0.34	0.37
Brown Trout	0.01	0.01	0.01	0.01	0.01	0.01
Kokanee	0.0	0.0	0.1	0.1	0.01	0.01
Yellow Perch	0.37	0.37	0.13	0.12	0.16	0.39
Walleye	0.0	0.0	0.0	0.0	NR	0.27

NR-Not Reported

Lower Yellowstone

MDFWP personnel conducted gill net electrofishing surveys at five locations along the lower Yellowstone during the fall of 1973 and the spring of 1974 (Haddix and Estes, 1976). Large concentrations of walleye were found to occur in the lower Yellowstone below Intake on a seasonal basis. The walleye were present in the spring, but not the fall. It was hypothesized that these fish resided in Garrison Reservoir and used the lower Yellowstone for spawning. Work conducted by Graham et al., (1979) again showed that walleye residing in Garrison Reservoir, on the Missouri River below the confluence of the Yellowstone and Missouri Rivers, migrate as far upstream as the Intake diversion for spawning.

Bighorn Reservoir

Creel census data have been collected at Bighorn Reservoir for twenty years, from 1967-1986. Table 9 presents the results of these efforts. The average catch of walleye/hour over this period was 0.20. The reader will recall that Nelson Reservoir and Holter Reservoir had a catch rate of .27 walleye per hour. A catch rate of .30 walleye/hour is generally considered good for the better midwestern walleye lakes.

Catch rates for walleye during the 6 month period (April-September) of the 1983 census were very similar to those during the 1982 census. Catch rates were low (.14) in April, May and July. Catch rates during June, August and September were .22,.20 and .34 respectively.

Table 9. Results of creel census suveys conducted on Bighorn Reservoir (Montana portion) 1967-1988.

Year	Fishermen Surveyed	Hours Fished	Walleye Caught	Catch Rate
1967	36	66	13	.20
1968	209	654	115	.18
1969	119	249	65	.26
1970	156	527	63	.12
1971	114	490	38	.08
1972	283	1162	126	.11
1973	518	2155	171	.08
1974	817	3641	514	.14
1975	827	4355	918	.21
1976	1358	7277	1753	.24
1977	992	4319	554	.13
1978	442	1884	798	.42
1979	341	1665	372	.22
1980	206	934	150	.16
1981	89	238	100	.42
1982	539	2958	489	.17
1983	760	4359	687	.16
1984	628	3628	942	.26
1985	682	3754	866	.23
1986	668	3249	525	.16
1987	601	3356	358	.11
1988	454	1284	339	.26
			Mean	.20

The contents of 28 walleye stomachs collected from May-September of 1984 were examined to determine walleye food habits. Overall, yellow perch ranked as the most important food item followed closely by carp and green sunfish. Together these three species comprised over 97% of the volume of identifiable fish remains found in the stomachs.

Growth of walleye was compared to other waters near the same latitude including Lac La Ronge, Saskatchewan, and Red Lakes, Minnesota. Bighorn Reservoir walleye grew faster than walleye from these northern lakes, but more slowly than walleye in more southern lakes such as Clear Lake, Iowa, and Lake Francis Case, South Dakota. Growth rates for Bighorn Reservoir walleye are very similar to those for walleye from Nelson Reservoir. Based upon this information it appears that forage is not the problem in Bighorn Reservoir that it is in Tiber Reservoir.

Cooney Reservoir, Montana

Cooney Reservoir is an irrigation reservoir located in south central Montana. Its proximity to Billings makes it an attractive recreational fishery. The reservoir is stocked heavily with rainbow trout on a put-grow-and-take basis. The planted rainbow are generally in the 4-6 inch size class.

In the early 1980's the MDFWP observed that as the sucker population in the reservoir increased, the growth rate of rainbow trout was declining. It was decided to stock walleye sac fry in hopes that the walleye would utilize the sucker as forage.

Stocking was undertaken in 1984. The walleye grew tremendously the first year as they preyed upon the abundant forge base. Gill netting surveys conducted in 1988 yielded large numbers of both walleye and trout. Adult sucker were also taken, but very few smaller sucker were collected. It would appear that the walleye have very effectively reduced the population of the younger sucker.

Walleye growth rates have been variable since the first year. While some walleye from this stocking are now in the 5 pound class, others are only 11 inches in length. It is not clear why there is such variation in the growth rates.

There are a number of questions surrounding this introduction. There is no evidence that the trout fishery has suffered. To date there is no evidnece to indicate that a signifiant walleye fishery has developed. It is also unclear if the walleye are spawning successfully in the reservoir or the inflowing streams.

The introduction of walleye into Cooney can provide important insights into the pros and cons of utilizing this management approach in reservoirs supporting trout fisheries. To date there are more questions than answers regarding this introduction. It is important for MDFWP to closely monitor the population dynamics of the trout, walleye, sucker and chub in this reservoir.

CASE HISTORIES

The information presented in the Walleye Ecology section of this paper, indicates significant differences in the habitat preferences of salmonids, percids (including walleye) and centrarchids. Based upon this information, it appears that when walleye inhabit the same lakes as salmonids or centrarchids, they should be found in different parts of the lake than these other fish. The division of the habitat would be largely on a the basis of temperature, light and food preferences. This would lead one to believe that it is possible for walleye and these other fish to co-exist and thrive in the same lake although competition for food might limit both populations.

There are several reasons why the ecological model of resource partitioning by these families of fish may not describe the actual situation in any given lake or reservoir. The habitat peferences of walleye and trout as described above pertain to the adult forms of these fish. It is the trout fry and fingerlings that are most susceptible to predation by walleye. Therefore, it is the habitat preferences and behavior of trout fry and fingerlings that will determine the important interactions between trout and walleye.

When reading the descriptions of the habitat preferences of the different fish species, they seem to be quite narrowly defined. In fact, all species of fish that are successful are able to survive over a wide range of conditions. Different strains of the same species can have significantly different habitat preferences as well. In addition, the amount of information upon which these habitat preferences are based is quite small. The important point is that with regard to the habitat preferences described in the previous section, percids and salmonids are more plastic in their ecological requirements than they would appear on paper.

Assuming the habitat preferences were very accurately described for the life stage of interest, there is an additional confounding factor to habitat segregation. The lakes in question may not provide clearly distinguishable habitats. For example, many reservoirs have short water retention times. Because the water is in the lake for only a short period, there is not enough time to develop the thermal stratification necessary for trout and walleye to segregate on the basis of water temperature (Willis and Stephen, 1987).

Case histories of walleye-salmonid and walleye-centrarchid interactions were sought in an attempt to document actual experiences rather than relying on the ecological model of resource partitioning presented earlier. Examples of situations where walleye have been introduced into salmonid or centrarchid waters, or vice versa, are not particularly widespread or well studied. One reason for the lack of case histories is that management agencies have been loathe to introduce a major predator (walleye) into good trout fishing waters. Given the high recreation values generally attributed to productive salmonid fisheries, management agencies in the west have decided not to even take the chance of upsetting these fisheries through the introduction of walleye.

Three well-documented examples of walleye-salmonid interactions were located during research for this paper as were several examples of walleye being introduced into historically centrarchid dominated lakes. One of the latter is included because it demonstrates the differences between theory and actual practice.

Seminoe Reservoir, Wyoming

The best documented introduction of walleye into a productive reservoir trout fishery comes from the North Platte River of Wyoming. The lower North Platte River system in Wyoming consists of several reservoirs and 271 miles of river. High quality fishing, particularly for rainbow trout was found throughout most of the system. In the early 1960's, large walleye populations developed in the upstream reservoirs (Seminoe and Pathfinder) with detrimental effects on the traditional trout fishery. It is not clear how walleye got into the reservoir system. They were not planted by the Wyoming Game and Fish Department (WGFD). They may have been planted illegally or accessed into the system from Colorado. In an case, they eventually extended their range throughout the entire system.

A study was undertaken by the WGFD directed toward developing a management approach for the system that would maintain fishable trout populations in the face of the expanding walleye populations. The introduction to the completion report for the study (McMillan, 1984) states that "literature applicable to the managment of a salmonid fishery in the face of a well-developed population of walleye or similar predatory species is directed toward the development of a "two-story" fishery, using warm water species in the upper, warm water strata of impoundments in combination with cool or cold water species in the lower strata." In fact, it has been demonstrated that while temperature preferences of walleye and trout differ, their temperature tolerances overlap Hokanson (1977). An important aspect of the Seminoe Reservoir story is that the reservoirs of the North Platte system do not stratify sufficiently to thermally separate the species.

