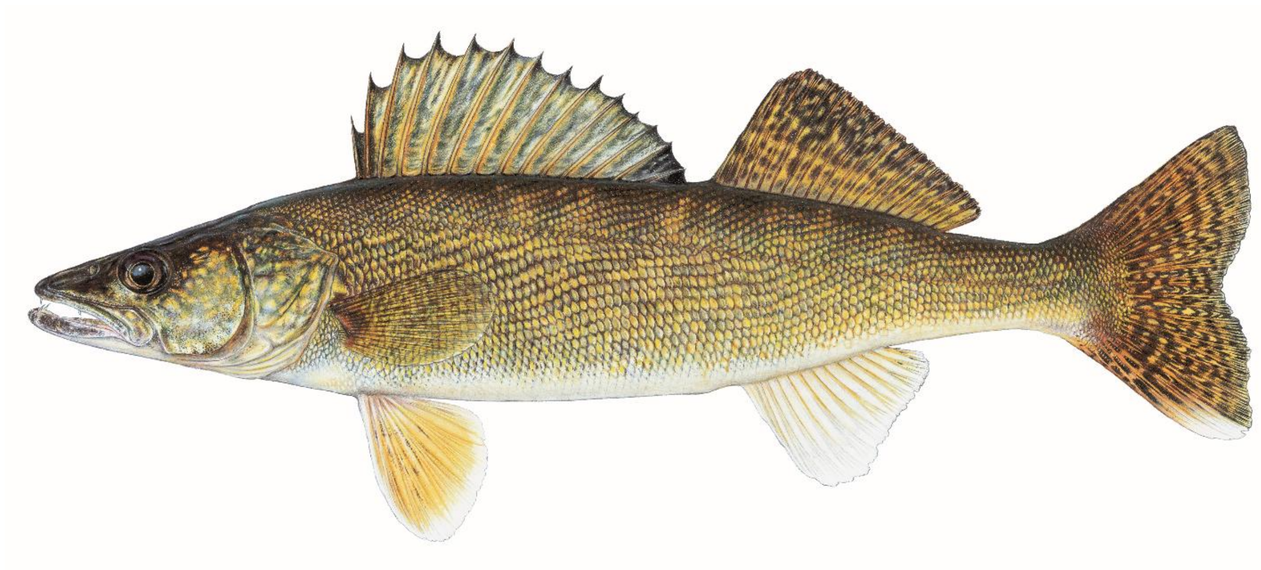
ECOLOGY AND MANAGEMENT OF MONTANA WALLEYE FISHERIES



MONTANA COOPERATIVE FISHERY RESEARCH UNIT

Montana Fish, Wildlife & Parks

Walleye illustration by Joseph R. Tomelleri

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EXECUTIVE SUMMARY

This document is an update and revision of the 1989 report by Peter Colby and Chris Hunter entitled “Environmental Assessment of the Introduction of Walleye Beyond their Current Range in Montana,” which was originally written in response to increased demand for Walleye fishing opportunities in Montana. In this document, Chapter 1 was written by Robert Bramblett and Alexander Zale of the Montana Cooperative Fishery Research Unit, and Chapter 2 was written by Montana Fish, Wildlife, and Parks (MFWP) staff.

Since 1989, the range of Walleyes in Montana has expanded greatly because of illegal introductions in Canyon Ferry Reservoir, Noxon Rapids Reservoir, and Swan Lake. Although the introduction of Walleyes beyond their current range in Montana could provide Walleye fishing opportunities, it may negatively affect valuable existing recreational fisheries. To assess the tradeoffs associated with Walleye management in Montana, this report summarizes:

- Walleye distribution, habitat, reproduction, life history, behavior, forage, growth, mortality, and species interactions,
- Management and characteristics of Walleye fisheries including fishing regulations, diurnal and seasonal changes in fishing success, sport fish catch rates and yield, reservoir water retention time, control of predation and competition, stocking, and introductions,
- Status of Walleye in Montana, including profiles of Walleye fisheries in Canyon Ferry, Holter, Lake Frances, Tiber, Fort Peck, Fresno, Nelson, Cooney, and Bighorn reservoirs,
- Case histories of the effect of introduced Walleyes on existing recreational fisheries from the North Platte reservoirs in Wyoming, John Day Reservoir on the Columbia River, Escanaba Lake in Wisconsin, and Canyon Ferry Reservoir in Montana.
- An evaluation of the costs and benefits of current management and recommendations for considerations prior to any introduction of Walleyes beyond their current range in Montana

The Walleye is not native to Montana; their natural range is from Canada (east of the Continental Divide) south to Louisiana, and from the Dakotas east to the Appalachian Mountains. The Walleye is a coolwater species and occur primarily in moderately productive and turbid lakes, large rivers, and reservoirs that provide an abundant forage base and have suitable spawning habitat. Other habitat considerations include a pH range of 6.0 to 9.0, dissolved oxygen concentration greater than 6.0 ppm, mean weekly water temperature during the summer in the range of 64.4 to 77.0 °F, and a rising or stable water level during spawning and embryo development periods.

Walleye spawn in spring when water temperatures are in the 40s to low 50s °F, primarily over rocky substrates. Each female produces many thousands of eggs, but first-year survival is low (generally < 1%). Walleye are sensitive to light, and are most active in low light levels at dawn and dusk or during the day in turbid waters. Juvenile Walleyes eat zooplankton and other invertebrates, but their diet switches to primarily fish in the first year of life. Adult Walleyes consume a wide variety of fishes, including minnows, Yellow Perch, and salmonids.

Walleyes can influence fish assemblages through species interactions such as predation or competition with other predaceous fish species. Species interactions are strongest when interacting species are not spatially separated based on habitat preferences. Examples include Walleyes and Yellow Perch in coolwater systems, and Walleyes and stocked trout in reservoirs that do not thermally stratify.

Recreational Walleye fisheries are typically managed with fishing regulations such as possession (bag, creel) limits and length limits. Many states have a year-round open angling season for Walleye. Angling success is generally greatest at dawn and dusk. A catch rate of 0.30 Walleye per hour is considered very good in most of the United States and Canada. Special management considerations in reservoir fisheries include reservoir water retention time and control of water levels. Long retention times and stable water levels are typically conducive to maintaining quality Walleye fisheries.

Montana has Walleye fisheries in a number of reservoirs and also some large rivers such as the Missouri, Yellowstone, and Milk rivers. The status of Walleye fisheries in nine Montana reservoirs with long-term data sets are profiled in this report. The quality of Walleye fisheries as indicated by the catch rate of anglers targeting Walleye varies across time and among reservoirs; Walleye angler catch rate ranged from less than 0.1 to over 1.0 fish per hour during 2001 to 2014. The factors that generally appear to limit Walleye populations in Montana reservoirs are forage fish abundance, widely fluctuating reservoir water levels, and short water retention times.

The effects of introduced Walleye populations on established fisheries are reviewed in four case histories. In a series of reservoirs on the North Platte River in Wyoming, excellent existing Rainbow Trout fisheries crashed because of predation on trout by introduced Walleyes. Fishery managers responded with a variety of management tools, including stocking trout at different sizes, locations, and times of the year, stocking alternative forage fish, and attempting to manage Walleye abundance and size structure with angling regulations. The success of these strategies in maintaining trout fisheries varies with reservoir location from upstream to downstream, with the highest success in the upstream reservoirs where physical conditions inherently favor trout over Walleye and the lowest in downstream reservoirs where conditions favor Walleye over trout.

In John Day Reservoir on the Columbia River, the role of predation on outmigrating juvenile salmonids by predaceous fish was quantified. Northern Pikeminnow, Walleye, Smallmouth Bass, and Channel Catfish consumed an average of 9 to 19% of the juvenile salmonids estimated to enter the reservoir, and Northern Pikeminnow accounted for 78% of this total. Smaller Walleye consumed salmonids and crustaceans. Consumption of salmonids by Walleye peaked when Walleye were age-2; older Walleyes did not eat salmonids. Overall, Prickly Sculpin and suckers were the most important prey fish species for Walleyes. Management strategies to decrease losses of juvenile salmonids by reducing the number of large Northern Pikeminnow were implemented.

Walleyes and Northern Pike were introduced into Escanaba Lake, Wisconsin in the 1930s and early 1940s and Walleye harvest has varied erratically with generally lower Walleye harvest and density since 1992. The establishment of Walleyes and Northern Pike appeared to have a large influence on the sport fish assemblage composition. Smallmouth Bass and Largemouth Bass were the two primary gamefish prior to the establishment of Walleyes and Northern Pike but the harvest of bass and panfish crashed by the mid-1960s. Smallmouth Bass, thought to be virtually extirpated have again entered the harvest in 2000s as Walleye densities declined.

Canyon Ferry Reservoir on the Missouri River in Montana was a popular and productive Rainbow Trout and Yellow Perch fishery prior to an illegal introduction of Walleyes in the 1980s. A small Walleye spawning population in 1996 produced a very strong year class of fish that resulted in a well-established Walleye fishery at Canyon Ferry Reservoir. Subsequently, Yellow Perch abundance and angler catch rates have plummeted to historically low levels. Rainbow Trout abundance has apparently declined post-Walleye, but Rainbow Trout angler catch rates have been maintained by stocking of larger Rainbow Trout. However, why Rainbow Trout angler catch rates have not declined commensurate with apparent declines in Rainbow Trout abundance is currently not well understood. The abundance of forage fish, such as White Suckers, has also declined to historically low levels. Burbot population abundance has declined from historic levels, however this may not be due to Walleye predation because Burbot abundance has increased in the last decade as Walleye abundance has increased (Eric Roberts, MFWP, personal communication).

Walleye population size structure in Canyon Ferry Reservoir is currently fairly balanced with fish of all size classes present; however, the relative weight (the weight of an individual fish compared to an expected standard weight of a fish of that same length) of all size classes of

Walleyes have declined moderately since the late 1990s. Walleye average length has also declined since the late 1990s. The general decline in average relative weight has occurred in all size classes of adult Walleyes, which probably reflects loss of plumpness due to a declining food base for Walleyes, namely Yellow Perch and stocked fingerling Rainbow Trout. Walleye angler catch rates have increased since the late 1990s but have been irregular. Summer catch rates for anglers targeting Walleyes peaked at 0.49 Walleyes per hour in 2011, but declined to 0.35 in 2012 and 0.21 in 2013. Winter Walleye angler catch rates have been variable, peaking at 0.59 Walleyes per hour in 2003, but were at essentially zero from 2008 to 2013.

Angling pressure at Canyon Ferry typically ranks near the top of the statewide angling pressure survey, averaging about 102,555 angler days from 1999 to 2013. Angling pressure peaked at 133,200 angler days in 2009. About one third of the angling pressure at Canyon Ferry (average of 35,000 angler days) occurs during the relatively short ice-fishing season of January, February, and early March. The percent of all anglers that are specifically targeting Walleye has steadily increased from about 10% in 1997 to about 50% since 2007. However, results from an angler satisfaction survey completed during the 2007 license year indicate a general lack of satisfaction with the current fishery in Canyon Ferry Reservoir.

The primary fishery management concern at Canyon Ferry Reservoir is that Walleye reproductive potential is very high, leading to potential for creating a high-density Walleye population that could deplete prey species, including sport fish such as Yellow Perch, Rainbow Trout, and Burbot. If the forage base is depleted, Walleye growth may be diminished, which would negatively affect the quality of the existing Walleye fishery. Determination of Walleye densities that can be maintained without depressing the prey populations is monitored using annual fish sampling and angler creel surveys. Because Walleye year class strengths vary naturally, it is likely that another large year class, such as that produced in 1996, will occur with unknown effects on the overall Canyon Ferry Reservoir fishery.

Fish species have long been introduced to areas outside of their native range in part because historically the social value of recreational fishing was considered to be more important than conservation of biodiversity. However, introduced fish species are now recognized as one of the largest global threats to fish conservation. Prevention of unwanted introductions and a precautionary approach to intentional introductions are important because introductions are generally irreversible in open systems. Moreover, introductions increase the uncertainty of the outcomes of fish management activities, such that even fisheries in unnatural habitats with nonnative species can be changed in unexpected ways by introductions.

The Walleye has strong potential to affect existing recreational fisheries through direct predation on sport fishes as well as through competition for forage fish. In three of the four case studies presented in this report the introduction of Walleyes had negative effects on existing recreational fisheries. Currently, MFWP is not considering the introduction of Walleye into any new waterbody. Nonetheless, MFWP will continue to follow their existing policy to conduct a formal Environmental Assessment (EA) under the authority of the Montana Environmental Policy Act (MEPA) for any proposed introduction of a fish species into a waterbody. Moreover, the 10 questions provided by the American Fisheries Society will be explicitly included in any EA that evaluates the risks and benefits from any proposed introduction of Walleye beyond their current range in Montana.

CHAPTER 1. WALLEYE ECOLOGY AND MANAGEMENT, STATUS IN MONTANA, AND CASE HISTORIES OF INTRODUCTIONS

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INTRODUCTION

Although the Walleye *Sander vitreus* is not native to Montana, fishing for Walleye has become increasingly popular in the state over the past few decades. Initially, Walleye fisheries were established by fisheries managers in the eastern part of the state where coolwater reservoirs have often provided habitat suitable for Walleye introductions. As the popularity of Walleye fishing has increased, so has interest in stocking Walleyes beyond their current range in Montana, including lakes and reservoirs in the central and western portions of the state that have traditionally been regarded as trout waters. In some cases, illegal introductions of Walleyes have established or increased Walleye fisheries in areas such as Canyon Ferry, Hauser, and Holter reservoirs on the Missouri River. Walleyes were also illegally stocked west of the Continental Divide into Swan Lake in the Swan River drainage and Noxon Rapids Reservoir on the Clarks Fork River, where they have established a reproducing population.

The introduction of Walleyes into new systems has considerable risk for the established fisheries and fish assemblages (Kempinger and Carline 1977; McMahon and Bennett 1986; Kerr and Grant 2000). The Walleye is a top predator and preys heavily on forage fishes (Nate et al. 2011) and other sport fishes including Yellow Perch *Perca flavescens*, Smallmouth Bass *Micropterus dolomieu*, Largemouth Bass *Micropterus salmoides*, and Rainbow Trout *Oncorhynchus mykiss* (Kempinger and Carline 1977; McMillan 1984; McMahon and Bennett 1986; Nate et al. 2011). Therefore, Walleyes have strong potential to affect existing fisheries, through competition for forage fish as well as through direct predation on sport fishes. Several examples exist of the depletion of existing sport fisheries caused by the introduction of Walleyes (Kempinger and Carline 1977; McMillan 1984; McMahon and Bennett 1986). Given the excellent trout fisheries in western Montana waters, the MFWP has taken a cautious approach to introducing an effective predator into these systems. Potential benefits associated with introduction of Walleyes are the diversification of angling opportunities and the increased economic activity that might come from Walleyes in a waterbody.

The original version of this report was prepared in 1989 by independent consultants Peter Colby and Chris Hunter. Dr. Colby is widely regarded as a foremost authority on the Walleye. The purpose of the original document was 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." This was accomplished in four major sections: 1) describing habitat requirements and preferences of the Walleye; 2) a description of Walleye fisheries of the Midwestern sections of the United States and Canada; 3) describing the Walleye fisheries in Montana; and 4) a discussion of the interactions between introduced Walleyes and existing fisheries. The report concluded with a description of an approach that could be used to determine the appropriateness of stocking Walleyes in any particular lake.

The primary impetus for this new report is to incorporate the considerable body of knowledge that has been developed since 1989 about Walleye ecology and management, particularly in Montana. These updates include new information on trends in Walleye populations and management in nine Montana reservoirs, and updates to three case studies of interactions between introduced Walleyes and existing fisheries. A new case study for Canyon Ferry Reservoir has been added for this report. The Colby and Hunter (1989) report is updated and revised here by Robert G. Bramblett and Alexander V. Zale.

The original report also included habitat criteria and a list of 10 risk-based questions that should be answered in the affirmative in order to determine the appropriateness of introducing Walleyes to a new waterbody. This new report revisits the 10 questions, providing answers which clarify the reasons and concerns that have guided MFWP in their approach toward new Walleye introductions. The current report concludes with a section on the issue of illegal fish introductions, which have numbered in the hundreds since 1990, including Walleye introductions into 13 different waters. The consequences of these illegal activities and the effectiveness of the approaches MFWP has taken to combat this activity are discussed. The second chapter is written by MFWP staff.

WALLEYE ECOLOGY

The purpose of this section of the report is to describe the habitat, life history, and food requirements of the Walleye. Walleyes use different habitats at different stages of their life cycle, as well as at different times of the year. Understanding the requirements of Walleyes throughout their life cycle as well as the seasonal cycle is needed for effective management of a Walleye fishery.

Distribution and Habitat

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 Appalachians (Bozek et al. 2011b). The range of the Walleye has been expanded by stocking to include the Atlantic Coast, parts of the Colorado and Columbia River systems, and the western Great Plains. The species is not native to Montana (Brown 1971; Gould 1995). Walleyes were apparently first introduced into Montana in Nelson Reservoir circa 1922, and into the Missouri River below Great Falls in 1933 (Gould 1995).

Walleyes occur in rivers, lakes, and reservoirs. Lakes with Walleyes are primarily large, shallow, moderately turbid, and mesotrophic (moderately fertile). Walleye rivers are typically large, deep turbid rivers such as the Missouri, Mississippi, and St. Lawrence that provide abundant spawning areas and plentiful forage fish. Reservoirs with successful Walleye fisheries have suitable water quality and habitat for all life stages in the reservoir proper or in tributaries (Bozek et al. 2011b).

Walleyes 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 (shallow) areas, moderate turbidities (Secchi disc depths of 3 to 10 feet), extensive areas of clean rocky substrate, and mesotrophic conditions. However, smaller lakes may contain natural populations, especially if they form part of a large, contiguous system. Walleyes may also be found in oligotrophic, clear-water lakes (usually dominated by salmonids) if the lakes are sufficiently large and deep and have extensive littoral areas. Walleyes also occur in some eutrophic lakes (usually dominated by centrarchids). Kitchel et al. (1977) suggested that the littoral and sublittoral habitats occupied by Walleyes in lakes are the equivalent of extensions of suitable riverine habitat into the lake environment.

The Walleye is tolerant of a variety of environmental conditions. The Walleye is considered a coolwater species and tolerates temperatures from 0 to 86 °F (Hasnain et al. 2010), but prefers summer temperatures in the range of 68 to 75 °F (Bozek et al. 2011b). Dissolved oxygen concentrations above 5 to 6 parts per million are optimal for egg incubation and are generally preferred by adult Walleyes, whereas dissolved oxygen concentrations less than 1 part per million are lethal (Bozek et al. 2011b). Walleyes tolerate a pH range of 6.0 to 9.0 and up to 1,500 ppm dissolved solids. Walleyes 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 and concluded that light is principal among these. Kerr and Ryder (1977) also suggest that a critical limiting factor for Walleye populations is light intensity.

McMahon et al. (1984) presented a habitat suitability model that can be used to predict the habitat suitability of a given water body for Walleyes (Table 1). The variables included in the model include both physical and biological variables, and the values represent optimums for Walleye habitat for predictive purposes.

Table 1. Habitat variables and their associated optimum values for Walleye habitat suitability (McMahon et al. 1984).

Variable	**Optimum value**
Transparency	3 to 10 feet Secchi disk (a disk used to measure water transparency) depths
Relative abundance of small forage fishes during spring and summer	High abundance of forage fish
Percent of waterbody 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)
pH	6.0 to 9.0
Minimum dissolved oxygen concentration above thermocline during summer	Greater than 4.5 ppm
Minimum dissolved oxygen concentration during summer-autumn along shallow shoreline areas (fry)	Greater than 5.0 ppm
Minimum dissolved oxygen concentration in spawning areas during spring (embryos)	Greater than 6.0 ppm
Mean weekly water temperature above thermocline during summer	64.4 to 77 °F
Mean weekly water temperature in shallow shoreline areas during late spring-early summer (fry)	64.4 to 73.4 °F
Mean weekly water temperature during spawning in spring (embryo)	51.8 to 64.4 °F
Spawning habitat index[a]	Greater than 40
Water level during spawning and embryo development	Rising or normal and stable
Trophic status of lake or lake section	Mesotrophic

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

Walleyes are migratory as adults, with migrations ranging to over 150 miles. In spring, sexually mature adults move from their over-wintering areas to their spawning areas. Walleyes have a diversity of spawning strategies including river resident-river spawning, lake resident-lake spawning, and lake resident-river spawning (Bozek et al. 2011a). The spawning areas may be located along rocky shores, reefs, and shoals of the lake in which Walleyes reside, or they may be found in upstream main-stem and tributary rivers. Following spawning, Walleyes move to their feeding grounds, which are generally located in moderately shallow, littoral portions of lakes. As the surface waters of the lake begin to warm Walleyes 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 deeper waters for the day.

As the lake begins to cool in autumn, Walleyes again move back into the littoral zone. Feeding continues but begins to taper off as the metabolism of the fish slows down in response to cooler water temperatures. Little information exists regarding the winter habitat selection of adult Walleyes. It is generally assumed that they seek deeper waters for over-wintering. In Canyon Ferry Reservoir on the Missouri River in Montana, Walleyes used deeper depths in autumn and winter than in spring and summer (Yerk 2000).

Reproduction and Early Life History

The age and size of Walleyes at maturity vary with water temperature and food availability (Bozek et al. 2011a). For example, female Walleyes mature from 2 to 3 years of age in Texas, and 9 to 10 years in the Northwest Territories of Canada (Colby and Nespzy 1981). Late maturity is usually associated with colder waters and late-maturing Walleyes tend to have a longer life span than those that mature early. Walleyes older than 20 years of age are not uncommon in the northern part of their range.

The annual water temperature regime and the quality and quantity of suitable substrate are major factors affecting Walleye reproductive success (Colby et al. 1979). Walleyes require water temperatures in winter to be less than 50 °F to allow gonadal maturation (Bozek et al. 2011a). Walleyes typically spawn in spring during periods of rapid warming soon after ice breakup. The specific timing of Walleye spawning varies with latitude; in the southern part of their range, Walleyes spawn as early as February, whereas in the northern part of their range Walleyes may spawn as late as mid-July (Barton and Barry 2011). Spawning usually peaks at water temperatures ranging from 39 to 57 °F but has been observed to occur over a range of 36 to 62 °F (Bozek et al. 2011a). Walleyes can spawn in rivers, lakes, or reservoirs, and spawning usually occurs in relatively shallow (less than 3 feet) water. Spawning habitats used by Walleyes are shallow shoreline areas, shoals, reefs, riffles, and dam faces with rock substrate and good water circulation from wave action or currents. Preferred spawning substrate appears to consist of gravel and rubble although they have been observed spawning over a wide range of substrate types, including flooded marsh vegetation (Preigel 1971; McMahon et al. 1984). Reported spawning depths typically range from as shallow as 4 inches up to 6.6 feet (Bozek et al. 2011b). Suitable spawning habitat is thought to be a limiting factor for Walleye populations in some lakes (Bozek et al. 2011b).

Walleyes have high fecundity, ranging from about 18,000 eggs per pound of female body weight in northern latitudes to 36,000 eggs per pound of female body weight in middle latitudes (Baccante and Colby 1996). Walleyes are broadcast spawners and the eggs are adhesive for one to five hours or more after spawning (Bozek et al. 2011). If the eggs are 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. Egg survival is dependent on adequate oxygen concentration (above 5 to 6 parts per million) and varies with spawning substrate. Johnson (1961) observed Walleye eggs on several bottom types in Lake Winnibigoshish, Minnesota, and found survival was lowest on the soft mud and detritus bottom, intermediate on fine sand bottom, and highest on gravel-rubble bottom. Walleyes often have high egg mortality, ranging from 50 to 99% (Bozek et al. 2011a).

Walleye eggs are robust to variation in water temperatures between 43 to 66 ° F (Smith and Koenst 1975; Schneider et al. 2002), but optimal incubation temperatures are 48 to 59 °F (Koenst and Smith 1976; Engel et al. 2000), with the highest hatching percentages occurring at about 59 °F (Engel et al. 2000). Incubation periods ranging from 10 to 27 days in the wild and from 5 to 30 days in laboratory settings have been reported (Bozek et al. 2011a), with incubation periods shorter in warmer water temperatures and longer in cooler water temperatures. The rate of development is also affected by oxygen concentrations. Eggs held at a lower oxygen concentration in the laboratory required longer to hatch. Other abiotic factors may be beneficial or detrimental to incubating Walleye eggs, and influence the mortality of Walleye eggs (Bozek et al. 2011a). Eggs spawned in shallow marshes are often left stranded above the water level during times of lower water. The same may be true of eggs laid in shallow waters of a reservoir. Moderate wave action helps provide sufficient dissolved oxygen for developing eggs, but large wind storms with severe wave action can reduce egg survival by burying, abrading, or stranding eggs (Bozek et al. 2011a).

The rate of development of Walleye embryos varies directly with incubation temperature. The embryo can develop in waters having temperatures ranging from 40 to 66.5 °F. Walleye embryos tolerate lower temperatures than the embryos of all other members of the perch family. Walleyes have no direct parental care, and first-year survival is low, generally less than

1% (Bozek et al. 2011a). 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 juvenile Walleyes is 71 to 72 °F.

Behavior

The Walleye is well-adapted to detect prey under low light conditions. The Walleye retina contains a layer of light-reflecting pigment known as the tapetum lucidum that makes them very sensitive to light. Consequently, Walleyes prefer low light habitats levels found in moderately turbid waters or "stained" waters colored by humic acids. Peak Walleye feeding occurs at Secchi disk water transparencies of about 3 to 6 feet. Feeding activity decreases greatly at Secchi disk transparencies of less than 3 feet and greater than 16 feet. Where waters are more transparent, Walleyes occupy greater depth where light intensity is reduced, and are often most active during low light periods at dawn and dusk and at night. Walleyes 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 more favorable at these times. However, Walleyes have been observed to feed throughout the day in turbid lakes, which provides further evidence of the relationship between feeding and light intensity.

Walleyes select depths based on temperature, oxygen, and light intensity. Depths used by Walleyes during non-spawning periods are moderate, typically ranging to 12 to 49 feet (Scott and Crossman 1973; Bozek et al. 2011b). Walleyes in Canyon Ferry Reservoir on the Missouri River in Montana were most often found at depths less than 33 feet (Yerk 2000). During the day, Walleyes seem to prefer a clean, hard substrate where they will spend the day resting in contact with the bottom. Cover in the form of boulders, logs, or rooted aquatic vegetation is often used. Some conflicting evidence exists as to whether Walleyes move inshore to feed during the evening or if they remain at the same depths that they use for resting during the day. Carlander and Cleary (1949) observed that Walleyes 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 Walleyes movement in Lake Bemidji, Minnesota, Holt et al. (1977) found no diel pattern of inshore or offshore movement. Instead, Walleyes moved chiefly parallel to the shore at depths ranging from 5 to 16 feet. The behavior of Walleyes 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, Walleyes will move to deeper water during the day. In such case, they would probably move inshore with declining light and temperatures in the evening to feed. If, on the other hand, temperature and turbidity allowed the fish to stay in shallow, littoral areas during the day, they would be less likely to move offshore during the day and inshore to feed in the evening.

Forage

The prey of Walleyes changes with life stage and season. Larval Walleyes begin to feed before yolk sac absorption is complete (Engel et al. 2000), which occurs at about 0.35 inches in length. Walleye fry are pelagic (inhabit open water) and feed on plankton from shortly after hatching until they reach a length of about 0.4 to 0.8 inches (Chipps and Graeb 2011), at which time, they move inshore and begin to feed on benthic (inhabiting the bottom) aquatic invertebrates. Juvenile Walleyes typically begin to eat fish when they reach lengths of 2.0 to 3.2 inches in length (Chipps and Graeb 2011). Walleyes continue to feed primarily on fish as juveniles.

Adult Walleyes are largely piscivorous, feeding on a great variety of prey fishes (Scott and Crossman 1973; Chipps and Graeb 2011). However, Walleyes will consume invertebrates when the abundance of prey fish is low (Chipps and Graeb 2011). In many lakes, invertebrates form a large part of the diet of Walleyes in late spring and early summer. Ritchie and Colby (1988) found that young-of-the-year Walleyes were more abundant in even-numbered years in Savanne Lake, Ontario, which was related to the much greater emergence of *Hexagenia* mayflies in even-numbered years. The authors hypothesized that the greater abundance of mayflies in even-numbered years buffered the young Walleyes against predation and cannibalism. Invertebrate food is gradually replaced by a diet consisting mainly of fish later in the summer, which 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.

Walleye fish prey species include Emerald Shiners *Notropis atherinoides* and other minnows, suckers, Trout-perch *Percopsis omiscomaycus*, Alewives *Alosa pseudoharengus*, Rainbow Smelt, Cisco *Coregonus artedi*, Ninespine Sticklebacks *Pungitius pungitius*, white perch *Morone americana*, Yellow Perch, and centrarchids. Swenson (1977) suggested that the predominance of nocturnal feeding and relatively high percentages of age-0 Yellow Perch, Rainbow Smelt *Osmerus mordax*, and *Notropis* sp. in their daily meals indicated that Walleyes in several Minnesota lakes use pelagic prey. Populations of Walleyes with abundant pelagic fish prey often have fast growth rates and large maximum sizes (Chipps and Graeb 2011). 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 (Scott and Crossman 1973). In western reservoirs with introduced populations of Walleyes, trout, juvenile salmon, minnows, suckers, darters, Yellow Perch, and crayfish are consumed (McMillan 1984; Rieman et al. 1991; McMahon and Bennett 1996; Marwitz and Hubert 1997; Mavrakis and Yule 1998; Yule et al. 2000; Gerrity 2009; Hahn 2013).

In the Great Lakes, specifically western Lake Erie, Saginaw Bay, Lake Huron, and Green Bay Wisconsin, Walleyes seem to prefer Alewives, Rainbow Smelt, and shiners over Yellow Perch. Ryder and Kerr (1978) ranked Yellow Perch, whitefish *Coregonus* sp., and Ninespine Stickleback as the top forage items most frequently occurring in Walleye stomachs from four lakes. Colby et al. (1987) reported on the importance of whitefish in the diet of larger Walleyes, which demonstrates that Walleyes occupy the same temperatures as young whitefish, which have thermal preferences similar to those of trout.

Young-of-the-year and yearling Walleyes in Lake Erie exhibited a size preference for forage fishes (Parsons 1971). Mean prey length of age-0 Walleyes longer than 1.9 inches was about 30% of predator length (Johnson et al. 1988). As Walleyes increase in length, the mean and range in length of preferred forage increases. 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. Yellow Perch were the preferred forage species of Walleyes in Utah Lake, Utah, although other forage species of similar size (Utah Chub *Gila atraria*, Common Carp *Cyprinus carpio*) were more numerous (Arnold 1960). In other cases, it appears that Walleyes may prefer smaller prey. Emerald Shiners were preferred over the more numerous and larger Freshwater Drum *Aplodinotus grunniens* in Lake Winnebago, Wisconsin (Priegel 1962a; 1962b) and Walleyes in Many Point Lake, Minnesota, avoided White Suckers even though they were numerous in the lake (Olson 1963).

Growth

Water temperature and food availability are the primary factors influencing Walleye growth (Bozek et al. 2011a). In general, Walleyes grow slower and live longer in the more northern portions of their range and grow faster with a shorter lifespan in the more southern regions. In the northern part of their range, Walleyes attain a length of about 14 inches in five years and may live as long as 30 years, whereas in the southern portions of their range Walleyes attain 14 inches in length in 2 years and maximum lifespan is about 10 years (Bozek et al. 2011a). Optimum water temperatures for growth of adults are 64 to 72 °F (Christie and Regier 1988).

Food availability appears to be the main factor influencing the body weight and condition of adults. Walleye condition tends to be low in areas where forage is scarce and high in areas where forage is abundant. Similarly, Walleye growth is often high when Walleye population density is low because there is adequate food for all members of the population. In contrast, a high density of Walleyes usually results in a scarcity of forage. Moreover, a general trend of Walleyes attaining a larger body size when larger prey fish are available has been observed (Bozek et al. 2011a). Excellent forage abundance had been cited as a chief reason for good Walleye growth in a number of lakes. Forage abundance not only influences adult growth, but may directly affect recruitment. Forney (1977) observed the production of strong year classes of Walleyes in years when growth of older Walleyes was rapid. Walleye may compete for forage with such piscivorous fishes as Northern Pike *Esox lucius*, Yellow Perch, Sauger *Sander canadensis*, and Smallmouth Bass.

Mortality

The mortality rates of Walleyes vary widely among populations, but the highest mortality rates occur at early life stages. Reported egg mortality rates vary from 50% to over 99% (Bozek et al. 2011a). Egg mortality occurs when eggs are not fertilized or not viable, when dissolved oxygen concentrations are insufficient or temperatures are unsuitable, and from siltation, severe wave action, exposure to air, or predation. Egg predation is common but population-level effects attributable to egg predation have not been demonstrated (Bozek et al. 2011a).

First year survival is very low, on the order of 0.01% (Baccante and Colby 1996) and age-0 Walleye die from abiotic factors and biotic factors such as predation, starvation, or disease. Variability in first-year survival is thought to be influential in the recruitment of older age classes. Important abiotic factors are water temperature, wind, and water levels. Biotic factors include competition, cannibalism, and predation. Walleye fry may have to compete with other planktivorous fishes, such as the fry of Freshwater Drum or Kokanee, for zooplankton. Competition for food occurred mostly in the first 60 days of life when young Walleyes were feeding mostly on zooplankton and insects, and was a factor limiting survival in two Minnesota lakes (Johnson 1969). Cannibalism was a decisive factor in the determination of Walleye year-class strength when larval Yellow Perch were scarce (Forney 1976), which is congruent with the hypothesis of Ritchie and Colby (1988) that year class strength was influenced by even-year abundance of *Hexagenia* mayflies buffering young-of-the-year Walleyes against cannibalism.

Annual mortality of adult Walleye is lower than first-year and juvenile mortality, primarily because predation risk decreases as Walleye size increases. Angling is a major source of mortality in most populations because of the popularity of Walleye as a food fish. Adult mortality appears to be similar among sexes; estimated mortality was 28% in females and 30% in males in 296 Ontario Walleye populations (Morgan et al. 2003).

Species Interactions

As top predators in many systems, Walleye can influence the fish assemblage (Nate et al. 2011). For example, Walleye can decrease the abundance of forage fish (Kerr 2011). Yellow Perch populations can respond rapidly to changes in Walleye abundance, with lower abundance but faster growth of Yellow Perch with increased Walleye abundance. If Yellow Perch are absent or scarce, Walleye predation can reduce the abundance of other fishes, including Fathead Minnow

Pimephales promelas, White Perch, young Walleyes, and stocked Rainbow Trout (Kerr 2011). Cannibalism by Walleye may affect the abundance of younger year classes. Stocking Walleyes outside of their native range is often controversial because of concerns regarding depletion of the forage base, negative effects on existing fisheries, and predation on native fishes (McMahon and Bennett 2006).

Walleye may compete with other fish species that share similar diets and habitats where these resources are limiting. Walleye diets overlap with those of several fish species including Northern Pike (Colby et al. 1987; Cohen et al. 1993), Largemouth Bass (Fayram et al. 2005), and Sauger (Bellgraph et al. 2008). Walleye can coexist with other top predators in large lakes (Johnson et al. 1977). However, Walleye abundance is often low when abundances of other top predators are high. Although the mechanism responsible for this pattern is often unknown, it may be competition for forage or in some cases be caused by predation on young Walleyes by fish such as Smallmouth Bass (Zimmerman 1999), Largemouth Bass (Fayram et al. 2005), Muskellunge (Bozek et al. 1999), Yellow Perch (Wolfert et al. 1975), White Crappies (Quist et al. 2003), and adult Walleyes (Chevalier 1973).

Species interactions are influenced to a large extent by habitat preferences. Salmonids, percids, and centrarchids have different relative abundances in lakes across gradients of latitude, water temperature, and productivity. In general, salmonids are most abundant in cold, northern, oligotrophic (low nutrients and productivity) lakes, percids are most abundant in cool, mid-latitude, mesotrophic (moderate nutrients and productivity) lakes, and centrarchids are most abundant in warm, southern, eutrophic (high nutrients and productivity) lakes. Salmonids require colder water and higher dissolved oxygen levels than do 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). Optimal temperature ranges for Lake Trout *Salvelinus namaycush* are 46 to 54 °F (Christie and Regier 1988). In contrast, Walleye optimal temperatures are 61 to 72 °F (Christie and Regier 1988; McMahon et al. 1984). Centrarchids dominate in more productive, warmwater environments (Kitchel et al. 1977).

Water temperature plays an important role in resource partitioning among percids, salmonids, and centrarchids (MacLean and Magnuson 1977). 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 available temperatures including those preferred by coolwater fish such as Yellow Perch and Walleye, warmwater fish such as centrarchids, and coldwater species such as salmonids. The highest potential for interaction between salmonids and percids in these lakes occurs during the early spring and late autumn when the lakes become isothermal. During this time, no segregation by temperature occurs because the entire lake is the same temperature. During isothermal conditions, salmonids should have the advantage over percids and centrarchids because temperatures then are optimal only for salmonids (Maclean and Magnuson 1977). During the winter, salmonids, percids, and centrarchids are not expected to segregate by temperature because all apparently prefer the warmest water available. However, potential interactions are probably reduced in intensity then because metabolic processes and food demands are low.

The role of temperature in potential species interactions is different in lakes that do not thermally stratify. In these cases, little opportunity exists 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 reservoirs, water is not in the reservoir for a long enough period of time to stratify. Assuming that predation and competition are most intense when the temperature is within the optimal range of two species, this would occur in spring and autumn for Walleyes and salmonids in non-stratifying lakes (Maclean and Magnuson 1977).

Management and Characteristics of Walleye Fisheries

In this section, we describe management of Walleye fisheries in other areas of the United States and Canada to provide context for management of Montana Walleye fisheries.

Fishing Regulations

Harvest regulations are one of the most common management tools used when attempting to manage the quality of recreational Walleye fisheries (Isermann and Parsons 2011). Typical recreational harvest regulations include bag (creel) and possession limits, length limits, and closed seasons (Isermann and Parsons 2011). Harvest regulations vary geographically and in complexity from simple bag limits or minimum size restrictions to more complex regulations such as slot-length limits.

Daily bag and possession limits are the most common type of regulation used in managing Walleye fisheries (Isermann and Parsons 2011). Bag limits may be state or province-wide or apply only to specific water bodies. In Montana, Walleye bag limits range from 5 fish to 20 fish daily depending on the location, and no limit exists for Walleyes on the Missouri River from below Holter Dam to the Cascade Bridge and on Noxon Rapids Reservoir (MFWP 2015). Walleye bag limits have sometimes been considered be too liberal to reduce the potential for over-harvest (Munger and Kraal 1997; Cook et al. 2001; Radomski et al. 2001). However, despite the harvest-oriented nature of many Walleye fisheries (Fayram 2003), most anglers typically do not catch a limit of Walleyes (Cook et al. 2001). Reducing creel limits to a level low enough to prevent over-harvest may not be socially acceptable because many Walleye anglers are harvest-oriented (Isermann and Parsons 2011). However, an indirect reduction in Walleye harvest may occur if reduced bag limits suppresses fishing effort on low-bag-limit waters because anglers may choose not to fish there (Beard et al. 2003; Fayram and Schmalz 2006).

The goal of setting minimum length limits is usually to maximize catch rates or to increase the abundance and size structure of Walleyes in a recreational fishery (Isermann and Parsons 2011). Minimum length limits have had mixed success in meeting management objectives (Isermann and Parsons 2011). Minimum length limits have been associated with reduced harvest or exploitation in Wisconsin (Fayram et al. 2001) and Alberta (Sullivan 2003), with increased catch rates or abundance in a Texas reservoir (Munger and Krall 1997) and in Alberta (Sullivan 2003), and with increased abundance of larger Walleyes in Texas (Munger and Krall 1997) and South Dakota (Stone and Lott 2002). However, in other cases no improvements in harvest, catch rates, abundance, or size structure were observed (Serns 1978; Fayram et al. 2001; Isermann 2007). Some evidence suggests that Walleye growth rates and condition may actually decline following implementation of minimum length limits, although other factors may have been involved (Serns 1978; 1981; Isermann 2007). Minimum size limits may also cause more large Walleyes to be harvested, thereby reducing any expected improvements in size structure (Larscheid and Hawkins 2005).

Brousseau and Armstrong (1987) caution that minimum size limits should not be used as a broad management technique, because the rates of growth and natural mortality of Walleyes may vary considerably from one population to another. They 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.

Slot-length limits, maximum length limits, and modified length limits such as “one-over” length limits are other management regulations used to manage Walleye recreational harvest (Isermann and Parsons 2011). Slot-length limits specify a protected range and an allowable harvest range. Maximum length limits prohibit harvest of fish larger than a specified maximum size. The effectiveness of slot-length limits and maximum length limits on Walleye have not been thoroughly evaluated (Isermann and Parsons 2011). Modified length limits such as “one-over” length limits typically specify that in addition to other size limits, only one fish over a specified size may be kept. In Big Sand Lake, Minnesota, a 20-inch one-over regulation had little effect on Walleye harvest because most large fish were rarely caught by anglers, and when caught were often voluntarily released (Jacobson 1994).

Many states and Canadian provinces have a year-round open angling season for Walleye. Those states and provinces that do not have year-round angling usually close the angling season for 1 to 3 months in the spring to allow the fish to spawn unmolested. In some cases, certain portions of a water body (commonly referred to as sanctuaries) are closed to Walleye angling during Walleye spawning periods with the intent of protecting spawning fish (Isermann and Parsons 2011). The effects of closed seasons on Walleye populations have not been evaluated (Isermann and Parsons 2011).

Although widely used, Walleye harvest regulations have rarely been meaningfully evaluated (Isermann and Parsons 2011). The differing results of management regulations described above may in part be due to population-specific characteristics such as recruitment, growth, food supply, natural and angling mortality, and differing fish assemblages with differing levels of competition and predation. Moreover, because of natural variation in Walleye recruitment and growth, the duration of studies evaluating the effectiveness of fishing regulation is often insufficient to adequately address them (Isermann 2007). However, Hansen and Nate (2014) concluded that recruitment and growth, rather than exploitation (the percent of fish in a population that are harvested) were the strongest drivers of Walleye population size structure in a long-term study (21 years) of 205 northern Wisconsin lakes.

Diurnal and Seasonal Changes in Fishing Success

Angling success is generally greatest at dawn and dusk (Ryder 1977) when light conditions for feeding are optimum and Walleyes are most active (Kelso 1978). Walleyes are very sensitive to light and will move into deeper waters during the day to avoid bright sunshine, and also seek cover in clear waters (Ryder 1977). Walleyes 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. However, Walleyes are more vulnerable to angling throughout the day in moderately turbid waters than in clear waters, and also during periods of diminished light caused by storm clouds and increased wave action (Ryder 1977). In a study in Ontario lakes, the total number of Walleyes caught and the catch rate increased with decreasing light levels (Ryder 1977).

Fishing success is usually high in the spring and early summer, tapers off as the summer progresses, and may increase again in autumn (Lux and Smith 1960; Potter and Lott 2006). For example in Lake Sharpe, a reservoir on the Missouri River in South Dakota, monthly open water angler catch rates were 0.36 fish per angler hour in April, 0.67 in May, 0.68 in June, 0.58 in July, 0.46 in August, and 0.66 in September (Potter and Lott 2006). This same phenomenon has been observed in several Montana reservoirs. It is generally believed that Walleyes move into deeper water as summer progresses to avoid high water temperatures in the littoral zone and are therefore less vulnerable to angling.

Sport Fish Catch Rates and Yield

Sport fishing catch rates are usually stated as the number or weight of Walleyess 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 Walleyess. In such cases, comparisons of catch rates from one lake to another may not be appropriate. The catch rates reported may appear unreasonably low to an experienced Walleye angler. Moreover, these rates are seasonal averages; they can 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.

In general, a good fishery exists when Walleyes are caught at a rate of 0.3 Walleyes per hour or more for anglers fishing for all species (Colby et al. 1979). Walleye catch rates at Oneida Lake, New York, ranged from 0.04 to 0.47 Walleyes per hour in six years from 1957 to 2003 (VanDeValk et al. 2005). Walleye catch rates at Caribou Lake, Minnesota, (based on number of hours fished for Walleyes only) over three years ranged from 0.18 to 0.32 Walleyes per hour (Micklus 1959). Catch rates were 0.14 to 0.31 Walleyes per hour over three summers on the Mississauga River (Payne 1965) and 0.33 for Polly Lake (Ryder 1968) in Ontario. Savanne Lake, Ontario, was a relatively unexploited lake since its closure to the public in 1969. The Walleye catch rate (based on the number of hours fished for all species) for 1977 to 1982 when the lake was first lightly fished ranged from 0.51 to 1.05 (Colby 1984). In 111 northern Wisconsin lakes, catch rates in 1990 to 1997 ranged from near 0 to about 1.5 fish per hour (Hansen et al. 2000). In Lake Sharpe, a reservoir on the Missouri River in South Dakota, annual Walleye catch rates ranged from 0.37 to 1.16 fish per angler hour from 1993 to 2006. However, catch rate was higher for those anglers specifically targeting Walleyes, and was 1.45 fish per angler hour in 2006 (Potter and Lott 2006).

Walleye yield is variable across the species' range. Baccante and Colby (1996) summarized Walleye yield data from 168 North American waters. Walleye yield ranged from near zero to over 9 pounds per acre per year; 25% of yields were less than 0.45, 50% of yields were less than 1.1, and 75% of yields were less than 2.6 pounds per acre per year. However, the authors caution that some of these yields may not be sustainable in the long term. A yield of 3.0 pounds per acre per year was considered by Olson and Wesloh (1962) to be characteristic of Walleye production in many of Minnesota's natural Walleye waters.

Sustainable yields of Walleyes are variable but are thought to be about 1.0 pound per acre per year. Adams and Olver (1977) determined that few of 70 northern Ontario lakes were capable of sustaining commercial yields of percids (primarily Walleyes) greater than 1.34 pounds per acre per year. They stated that a sustainable commercial percid yield of 0.9 to 1.1 pounds per acre per year, or about one third of the total fish 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. In a study on the dynamics of an experimentally-exploited Walleye population in Lake Savanne, Ontario, Colby and Baccante (1996) considered that a harvest level of about 0.89 pounds per acre would be sustainable because the estimated annual Walleye production was 1.24 pounds per acre and that this level of yield would not diminish the overall population size.

Reservoir Water Retention Time and Control of Water Levels

Although reservoir Walleye fisheries can be self-sustaining if suitable habitat for all life stages is present (Haxton and Findlay 2009), the retention time of water in a reservoir can influence its fish populations (Miranda and Lowery 2007). Water remains in a reservoir with a high retention time longer than it does in a reservoir with a low retention time. Water retention time was positively related to Walleye recruitment or harvest in Ohio (Johnson et al. 1988), Kansas (Willis and Stephen 1987; Quist et al. 2003), and Nebraska (DeBoer et al. 2013). Johnson et al. (1988) hypothesized that large numbers of Walleyes, particularly juveniles, are lost downstream from reservoirs with low retention times. Walleyes appear to be very susceptible to downstream movement via dam surface discharges (J. McMillan, Wyoming Game and Fish Department (WGFD); personal communication). Willis and Stephen (1987) found that Walleye density and stocking success in Kansas reservoirs were directly related to retention time and stated that Walleye stocking is not justified in reservoirs with retention times of less than one year. Johnson et al. (1988) stated that Ohio impoundments supporting the best Walleye harvests generally had retention times greater than about 0.7 years. Retention time is also important because reservoirs with low retention times may not become thermally stratified during summer. Lack of stratification can increase interactions between coolwater species (Walleye) and coldwater species (trout). Water retention time is a particularly important consideration for Walleye management in Montana because most Walleye fisheries occur in reservoirs.

The effects of water levels on Walleye recruitment probably vary among reservoirs. Potential influencing factors include whether optimal or suitable habitat is left dry by reduced water levels or flooded by increased water levels, the effects of water levels on reservoir retention time, the timing and rate of water level fluctuations relative to Walleye spawning, and the effects of water levels on abundance of competing or predator fish abundance. Low spring reservoir elevation was positively associated with Walleye recruitment in Kansas and Nebraska irrigation reservoirs (Quist et al. 2003; DeBoer et al. 2013) but the responsible mechanisms were not known with certainty (Quist et al. 2003; DeBoer et al. 2013). However, Walleye abundance was negatively associated with White Crappie abundance which may have had an overriding influence on Walleye recruitment in the Kansas study (Quist et al. 2003). Low reservoir levels in Nebraska may delay irrigation withdrawals, thereby reducing entrainment of larval or juvenile Walleyes (DeBoer et al. 2013).

Most state agencies in the United States attempt to maintain stable or slightly rising water levels in reservoirs during spawning and incubation (Klingbeil 1969). Sharply reduced water levels during this period have the potential to cause direct mortality of stranded Walleyes eggs and larvae (Bozek et al. 2011a). However, stable levels have not proved to be necessary at other times during the year. In certain Kansas reservoirs, Walleyes populations improved because raising the water level in spring improved spawning and nursery conditions, and a mid-summer drawdown allowed for shoreline revegetation, which in turn improved the forage base and water quality for Walleyes (Groen and Schroeder 1978). Erickson (1972) observed that on-stream impoundments that 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 dams during periods of rapid water drawdown.

Control of Predation and Competition

"Rough" fish (Common Carp *Cyprinus carpio*, suckers, and other nongame species) removal programs have often been attempted in hopes of increasing Walleye populations by reducing competition. Ricker and Gottschalk (1941) reported that following the removal of rough fish from Bass Lake, Indiana, game fish populations, including Walleyes, showed a large increase. In contrast, removal of 34% of the adult sucker population in Many Point Lake, Minnesota, was not considered successful in reducing interspecific competition between suckers and Walleyes. Similarly, 12 years of intensive Freshwater Drum removal on Lake Winnebago, Wisconsin, resulted in only a small increase in Walleye numbers (Priegel 1971). In these latter 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 the White Sucker *Catostomus commersonii* population must be removed to be effective. This rule may hold true for other rough fish species as well. However, it appears that use of rough fish removal as a management tool for Walleye fisheries is no longer a common management practice; a recent comprehensive review of the biology, management, and culture of Walleye makes no mention of rough fish removal (Barton 2011).

Stocking

Demand for Walleyes has led to Walleye aquaculture and stocking programs by many fisheries management agencies (Kerr 2011). Nearly one billion Walleyes were stocked in North American waters in 2006 (Kerr 2008). Stocking of Walleyes may be conducted to introduce

Walleyes into waters where they are not present, to rehabilitate depressed Walleye populations, and to supplement natural recruitment (Kerr 2011). Success of Walleye stocking varies with the specific instance and the management objective (Kerr 2011). Stocking was successful in 35 to 64% of introductions, 32 to 39% of rehabilitations, and less than 6% of supplementations (Laarman 1978; Bennett and McArthur 1990; Kerr 2007).

Both abiotic and biotic factors influence Walleye stocking success. Influential factors identified by Kerr (2011) were habitat suitability, resident aquatic community, age and size of stocked Walleyes, stocking density, time of stocking, frequency of stocking, genetics of stocked fish, stocking sites and methods of release, and angling exploitation. Stocking Walleyes can have negative ecological effects including predation, competition with and alterations of the fish assemblage, hybridization, and introduction of diseases or parasites (Kerr and Grant 2000).

Continuous planting of Walleyes in lakes in which no natural reproduction occurs has provided good angling returns in a number of lakes (Groebner 1959; Schneider 1969) whereas supplemental stocking in lakes which contain good reproducing populations is generally ineffective (Laarman 1978; Li et al. 1996b; Jacobson 2004; Jennings et al. 2005). However, a positive correlation between stocking and year class abundance has been observed in some lakes with naturally reproducing populations (Colby et al. 1979). Walleye abundance in some lakes with naturally reproducing populations can be measurably improved, but only at high stocking densities (Schneider 1969).

Stocking of Walleyes smaller than 3 inches in waters where established populations exist has generally met with little success (Klingbeil 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). Stocked Walleye fingerlings often compete with small native fish, particularly if they are stocked at a size too small to use forage fishes, and thereby compete with a variety of other fish species for invertebrates. Stocked Walleye fry or fingerlings may also be preyed upon by adult Walleyes and other predators.

Introductions

Walleye introductions into natural lakes and reservoirs have met with varied success. Bennett and McArthur (1990) surveyed all state and provincial fish and game agencies in the continental United States and Canada and asked whether the agency had introduced Walleyes into any waterbodies where the species was not previously reported, and if the stocking resulted in a reproducing population. The survey indicated that stocked Walleyes established reproducing populations in 35% of waterbodies. Statistical analysis revealed that larger, deeper, older (date of dam closure), and higher pH reservoirs had higher success in Walleye introductions (Bennett and McArthur 1990). 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 predation and growth rates of panfish have met with limited success. Of eleven Wisconsin lakes containing stunted panfish populations that were stocked with Walleye fingerlings, one lake had significant survival of the stocked Walleyes (Klingbeil 1969).

STATUS OF MONTANA WALLEYE FISHERIES

The Walleye is not native to Montana (Brown 1971; Gould 1995; Hoagstrom and Berry 2006); the first known introduction of Walleyes by a public agency was in the Missouri River below Great Falls in 1933 (Gould 1995). As of this writing, Walleye populations exist in 118 waterbodies in Montana, of which 5 were the result of illegal introductions or invasions. Walleyes are popular sport fish in a number of Montana reservoirs east of the Continental Divide. The status of Walleye fisheries in nine reservoirs with long-term data sets is profiled below. Data were provided by MFWP.

Canyon Ferry Reservoir

Canyon Ferry Reservoir is a 35,200-acre reservoir located on the Missouri River near Helena (Appendix Table 1). Canyon Ferry has long been managed as a Rainbow Trout and Yellow Perch fishery, with Brown Trout *Salmo trutta* and Burbot *Lota lota* also contributing to the fishery. Walleyes were discovered in the reservoir sometime in the 1980s, likely as a result of an illegal introduction, and have since become a substantial component of the Canyon Ferry fishery. Walleyes are not stocked in Canyon Ferry (Appendix Table 2) and reproduce naturally in the reservoir. Because of Walleye predation, Yellow Perch have declined from historic levels, and stocking 8-inch Rainbow Trout (increased from X inches) has been implemented to reduce predation rates. Northern Pike have also recently been documented in Canyon Ferry, with unknown consequences for the existing fishery.

The Walleye population is monitored by MFWP during standardized annual gill-net surveys conducted in September (Appendix Table 3). Net catch rates have fluctuated from 2.1 to 10.4 Walleyes per net during 1996-2014, with peaks in net catch rates every 3 to 5 years (Figure 1). These peaks are seemingly caused by variation in Walleye year class size, with more small Walleyes entering the fishery during years with peaks. Average length of Walleyes captured in gill nets generally increased from 1996 to 1999, and has declined from 2004 to 2014 (Figure 2). The initial increase in average length probably represents growth of the initial Walleye year classes, and subsequent declines in average length indicate successful Walleye reproduction with smaller fish entering the population. A general declining trend in average relative weight (the weight of an individual fish compared to an expected standard weight of a fish of that same length) has occurred from 1996 to 2014 (Figure 2). Adult Walleye size classes are divided into four categories by fisheries managers: Stock (10—14.9 inches), Quality (15—19.9 inches), Preferred (20—24.9 inches), and Memorable (> 25 inches). The general decline in average relative weight has occurred in all size classes of adult Walleyes (Figure 3), which probably reflects loss of plumpness caused by a declining food base for Walleyes, namely Yellow Perch and stocked fingerling Rainbow Trout.

Angler catch rate of Walleyes in Canyon Ferry has been variable, with a general increasing trend during 2001-2009, a decline during 2012 and 2013, and an increase in 2014; values ranged from less than 0.1 fish per hour to about 0.5 fish per hour (Figure 4). Angler Walleye catch rates of anglers targeting Walleyes were always higher than Walleye catch rates of anglers not specifically targeting Walleyes. Increases in angler catch rates have occurred without any clear trends in Walleye abundance as indicated by gill-net catch rates (Figure 4). These increases were probably caused by greater knowledge and ability of anglers as they became familiarized with this new fishery. As angler catch rates increased, average Walleye relative weight also decreased (Figure 5). Although decreased relative weights may be caused by a declining food base, this could also increase angler catch rates because Walleyes would be more actively seeking forage.