Due to the lack of natural reproduction of trout in Seminoe Reservoir, stocking is an important management tool. In the late 1960's and early 1970's the stocking program utilized 3.0-4.0 inch fingerlings planted during late summer and early fall from a barge. Due to heavy walleye predation on the fingerlings, it became clear that a new management direction had to be taken in order to maintain the trout fishery. Intensive sampling had shown that walleye were more numerous along the lake shores than in the mid-lake areas. The preference of walleye for littoral and sub-littoral areas has been described previously. The WGFD tried planting the trout fingerlings in the mid-lake areas to reduce walleye predation. Unfortunately, many of the stocked fingerlings found their way to shore within a few hours of stocking. These fingerlings not only sought the shoreline, but they also formed schools. These two behavioral traits made them very susceptible to walleye predation (McMillan, 1984).

The WGFD attempted to counteract these behavioral traits by scattering the fingerlings more sparingly throughout the reservoir using a barge. The greater dispersion of the trout fingerlings appeared to increase the survival of the trout. From 1973-1975 stomach analysis of adult walleye during the post-stocking period showed that the stomachs containing rainbow fingerlings decreased from 72 to 49 to 24 percent, respectively. During this same period the gill net catch per hour of effort of rainbow increased from .12 to .33 to .46, respectively. Greater dispersion of the trout fingerlings was the only planting technique which reduced immediate predation and increased trout survival to the following spring.

These encouraging results were short-lived. After 1975, any gains in the short term survival of the trout due to scattering were largely negated by the continued predation over the remainder of the year. Increasing numbers of walleye were decreasing the populations of forage fish, and the walleye were turning to trout fingerlings increasingly as forage.

Over the ensuing few years the WGFD experimented with planting different sizes of trout. In 1979 three sizes of trout were stocked; 7.3 inches, 4.7 inches, and 3.8 inches. Fall sampling of the fish recovered only those rainbow from the 7.3 inch size group, in spite of the fact that they made up less than 5% of the total marked fish planted. Walleye predation during the the post-stocking period was heavy. The larger sized trout were preyed upon less heavily than the other size classes as demonstrated by their proportionally larger returns in the sampling.

In 1979 walleye preyed heavily on smaller stocked fingerlings, but larger stocked trout appeared to escape predation. This contrasted sharply with earlier plants when walleye preyed just as heavily on the larger as the smaller fingerlings. WGFD attributes this difference to the declining relative abundance of 18 inch and greater walleye in the 1979 population compared to the walleye population of the early 1970's. There simply were not as many large walleye in 1979 to prey on the larger trout fingerlings.

The decrease in abundance of larger walleye is attributed to the declining forage base in the reservoir. When the walleye originally entered the reservoir there was an abundant and under-utilized forage fish resource available. As the walleye population expanded, it severely depleted the forage fish base. The inability of the indigenous forage species to maintain healthy populations was the result of their being riverine species that were not well suited to the lake habitat created by the impoundment of the river. By the mid- to late-seventies, walleye growth rates had decreased and the population had become stunted. WGFD placed a bonus limit of 10 additional walleye on the population in hopes of decreasing the population.

The 1984 WGFD report contains the following recommendation for the trout fishery in Seminoe Reservoir: The present program of stocking 250,000 7.5 inch trout should be continued. The success of the program hinges on the numbers of walleye 16.0 inches and over in length in the population. Walleye larger than this can effectively prey upon the stocked trout. The planting of larger fish has greatly increased the costs of maintaining the Seminoe trout fishery. The fish that are being planted are yearling fish. The cost of keeping them in the hatchery until they reach this size has also greatly increased the costs associated with the trout stocking program. Also, the cost of transporting these larger fish is much greater (McMillan pers comm.).

The WGFD decided to introduce a new forage species with the intent of improving walleye growth rates sufficiently to eliminate stunting, buffering predation on stocked fingerling trout by providing numerous alternate prey for walleye, and improving the growth of 12.0 inch and larger trout by providing a desirable food item that was more energy efficient that zooplankton.

Experimental planting with gizzard shad and emerald shiners was attempted. The gizzard shad plants were very successful with brown trout and walleye using the shad extensively. Shad were also found in the stomachs of rainbow as well. However, the shad did not over-winter, thus annual plants of gizzard shad were required. The emerald shiner plants were not successful as the abundant walleye most likely preyed upon the introduced spawning stock and any progeny (McMillan 1984).

It was also found that part of the walleye population travels upstream from the reservoir to spawn. Some of the fish return to the reservoir after spawning while others remained in the river until the fall. Effects of the walleye on rainbow and brown trout populations in the river above Seminoe reservoir were not tested. Limited stomach analysis of walleye showed that they did prey on trout in the river, but the rate or frequency is unknown.

The WGFD study concludes with recommendations for the walleye fishery as well as the trout fishery. The recommended alternative for the walleye fishery was eradication of walleye from Seminoe Reservoir through chemical rehabilitation. This alternative was selected even though it was the most expensive and intensive management option in the short term. Over the long run, it was concluded that costs would not be appreciably higher than for other management options, particularly if it meant the difference between having or not having a trout fishery in the system.

It is clear that in this particular case the walleye and the trout did not divide the lake habitat spatially or temporally, thus minimizing contact between these species. Based upon the limnological information provided in the WGFD report, it does not appear that Seminoe Reservoir stratifies sufficiently to provide spatial segregation of trout and walleye on the basis of temperature. The lake is on the borderline between being a cool water and cold water fishery. Most of the lake is oligotrophic although some bays may be considered mesotrophic (McMillan pers comm.). Secchi disc readings are generally 10 feet or less. Residence time of water in the reservoir is approximately one year.

John Day Reservoir, Columbia River

The U.S. Fish and Wildlife Service (USFWS) conducted a four year (1983-1986) investigation into the predation by fish resident in John Day Reservoir on juvenile salmonids. The USFWS was interested in learning the extent of juvenile salmonid mortality in reservoirs that could be attributed to predation. The juvenile salmonids of interest are generally Chinook salmon smolts that were moving downstream to the ocean from their freshwater rearing grounds. Northern squawfish, walleye, smallmouth bass and channel catfish were the predators selected for study because previous studies of resident fishes in John Day Reservoir indicated that these species were abundant (Poe, 1988).

The USFWS concluded that northern squawfish, walleye, smallmouth bass and channel catfish consumed an average of 9-19% of the estimated juvenile salmonids that entered the reservoir. Northern squawfish was the dominant predator on juvenile salmonids in John Day Reservoir. The authors estimated that northern squawfish accounted for 78% of the total loss to predators in the reservoir. Most of the northern squawfish predation occurred at the afterbay of an upstream dam. Of the four predators, walleye exhibited the highest mean seasonal consumption rates of juvenile salmonids in the main pool of the reservoir (Vigg et al., in Poe, 1988).

The walleye consumption rate of juvenile salmonids peaked at two years of age. The proportion of walleyes' ration comprised of salmonids decreased with age from about 30% at two years to about one percent at eight years. Older walleye sampled did not eat salmonids.

Juvenile salmonids were the fourth most important food item in the walleye diet, accounting for 11.5% by weight and 3.8% by number of food items. Prickly sculpin and suckers were the most important prey fish species for walleye. Subyearling chinook salmon represented 80.0% of the identified salmonids, whereas yearling chinook accounted for the remainder. Importance of major food items in walleye stomachs varied with the length of the predator. The most important food items for smaller walleye were salmonids and crustaceans, but with an increase in predator size, crustaceans and salmonids decreased in importance (Gray et al., 1982). This was probably related to the size of the prey item relative to the predator.

Mainstem Missouri River Reservoirs, South Dakota

Prior to the development of the mainstem Missouri River reservoirs in South Dakota, walleye were scarce in the river. Walleye populations developed in Lake Francis Case, Lake Sharpe, Lewis and Clark Lake and Lake Oahe. Lake Sharpe has an excellent walleye fishery, with a mean walleye catch rate of .27 fish/angler hour in 1984 and .25 fish/angler hour in 1985 (Riis, 1986). All four reservoirs provide good to excellent walleye fishing.

Walleye distribution in these reservoirs agrees well with the preferred habitat described in the first section of this report. Peak abundance occurs in sections of intermediate depth and clarity. Walleyes are least abundant in highly turbid, flowing waters such as the upper portions of the reservoirs, and in the clear deep waters in the lower portion of Lake Oahe (Nelson and Walburg, 1977).