Summer and winter angling pressure (angler days per year) has been fairly steady from 1999 to 2013, with a high of nearly 90,000 summer angler days in 2009 (Figure 6). Angling pressure does not appear to be related to Walleye net catch rates (Figure 6). The percent of all anglers that are specifically targeting Walleyes has steadily increased from about 10% in 1997 to about 50% since 2007 (Figure 7). This increase does not appear to be related to Walleye net catch rates, but rather probably reflects increased awareness among the angling public about the recently established Walleye fishery in Canyon Ferry.

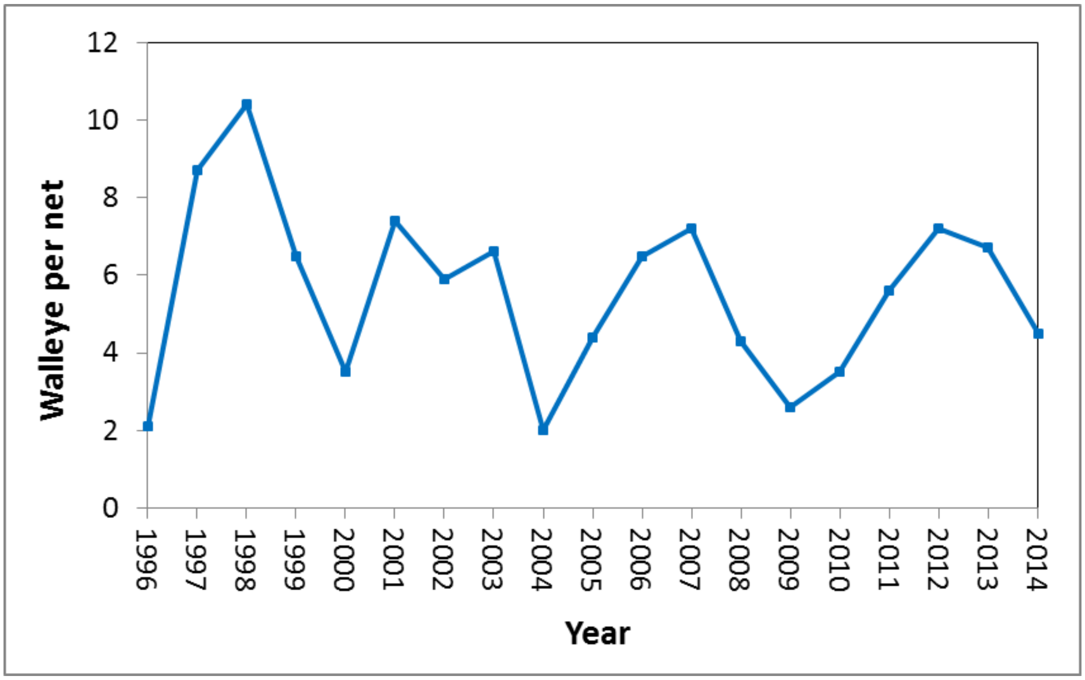

Figure 1. Walleyes captured per gill net in Canyon Ferry Reservoir, 1996 to 2014.

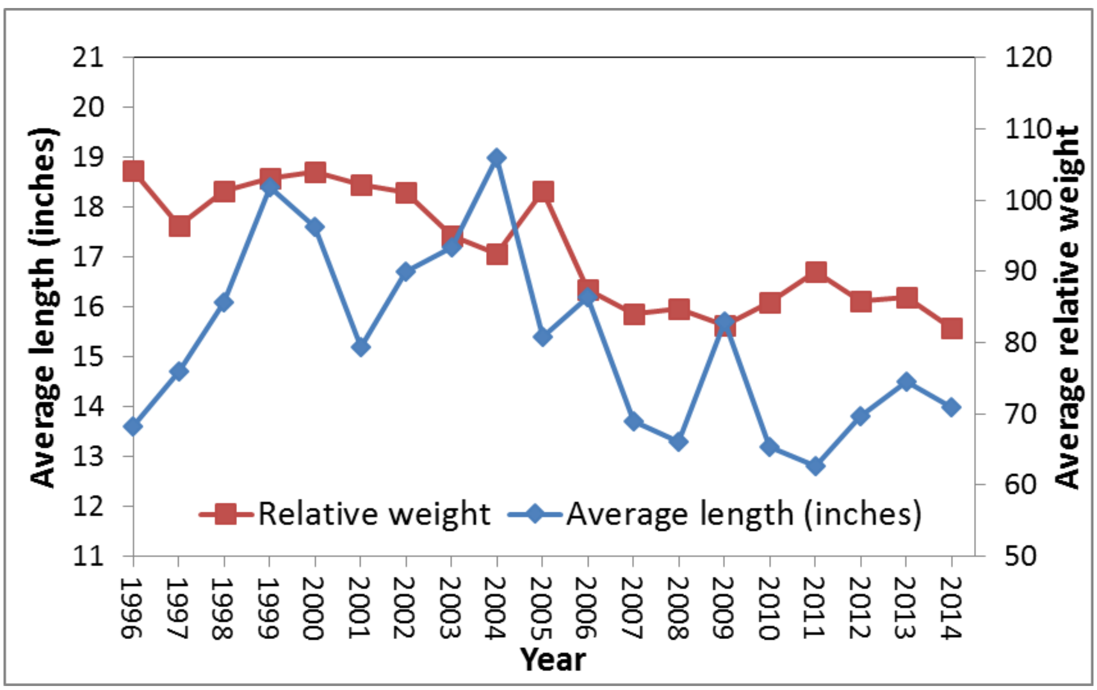

Figure 2. Walleye average length and relative weight from gill-net sets in Canyon Ferry Reservoir, 1996 to 2014.

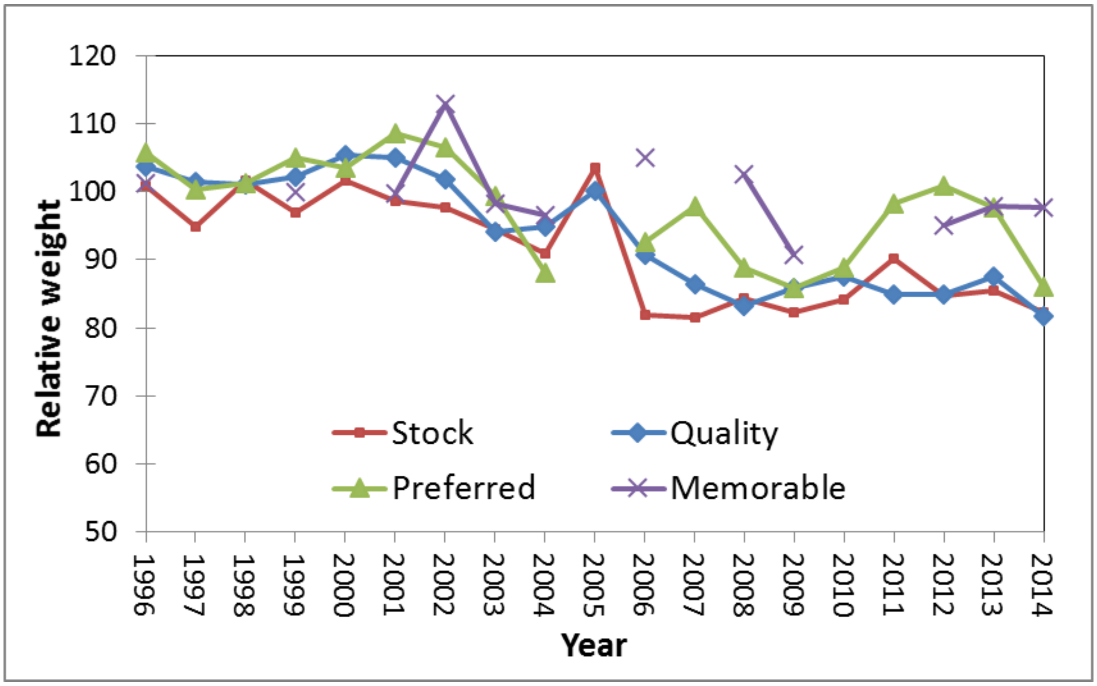

Figure 3. Relative weight of stock, quality, preferred, and memorable size Walleyes from gill nets in Canyon Ferry Reservoir, 1996 to 2014.

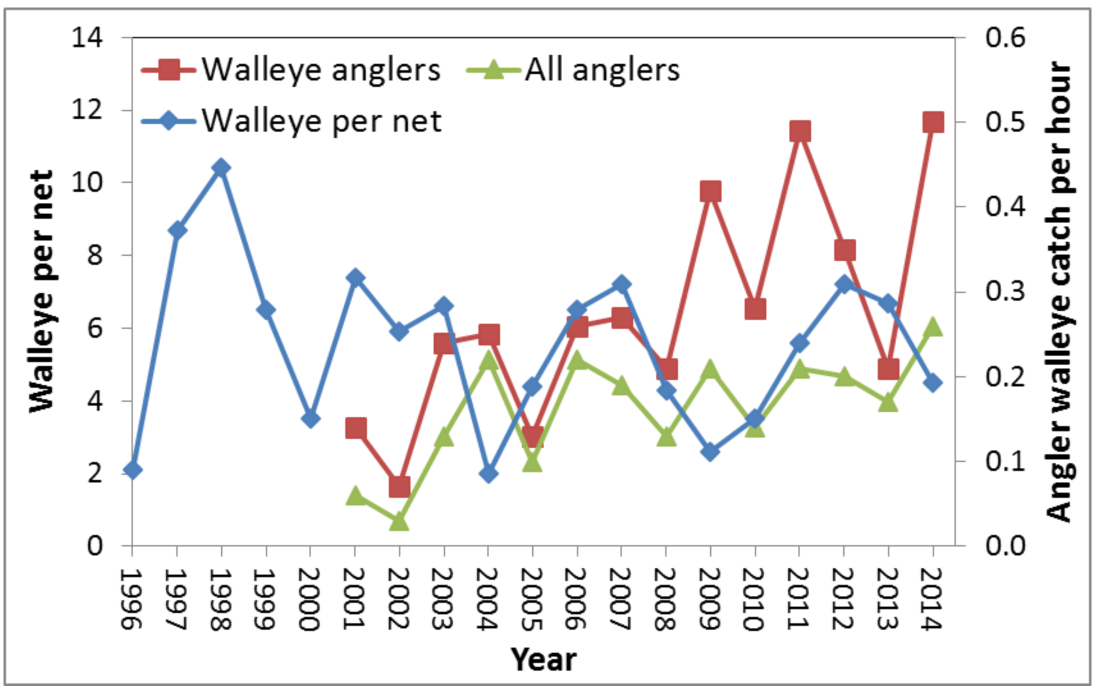

Figure 4. Walleye catch rates in gill-net sets, and by Walleye anglers, all anglers, Canyon Ferry Reservoir, 1996 to 2014.

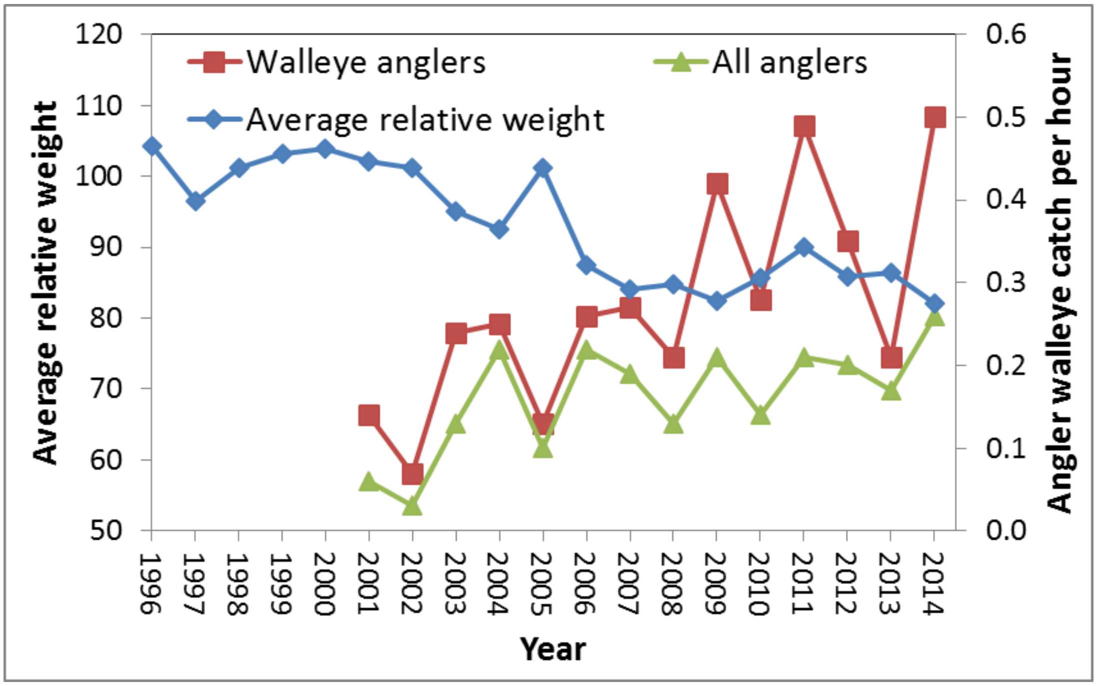

Figure 5. Walleye average relative weight and catch rates by Walleye anglers and all anglers in Canyon Ferry Reservoir, 1996 to 2014.

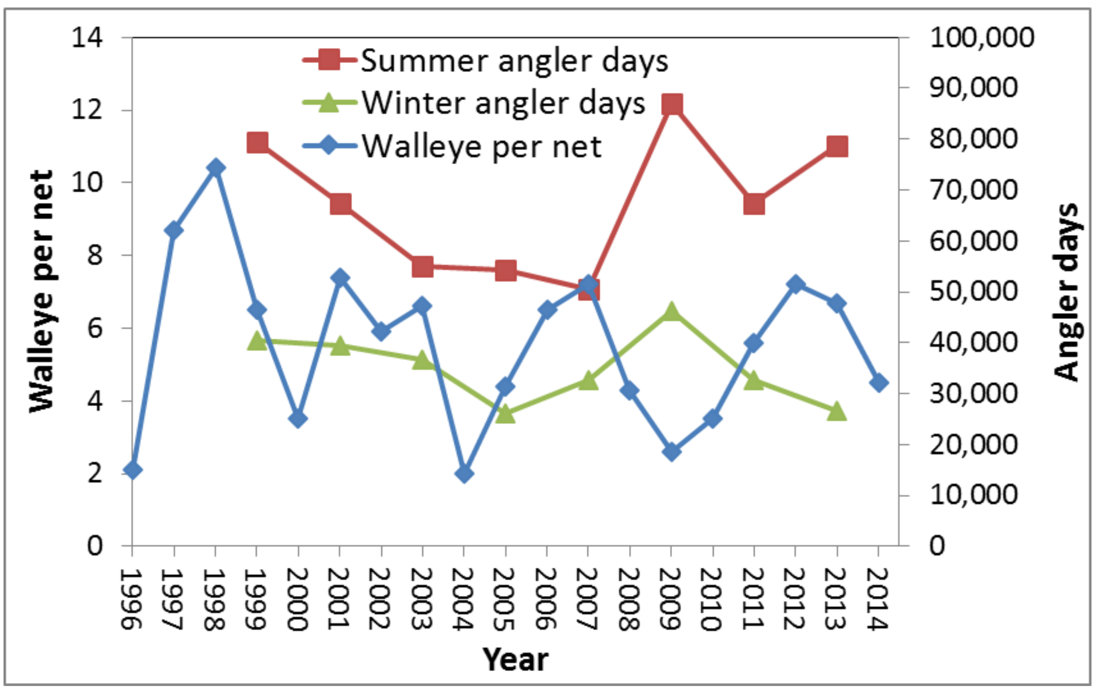

Figure 6. Walleye catch rates by gill-net sets and fishing pressure in summer and winter in Canyon Ferry Reservoir, 1996 to 2014.

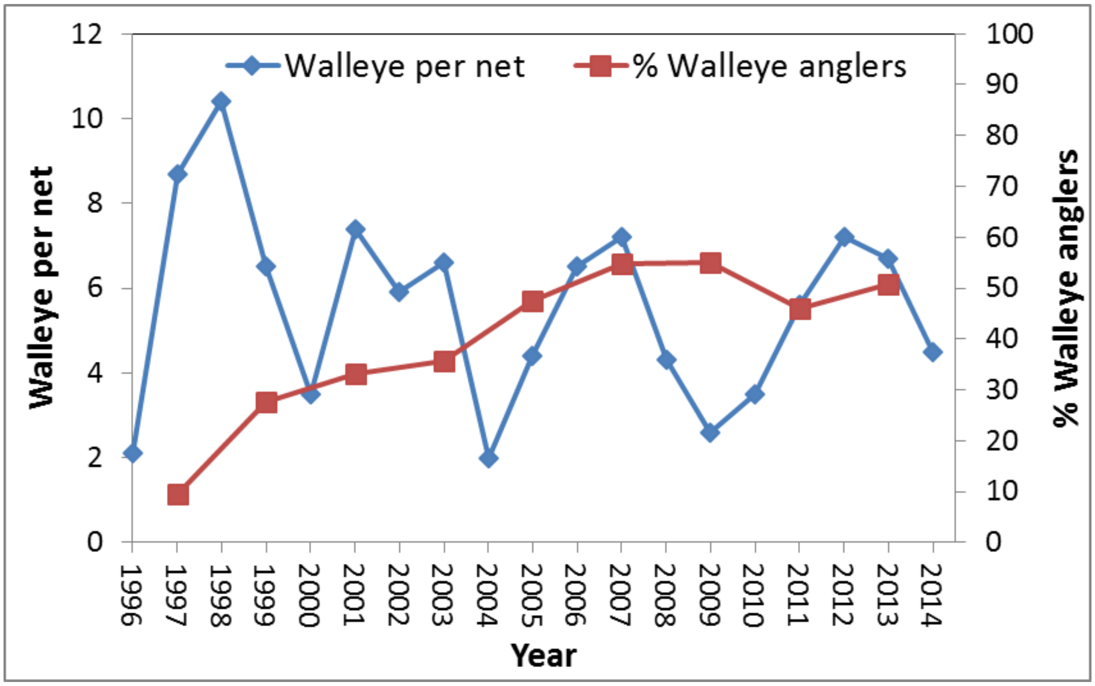

Figure 7. Walleye catch rates by gill-net sets and percent of anglers fishing for Walleyes in Canyon Ferry Reservoir, 1996 to 2014.

Holter Reservoir

Holter Reservoir is a 4,800-acre reservoir located on the Missouri River near Helena (Appendix Table 1). Holter has long been managed as a Rainbow Trout and Yellow Perch fishery, with a low level Walleye fishery. The Walleye population in Holter Reservoir probably resulted from the single plant made into Lake Helena in 1951, and also from escaped fish from Hauser Reservoir, and has since become a substantial component of the Holter fishery. Walleyes are not stocked in Holter (Appendix Table 2) and reproduce naturally in the reservoir. In addition, Walleye abundance in Holter increased substantially in the late 1990s, following establishment of Walleyes upstream in Canyon Ferry Reservoir. Because of Walleye predation, Yellow Perch have declined from historic levels, and stocking 8-inch Rainbow Trout has been implemented to reduce predation rates.

The Walleye population is monitored by MFWP during annual gill-net surveys conducted in October (Appendix Table 3). From 1986 to 1995 Walleye net catch rates fluctuated between 0.5 to 4.3 Walleyes per net. Following expansion of the Walleye population in Canyon Ferry, net catch rates have fluctuated from 0.5 to 11.3 Walleyes per net during 1996 to 2014, with peaks in net catch rates in 2000, 2008 to 2009, and 2013 (Figure 8). These peaks are probably caused by variation in Walleye year class size from natural reproduction or from Walleyes entrained in spill from upstream reservoirs (Canyon Ferry and Hauser), entering the Holter Reservoir fishery. Average length of Walleyes captured in gill nets decreased from 1996 to 2000, varied during 2001 to 2009, and has generally increased from 2009 to 2014 (Figure 9). The initial decrease in average length probably indicates successful Walleye reproduction with smaller fish entering the population. Relative weight has remained fairly steady from 1996 to 2014 and ranged from the high 80s to over 100, indicating an adequate forage base for Walleyes (Figure 9). Relative weight among all size classes of Walleyes also remained fairly steady from 1996 to 2014, although Stock (10 to 14.9 inches) Walleye relative weight has been relatively low since 2007 (Figure 10).

Angler catch rate of Walleyes in Holter was low from 1996 to 2006, and has been erratic since then, ranging from 0.23 to 1.36 Walleyes per hour (Figure 11). Angler catch rates of anglers targeting Walleyes were nearly always higher than catch rates for anglers not specifically targeting Walleyes. Changes in angler catch rates have occurred without any clear relationship to Walleye gill-net catch rates (Figure 11) or Walleye average relative weight (Figure 12).

Angling pressure has been fairly steady from 1999 to 2013 although summer angling pressure gradually declined from 1999 to 2007, and increased since then. Angling pressure does not appear to be strongly related to Walleye net catch rates (Figure 13). The percent of all anglers that are specifically targeting Walleyes generally increased from about 10% in 1997 to about

50% in 2007, and has declined somewhat since then (Figure 14). The increase through 2007 corresponds somewhat to Walleye net catch rates, but peak net catch rates in 2013 did not increase the percentage of anglers targeting Walleyes.

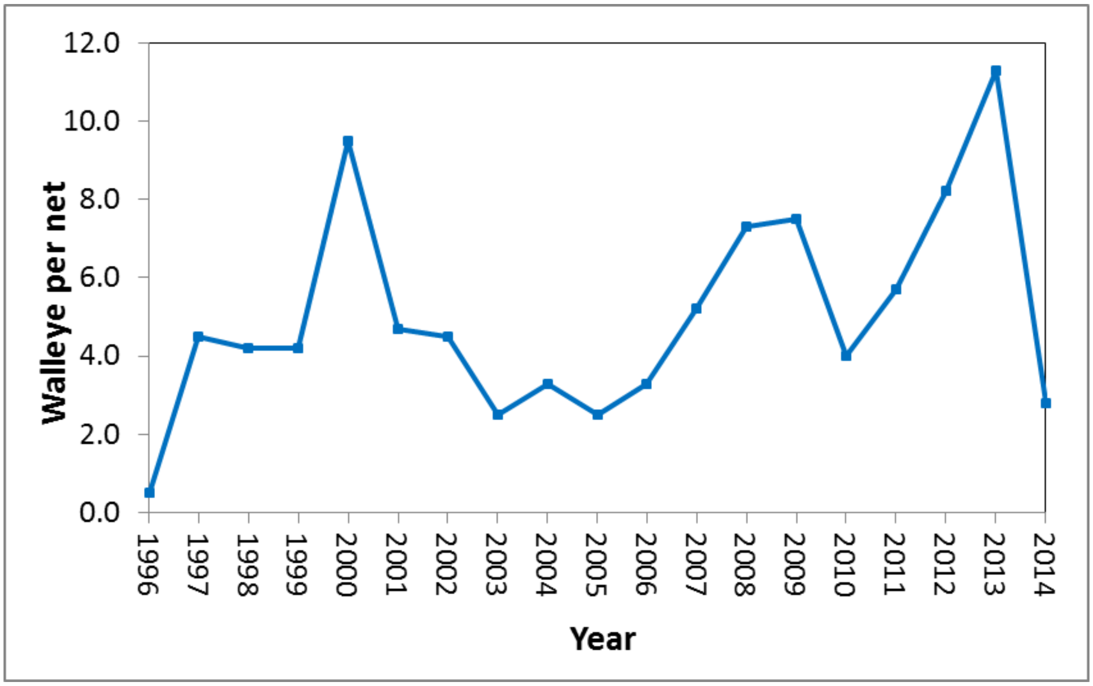

Figure 8. Walleyes captured per gill net in Holter Reservoir, 1996 to 2014.

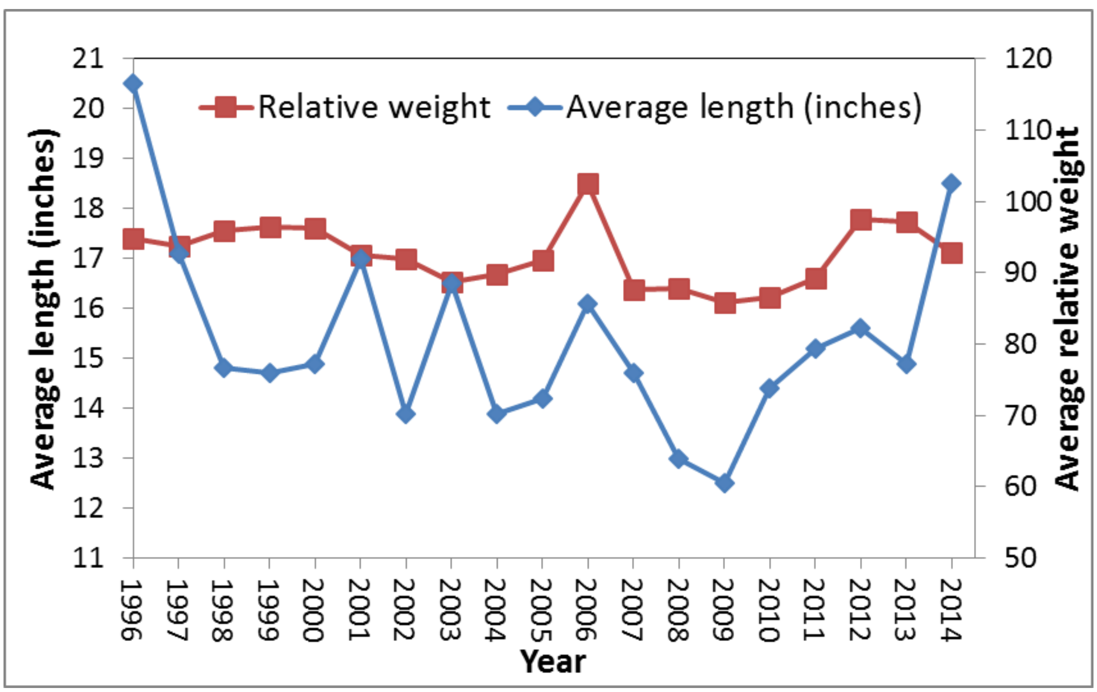

Figure 9. Walleye average length and relative weight from gill-net sets in Holter Reservoir, 1996 to 2014.

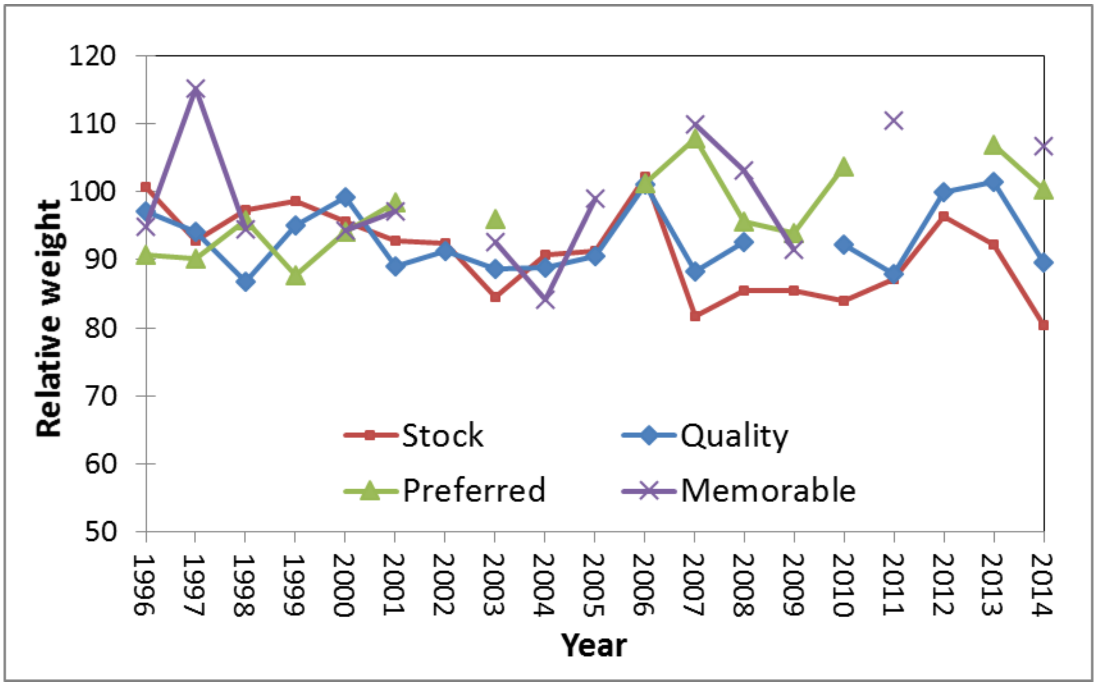

Figure 10. Relative weight of stock, quality, preferred, and memorable size Walleyes from gill nets in Holter Reservoir, 1996 to 2014.

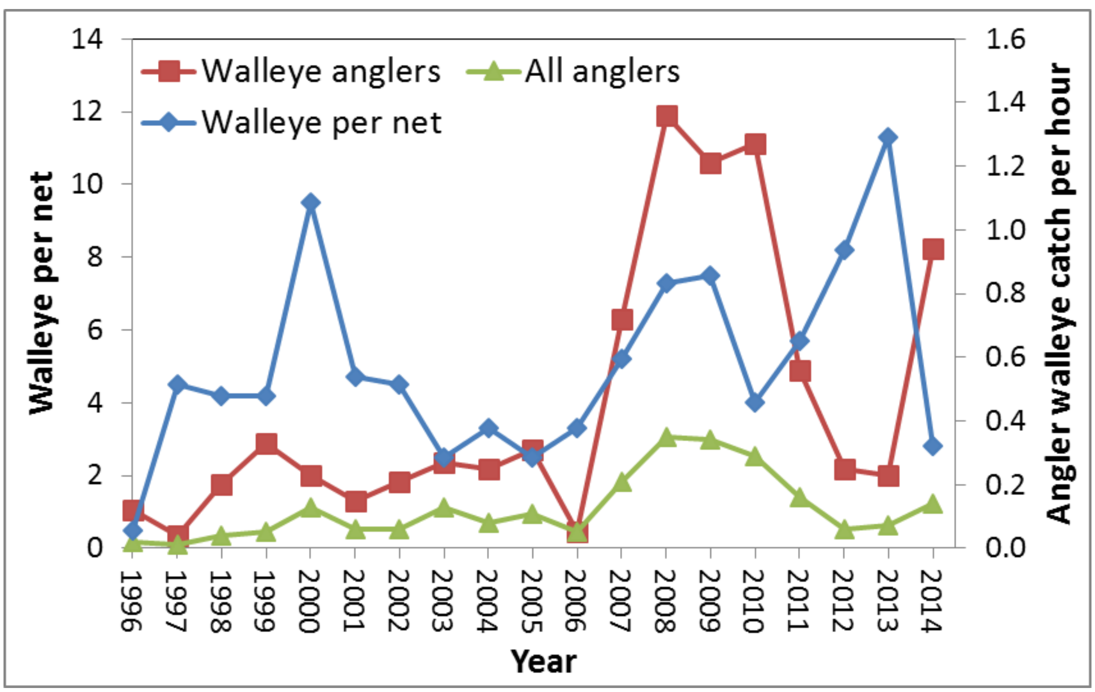

Figure 11. Walleye catch rates in gill-net sets, and by Walleye anglers, all anglers, Holter Reservoir, 1996 to 2014.

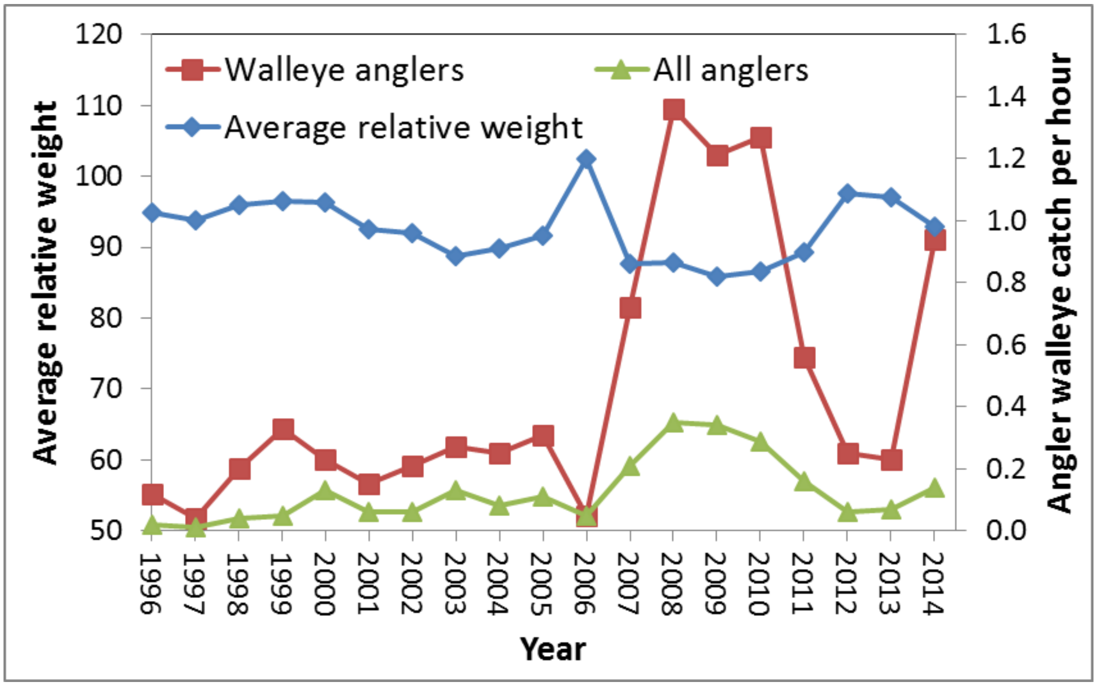

Figure 12. Walleye average relative weight and catch rates by Walleye anglers and all anglers in Holter Reservoir, 1996 to 2014.

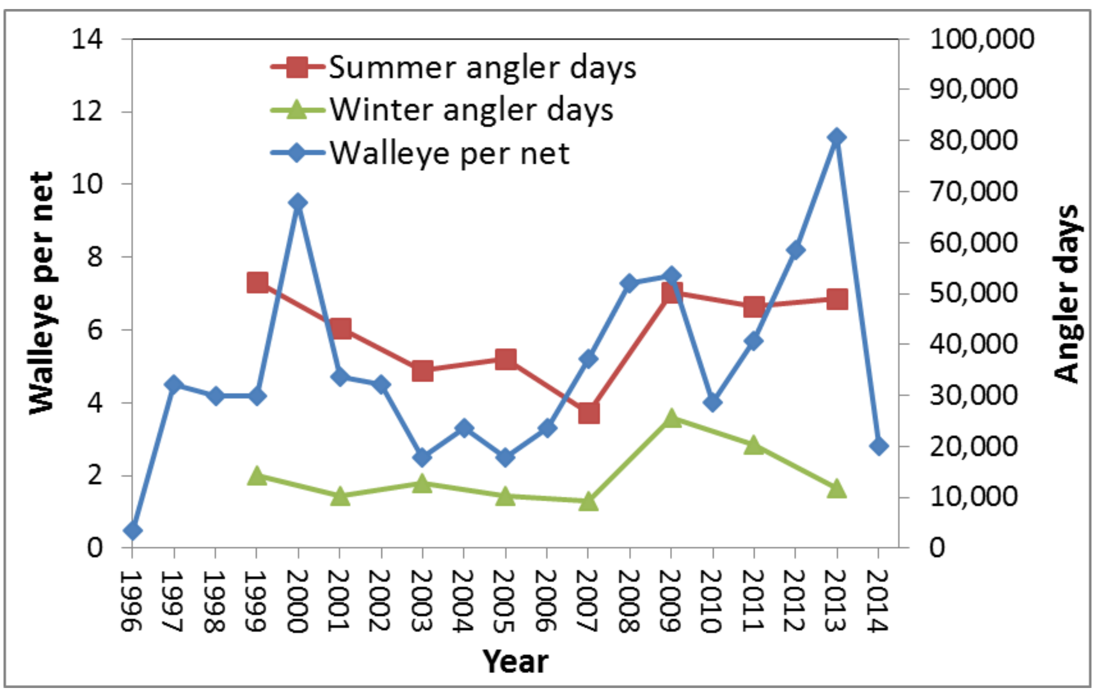

Figure 13. Walleye catch rates by gill-net sets and fishing pressure in summer and winter in Holter Reservoir, 1996 to 2014.

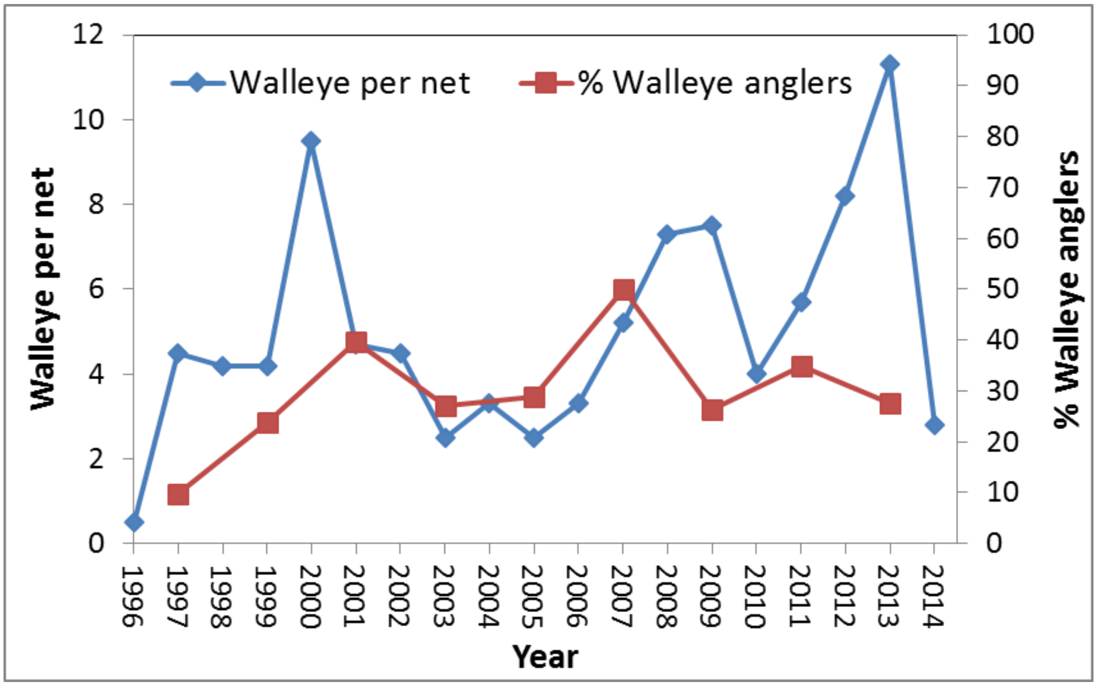

Figure 14. Walleye catch rates by gill-net sets and percent of anglers fishing for Walleyes in Holter Reservoir, 1996 to 2014.

Lake Frances

Lake Frances is a 5,500-acre reservoir located near Valier, Montana (Appendix Table 1). Walleye fry were first planted in the reservoir in 1969. They first began to appear in annual gill-net surveys in 1975. Lake Frances is managed as a multi-species fishery composed primarily of Walleye, Northern Pike, Yellow Perch, and Burbot. Management issues in Lake Frances include management of water levels, maintaining an abundant forage base, and variable Yellow Perch production. Walleye fingerlings are stocked in Lake Frances every other year in numbers ranging from 41,427 to 117,432 (Appendix Table 2).

The Walleye population is monitored by MFWP during annual gill-net surveys conducted in September (Appendix Table 3). Net catch rates have been variable, ranging from 3.3 to 11.7 Walleyes per net with peaks in net catch rates occurring every 2 to 5 years (Figure 15). Stocking in alternate years may have contributed to variability and peaks in net catch rates (Appendix Table 2; Figure 15).

Average length of Walleyes captured in gill nets was fairly large, ranging from 13.0 inches to 17.7 inches (Figure 16). Relative weight ranged from 83.5 to 104.5, suggesting that forage is variable, but is sometimes adequate for Walleyes to maintain weight (Figure 16). Relative weight among all size classes of Walleyes also followed the same general pattern (Figure 17).

Angler catch rate of Walleyes in Lake Frances has been fairly erratic, with a peak of 0.76 Walleyes per hour in 2004, a decline to about 0.1 to 0.2 Walleyes per hour during 2007 to 2012, and an increase to over 0.4 in 2013 and 2014 (Figure 18). Angler catch rates of anglers targeting Walleyes were generally only slightly higher than catch rates for all anglers (Figure 18). Changes in angler catch rates roughly follow the Walleye gill-net catch rates except in 2003 when angler catch rates were low and net catch rates were high (Figure 18). Angler catch rates did not did not appear to be related to Walleye average relative weight (Figure 19).

Angling pressure peaked at 11,807 summer angler days in 1999, declined in 2001 and has remained fairly steady at about 7,000 summer angler days since then (Figure 20). The percent of all anglers that are specifically targeting Walleyes has generally increased from 65% in 1997 to 88% in 2013 (Figure 21).

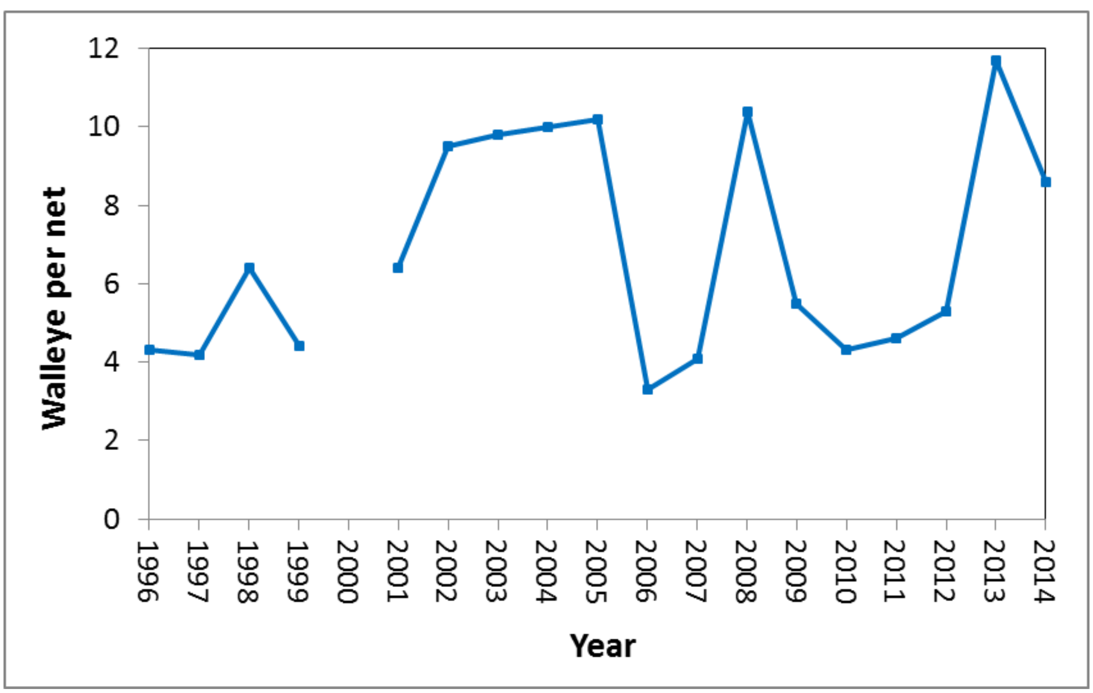

Figure 15. Walleyes captured per gill net in Lake Frances, 1996 to 2014.

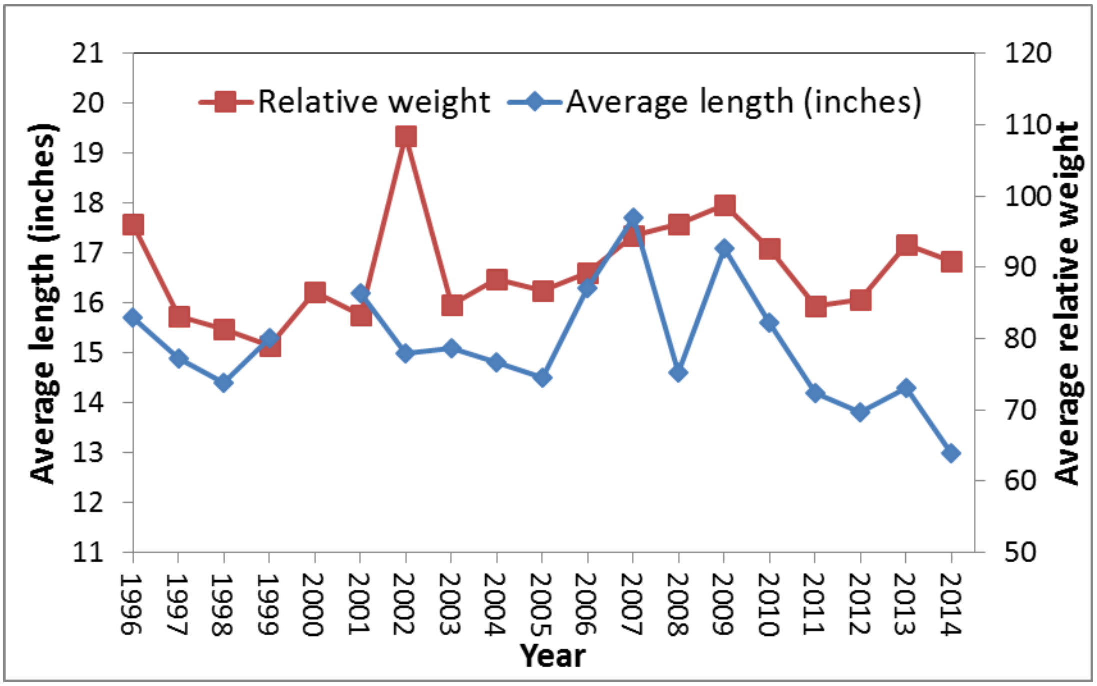

Figure 16. Walleye average length and relative weight from gill-net sets in Lake Frances, 1996 to 2014.

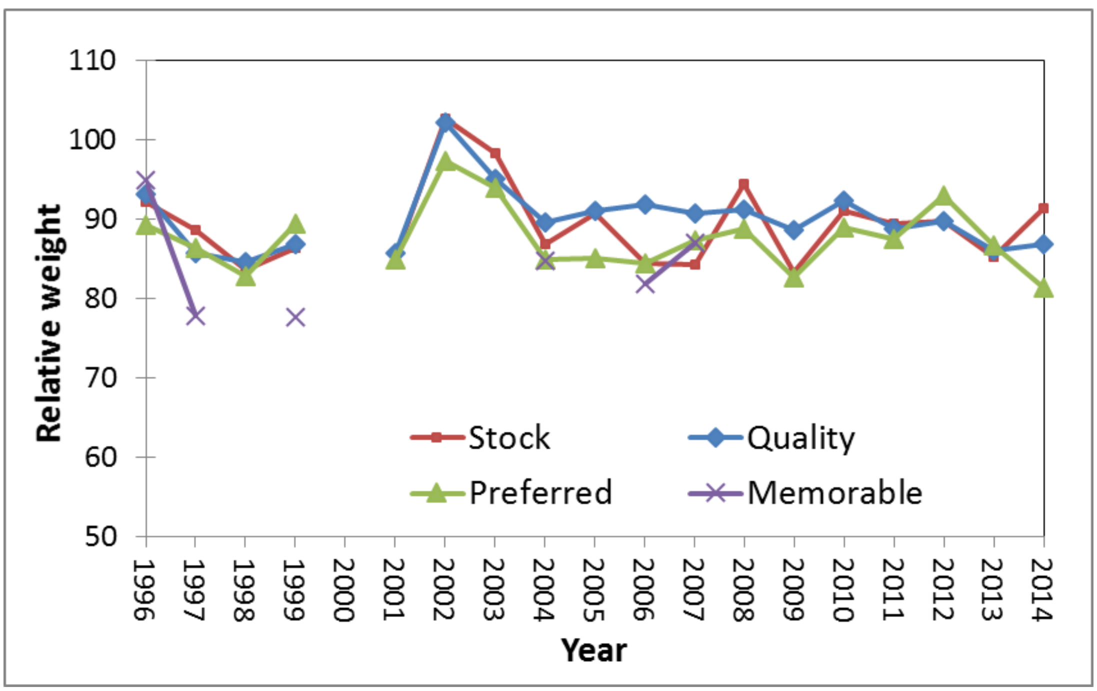

Figure 17. Relative weight of stock, quality, preferred, and memorable size Walleyes from gill nets in Lake Frances, 1996 to 2014.

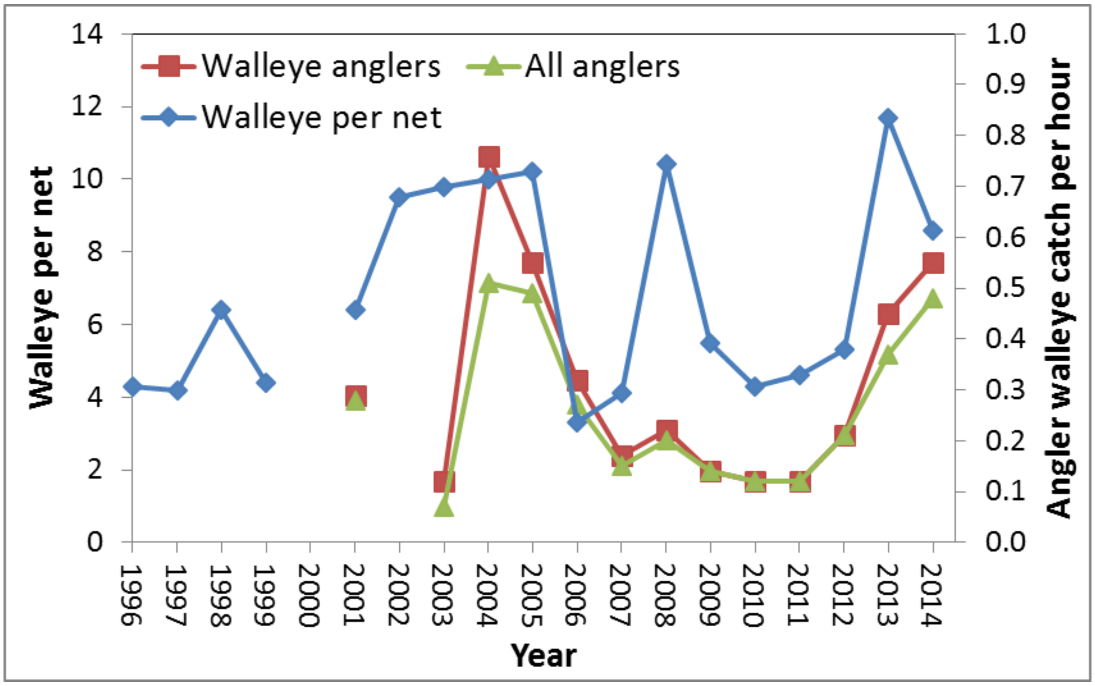

Figure 18. Walleye catch rates in gill-net sets, and by Walleye anglers, all anglers, Lake Frances, 1996 to 2014.

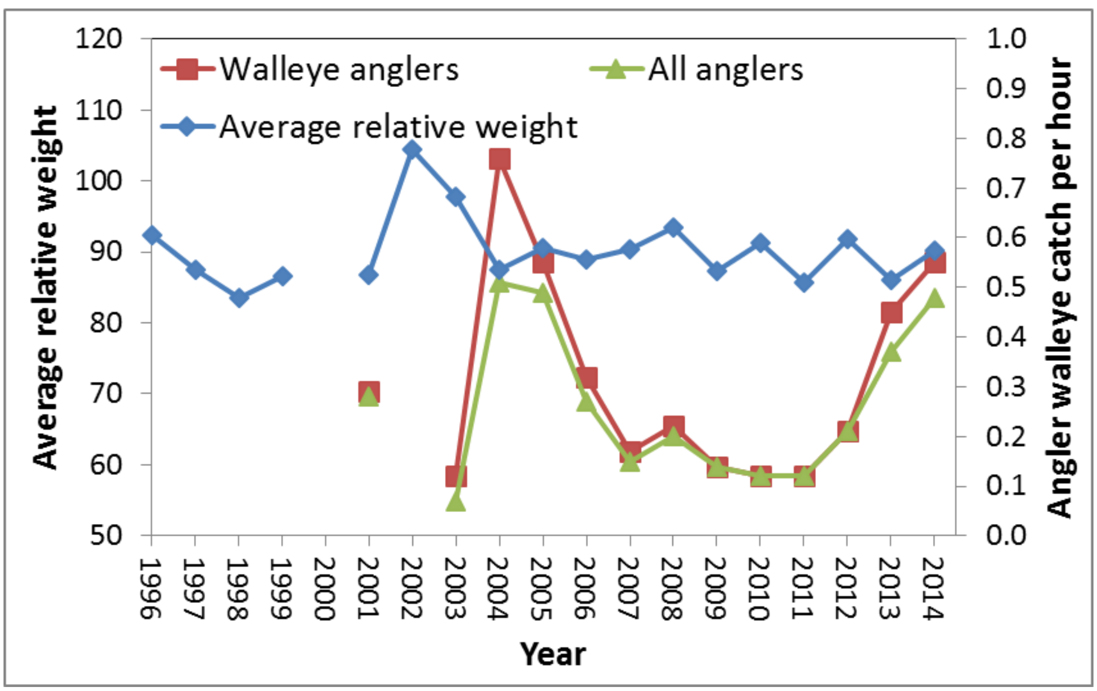

Figure 19. Walleye average relative weight and catch rates by Walleye anglers and all anglers in Lake Frances, 1996 to 2014.

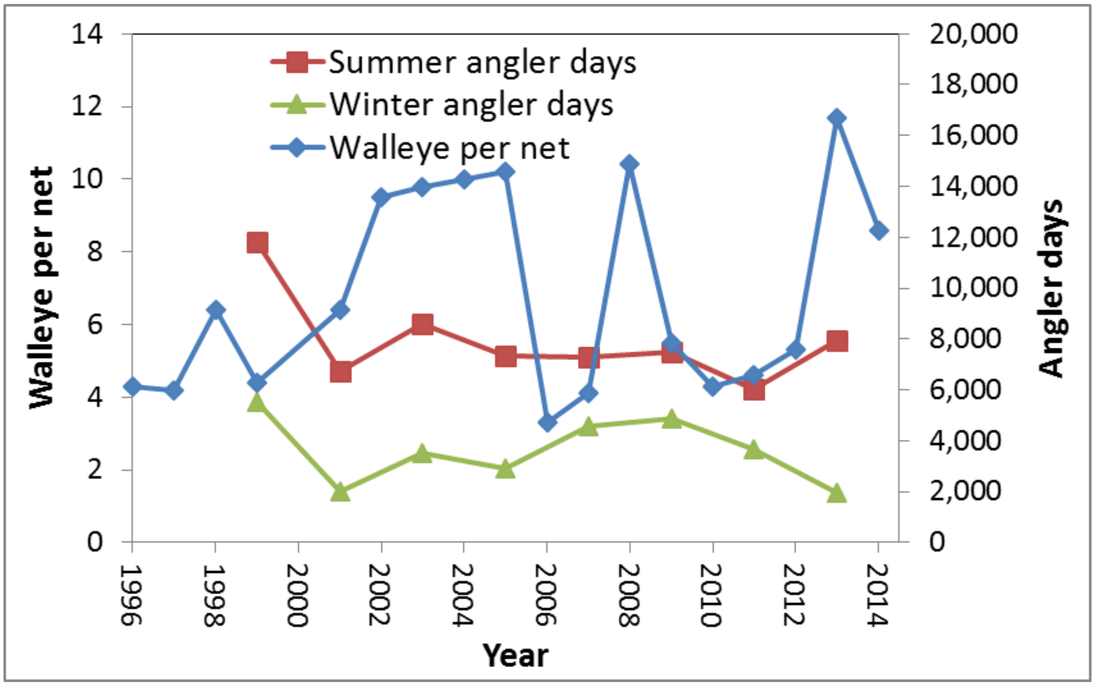

Figure 20. Walleye catch rates by gill-net sets and fishing pressure in summer and winter in Lake Frances, 1996 to 2014.