The South Dakota Department of Game, Fish and Parks has tried for many years to establish trout and salmon populations in these four mainstem Missouri River reservoirs (Warnick, 1987). The attempts to establish trout and salmon fisheries in the three downstream reservoirs have not been successful. Introductions of salmonids in the lower reaches of Lake Oahe have met with only limited success (Nelson and Walburg, 1977). The lack of success is thought to be due to the fact that, while these reservoirs have excellent coolwater habitat, they do not provide good coldwater habitat (D. Unkenholz, pers. comm.). As a result, the trout and salmon simply do not do well.

In this case, unlike the Seminoe Reservoir example, the habitat conditions in the lakes strongly favor one species over the other, almost to the exclusion of the coldwater salmonids.

Escanaba Lake, Wisconsin

The sport fish populations of Escanaba Lake have been studied since 1946. Yellow perch was the most numerous sport species in 1946 and smallmouth bass the major predator. Walleye constituted a minor part of the community at this time. The first natural reproduction of walleye occurred in 1943. Large year classes in 1947 and subsequent years led to the establishment of a large walleye population. Northern pike had also been planted in the early 1940's, but it was not until 1957 that a large year class firmly established pike in the lake. The establishment of these two new predators appeared to have a large influence on the sport fish community composition (Kempinger and Carline, 1977).

As walleye became abundant in the lake, smallmouth bass densities declined. Densities of other centrarchids and yellow perch also declined but were able to recover. Heavy predation of smallmouth bass by walleye, leading to greatly reduced bass populations, in other northern Wisconsin lakes appears to have been common during the 1940's when walleye were widely stocked (Kempinger and Carline, 1977)

Increasing northern pike numbers in the late 1950's coincided with declining densities of prey species adults. These numbers have remained low. Presently, walleye represent the largest part of the fish biomass of the lake, and northern pike rank second. In some lakes where predators dominate the biomass, the walleye are abundant and slow-growing. Presumably, the small number of walleye adults are able to produce large numbers of juveniles which are then cannibalized. Juvenile prey suffer high mortality and few survive to adulthood.

This is not the situation at Lake Escanaba, however. Walleye growth rates have remained fairly constant despite large variations in the densities of adult prey. As northern pike growth rates declined, reduced prey populations had more effect on northern pike than on walleye. Perhaps walleye were better able to exploit alternate food resources than were the pike (Kempinger and Carline, 1977).

This example again demonstrates the effect that introduced walleye can have not only on the forage base, but on other predators as well. In this case the original predator, smallmouth bass, was displaced and the forage fish biomass was greatly reduced.

DISCUSSION AND RECOMMENDATIONS

The introduction of a non-native fish is always a risky venture. The possibility of increasing fishing opportunities is balanced by the risk of affecting other fish species. Even introductions that are generally considered long term successes, such as the introduction of brown trout to the United States and closer to home, rainbow to the Yellowstone River drainage, have their down sides. The brown trout is now a popular mainstay of American trout fishing. However, it has caused declines in native trout populations including the golden trout, gila trout, and McCloud River Dolly Varden

(Rosen, 1989). The introduction of rainbow trout throughout the West has been partially responsible for the decline of native cutthroat species due to competition and inter-breeding.

Given the risk inherent in introducing fish beyong their native range, Drs. Christopher Kohler and Jon Stanley, experts in the field of introduced fish, have developed an 'opinionnaire' which they recommend that fishery biologists and administrators complete prior to any introduction (Rosen, 1989). The opinionniare is reproduced in large part below:

1. Is the need for the introduction valid and are there no native species available that could serve the stated need?
2. Is the exotic species safe from over-exploitation in its native range?
3. Are safeguards adequate to guard against importation of disease and parasites?
4. Would the exotic species be limited to closed systems?
5. Would the exotic species have only positive ecological impacts?
6. Would the exotic species be unable to establish a self sustaining population in the range of habitats that would be available?
7. Would all consequences of the exotic species be beneficial to humans?
8. Does the data base indicate desirability for introduction?
9. Would the benefits of the introduction exceed the risks?

This set of questions would be a good place for the MDFWP to begin in considering any fish species introduction in general and walleye specifically. There are two questions 4 and 6, that have particular relevance to walleye introductions. Question four is in regards to the ability of the fish to move from the location of introduction into other waters where its presence may not be desired. For example, assume that Seeley Lake in the Clearwater drainage contained excellent walleye habitat. From Seeley Lake walleye could move downstream into Placid and Salmon Lakes, the

Blackfoot River, the Clark Fork River and ultimately to Lake Pend Oreille. Regardless of any other considerations, the prospect of walleye gaining access to the Blackfoot and Clark Fork Rivers and Lake Pend Oreille, (all of which are important salmonid waters), would be sufficient reason not to plant them anywhere in the Clearwater Drainage.

Question six addresses whether the introduced fish will be able to establish a self sustaining population. An appropriate example may be Cooney Reservoir. It is not yet known if walleye are reproducing in Cooney. If the walleye do not establish a self sustaining population, this will give MDFWP added management flexibility. If it becomes apparent that walleye are having a negative effect on the trout fishery, the relative benefits of managing for walleye and/or trout can be reevaluated. If, on the other hand, the walleye population becomes self sustaining and adversely affects the trout fishery, the agency has lost most of its control of the situation.

While the introduction of any fish is subject to scrutiny, the introduction of walleye has been a particularly controversial subject in the western United States. The state of Idaho (1982) conducted an evaluation of the introduction of walleye in that state. In their evaluation they noted:

-Walleye have not been introduced in northern California because of concern for their possible impact on salmon, steelhead, sturgeon and striped bass.

-Utah has not introduced walleye and salmonids together because they believe that salmonids cannot compete with walleye.

-In New Mexico it is suspected that walleye are suppressing trout in the one lake where both species are present. The New Mexico department has resisted stocking walleye in salmonid waters.

-The policy of the Colorado Division of Wildlife is to not stock walleye in trout waters.

-Wyoming is opposed to the introduction of walleye into salmonid waters on the basis of the North Platte River reservoir experience.

In the course of evaluating Idaho waters for the introduction of walleye, the state considered:

-The physical suitability of the lake including size, depth, drawdown during spawning, availability of spawning substrate, water clarity and temperature.

-The presence or potential for an abundance of forage fish.

-The potential for the spread of walleye into connecting waters where their establishment would conflict with other fisheries.

-The adequacy of the existing fishery.

Another area of concern was the compatability of walleye with a highly-regarded existing fishery. The Idaho report states "It is an inescapable fact that walleye have the potential for making significant depletions of lower food chain fishes. We should heed the cautions expressed by other state fishery experts and not purposely create competition for desirable existing fisheries". Salmonids were not the only source of potential conflict considered by Idaho. The potential conflict with other popular game fish such as yellow perch was also considered in their evaluation.

Preceeding sections of this report have documented walleye introductions in Montana that have resulted in good walleye fisheries. Nelson, Bighorn and Holter reservoirs are noteworthy because the creel census data is available to show catch rates comparable to those of good walleye fisheries in other parts of the country. Walleye introductions in Montana have not been without their problems. The factors which appear to most frequently limit walleye populations in Montana are inadequate forage, water level fluctuations and short water retention times. In addition to these physical and biological limiting factors there are concerns, as in the rest of the West, regarding the effects of introductions on existing salmonid and other game fish fisheries.

One aspect of the effect of walleye on exisiting fisheries that has not been addressed is the cost of maintaining a trout fishery in the face of significant predation on stocked fingerling trout by walleye. For example, Canyon Ferry is one of the most valuable fisheries in the state. The current economic value of fishing at Canyon Ferry is approximately 3.5 million dollars per year. A large part of the fishery at Canyon Ferry is provided by 4.5 -5 inch stocked rainbow trout which grow rapidly to catchable size. If this fishery was threatened by predation of walleye on stocked fish, it would be necessary, based on the Seminoe Reservoir experience, to plant 7 inch fish. This would result in a 65% increase in stocking costs. These costs include food and distribution as well as facility maintenance and personnel. Unrecognized costs include the reservoirs and lakes that would not receive fingerlings because of the additional hatchery space required by the larger fish destined for Canyon Ferry.

It is obvious that there are many factors to consider in deciding whether to introduce walleye beyond their current range in Montana. The question is sufficiently complex that it must be answered on a case by case basis. It must also be addressed in a systematic way that guarantees that all the important issues are addressed each time. An environmental assessment should be completed for each lake considered for walleye introduction to insure that the action is carefully considered before a decision is made. The evaluation of criteria, such as those described by Rosen (1989) and the State of Idaho (1982) should be an integral part of each environmental assessment conducted. In addition, criteria specific to walleye and Montana should also be addressed. The following criteria are recommended:

-A trout, yellow perch or other gamefish catch rate of 0.25 or greater should preclude the introduction of walleye because in most situations it is not likely that the walleye catch rate will exceed this level.