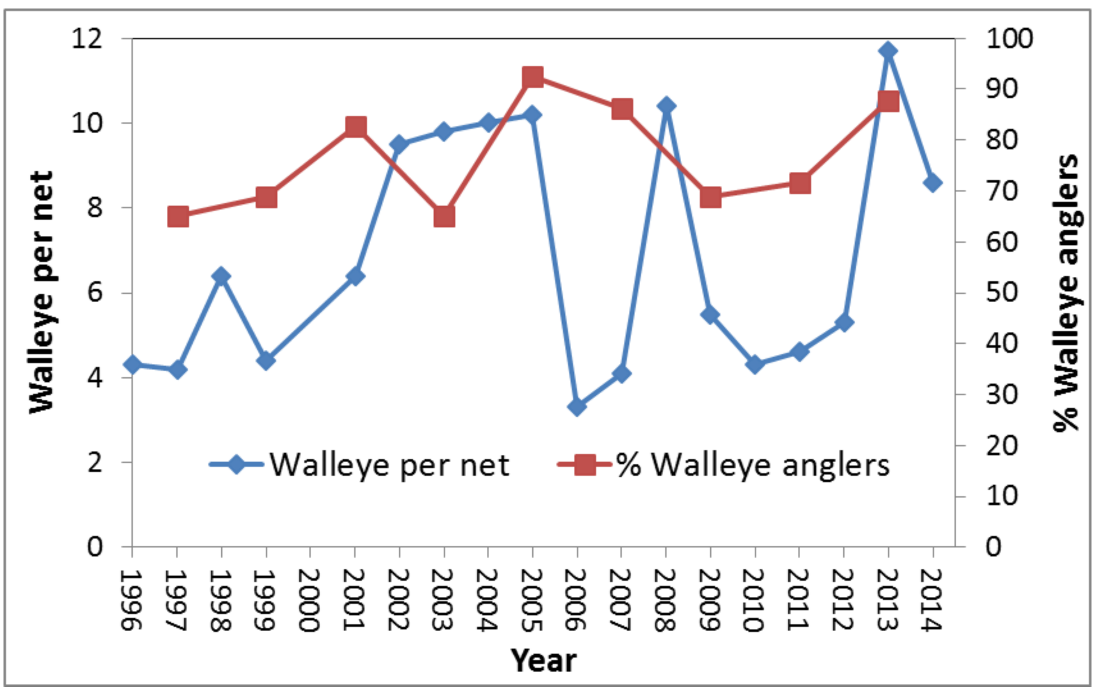

Figure 21. Walleye catch rates by gill-net sets and percent of anglers fishing for Walleyes in Lake Frances, 1996 to 2014.

Tiber Reservoir

Tiber Reservoir is a 17,800-acre reservoir located on the Marias River north of Great Falls, Montana (Appendix Table 1). In 1971, when Walleyes were introduced, Yellow Perch was the most abundant fish in the reservoir. The majority of the Walleyes introduced were stocked in Willow Creek Arm, which contains more littoral zone area than the rest of the reservoir. This area also has the best potential for Walleye spawning sites in the form of gravel and rubble. Tiber is currently managed as a multi-species fishery with Walleye, Yellow Perch, and Northern Pike. Management concerns at Tiber Reservoir include increased demands on the reservoir's water and providing an adequate forage fish base for the sport fishes. Walleyes are not stocked in Tiber (Appendix Table 2) and reproduce naturally in the reservoir.

The Walleye population is monitored by MFWP during annual gill-net surveys conducted in September (Appendix Table 3). Net catch rates have fluctuated from 1.7 to 4.0 Walleyes per net during 1996 to 2014, with generally increasing net catch rates since 1999 (Figure 22). Average length of Walleyes captured in gill nets was less than 14 inches in 1999 to 2005 and greater than 14 inches during 2006 to 2014 (Figure 23). Average relative weight was also generally lower in 1999 to 2005 and higher during 2006 to 2014 (Figure 23). A similar pattern in relative weight among all size classes of Walleyes is evident (Figure 24).

Angler catch rate of Walleyes in Tiber has been fairly erratic, with a peak of about 0.6 Walleyes per hour in 2002, a low point of 0.12 Walleyes per hour in 2004, and a general increase since 2010 (Figure 25). Angler catch rates of anglers targeting Walleyes were generally only slightly higher than catch rates of all anglers because most anglers are targeting Walleyes. Changes in angler catch rates have occurred without any clear relationship to Walleye gill-net catch rates (Figure 26) or Walleye average relative weight (Figure 27).

Angling pressure has been fairly steady from 1999 to 2013 although summer angling pressure gradually declined from 1999 to 2009, and increased in 2013 (Figure 27). Angling pressure declined sharply in 2011, when abundant precipitation caused flood water inflows which may have limited angler access on unpaved roads. Angling pressure does not appear to be strongly related to Walleye net catch rates (Figure 27). The percent of all anglers that are specifically targeting Walleyes is high, with over 80% of anglers targeting Walleyes in all years except 2013 (Figure 27). The percent Walleye anglers has been fairly steady as have Walleye net catch rates (Figure 28).

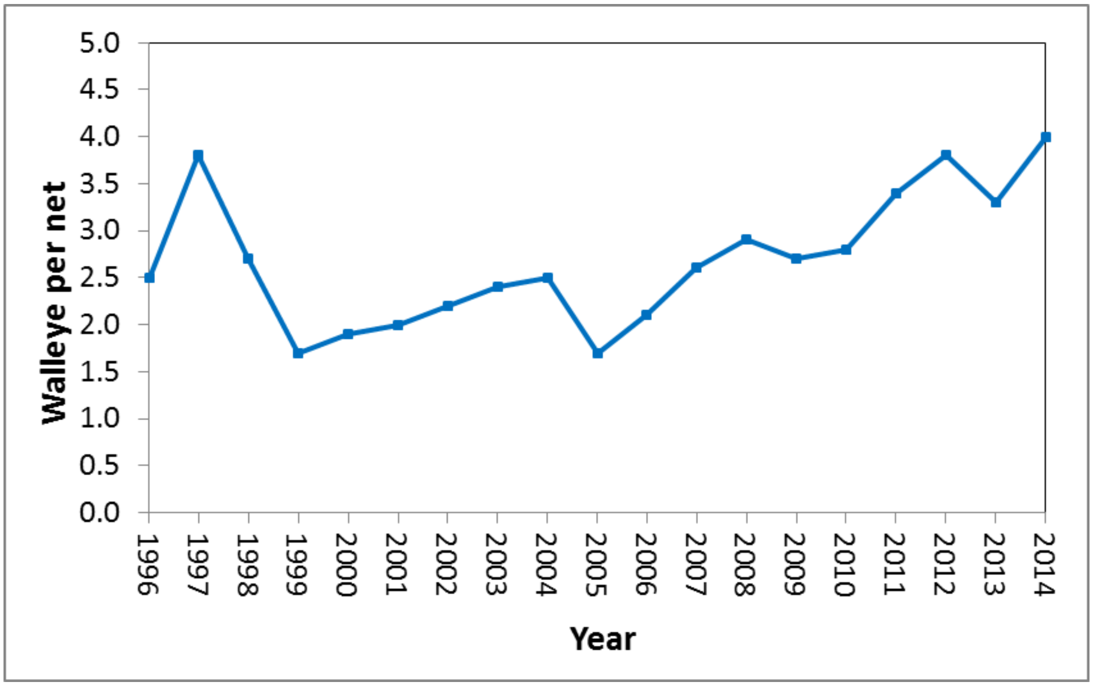

Figure 22. Walleyes captured per gill net in Tiber Reservoir, 1996 to 2014.

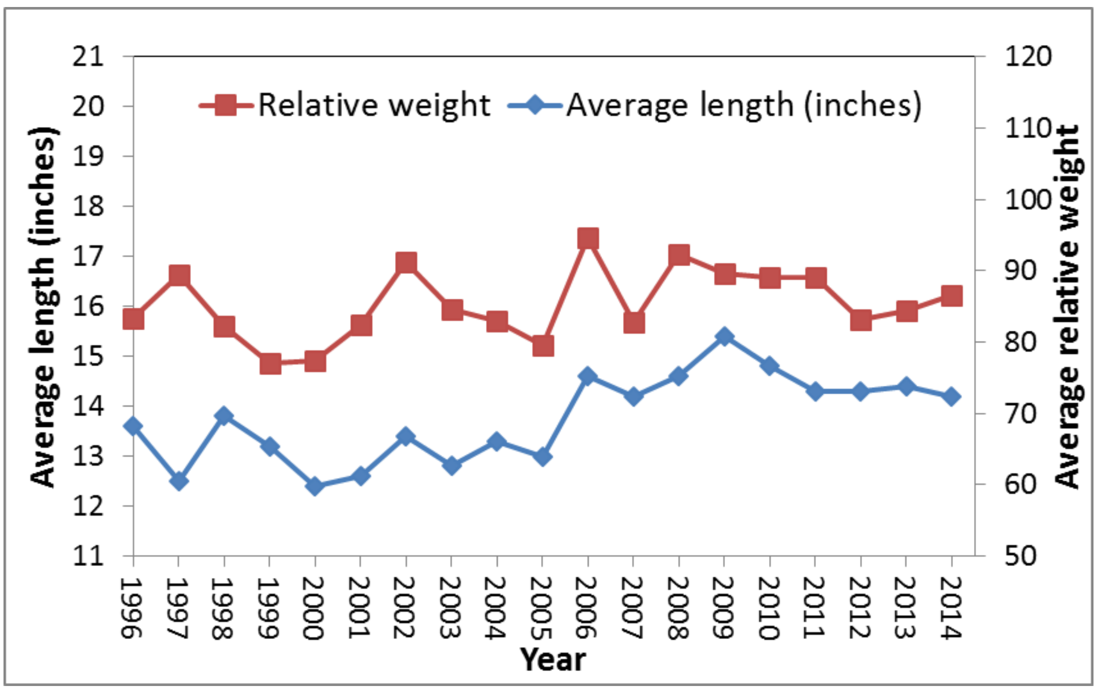

Figure 23. Walleye average length and relative weight from gill-net sets in Tiber Reservoir, 1996 to 2014.

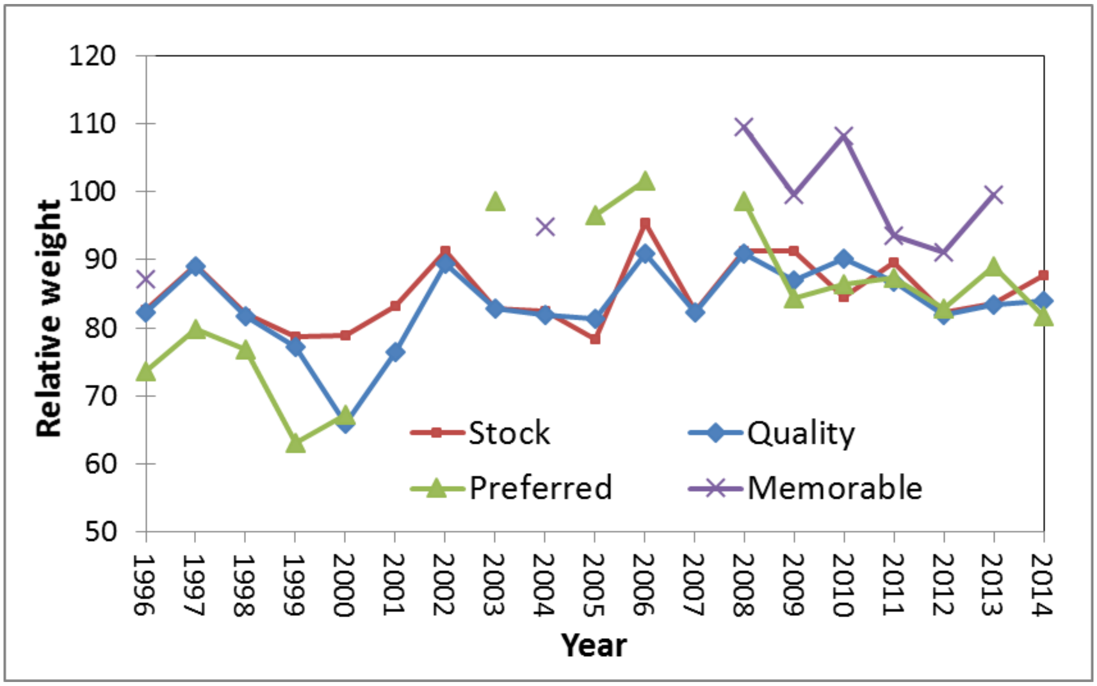

Figure 24. Relative weight of stock, quality, preferred, and memorable size Walleyes from gill nets in Tiber Reservoir, 1996 to 2014.

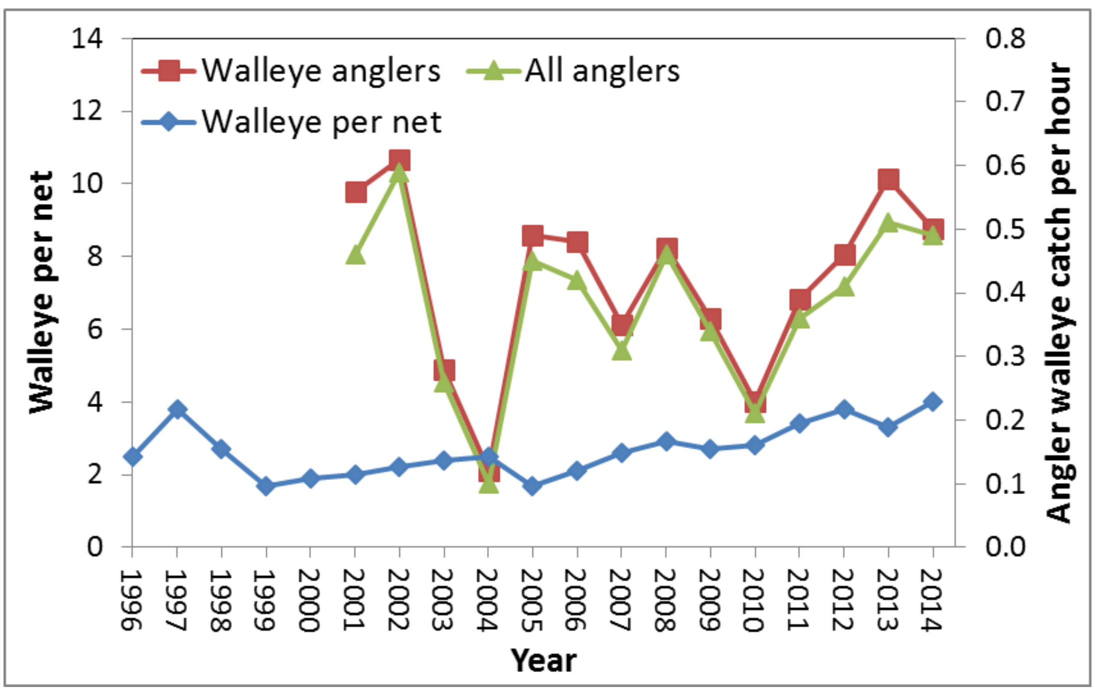

Figure 25. Walleye catch rates in gill-net sets, and by Walleye anglers, all anglers, Tiber Reservoir, 1996 to 2014.

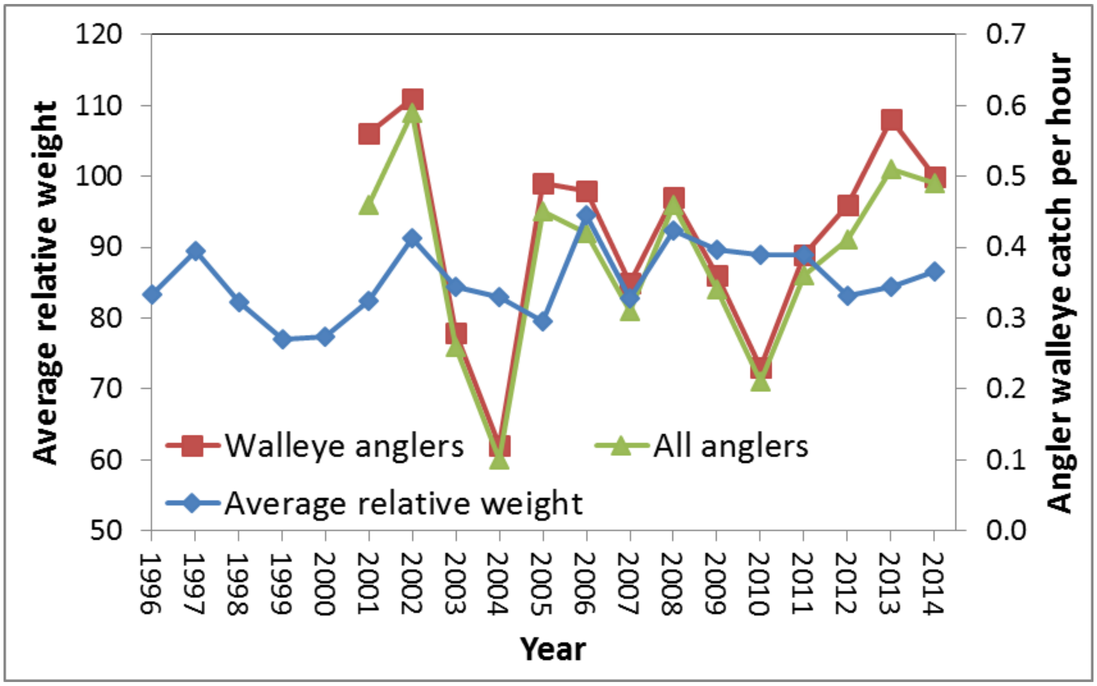

Figure 26. Walleye average relative weight and catch rates by Walleye anglers and all anglers in Tiber Reservoir, 1996 to 2014.

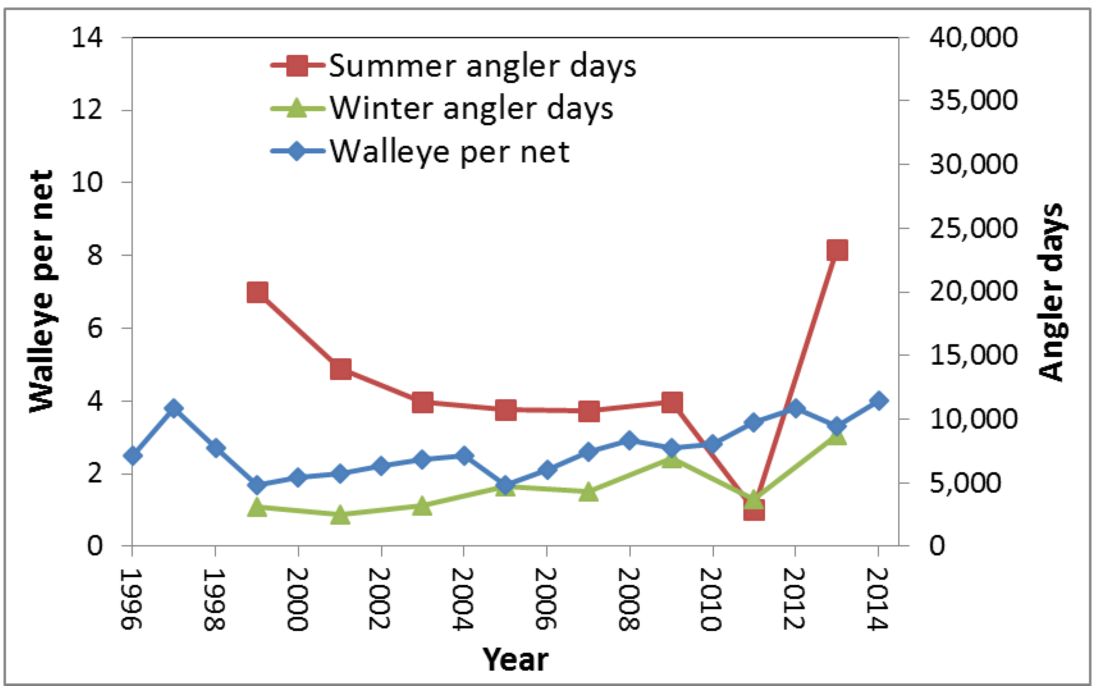

Figure 27. Walleye catch rates by gill-net sets and fishing pressure in summer and winter in Tiber Reservoir, 1996 to 2014.

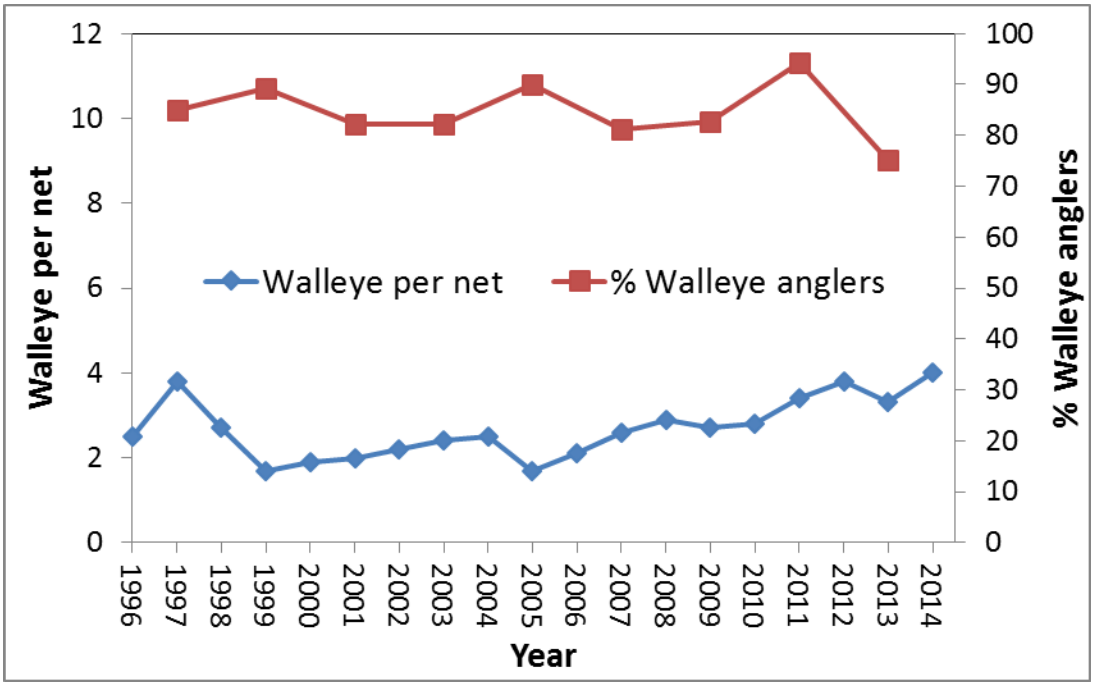

Figure 28. Walleye catch rates by gill-net sets and percent of anglers fishing for Walleyes in Tiber Reservoir, 1996 to 2014.

Fort Peck Reservoir

Fort Peck Reservoir is a 246,000-acre reservoir located on the Missouri River in northeastern Montana (Appendix Table 1). Fort Peck is a multi-species fishery including coldwater fish such as Lake Trout and Chinook Salmon *Oncorhynchus tshawytscha*, coolwater species such as Walleye, Smallmouth Bass and Northern Pike, and warmwater species such as Channel Catfish *Ictalurus punctatus* and Black Crappie *Pomoxis nigromaculatus*. Walleyes have been stocked in Fort Peck Reservoir since 1951. By the early 1970s, an excellent Walleye fishery had developed in the Big Dry Arm of the reservoir. Annual stocking was initiated in 1977 to maintain and expand the fishery. Fishery managers thought that natural reproduction was too erratic and insufficient to maintain a quality fishery. The sport fishery in Fort Peck is influenced by drought-related fluctuation in water levels, which causes variable reproduction of forage fish and other fish such as Northern Pike and Black Crappies. The Fort Peck fish hatchery was established in 2006 and has enabled MFWP to stock an additional 1.1 to 2.9 million Walleye fingerlings in Fort Peck Reservoir annually (Appendix Table 2). Prior to 2006, Walleye fingerling plants came primarily from the Miles City State Fish Hatchery. Numbers of Walleye fry stocked varied greatly from 1996 to 2014 and are dependent on total eggs collected and hatching success (Appendix Table 2). Walleyes also reproduce naturally in the reservoir.

Cisco *Coregonus artedi*, were first introduced into Fort Peck Reservoir in 1984 in an attempt to provide additional forage fish for Walleyes, Northern Pike, Lake Trout, and Chinook Salmon (Hadley 1982). Stocking of Cisco fry and fingerlings occurred in 1984, 1985, and 1986. Abundance of Cisco captured in floating commercial Goldeye *Hiodon alosoides* nets indicated good survival of the 1984 and 1985 plants. A naturally reproducing Cisco population has precluded the need for further plants.

The Walleye population is monitored by MFWP during annual gill-net surveys conducted in July and August (Appendix Table 3). Net catch rates have fluctuated from 2.4 to 6.8 Walleyes per net during 1996 to 2014, with peaks in net catch rates in 1998 and 2012 (Figure 29). These peaks are probably caused by variation in water levels, natural reproduction, magnitude of Walleye fry and fingerling stocking, survival, and forage abundance. Average length of Walleyes captured in gill nets ranged from 14.4 inches to 17.4 inches during 1999 to 2014 (Figure 30). Variation in Walleye average length is primarily related to the abundance of smaller size classes of Walleyes; when smaller Walleyes are abundant, average length is smaller. Relative weight has remained fairly steady from 1996 to 2014 and ranged from the low 80s to 91, suggesting that the forage base may be somewhat limiting Walleye condition (Figure 30). Relative weight among all size classes of Walleyes also remained fairly steady from 1996 to 2014, although Stock (10 to 14.9 inches) Walleye relative weight has often been lower than the relative weight of larger Walleyes, particularly prior to 2009, suggesting that fewer forage fish may have been available for smaller Walleyes during drought years (Figure 31).

Data on angler catch rate of Walleyes in Fort Peck is available for only four years (2004, 2008, 2011, and 2014); angler catch rate was highest in 2014. These changes in angler catch rates have coincided with a general increase in Walleye gill-net catch rates from 2012 to 2014 (Figure 32) and a decrease in Walleye average relative weight since 2011 (Figure 33).

Angling pressure has varied substantially on Fort Peck Reservoir from 1999 to 2014, and summer angling pressure was more variable than winter angling pressure (Figure 34). Summer angling pressure peaked at over 90,000 angler days in 1999, declined to about 29,000 angler days in 2007, and has increased since then to over 77,000 angler days in 2013 (Figure 34). Angling pressure may have been weakly related to Walleye net catch rates (Figure 34). The percent of all anglers that are specifically targeting Walleyes has remained generally steady; ranging from 67% to 84% (Figure 35), and does not appear to be related to Walleye net catch rates.