-The proposed body of water should have abundant forage fish or the potential to support abundant forage fish.

-The water retention time of the water body should be one year or longer because shorter retention times lead to downstream losses of walleye. In addition shorter retention times limit thermal stratification of lakes and reserviors.

-If the proposed water body is a reservoir, water levels should be managed in such a way as to optimize forage fish reproduction.

-The water body should provide the habitat requirements for walleye as described in Table 1 of this document.

In deciding whether or not to stock walleye in a particular water body, the Department should take a conservative approach. There are very few well documented examples regarding the effect of the introduction of walleye into salmonid waters. Two of the examples cited here, Seminoe Reservoir and John Day Reservoir, revealed that walleye preyed heavily on young salmonids. Given the lack of experience from which to extrapolate and the results of the few examples available, caution is in order.

The Department should closely monitor the situation at Cooney Reservoir as this may become an example for future introductions.

There have been successful introductions of walleye within Montana and it is likely that additional waters will be identified that meet the above criteria for future introductions. In addition, the completion of the Miles City hatchery will provide MDFWP with additional walleye fry and fingerlings with which to improve existing walleye fisheries. There are ample opportunities to enhance the walleye fisheries of Montana and still protect other valuable fisheries from the potentially adverse affects of introducing walleye beyond their current range in Montana.

LITERATURE CITED

Adams, G.F. and C.H. Olver. 1977. Yield properties and structure of boreal percid communities in Ontario. J. Fish. Res. Board Can., 34 (10): 1613-1625.

Anderson, J. K. 1971. Lake Champlain fishery investigations. Vermont Fish and Game Deprtment. 34 pp.

Anthony, D.D. and C. R. Jorgensen. 1977. Factors in the declining contributions of walleye to the fishery of Lake Nipissing, Ontario, 1960-1976. J. Fish. Res. Board. Can., 34 (10): 1703-1709.

Arnold, B.B. 1960. Life history notes on the walleye, in a turbid water, Utah Lake, Utah. M.Sc. Thesis, Utah State Univ., Logan, Utah. 114pp.

Brown, C.J. D. 1971. Fishes of Montana. Big Sky Books, Montana State Univ., Bozeman, MT. 207pp.

Carlander, K.D. and L.E. Hiner. 1949. The daily activity patterns of some freshwater fishes. Am. Midl. Nat., 41 (2):447-452.

Chesire, W.F. 1968. Long term walleye study in the Tweed Forest District, progress report no. II. Manuscr. Rep. Ont. Dep. Lands For., 37pp.

Cristie, G.C. and H.A. Regier. 1988. Measures of optimal thermal habitat and their relationship to yeilds of four commercial fish species. Can. J. Fish. Aquat. Sci. 45: 301-314.

Colby, P.J. 1984. Appraising the status of fisheries: rehabilitation techniques. pages 233-257 in V.W. Cairns and P.V. Hodson, eds. Contaminant effects on fisheries. John Wiley and Sons, Inc., New York, New York.

Colby, P.J. and S.J. Nepszy. 1981. Variation among stock of walleye: management implications. Can. J. Fish. Quat. Sci. 38: 1814-1831.

Colby, P.J., P.A. Ryan, D.H. Schupp, and S.L. Serns. 1987. Interaction in north-temperate lake fish communities. Can. J. Fish. Quat. Sci. (Suppl. 2): 104-128

Colby, P.J., R.E. McNicol and R.A. Ryder. 1979. Synopsis of biological data on the walleye (Stizostedion v. vitreum (Mitchill 1818)). FAO Fish. Synop. No. 119. 139pp.

Erickson, J. 1972. Evaluation of environmental factors of Ohio reservoirs in relation to the success of walleye stocking. Ohio Dep. Nat. Resour., Div. Wildl. Inland Fish. Res., Project F0-29-R:19 pp.

Forney, J.L. 1966. Factors affecting first year growth of walleyes in Oneida Lake, New York. New York Fish and Game Journal 13-146-167.

Forney, J.L. 1977. Evidence of inter- and intraspecific competition as factors regulating walleye biomass in Oneida Lake, New York. J. Fish. Res. Board. Can., 34(10):1812-1820.

Gray, G.A.,G.M. Sonnevil, H.C. Hansel, C.W. Huntington and D.E. Palmer. 1982. Feeding activity, rate of consumption, daily ration and prey selection of major predators in the John Day Pool, 1982 Annual Report. U.S. Fish and Wildlife Service. NFRC-Willare Substation, Cook Washington. 81pp.

Gregory, R.W. and T.G. Powell. 1969. Walleye fry stocking. Colordo Department Game, Fish and Parks. Federal Aid Fish and Wildlife Restoration Project F-34-R-4, Job 4:12 pp.

Groebner, J.F. 1960. Appraisal of the sport fishery catch in a bass-panfish lake of southern Minnesota, Lake Francis, Le Sueur County, 1952-1957. Invest. Rep. Minn. Dep. Conserv., (255) : 17pp.

Groen, C.L. and T.A. Schroeder. 1978. Effects of water level management on walleye and other coolwater fishes in Kansas reservoirs. Paper presented at a Symposium on Selected Coolwater Fishes of North America, St. Paul-Minneapolis,Minn., March 7-9.

Hokanson, K.E.F. 1977. Temperature requirements of some percids and adaptation to the sesonal temperature cycle. J. Fish. Res. Board Can 34: 1524-1550.

Idaho Department of Fish and Game. 1982. Evaluation of Walleye for an Expanded Distribution in Idaho. Boise, ID. 60 pp.

Johnson, B.L., D.L. Smith and R.F. Carline. 1988. Habitat preferences, survival, growth, foods, and harvests of walleyes and walleye x sauger hybrids. N. Am. Jrnl. Fish. Management 8: 292-304.

Johnson, F.H. 1971. Survival of stocked walleye fingerlings in northern Minnesota lakes as estimated from the age-composition of experimental gill net catches. Invest. Rep. Minn. Dep. Nat. Resour., (314) : 12pp.

Johnson, F.H. 1961. Walleye egg survival during incubation on several types of bottom in Lake Winninbigoshish, Minnesota, and connecting waters. Trans. Am. Fish. Soc., 90 (3): 312-322.

Johnson, F.H. 1977. Responses of walleye and yellow perch populations to removal of white sucker from a Minnesota lake, 1966. J. Fish. Res. Board Can. 34 (10): 1626-1632.

Johnson, F.H. 1969. Environmental and species associations of the walleye in Lake Winnibigoshish and connected waters including observations on food habits and predator-prey relationships. Minn. Fish Invest., (5) : 5-36.

Johnson, F.H. and M.W. Johnson. 1971. Characteristics of the 1957-1958 and 1939 sport fishery of Lake Winnibigoshish and connecting waters with special emphasis on the walleye population and catch. Invest. Rep. Minn. Dep. Nat. Resour., (312) : 30pp.

Johnson, M.G., J.H. Leach, C.K. Minns, and C.H. Olver. 1977. Limnological characteristics of Ontario lakes in relation to associations of walleye, northern pike, lake trout, and small mouth bass. J. Fish. Res. Board Can 34 (10) : 1592-1601.

Johnson, M.W. 1964. A five-year study of the sport fishery of Mille Lacs Lake, Minnesota, 1958-1962. Invest. Rep. Minn. Dep. Conserv., (273) : 16pp.

Kelson, J.R.M. and F. J. Ward. 1977. Unexploited percid populations of West Blue Lake, Manitoba, and their interactions. J. Fish. Res. Board Can., 34 (10) : 1655-1669.

Kempinger, J.J. and R.F. Carline. 1977. Dynamics of the walleye ppulations in Escanaba Lake, Wisconsin. J. Fish. Res. Board Can., 34 (10) : 1800-1811.

Kerr, S.R. and R.A. Ryder. 1977. Niche theory and percid community structure. J. Fish. Res. Board Can., 34 (10) : 1952-1958.

Kitchell, J.F., M.G. Johnson, C.K. Minns, K.H. Loftus, L. Greig, and C.H. Olver. 1977. Percid habitat: the river analogy. J. Fish. Res. Board Can., 34 (10) : 1936-1940.

Klingbiel, J. 1969. Management of walleye in the upper midwest. Bur. Fish. Manage. Rep. Wisc. Dep. Nat. Resour., (18) : 14pp.

Leach, J.H. 1964. The Georgian Bay walleye (yellow pickeral) study. A progress report, 1962. Resour. Manage. Rep. Ont., (73) : 53-68.

Lux, F.E. and L.L. Smith, Jr. 1960. Some factors influencing seasonal changes in angler catch in a Minnesota Lake. Trans. Am. Fish. Soc., 89 (1) : 67-79.

McMahon, T.E., J.W. Terrell and P.C. Nelson. 1984. Habitat suitability information: Walleye. FWS/OBS-82/10.56 ,USFWS, Washinton D.C. 43 pp.

McMillan, J. 1988. Personal Communication. Fishery Biologist, Wyoming Game and Fish Department.

McMillan, J. 1984. Evaluation and enhancement of the trout and walleye fisheries in the North Platte River sytem of Wyoming with emphasis on Seminoe Reservoir. Wyoming Game and Fish Department, Laramie, Wyoming. 169 pp.

MacLean, J.H. and J.J. Magnuson. 1977. Influences on species interactions in percid communities. J. Fish. Res. Board Can., (34) 10 : 1941-1951.

Micklus, R.C. 1959. A three year creel census of a soft-water walleye population in northeastern Minnesota, Caribou Lake.,Cook County. Invest. Rep. Minn. Dep. Conserv., (220) : 5 pp.

Nelson, W.R. and C. H. Walburg. 1977. Population dynamics of yellow perch, sauger and walleye in four main stem Missouri River reservoirs. J. Fish. Res. Board Can., 34 (10) : 1748-1763.

Olson, D.E. and M. Wesloh. 1962. A record of si xyears of angling on Many Point Lake, Becker County, Minnesota, with special reference to the effect of walleye fingerling stocking. Inves. Rep. Minn. Dep. Conser., (247) : 5 pp.

Olson, D.E. . 1963. Role of the white sucker in Minnesota waters. Proc. Minn. Acad. Sci. 31 (1) : 68-73.

Parsons, J.W. 1971. Selective food preferences of walleyes of the 1959 year class in Lake Erie. Trans. Am. Fish. Soc., 100 (3) : 474-485.

Payne, N.R. 1964. Progress report on the Bright Lake fisheries investigation, Sault Ste Marie District. Manuscr. Rep. Ont. Dep. Lands For., 8 pp.

Payne, N.R. 1965. A progress report on the Mississagi River Walleye study, Sault Ste. Marie District. Manuscr. Rep. Ont. Dep. Lands For., 29 pp.

Poe, T.P. 1988. Predation by resident fish on juvenile salmonids in John Day Reservoir, 1983-1986. Volume I-Final Report of Research. USFWS National

Fishery Research Center, Cook, WA.

Priegel, G.R. 1962. Food of walleye and sauger in Lake Winnebago. Misc. Res. Rep. Wisc. Conserv. Dep., (6) : 10 pp.

Priegel, G.R. 1962. Winnebago studies. Annual progress report for the period January 1 to Decmeber 31, 1961. Annu. Progr. Rep. Wisc. Conserv. Dep., 75 pp.

Priegel, G.R. 1971. Evaluation of intensive freshwater drum removal in Lake Winnebago Wisconsin, 1955-1966. Tech. Bull. Wisc. Dep. Nat. Resour., (47) : 28 pp.

Rice, D.J. 1964. Report on the White Lake Fishery Project, 1963. Resour. Manage. Rep. Ont. Dep. Lands For., (78) : 50-58.

Ricker, W.E. and J. Gottschalk. 1941. An experiment in removing coarse fish from a lake. Trans. Am. Fish. Soc., 70 (1940) : 382-390.

Riis, J.C. 1986. Angler use and sport fishing harvest survey on Lake Sharpe, South Dakota, 1984-1985. South Dkaota Department of Game, Fish and Parks, Pierre, South Dakota. 33 pp.

Ritchie, B.J. and P.J. Colby. 1988. Even-odd year differences in walleye year-class strength related to mayfly production. N. Am Jrnl. Fish. Management 8: 210-215.

Rosen, R. 1989. Introduced fish-when to say "No". The In-Fisherman 83: 36-39.

Ryder, R.A. 1965. A method for estimating the potential fish production of north-temperate lakes. Trans. Am.Fish. Soc. 94 (3) : 214-218.

Ryder, R.A. 1968. Dynamics and exploitation of nature walleyes in the Nipigon Bay region of Lake Superior. J. Fish. Res. Board Can., 25 (7) : 1347-1376.

Ryder, R.A. 1977. Effects of ambient light variations on behavior of yearling, subadult , and adult walleyes. J. Fish. Res. Board Can., 34 (10) 1481-1491.

Schneider, J.C. 1978. Selection of minimum size limits for walleyes fishing in Michigan. Paper presented at a Symposium on Selected Coolwater Fishes of North America, St. Paul-Minneapolis, Minn., March 7-9, 1978.

Scott, W.B. and E.J. Crossman. 1973. Freshwater Fishes of Canada. Bull. Fish. Res. Board Can., (184) : 966 pp.

Wipperman, Al. Habitat Bureau Chief, Fisheries Division, MDFWP, Helena. Personal Communication.

Wiedenheft, Bill. Fishery Biologist, Fisheries Division, MDFWP, Fort Peck. Personal Communication.

Willis, D.W. and J.L. Stephen. 1987. Relationships between storage ratio and population density, natural recruitment, and stocking success of walleye in Kansas reservoirs. N. Am. Jrnl. Fish. Management 7: 279-282.

APPENDIX A
RESUMÉS

PETER J. COLBY

Education and Experience

Professional Address

Ontario Ministry of Natural Resources
Fisheries Research Section
Walleye Unit
P.O. Box 5000
435 James Street, South
Thunder Bay, Ontario
CANADA P7C 5G6

Educational Background

Received B.S. (1955) and M.Sc. (1958) degrees in Fisheries Biology from Michigan State University.

Received Ph.D. (1966) degree in Fisheries Biology from the University of Minnesota under the direction of the late Dr. Lloyd L. Smith, Jr. The research consisted of laboratory and field studies to determine the influence of wood fiber-sludge deposits on the survival of fish eggs, fry, and fish-food organisms. The project was sponsored by the National Institute of Health.

Employment History

1971 - Present: Research Scientist in charge of the Walleye Research Unit, Research Section, Ontario Ministry of Natural Resources, Thunder Bay, Ontario.

1987-88. Consultant, State of Wisconsin. Expert Witness regarding impact of Native fishing agreements on their inland lake walleye fisheries.

1976-77. Consultant, Woods Hole Oceanographic Institution. Reviewed the status of their Atlantic Salmon Research Program in the Province of Quebec.

1970-71. Aquatic Biologist and Project Leader, Bureau of Sport Fisheries and Wildlife and Research Associate, Department of Environmental and Industrial Health, School of Public Health, University of Michigan, Ann Arbor, Michigan.

1966-70. Aquatic Biologist and Project Leader, Bureau of Commercial Fisheries, U.S. Fish and Wildlife Service, Ann Arbor, Michigan.

1962-66. Research Assistant, National Institute of Health Fellowship, Department of Entomology, Fisheries and Wildlife, University of Minnesota.

1957-62. Food Technologist, Research Department, General Food Corporation, Battle Creek, Michigan.

1956-75. 2/LT USAR, Artillery, U.S. Artillery and Missile School, Fort Sill, Oklahoma.

1955-56. Graduate Assistant, Agricultural Experiment Station fellowship, Department of Fisheries and Wildlife, Michigan State University.

Work Experience

1957-62. Industrial research experience at General Foods Corporation consisted of developing and improving food products and processes, preparing quality control manuals, raw material specifications and project reports.

1966-71. Aquatic Biologist with the U.S. Bureau of Commercial Fisheries, at Ann Arbor, Michigan and Research Associate with the Department of Environmental and Industrial Health, School of Public Health, University of Michigan.

Duty assignment was project leader, biology and ecology. As principal investigator, the work involved gaining a better understanding of the intrinsic and extrinsic factors responsible for large scale changes in the Great Lakes fish community, including an attempt to describe the physiological and behavioral response of important species under optimum and suboptimum conditions. Also assisted the Federal Aid Supervisor in evaluating physiological studies sponsored by the U.S. Bureau of Commercial Fisheries at various midwestern universities.

Faculty appointment at the University of Michigan consisted of advisor on heavy metal toxicity studies.

1971-Present. Research Scientist, Ontario Ministry of Natural Resources, Thunder Bay, Ontario. Unit Leader, Walleye Unit, in charge of providing scientific generalizations and inferences for managing the provincial walleye fisheries, (i.e., description of life history, population and community dynamics and ecology of walleye, and their response to both aberrant and simulative stresses. Other duties include organizing or chairing international meetings for the purpose of developing and transferring corporate science policy. Serving as scientific advisor to North Central Region Assessment Units and consultant on fishery problems and initiatives, throughout the Great Lakes area.