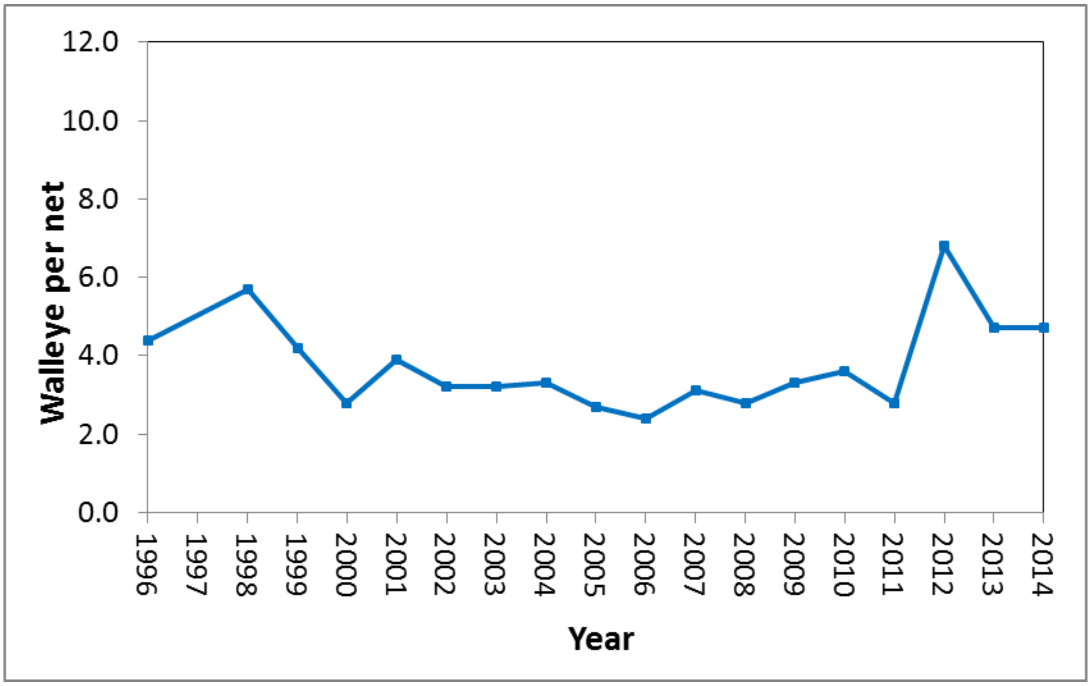

Figure 29. Walleyes captured per gill net in Fort Peck Reservoir, 1996 to 2014.

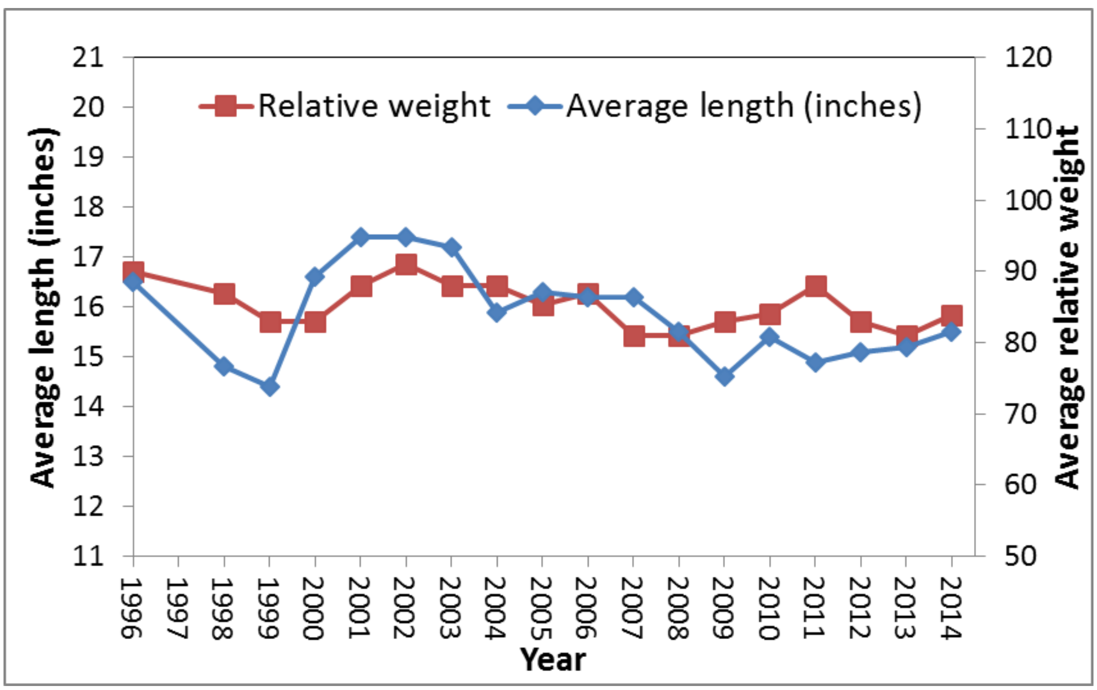

Figure 30. Walleye average length and relative weight from gill-net sets in Fort Peck Reservoir, 1996 to 2014.

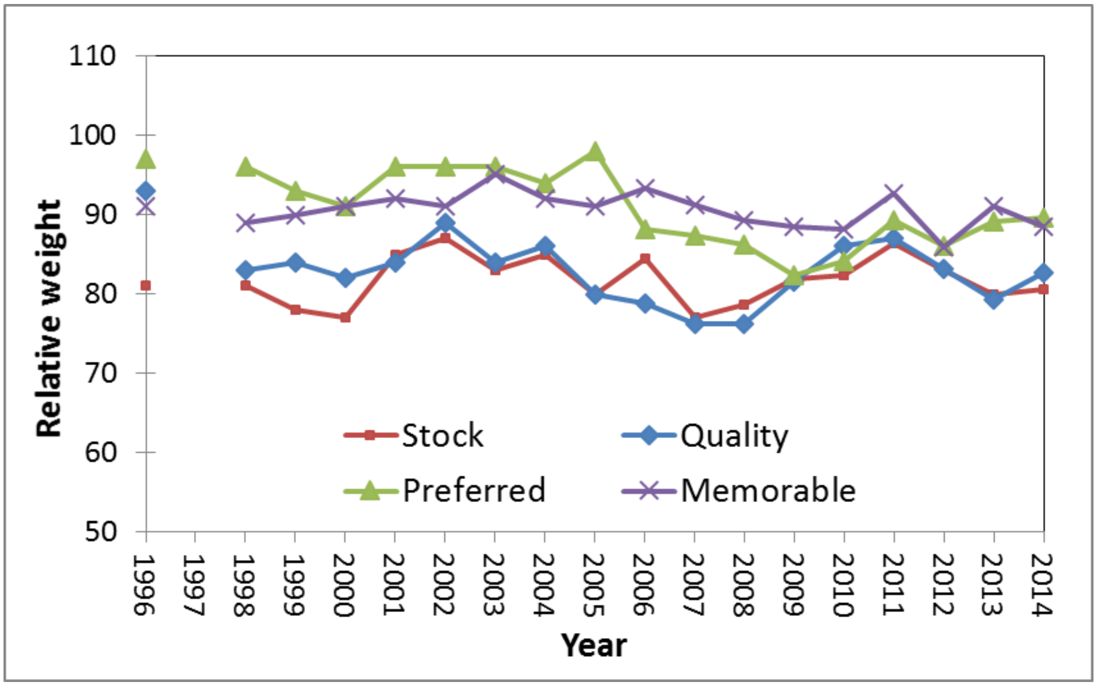

Figure 31. Relative weight of stock, quality, preferred, and memorable size Walleyes from gill nets in Fort Peck Reservoir, 1996 to 2014.

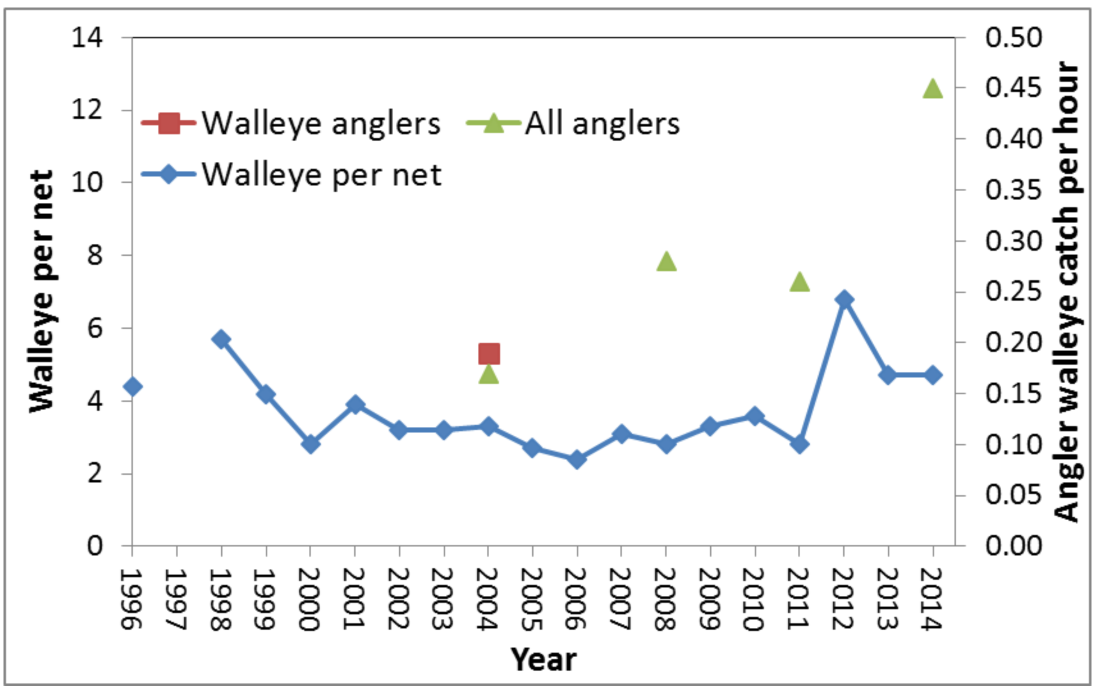

Figure 32. Walleye catch rates in gill-net sets, by Walleye anglers, and all anglers, Fort Peck Reservoir, 1996 to 2014.

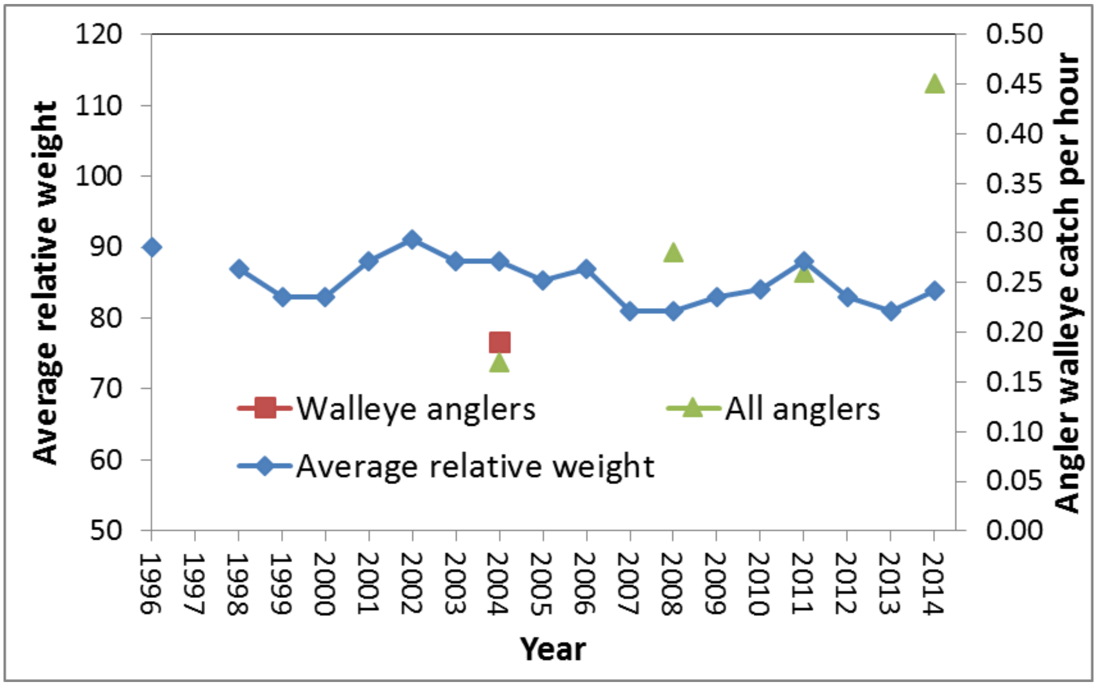

Figure 33. Walleye average relative weight and catch rates by Walleye anglers and all anglers in Fort Peck Reservoir, 1996 to 2014.

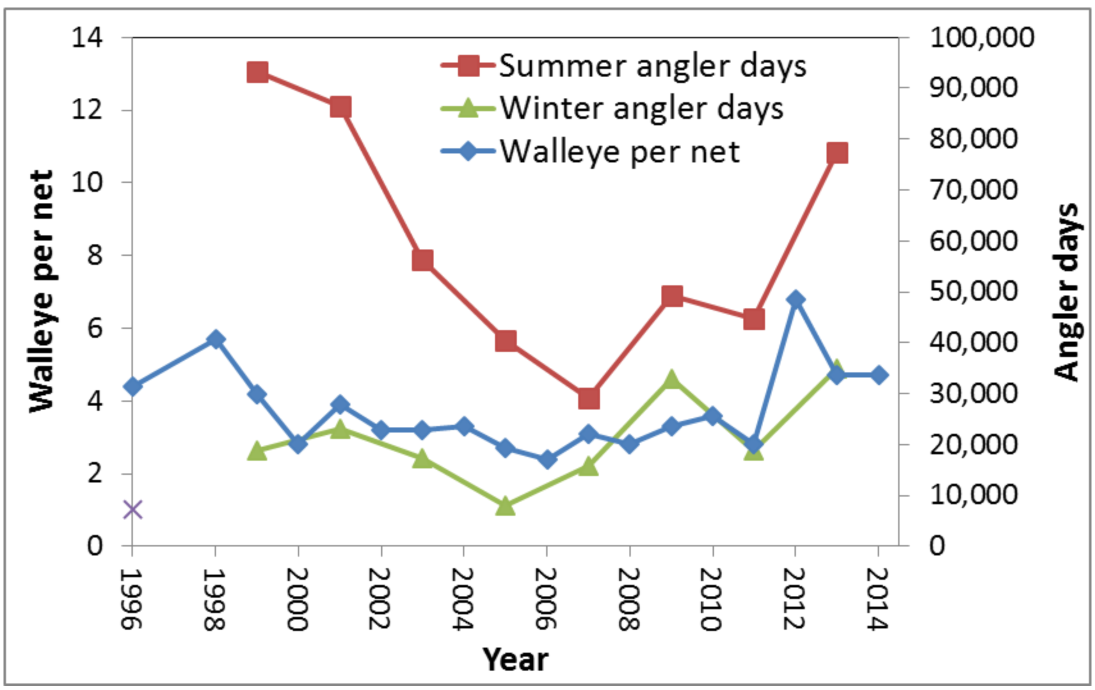

Figure 34. Walleye catch rates by gill-net sets and fishing pressure in summer and winter in Fort Peck Reservoir, 1996 to 2014.

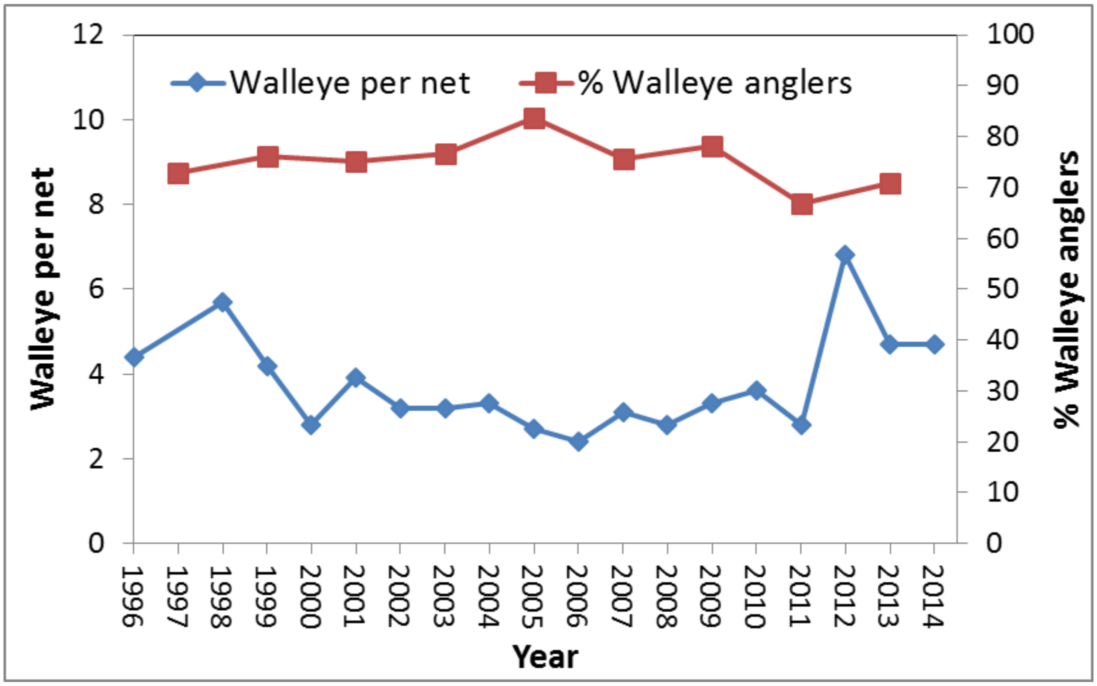

Figure 35. Walleye catch rates by gill-net sets and percent of anglers fishing for Walleyes in Fort Peck Reservoir, 1996 to 2014.

Fresno Reservoir

Fresno Reservoir is a 5,757-acre reservoir located on the Milk River near Havre, Montana (Appendix Table 1). According to a 1975 MFWP annual report, Fresno was historically known for its production of large Rainbow Trout. However, stocking of rainbow was discontinued in 1959 after a flourishing population of Northern Pike had developed. Walleye introductions were made from 1957 to 1961 resulting in a good population of this species. Fresno is currently managed as a multi-species fishery with Walleye, Sauger, Burbot, Northern Pike, Yellow Perch, Black Crappie, and Lake Whitefish *Coregonus clupeaformis*.

Drought-related fluctuating water levels and low reservoir water retention times are a hindrance to spawning, survival, and recruitment of forage and sport fish. Apparently, water level fluctuations were responsible for a decline in the Northern Pike population and Rainbow Trout stocking was experimentally reinstated in 1973 and 1974. No Rainbow Trout 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 Northern Pike was attributed to the 34-foot 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 Walleyes remained good compared to previous years, indicating that the intense drawdown did not permanently harm this population (C. Nagle, MFWP, personal communication).

The year 1984 was an extremely low water year at Fresno, as it was at many of the irrigation reservoirs. Despite low water levels, Walleyes 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 *Notropis hudsonius* were planted in the reservoir in an attempt to increase the forage base for the Walleye and Northern Pike populations.

A proposal to install low-head hydroelectric generators at Fresno Reservoir initiated a study to determine movement of Walleyes 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 fishery was affected in 2001 and 2002 when severe drought reduced the reservoir to 8% and 4% of storage capacity, respectively. Forage fish populations were drastically reduced and the abundance and condition of key sport fishes was at an all-time low. As a result, a supplemental stocking of 170,000 pre-spawn adult Yellow Perch obtained from Lake Mary Ronan was conducted from 2001 to 2004 to increase population levels. This management action was implemented to increase forage populations when water levels increased. From 2005 to 2014, water levels remained high during spring spawning and early summer rearing periods, allowing sport and forage fish populations to attain densities never before documented. The continued production of this fishery is dependent on maintaining water levels that will allow the successful spawning, recruitment, and overwintering of forage and sport fishes. Walleyes are sporadically stocked in Fresno, primarily as fingerlings in numbers ranging from 10,000 to 200,000 per year (Appendix Table 2).

The Walleye population is monitored by MFWP during annual gill-net surveys conducted in September (Appendix Table 3). Net catch rates have fluctuated from 2.1 to 29.5 Walleyes per net during 1996 to 2014, with high net catch rates in 1998 and again from 2007 to 2014 (Figure 36). The high catch rates since 2007 were probably caused by stocking. About 100,000 fingerling Walleyes were stocked annually from 2003 to 2010, with about 200,000 fingerling Walleyes stocked in 2006 (Appendix Table 2).

Average length of Walleyes captured in gill nets was between 13 and 14 inches from 1996 to 2000, increased to about 17 inches in 2004, and then decreased to 12 to 14 inches from 2006 to 2014 (Figure 37). This pattern is consistent with high stocking rates since 2003 causing smaller fish to enter the population and intraspecific competition among and within Walleye year-classes. Relative weight has fluctuated, but has been in the high 80s or higher since 2002 indicating adequate forage base was available for Walleyes during some years (Figure 37).

Relative weight among all size classes of Walleyes has also remained fairly high from 2002 to 2014 (Figure 38).

Angling pressure declined from 1999 to 2001, but has increased since then (Figure 39). Angling pressure appears to be related to Walleye net catch rates (Figure 39), which are probably related to stocking. The percent of all anglers that are specifically targeting Walleyes has ranged from 59% to 87% and roughly follows the Walleye net catch rates (Figure 40). No data are available on angler catch rates.

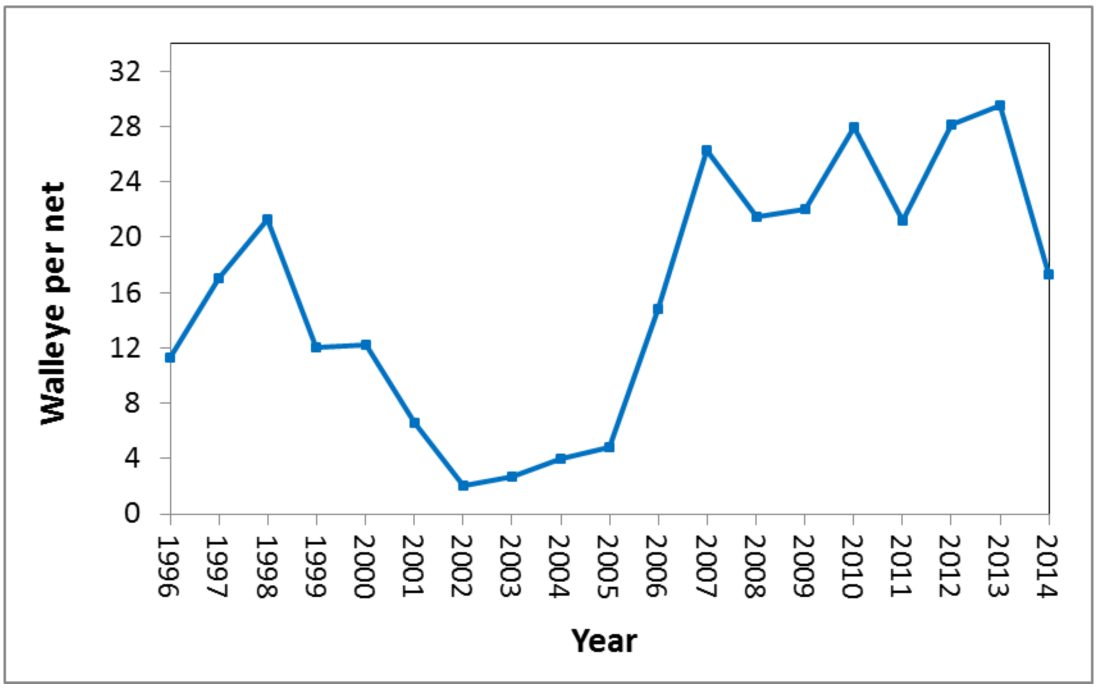

Figure 36. Walleyes captured per gill net in Fresno Reservoir, 1996 to 2014.

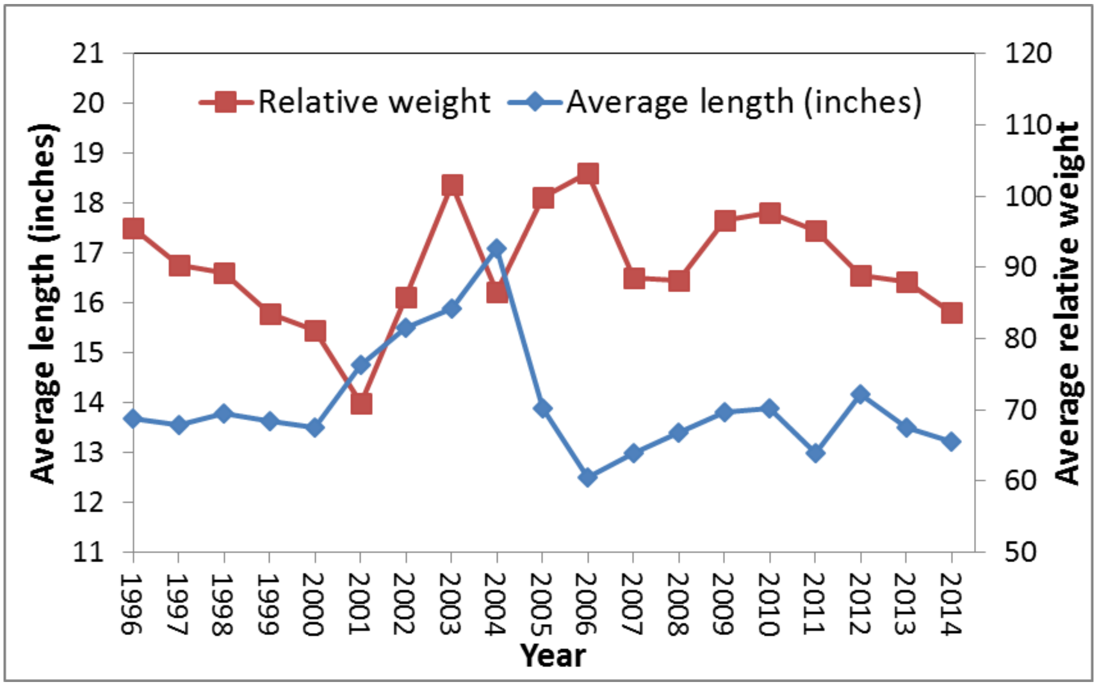

Figure 37. Walleye average length and relative weight from gill-net sets in Fresno Reservoir, 1996 to 2014.

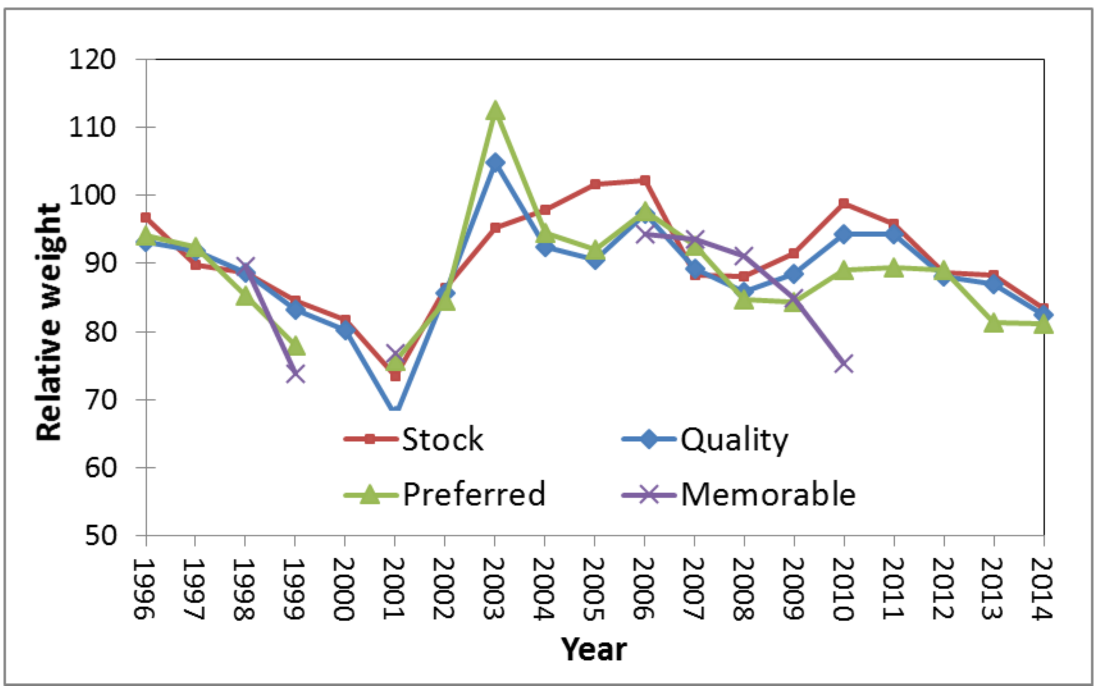

Figure 38. Relative weight of stock, quality, preferred, and memorable size Walleyes from gill nets in Fresno Reservoir, 1996 to 2014.