Accomplishments (Research and Science Transfer)

Research accomplishments, while employed in industry, must be considered as part of a team approach to problem solving and are as follows: assisted in developing an enzyme process for modifying a certain vegetable flour, developing the beverage drinks "Tang" and "Grapefruit Tang", writing their quality control specifications, and assisted in designing and developing certain commercial breakfast cereal processes and processing equipment.

At the University of Minnesota, developed a microstrata water sampler for determining water quality in the vicinity of the substrate water interface of river bottoms, an open system continuous flow bioassay apparatus for studying the effect of H_2S on aquatic organisms and, with this equipment, demonstrated that toxic materials evolve from wood fiber-sludge deposits in concentrations that are lethal to certain aquatic organisms.

With the assistance of the Federal Aid Supervisor, organized a task force of scientists to study the underlying cause of the mass alewife mortalities which periodically plague the Great Lakes. Developed criteria and procedure for assessing the effect of heated discharges on the egg incubation time of Great Lakes fishes.

Research results were used for establishing water quality criteria for hydrogen sulphide and waste heat (see National Academy of Science and Engineering, 1973; Water Quality Criteria, 1972, EPA-R3-73-033, March, 1973).

In 1975, developed a cooperative research team with Lakehead University to study the effects of various exploitation perturbations on walleye populations and communities. As scientific advisor or committee member, I advised 8 M.Sc. and 3 Honor's B.Sc. students in obtaining their degrees.

Organized, chaired and edited the Percid International Symposium (PERCIS) held at Quetico Center, Ontario, Sept. 24-Oct. 5, 1976. Proceedings were published as a special issue of the J. Fish. Res. Board Can. 34(10): 1445-2000. The information obtained from this symposium contributed significantly to the design of Ontario's future fishery management plans for the 1980's (Strategic Planning for Ontario Fisheries, or S.P.O.F.).

Reviewed and synthesized all published research up to 1979 on the walleye (Stizostedion vitreum vitreum) for FAO, Rome. This synopsis, published in 1979, incorporates synthesized material which is valuable in assessing the status of our walleye stocks in Ontario. Presently preparing an updated walleye bibliography in cooperation with Minnesota DNR.

As chairman of SPOF Working Group 12 (1982), I was instrumental in developing guidelines for partitioning yield estimates into individual species yields thereby reducing to practice one of the world's first useful multispecies harvest models. I also contributed significantly to developing indices for identifying overexploitation (SPOF Working Group 15).

At the request of the Lake Huron Fisheries Management Committee, I co-authored the Georgian Bay Walleye Report in 1982. The status of the walleye fisheries was assessed and critical needs identified following interviews and a review of about 70 internal reports.

In 1982, I contributed to the satisfactory defence of the Ministry's position of regulating fish harvests on Lake Nipigon before the Game and Fish Hearing Board in 1982.

In 1983, I was a member of an inter-agency, working group to develop strategies and alternatives for fisheries research in Ontario. Our report was the basis for providing direction for modernizing the provincial research program and maintaining internal research capabilities.

The Walleye Unit staff was a prime mover in establishing and supporting in Northwestern Ontario, the first all-Canadian Chapter of the American Fisheries Society. The unit handled much of the initial administrative responsibilities and initiated the first special publication (Walleye and Tourism, 1985).

Presently the Walleye Unit is aiding the Ministry in developing fishery initiatives for the nineties. For example, the unit played a primary role in transferring science and management options to the tourist industry in a recent (March 1985) AFS (Northwestern Ontario Chapter) workshop titled "Walleye and Tourism: Future Management Strategies". The published proceedings served as a milestone in transferring fishery science to the Northern Ontario tourist industry and public in general.

As Ministry consultant and resource person, reviewed Atikokan District Tourism Development Study.

I played a significant role developing or defending management strategies for Lake Nipissing, Nipigon, Lake of the Woods, Shoal Lake, and Rainy Lake. I also participated in the development of the Minnesota-Ontario Boundary Waters Atlas for Lake of the Woods, Rainy Lake and Rainy River - a background document necessary for the development of options for managing the resource, which in turn facilitated the development of long-term solutions to the management of the borders waters (e.g., establishing non-resident user fees).

Presently reviewing potential changes in management strategies and regulations for Eagle Lake and Lac Suel.

Also served as a resource person for reviewing the Post-Operational Environmental Monitoring at the Atikokan Thermal Generating Station, Impact of Hydro-electric Development on the Magpie River System at Wawa, and Development of an Effects Monitoring Program for Timber Management Guidelines for Ontario.

Also served as a resource consultant on the NOC Committee to review Northern District Fisheries Management plans and the Lake Superior Management plan.

In 1985, as Great Lakes Coordinator, and Steering Committee Member, assisted in organizing the International Symposium on Stock Assessment and Yield Predictions (ASPY) - primarily for the purpose of developing science for managing the fisheries of the Great Lakes.

Presently, I'm organizing a workshop for the Great Lakes Fishery Commission to evaluate the status and ecological consequences of the walleye rehabilitation programs in the Great Lakes.

Honors and Awards

Certified as a Fisheries Scientist by the Board of Professional Certification of the American Fisheries Society in August, 1971.

Elected Fellow in the American Institute of Fishery Research Biologists, March 11, 1978.

Nominated for President of AIFRB 1981 by Search Committee.

Treasurer of the Thunder Bay Tennis Club, 1979-1981.

Listed in the American Men and Women of Science, Who's Who in the Midwest, Who's Who in the East, Dictionary of International Biography, Community Leaders and Noteworthy Americans, and Men of Achievement.

Scientific paper (1971) entitled "Effect of temperature on electrolyte balance and osmoregulation in the alewife (*Alosa pseudoharengus*) in fresh and sea water" (Trans. Am. Fish. Soc. 100: 624-638) voted 2nd best paper published in Volume 100 by the awards committee, and received honorable mention.

Received the James W. Moffett award for "Response of the alewives, *Alosa pseudoharengus* In: Response of Fish to

Environmental Change" published by Charles C. Thomas, Springfield, Illinois p. 163-198. Selected as the outstanding scientific paper published by a Great Lakes Fishery Laboratory staff member in 1973.

Presentation of Papers

Presented paper on problems in establishing water quality requirements at the 18th Annual AIBS Meeting at College Station, Texas, in 1967. The paper was a summary of the recommendations compiled while serving on a Bureau of Commercial Fisheries committee to review proposed water quality criteria submitted by various states to FWPCA for protecting aquatic life.

Presented paper on the effect of temperature on survival and development of lake herring at the First International Symposium on the Biology of Coregonid Fishes held at Winnipeg, Manitoba in 1969.

Presented paper on "Response of the alewife, *Alosa pseudoharengus*, to environmental change" at a Japan-U.S.A. Cooperative Science Program in Tokyo, Japan, November 23-26, 1970.

Guest Speaker at 40th Midwest Fish and Wildlife Conference on Dec. 10, 1978 in Columbus, Ohio. Discussed the reproductive potential and population self-regulation of fishes.

Keynote speaker for Minnesota, North and South Dakota Chapter of AFS at Fargo North Dakota, Feb. 1984. Discussed walleye management in Ontario.

Convened numerous sessions at International meetings and symposia.

Participation in Technical Conference and Workshop

Participated in a technical symposium at Hercules Powder Company, Delaware, concerned mainly with the thixotrophic properties of cellulose gums, starches and proteins. Participated in a technical flavor symposium at General Foods Central Laboratories, Tarrytown, New York.

Participant in the Federal Workshop to prepare a position paper on effects of heated discharge into Lake Michigan, and was one of the anonymous authors of the Federal White Paper, "Physical and Ecological Effects of Waste Head on Lake Michigan". Presented personal views regarding this subject on national television news (NBC Brinkley Report, October 1970).

Advisory Experiences

1966-1970

Advised the Environmental Protection Agency (EPA) temperature study team during their preparation of prepared water quality standards for the Great Lakes.

Advised Argonne National Laboratories in developing a program to study the effects of nuclear power plants on the ecology of the Great Lakes.

Member of American Institute for Fisheries Research Biologist Committee to advise the American Nuclear Society on standards to protect aquatic life from adverse effects of thermal power plants.

1971-Present

Member of National Academy of Sciences peer review team to evaluate the quality and vitality of the U.S. (NOAA) Oceanic Research and Development program (1967-1977). In the fall of 1975, I was leader of the peer review team that evaluated the Northwest Fisheries Center NOAA National Marine Fisheries Service at Seattle, Washington, Auk Bay and Kodiak, Alaska. Results of the NOAA review were published as a public document by the National Academy of Sciences in 1977.

Consultant to Woods Hold Oceanographic Institution on the Atlantic Salmon research program in the Province of Quebec.

Serve on Graduate Advisory Committees, frequently as research advisor, of Master of Science candidates at Lakehead University, Thunder Bay, Ontario.

I was also an External Examiner of a M.Sc. thesis at Laurentian University in 1985.

Referee papers for the Canadian Journal of Fisheries and Aquatic Sciences (formerly the Journal of Fisheries Research Board of Canada), the Drottningholm Report of the Institute of Freshwater Research, Sweden, the American Fisheries Society, Environmental Biology of Fishes, and the Fishery Bulletin.

Review grant proposals for National Science Foundation, Washington, D.C., U.S. Environmental Protection Agency (Duluth, Minn.), Michigan and Minnesota Sea Grant Programs, and National Sciences and Engineering Research Council of Canada.

Consultant to the State of Wisconsin: Provide expert advice or testimony regarding scientific generalizations and inferences for managing walleye fisheries, including a description of life history, population and community dynamics and ecology of walleye, and their response to both aberrant and simulative stresses.

Discuss work as scientific advisor on fishery problems and initiatives throughout the Great Lakes area.

Membership in Professional Societies

American Fisheries Society
American Institute of Fishery Research Biologists
The International Association for Great Lakes Research
Canadian Society of Zoologists

Publications

Colby, Peter J. and Lloyd L. Smith, Jr. 1967. Survival of walleye eggs and fry on paper fiber sludge deposits on the Rainy River, Minnesota. Trans. Am. Fish. Soc. 96: 278-296.

Colby, Peter J. and Lloyd L. Smith, Jr. 1968. A microstrata water sampler for stream study. Prog. Fish-Cult. 30: 116-117.

Colby, Peter J. and Larry T. Brooke. 1969. Cisco (Coregonus artedii) mortalities in a southern Michigan Lake. Limnol. Oceanogr. 14: 958-960.

Colby, P.J. and L.T. Brooke. 1979. Survival and development of lake herring (Coregonus artedii) eggs at various incubation temperatures. Pages 417-428 in C.C. Lindsey and C.S. Woods, eds. Biology of Coregonid Fishes. University of Manitoba Press, Winnipeg, Manitoba.

Lucas, Henry F., Jr., David N. Edgington and Peter J. Colby. 1970. Concentrations of trace elements in Great Lake fishes. J. Fish. Res. Board Can. 27: 677-684.

Edsall, Thomas A. and Peter J. Colby. 1970. Temperature tolerance of young-of-the-year cisco (Coregonus artedii). Trans. Am. Fish. Soc. 99: 526-531.

Colby, Peter J. 1971. Alewife dieoffs: why do they occur? Limnos. 4: 18-27.

Stanley, Jon G. and Peter J. Colby. 1971. Effect of temperature on electrolyte balance and osmoregulation in the alewife (Alosa pseudoharengus) in fresh and sea water. Trans. Am. Fish. Soc. 100: 624-638.

Colby, P.J., G.R. Spangler, D.A. Hurley and A.M. McCombie. 1972. Response of S.C.O.L. lakes to eutrophication. J. Fish. Res. Board Can. 29: 975-983.

Colby, Peter J. and George N. Washburn. 1972. Feeding behavior of lake whitefish and lake herring in Torch Lake, Michigan. Prog. Fish-Cult. 34: 151.

Colby, Peter J. and L.T. Brooke. 1973. Effects of temperature on embryonic development of lake herring (Coregonus artedii). J. Fish. Res. Board Can. 30: 799-810.

Colby, Peter J. 1973. Response of alewives, Alosa pseudoharengus, to environmental change. Pages 163-197 in Walter Chavin, ed. Response of Fish to Environmental Changes. Charles C. Thomas, Springfield, Illinois.

Colby, P.J. and R.H. Wigmore (eds.). 1977. Proceedings of the 1976 Percid International Symposium (PERCIS). J. Fish. Res. Board Can. 34: 1447-1999.

Colby, Peter J., Richard E. McNicol and Richard A. Ryder. 1979. Synopsis of biological data on the walleye (Stizostedion vitreum vitreum) (Mitchill). FAO Fisheries Synopsis No. 119. 139 p.

Brooke, L.T., and P.J. Colby. 1980. Development and survival of embryos of Lake herring at different constant oxygen concentrations and temperatures. Prog. Fish-Cult. 42: 3-9.

Colby, P.J. and S.J. Nepszy. 1981. Variation among stocks of walleye (Stizostedion vitreum vitreum): management implications. Can. J. Fish. Aquat. Sci. 38: 1814-1831.

Colby, P.J. 1984. Appraising the status of fisheries: rehabilitation techniques. Pages 233-257 In Victor W. Cairns, Peter V. Hodson and Jerome O. Nriagu (eds.) Contaminant Effects on Fisheries. John Wiley & Sons, New York.

Christie, W.J., G.R. Spangler, K.H. Loftus, W.A. Hartman, P.J. Colby, M.A. Ross, and D.R. Talhelm. 1987. A perspective on Great Lakes fish community rehabilitation. Spec. Publ. J. Fish. Aquat. Sci. 44 (Suppl. 2): 486-499.

Colby, P.J., P.A. Ryan, D.H. Schupp, and S.L. Serns. 1987. Interactions in north-temperate lake fish communities. Spec. Publ. Can. J. Fish. Aquat. Sci. 44 (Suppl. 2): 104-128.

Loftus, D.H., C.H. Olver, E.H. Brown, P.J. Colby, W.L. Hartman, and D.H. Schupp. 1987. Partitioning potential fish yields from the Great Lakes. Spec. Publ. Can. J. Fish. Aquat. Sci. 44 (Suppl. 2): 417-424.

Mosindy, T.E., W.F. Momot, and P.J. Colby. 1987. Impact of angling on the production and yield of mature walleye and northern pike in a small boreal lake in Ontario. N. Am. J. Fish. Manage. 7: 493-501.

Colby, P.J., and D. Baccante. (In Prep.). Quality Fishing Index: A descriptive tool for walleye angling fisheries.

Colby, P.J., and D. Baccante. (In Prep.). Response of a walleye population to a controlled harvest strategy.

Ebbers, M., P.J. Colby, and C. Lewis. (In Prep.). Walleye bibliography updated through 1986. Minn. Dept. Nat. Res., Spec. Publ.

Ritchie, B., and P.J. Colby. (In Press). Even-odd year differences in walleye year-class strength related to mayfly production. N. Am. J. Fish. Manage. 00: 000-000.

Reviews

Colby, P.J. 1971. Fish and Invertebrate Culture (Stephen H. Spotte). Trans. Am. Fish. Soc. 100: 598.

Colby, Peter J. 1975. Thermal Ecology: Proceedings of a Symposium held at Augusta, Georgia, May 3-5, 1973. (J. Whitefield Gibbons and Rebecca R. Sharitz, eds.). Trans. Am. Fish. Soc. 104: 838.

Colby, Peter J. 1980. Selected Coolwater Fishes of North America: Proceedings of a Symposium held at St. Paul-Minneapolis, Minnesota, March 7-9, 1978. (Robert L. Kendall, ed.). Trans. Am. Fish. Soc. 109: 344-346.

Academic Affiliations

I have served on numerous graduate committees either as Research Advisor and Internal Examiner or External Examiner. Following are graduate committees I've served on to date:

As Research Advisor and Internal Examiner, M.Sc. Thesis, Lakehead University -

Sandhu, Jagraj S. 1979. Annual Production and Population Dynamics of a Relatively Unexploited Walleye, _Stizostedion vitreum vitreum_ (Mitchill 1818), Population in Savanne Lake, Ontario.

Mosindy, Thomas. 1980. The Ecology of Northern Pike, _Esox lucius_ Linnaeus, in Savanne Lake, Ontario.

Ritchie, Beverlee J. 1984. Comparison of the Yellow Perch _Perca_ flavescens (Mitchill), Populations in Henderson Lake and Savanne Lake, Ontario.

As Internal Examiner, M.Sc. Thesis, Lakehead University -

Nunan, Christopher P. 1982. Initial Effects of the Exploitation of Walleye (Stizostedion vitreum vitreum (Mitchill) on the Boreal Percid Community of Henderson Lake, Northwestern Ontario.