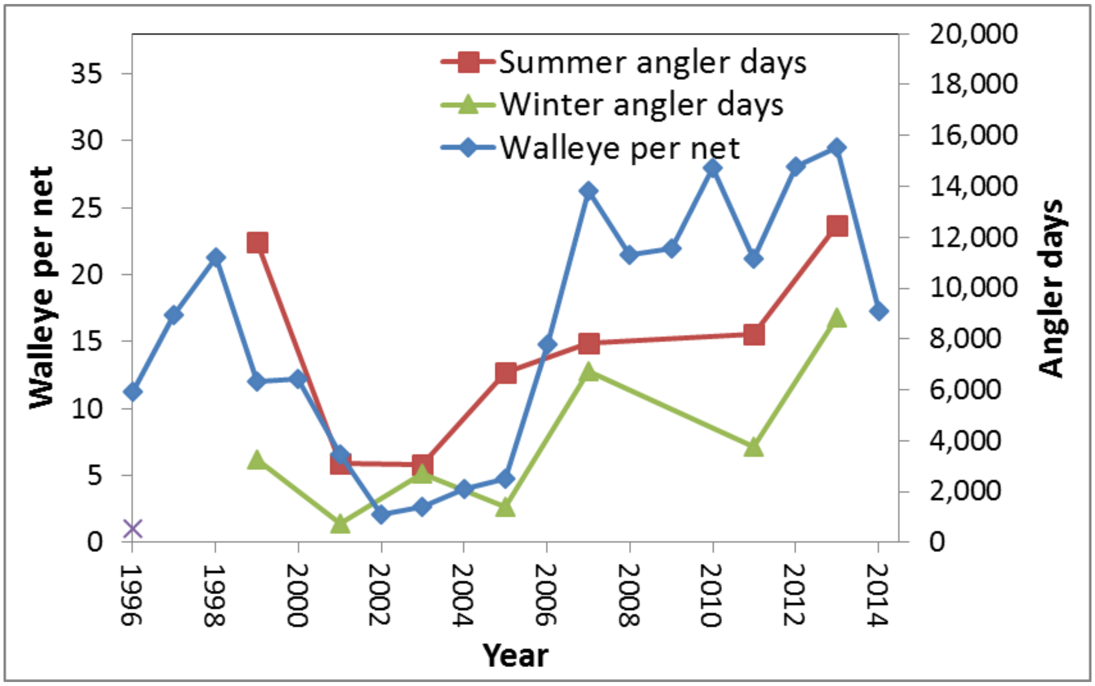

Figure 39. Walleye catch rates by gill-net sets and fishing pressure in summer and winter in Fresno Reservoir, 1996 to 2014.

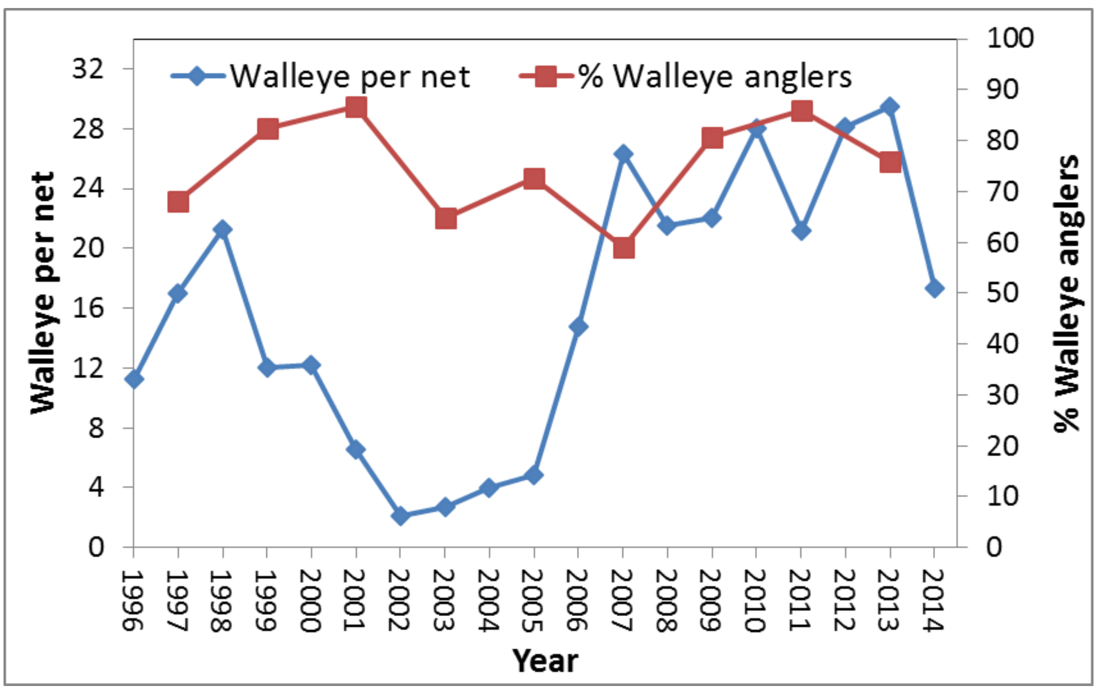

Figure 40. Walleye catch rates by gill-net sets and percent of anglers fishing for Walleyes in Fresno Reservoir, 1996 to 2014.

Nelson Reservoir

Nelson Reservoir is a 4,320-acre off-channel irrigation storage reservoir located near the Milk River near Malta, Montana (Appendix Table 1). Commercial fishing for Common Carp, Bigmouth Buffalo *Ictiobus cyprinellus*, and Goldeye was conducted in the 1920s and 1930s, and again in the mid-1960s. Nelson has about 26 fish species and is managed as a multi-species fishery with Walleye, Northern Pike, Yellow Perch, Channel Catfish, Black Crappie, and Lake Whitefish. Drought-related fluctuating water levels affect spawning, survival, and recruitment of forage and sport fish. Spawning shoals were constructed in 1993 at three locations within the reservoir to improve the spawning habitat for Walleyes. Their contribution to the overall spawning success of Walleyes is unknown but may provide Walleye rearing habitat. Walleyes are stocked in Nelson as fingerlings in numbers ranging from 10,000 to 210,000 per year, with at least 100,000 stocked each year from 2004 to 2013 (Appendix Table 2).

The Walleye population is monitored by MFWP during annual gill-net surveys conducted in September (Appendix Table 3). Net catch rates have been fairly high and have fluctuated from 8.8 to 18.3 Walleyes per net during 1996 to 2014, with peaks every 3 to 5 years (Figure 41). The high stocking rates since 2004 have not noticeably increased Walleye net catch rates (Figure 41).

Average length of Walleyes captured in gill nets has ranged from 13.7 inches to 16.8 inches from 1996 to 2014 and decreased somewhat since a peak in 2002 (Figure 42). This pattern is consistent with high stocking rates since 2004 causing smaller fish to enter the population that probably create intraspecific competition among Walleye year-classes. Relative weight has been in the 80s and 90s indicating that the forage base for Walleyes is slightly low most years (Figure 42). Relative weight among all size classes of Walleyes has also been in the 80s and 90s most years except for Memorable (> 25 inches) Walleyes, which fluctuated more, probably because of small sample sizes of these large Walleyes (Figure 43).

Angling pressure has increased since 2005, and winter angling pressure approaches or even exceeds summer angling pressure in some years (Figure 44). The percent of all anglers that are specifically targeting Walleyes was generally high and has ranged from 78% to 100% (Figure 45). Angler creel surveys conducted from May to September in 1999 and 2014 documented Walleye catch rates of 0.50 fish per hour and 0.59 fish per hour respectively. The percentages of anglers specifically targeting Walleyes that went fishless were 30% and 15%, respectively.

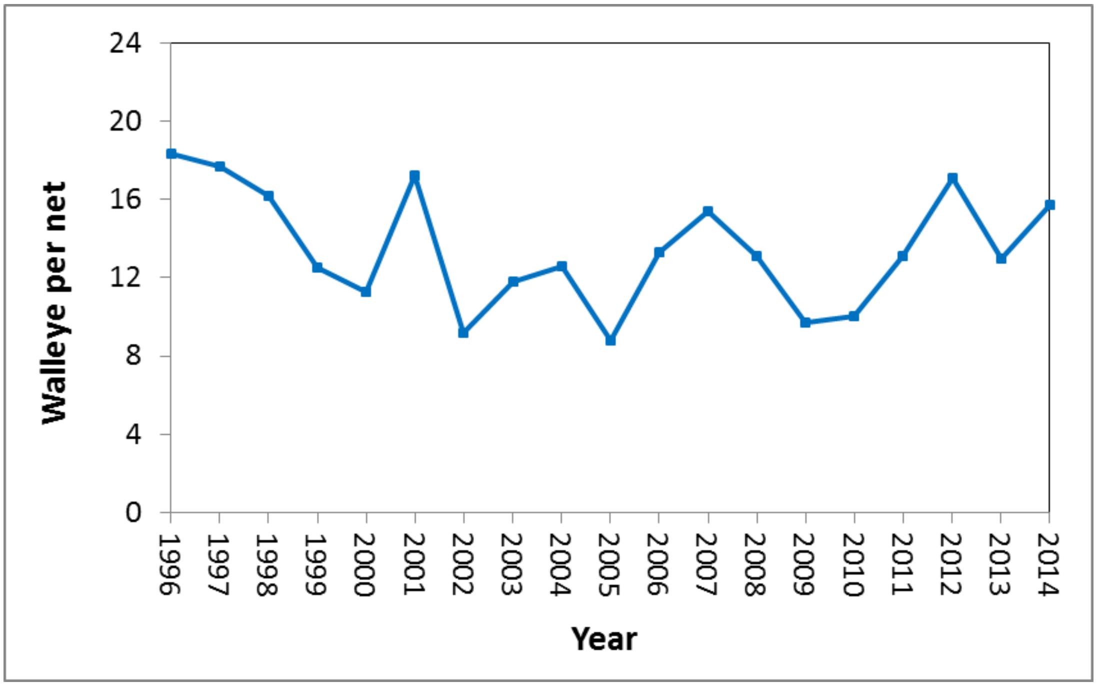

Figure 41. Walleyes captured per gill net in Nelson Reservoir, 1996 to 2014.

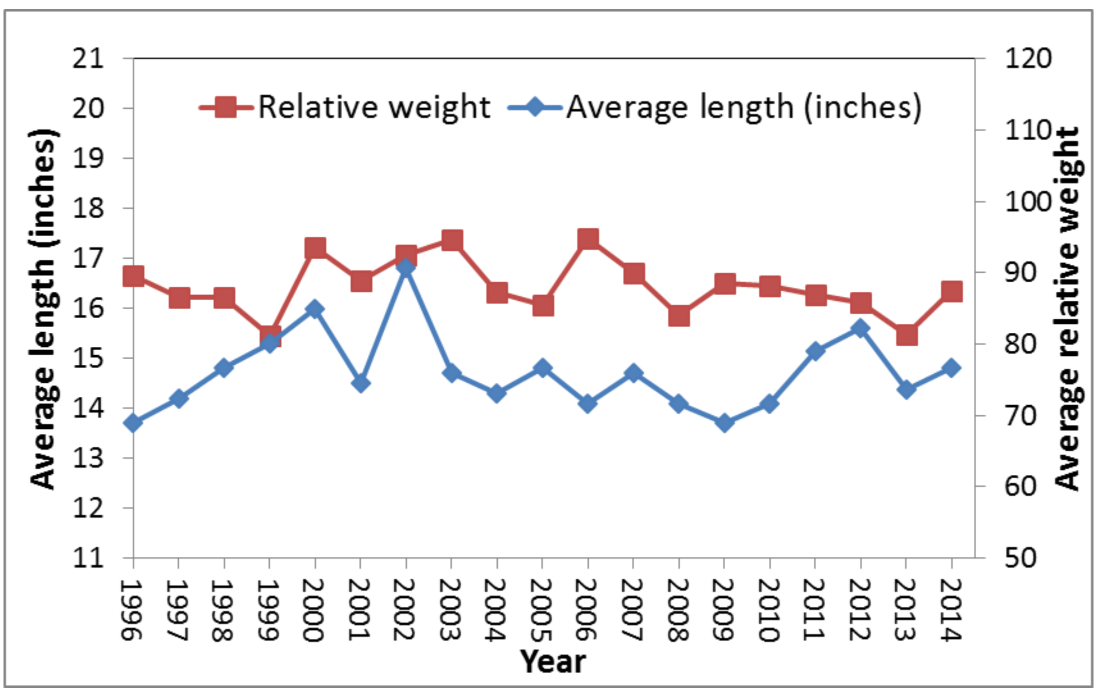

Figure 42. Walleye average length and relative weight from gill-net sets in Nelson Reservoir, 1996 to 2014.

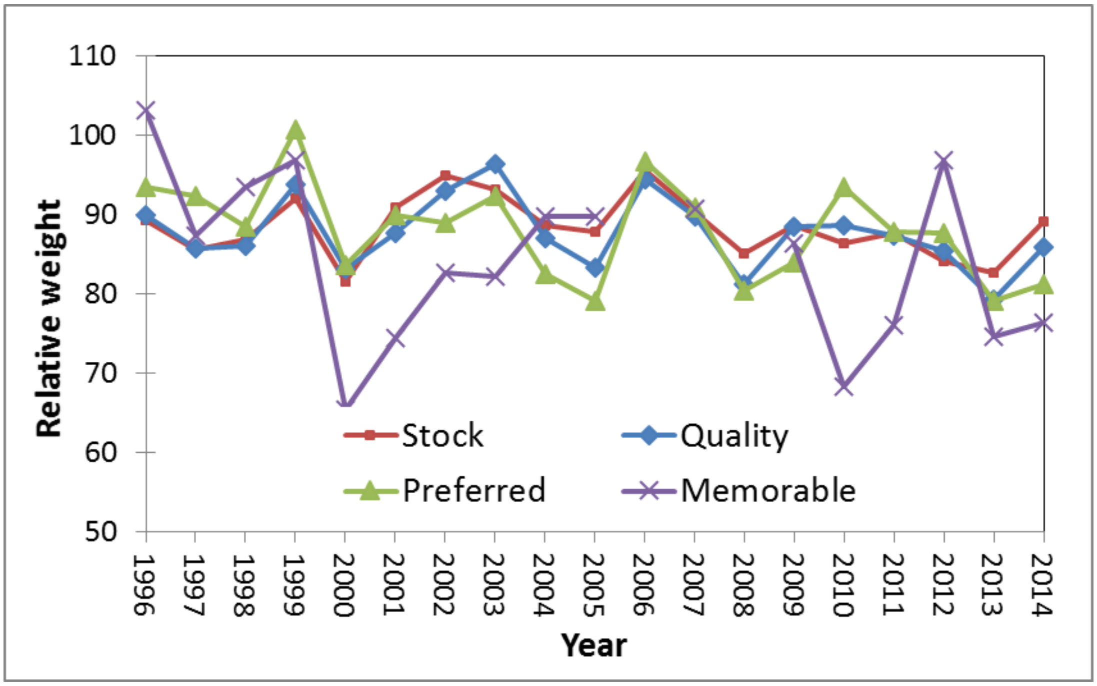

Figure 43. Relative weight of stock, quality, preferred, and memorable size Walleyes from gill nets in Nelson Reservoir, 1996 to 2014.

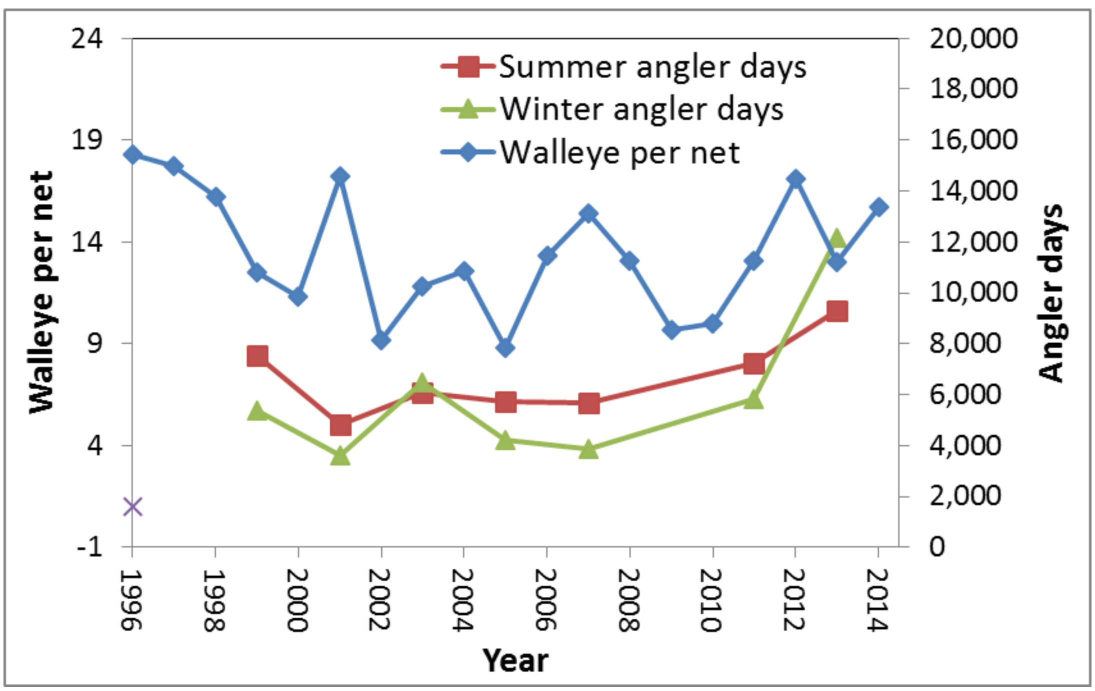

Figure 44. Walleye catch rates by gill-net sets and fishing pressure in summer and winter in Nelson Reservoir, 1996 to 2014.

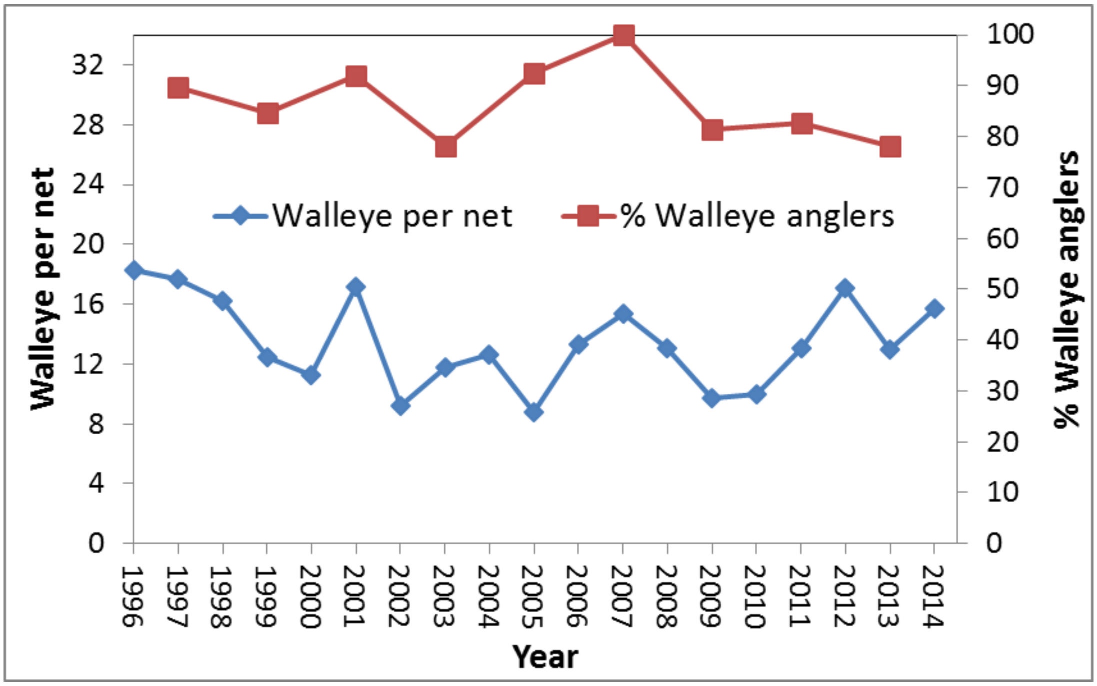

Figure 45. Walleye catch rates by gill-net sets and percent of anglers fishing for Walleyes in Nelson Reservoir, 1996 to 2014.

Cooney Reservoir

Cooney Reservoir is a 768-acre reservoir located southwest of Billings, Montana (Appendix Table 1). Its proximity to Billings makes it a popular recreational fishery. It is fed by two major tributaries: Red Lodge and Willow creeks. Cooney has been managed as a put-grow-and-take fishery for Rainbow Trout for many years. In 1984, Walleyes were introduced to the reservoir in an attempt to decrease an overabundant White Sucker population. The Walleyes grew rapidly the first year as they preyed on the abundant forage base. Gill-net surveys conducted in 1988 yielded large numbers of both Walleyes and Rainbow Trout. Adult suckers were also taken, but very few smaller suckers were collected. The Walleyes had apparently reduced the number of young suckers. Burbot were also stocked recently in an attempt to further control abundant White Suckers and other forage fish. Walleye fry were stocked in Cooney during 1996 to 2005 in numbers ranging from 50,000 to 100,000 stocked annually (Appendix Table 2). Walleye stocking ceased in 2006 because Walleyes were found to reproduce naturally in Cooney Reservoir.

The Walleye population is monitored by MFWP during annual gill-net surveys conducted in October (Appendix Table 4). Net catch rates were quite variable, but generally high, ranging from 6.8 to 31.3 Walleyes per net with peaks in net catch rates occurring every 2 to 4 years (Figure 46). Net catch rates do not appear to have been influenced by fry stocking because similar levels and variability of net catch rates have occurred both before and after cessation of fry stocking in 2006 (Appendix Table 2; Figure 46).

Average length of Walleyes captured in gill nets was relatively small, ranging from 11.4 inches to 13.6 inches (Figure 47). Relative weight ranged from 81.3 to 108.4, suggesting that forage was sometimes adequate for Walleyes to maintain weight (Figure 47). Relative weight among all size classes of Walleyes also followed this general pattern. However, large Walleyes occasionally had relative weights exceeding 100 (Figure 48), suggesting that these fish may have attained high weights because they could eat the abundant larger suckers that the smaller Walleyes could not consume.

Angling pressure peaked at 25,684 summer angler days in 1999, declined to 8,391 in 2007, and has increased somewhat since then (Figure 49). The percent of all anglers that are specifically targeting Walleyes has typically been < 50%, but peaked at 72% in 2005 (Figure 50). No data are available on angler catch rates.

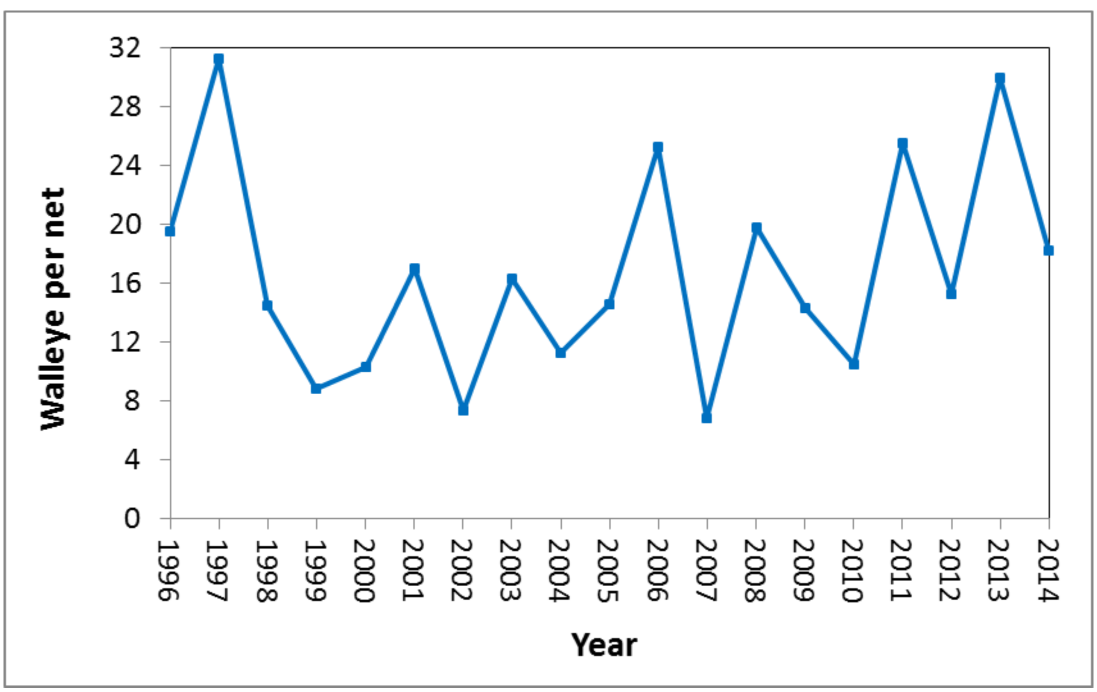

Figure 46. Walleyes captured per gill net in Cooney Reservoir, 1996 to 2014.

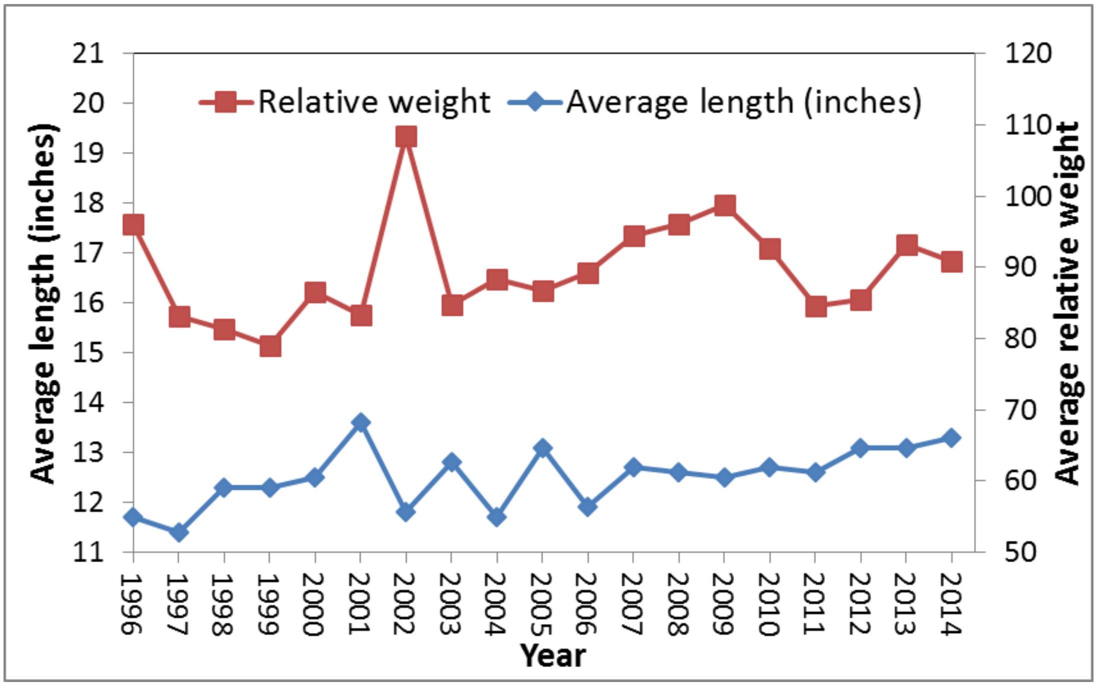

Figure 47. Walleye average length and relative weight from gill-net sets in Cooney Reservoir, 1996 to 2014.