Reid, David M. 1985. Effects of an Episodic Removal Scheme on a Walleye (Stizostedion vitreum vitreum), Population.

Armstrong, Kimberly B. 1984. The Biology of Proteocephalus amploplitis (Leidy, 1887) in Walleye.

Trimble, K. 1988. Ecology of Forage Fish Following Cessation of Overharvest of Walleye in Henderson Lake, Ontario.

Wisenden, Brian D. 1988. Community Dynamics Resulting from an Experimental Pulse Fishery on the Walleye (Stizostedion vitreum vitreum) in Henderson Lake, Ontario.

As External Examiner, M.Sc. Thesis, Laurentian University -

Schryer, Richard. 1985. Age, growth, feeding and fecundity in the walleye (Stizostedion vitreum vitreum) (Mitchill 1818) populations of Lake Nosbosing.

Additional Publications or Manuscripts Associated with the Walleye Research Unit

Varey, R.B. 1974. Population estimates of Stizostedion vitreum vitreum (walleye) Savanne Lake 1973. Honours B.Sc. Thesis, Lakehead University, Thunder Bay, Ontario. 23 p.

Riklik, Louis. 1981. Production ecology of the burrowing mayfly Hexagenia limbata in Savanne Lake, Ontario. Honours B.Sc. Thesis, Lakehead University, Thunder Bay, Ontario. 35 p.

Harvey, Paul Joseph. 1982. The determination of population size using estimated numbers of surviving marked walleye (Stizostedion v. vitreum) in Savanne Lake, Ontario (1972-1981) of this species to an ongoing experimental harvest. Honours B.Sc. Thesis, Lakehead University, Thunder Bay, Ontario. 59 p.

Riklik, L., and W.T. Momot. 1982. Production ecology of Hexagenia limbata in Savanne Lake, Ontario. Can. J. Zool. 60: 2317-2323.

Baccante, D., and J. Sandhu. 1983. Annulus formation and growth characteristics of tagged walleye in a lightly exploited lake. Ontario Fisheries Technical Report Series No. 9. 5 p.

Baccante, D. (Ed.). 1985. Walleye and Tourism: future management strategies. Proceedings of Conference sponsored by the Northwestern Ontario Chapter of the American Fisheries Society, September 18-21, 1984, Quetico Centre, Ontario. 170 p.

Brousseau, C.S., D. Baccante, and L.W. Maki. 1985. The role of bedrock and surficial geology in determining the sensitivity of Thunder Bay area lakes to acidification. J. Great Lakes Res. 11: 501-507.

Colby, P.J. 1985. Development of the MEI and partitioning yields estimated from the morphoedaphic index into individual species yields. Pages 62-77 In Proceedings of Conference on Walleye and Tourism: future management strategies, sponsored by the Northwestern Ontario Chapter of the American Fisheries Society, September 18-21, 1984, Quetico Centre, Ontario. 170 p.

McIver, S.E. 1985. Age and growth of the white sucker *Catostomus commersoni* (Lacepede) in Henderson Lake, Ontario. B.Sc. Thesis, Lakehead University, Thunder Bay, Ontario. 27 p.

Reid, D.M., and W.T. Momot. 1985. Evaluation of pulse fishing for the walleye, *Stizostedion vitreum vitreum*, in Henderson Lake, Ontario. J. Fish. Res. Biol. 27: 235-251.

Baccante, D.A., and D.M. Reid. (In Press). Fecundity changes in two exploited walleye populations. N. Am. J. Fish. Manage. 00: 000-000.

ADMINISTRATIVE REPORTS

National Academy of Sciences. 1977. The quality of NOAA's ocean research and development program--an evaluation. Ocean Sciences Board, National Research Council, Washington, D.C., 144 pp. (one of the multiple authors, summarized and edited by the steering committee).

Ontario Ministry of Natural Resources. 1982. Partitioning Yields Estimated from the Morphoedaphic Index into Individual Species Yields. Report of SPOF Working Group Number Twelve. 71 p.

Colby, P.J., and C.H. Olver. (eds.). 1978. Management Implications derived from the Percis Training Session held December 4-8, 1978 at Geneva Park Conference Centre.

Olver, C.H., J.M. Casselman, P.J. Colby, and N.R. Payne. 1982. The report of the Georgian Bay walleye review committee. Ont. Min. Nat. Res. Intra-ministry Rep. 68 p.

Ontario Ministry of Natural Resources. 1985. Fisheries Research Activities: 1984-85. Annual Report on Research Programs of Fisheries Branch, Ministry of Natural Resources. 94 p.

Ontario Ministry of Natural Resources. 1986. Fisheries Research Activities 1985/86. Ont. Min. Nat. Res. Rep. 55 p.

INTERNAL UNIT REPORTS

Romani, D. 1980. Maturity and fecundity of walleyes from Savanne Lake. Ont. Min. Nat. Res., Internal Rep. 22 p.

Baccante, D. 1981. Creel census report, Savanne Lake 1980. Ont. Min. Nat. Res., Internal Rep. 17 p.

Baccante, D. 1981. Creel census report, Savanne Lake 1981. Ont. Min. Nat. Res., Internal Rep. 15 p.

Baccante, D. 1981. Maturity and fecundity of Savanne Lake walleyes, Fall 1980. Ont. Min. Nat. Res., Internal Rep. 28 p.

Baccante, D. 1981. Walleye Removal Program, Savanne Lake 1980. Ont. Min. Nat. Res., Internal Rep. 13 p.

Baccante, D. 1981. Electrofishing in Savanne Lake, Ontario, August 25-28, 1981. Ont. Min. Nat. Res., Internal Rep. 25 p.

Baccante, D. 1982. Maturity and fecundity of Savanne Lake walleye, Fall 1981. Ont. Min. Nat. Res., Internal Rep. 31 p.

Baccante, D. 1982. Walleye removal program, Savanne Lake 1981. Ont. Min. Nat. Res., Internal Rep. 15 p.

Baccante, D. 1982. Maturity and fecundity of Savanne Lake walleyes, Fall 1982. Ont. Min. Nat. Res., Internal Rep. 20 p.

Baccante, D. 1982. Walleye removal program, Savanne Lake 1982. Ont. Min. Nat. Res., Internal Rep. 4 p.

Baccante, D. 1983. Creel census report, Savanne Lake 1982. Ont. Min. Nat. Res., Internal Rep. 17 p.

Roberts, K. 1983. Walleye removal program, Savanne Lake 1983. Ont. Min. Nat. Res., Internal Rep. 3 p.

Roberts, K. 1984. Creel census report, Savanne Lake 1983. Ont. Min. Nat. Res., Internal Rep. 15 p.

Roberts, K. 1984. Creel census report, Savanne Lake 1984. Ont. Min. Nat. Res., Internal Rep. 15 p.

Sein, R. 1985. Creel census report, Savanne Lake 1985. Ont. Min. Nat. Res., Internal Rep. 15 p.

Ritchie, B. 1985. Walleye removal program, Savanne Lake 1984.

Ont. Min. Nat. Res., Internal Rep. 4 p.

LIST OF COMMITTEES

Served either as a member or resource person on the following committees:

1. Chairman of PERCIS steering committee: organized and edited the Percid International Symposium (PERCIS) held at Quetico Centre, Ontario (1976).

2. Chairman of SPOF Working Group 12 (1982). I was instrumental in developing guidelines for partitioning yield estimates into individual species yields, thus reducing to practice one of the world's first useful multispecies harvest models.

3. Strategies for Fishery Research in Ontario. Report of the Fisheries Research Working Group, October 1983.

4. Post-Operational Environmental Monitoring at the Atikokan TGS. Environmental and Social Systems Analysts Ltd. (ESSA-1984).

5. Minnesota-Ontario Boundary Waters Fisheries Atlas. Lake of the Woods, Rainy Lake, Rainy River. (1984).

6. Assessment of Stock and Prediction of Yield Symposium - ASPY Steering Committee Member and Great Lakes Co-ordinator. (1985-1987).

7. Atikokan District Tourism Development Study. (1986).

8. Development of an Effects Monitoring Program for Timber Management Guidelines. (In prep.).

9. Great Lakes Fishery Commission Walleye Rehabilitation Workshop - Chairman of Steering Committee. (1986-1989).

10. Northern Ontario Committee (NOC) - A committee comprised of the Northern ADM and Regional Directors. I assisted in reviewing northern District Fisheries' management programs. (1986-87).

COMMITTEES AND PROJECTS

Advisor to Geraldton District on their study - Impact of Sport Fishing on Walleye Mortality in Northwestern Ontario - Wayne Schaeffer primary investigator. (1985).