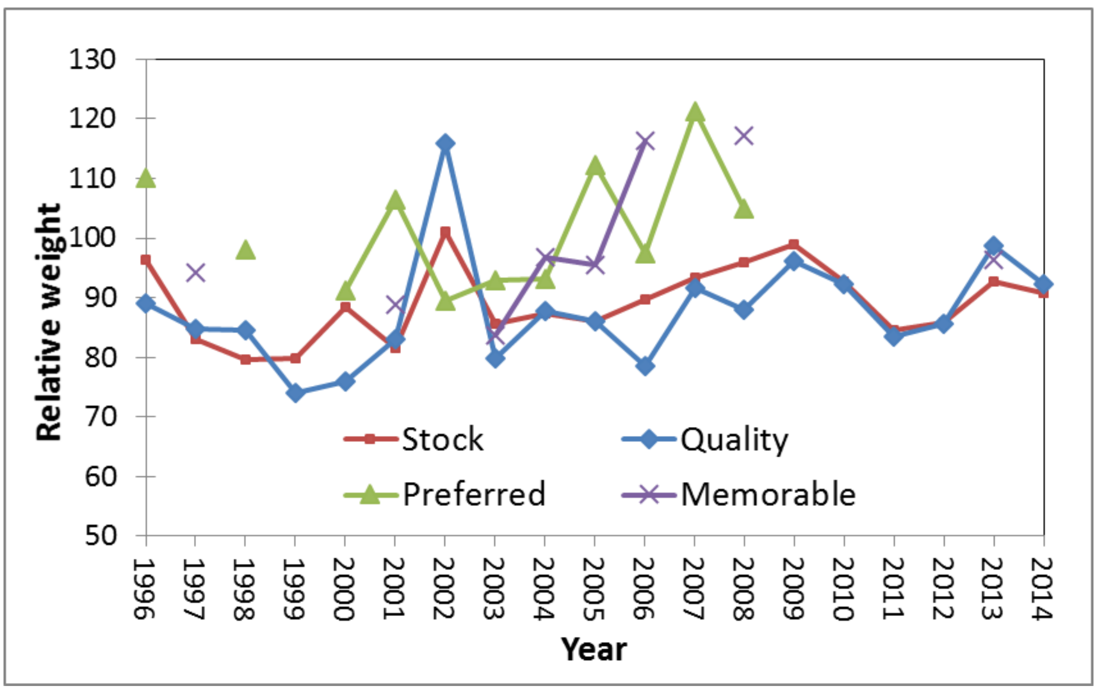

Figure 48. Relative weight of stock, quality, preferred, and memorable size Walleyes from gill nets in Cooney Reservoir, 1996 to 2014.

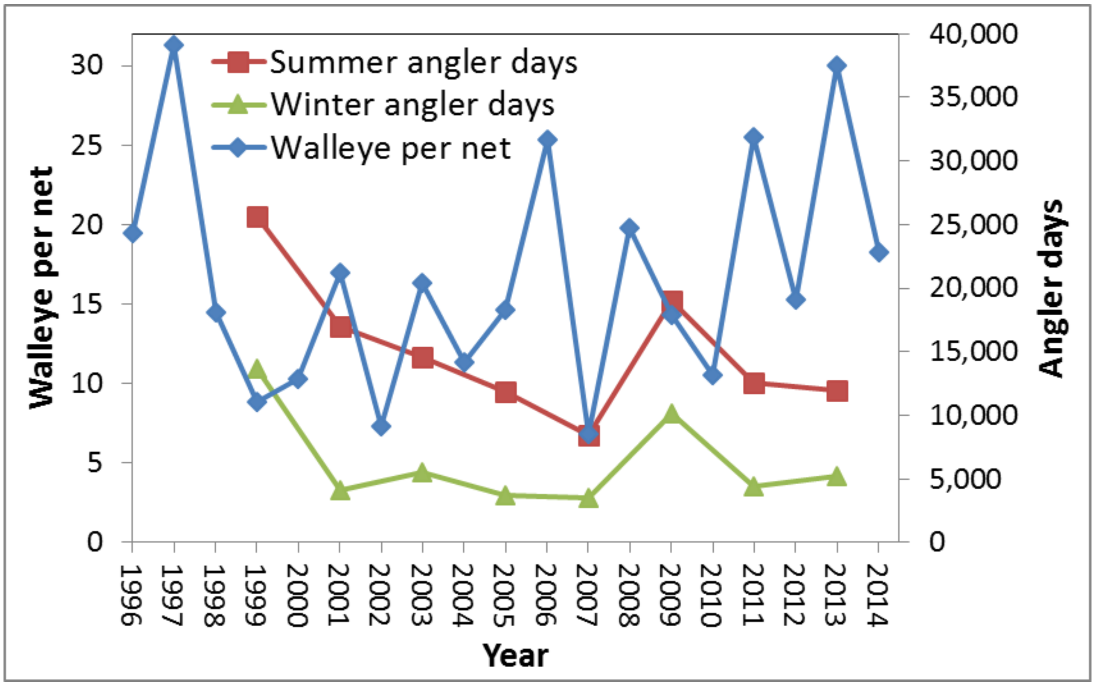

Figure 49. Walleye catch rates by gill-net sets and fishing pressure in summer and winter in Cooney Reservoir, 1996 to 2014.

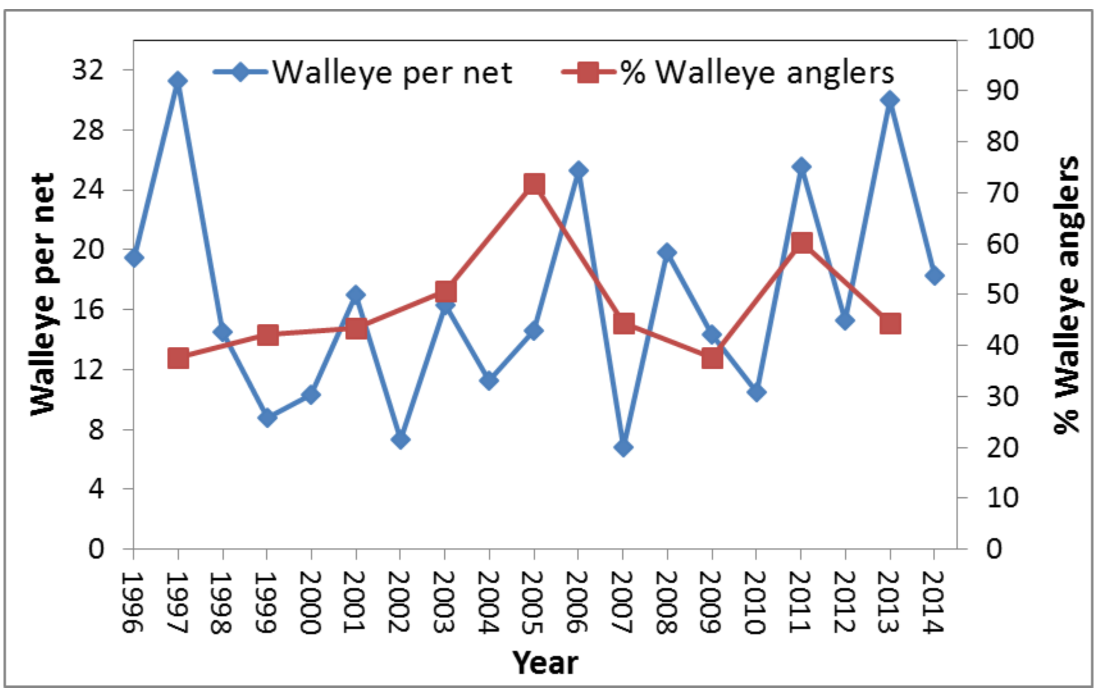

Figure 50. Walleye catch rates by gill-net sets and percent of anglers fishing for Walleyes in Cooney Reservoir, 1996 to 2014.

Bighorn Reservoir

Bighorn Reservoir is a 12,598-acre reservoir located on the Bighorn River in south-central Montana and north central Wyoming (Appendix Table 1). Bighorn Reservoir is co-managed with Wyoming as a multi-species fishery with Walleye, Sauger, crappie, Yellow Perch, Smallmouth Bass, Channel Catfish, Burbot, Brown Trout, and Rainbow Trout. Drought-related water level fluctuations affect spawning, survival, and recruitment of forage and sport fish.

Walleyes have been stocked in Bighorn as fry and fingerlings, with 4,000,000 fry stocked annually from 1996 to 2007 and 118,000 to 551,000 fingerlings stocked annually from 1996 to 2008 (Appendix Table 2). From 2009 to 2014, experimental stocking of sterile (triploid) Walleye fingerlings was conducted in an effort to reduce the potential for hybridization of Walleyes with native Saugers. Walleye fry stocking was discontinued and Walleye fingerling stocking was decreased to 625—127,484 sterile Walleye fingerlings stocked per year (Appendix Table 2. Stocking of genetically pure Saugers produced from wild Wyoming Saugers was initiated in 2011 and continued through 2014 with a total of 329,304 Saugers stocked. The Sauger spawning effort did not meet the Sauger stocking request of 250,000 fingerlings minimum annually and the effort was terminated in 2015. The MFWP annual Walleye stocking request starting in 2015 will be 500,000 sterile Walleye fingerlings (M. Ruggles, MFWP, personal communication).

The Walleye population is monitored by MFWP during annual gill-net surveys conducted in spring and fall in the upper and lower reservoir (Appendix Table 3). Prior to 2001, netting occurred only in the lower reservoir from the Slide at Big Bull Elk to OK-A-Beh in the fall with 6 nets. In 2001, sampling in the upper reservoir near Barry's Landing was added with spring netting added in 2004. Since 2005, the netting has been standardized to 24 nets with 6 net sets in the lower and upper reaches in the spring and fall, with the exception of 2010, when 2 additional nets were set in the upper fall netting series. This increase was initiated to increase the sample of Walleyes and Saugers for fish health testing requirements prior to spawning Saugers in Wyoming. Netting did not occur in 1996 due to time constraints, or in 2002 due to low water which prohibited boat access. Net catch rates have been quite variable, ranging from 1.0 to 11.0 Walleyes per net. Notable peaks in net catch rates occurred in 1997 and 2011 (Figure 51), which were both high water years. Net catch rates do not appear to be influenced by fry stocking rates. For example low net catch rates occurred in 2000-2004 when fry stocking rates were high, and a peak net catch rate of 6.4 Walleyes per net in 2011 occurred following 4 years of no stocking of Walleye fry (Appendix Table 2; Figure 51).

The average length of Walleyes captured in gill nets ranged from 12.8 inches to 17.7 inches from 1996 to 2014, with a general increase in size from 2003-2014 (Figure 52). This pattern may have been related to cessation of fry stocking in 2008, which would perhaps lead to fewer smaller fish being captured, thereby resulting in an increase in average size of fish. However, improved forage availability and growth resulting from decreased drought effects seems more likely. Emerald Shiners that were stocked in Wyoming reservoirs upstream of Bighorn Reservoir appeared in the Wyoming section of the Bighorn Reservoir in 1992. In 1996, the first Emerald Shiners were documented in the Montana portion of the reservoir and are now very abundant. This improved forage availability probably contributed to improved growth and relative weights. Relative weight was lower from 1997 to 2001 than from 2003 to 2014 (Figure 52), which also suggests improved forage availability in the latter period. Relative weight among all size classes of Walleyes also followed this general pattern, and Memorable size Walleyes (> 25 inches) first appeared in 2004 and have remained in the fishery through 2014 (Figure 53).

Although anglers often have a difficult time coaxing Walleyes to bite when relative weights are near 90 or higher, it is thought that angler catch rates generally improved as reservoir maximum elevations increased following drought-related low reservoir elevations in 2001 through 2003 (Figure 54; M. Ruggles, MFWP, personal communication). Angling pressure was variable and peaked at 27,594 summer angler days in 2001, but summer angler days were less than 12,000 during 2003-2013 (Figure 55). The percent of all anglers that are specifically targeting Walleyes was also variable, and ranged from 50% to 87% (Figure 56). There are no data available on angler catch rates.

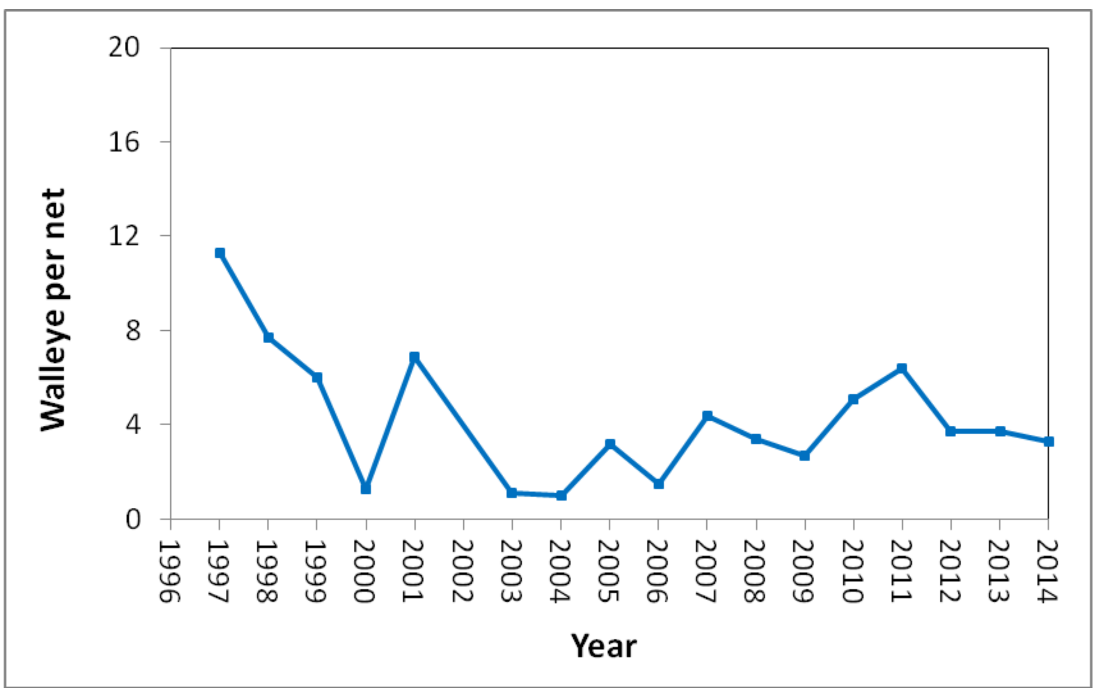

Figure 51. Walleyes captured per gill net in Bighorn Reservoir, 1996-2014.

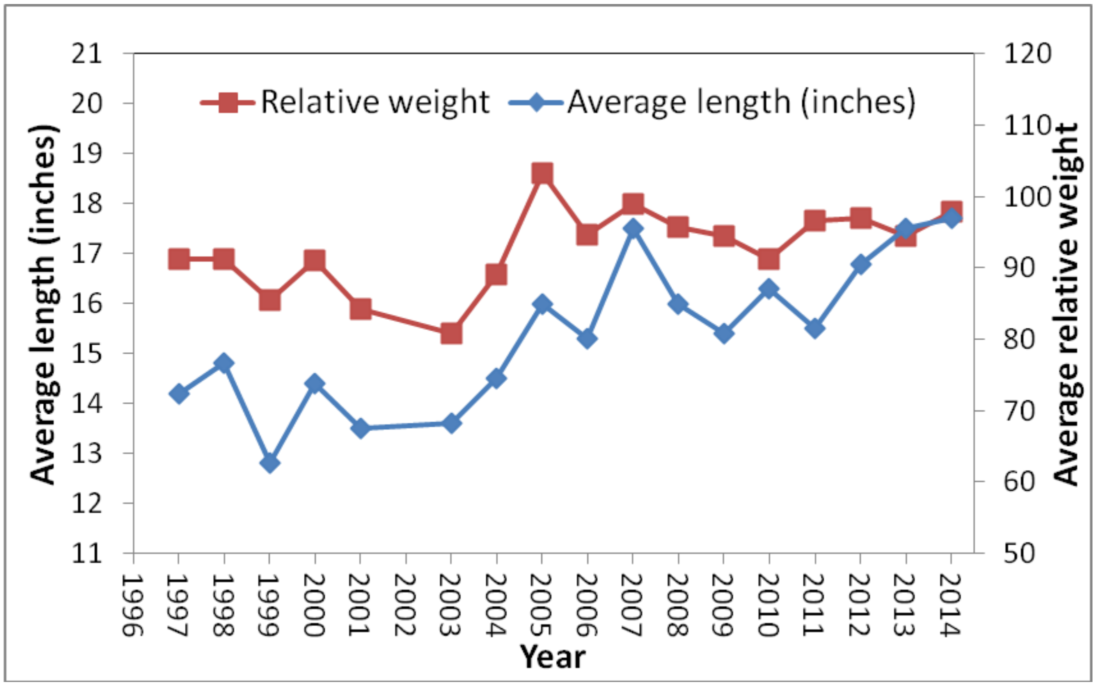

Figure 52. Walleye average length and relative weight from gill-net sets in Bighorn Reservoir, 1996-2014.

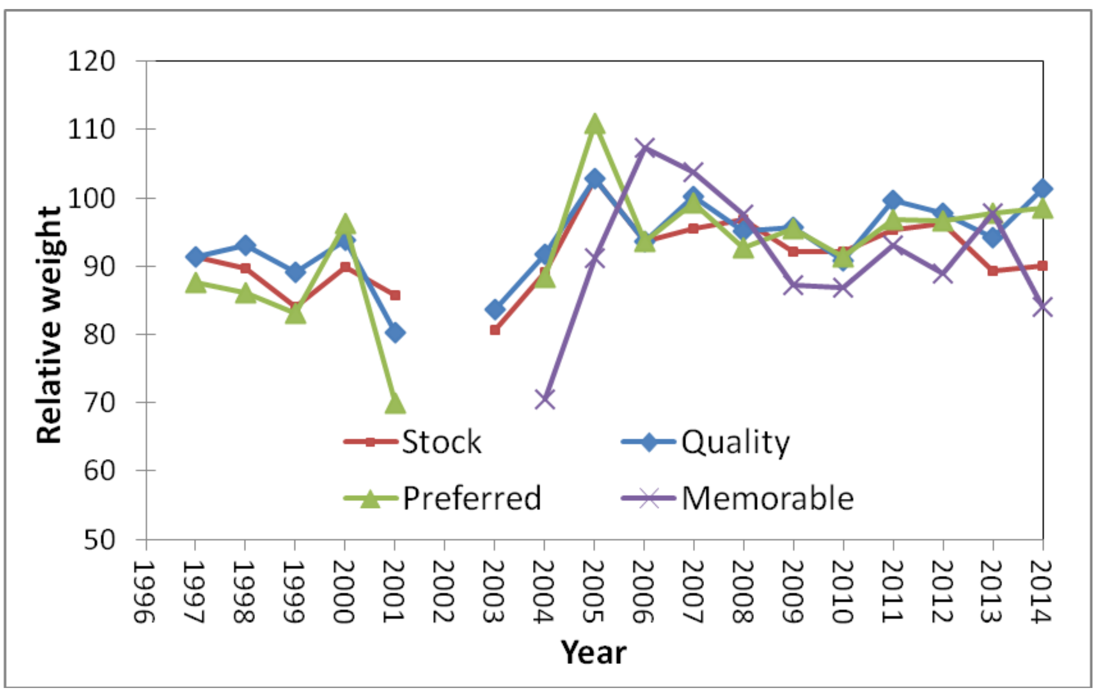

Figure 53. Relative weight of stock, quality, preferred, and memorable size Walleyes from gill nets in Bighorn Reservoir, 1996-2014.

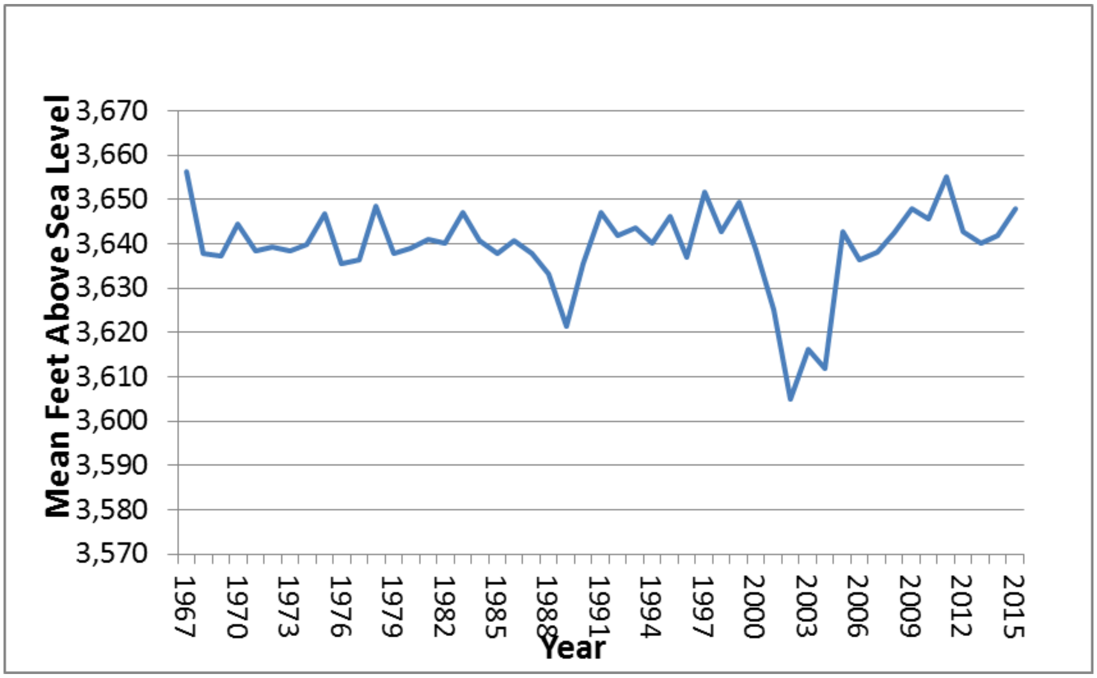

Figure 54. Bighorn Reservoir maximum pool elevations from 1967 to 2015.

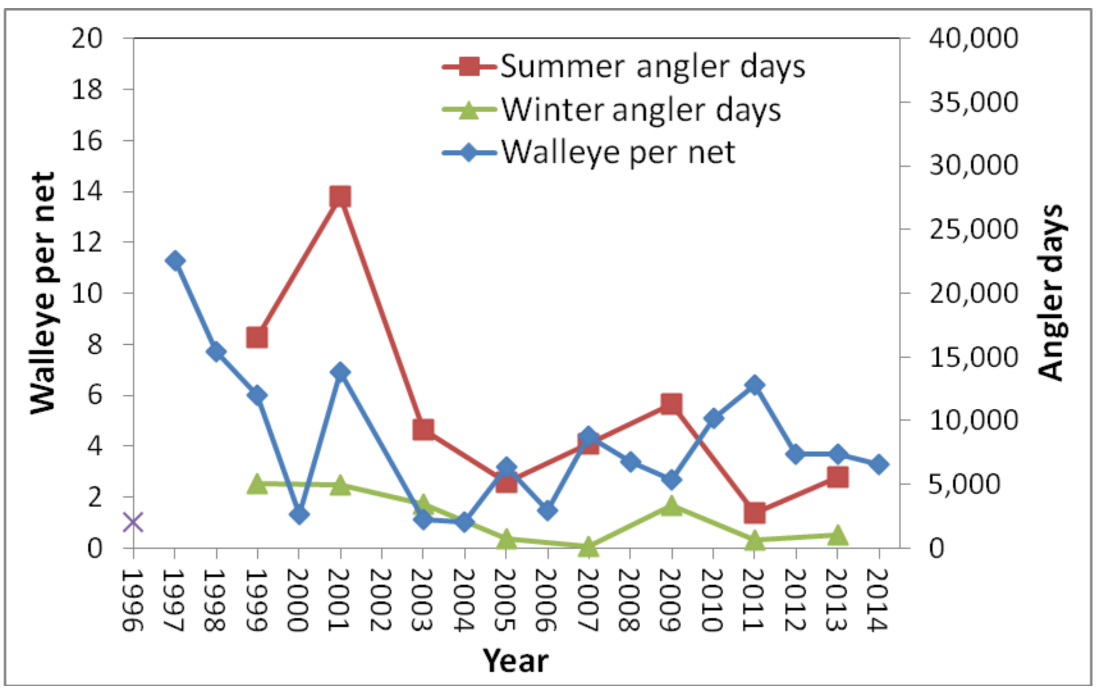

Figure 55. Walleye catch rates by gill-net sets and fishing pressure in summer and winter in Bighorn Reservoir, 1996-2014.

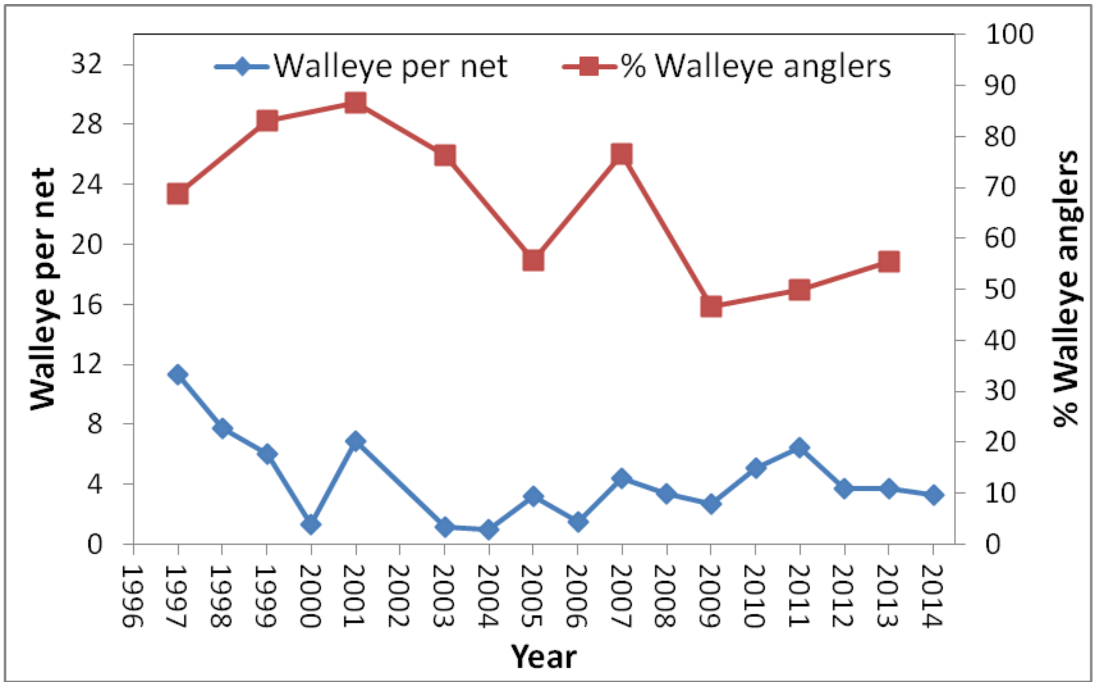

Figure 56. Walleye catch rates by gill-net sets and percent of anglers fishing for Walleyes in Bighorn Reservoir, 1996-2014.

Summary of Status of Montana Walleye Fisheries

Walleye abundance, as indicated by MFWP standardized gill-net surveys, varies within each reservoir across time, and also among the nine reservoirs. Fresno, Nelson, and Cooney reservoirs generally have higher Walleye abundance than the other six reservoirs. Variability in Walleye abundance within individual reservoirs is probably caused by variation in physical and biological factors including reservoir water levels, natural reproduction, level of Walleye fry and fingerling stocking in stocked reservoirs, survival, and forage abundance.

The average length of Walleyes also varied within and among reservoirs. Walleye average length was generally smaller in Lake Francis and Cooney, Fresno, and Tiber reservoirs. Variability in average length can be caused by variability in growth or relative abundance of Walleye year classes; more small fish causes lower average size. Walleye relative weight, which is related to the amount of available forage, averaged less than the ideal of 100 in all reservoirs, suggesting that forage abundance generally limited Walleye condition. Walleye relative weights declined across time in the newly-established Walleye fisheries in Canyon Ferry and Holter reservoirs, probably because the forage base was depleted as the Walleye population became established and increased. Walleye relative weights were more stable in the established Walleye fisheries. However, variability in relative weights occurred, which was probably due to Walleye and forage fish population dynamics caused by drought-related water level fluctuations, and in some cases, introduction of new forage fish species. Decreased relative weights may lead to increased angler catch rates because Walleyes would be more actively seeking forage.

Walleye angler catch rate data were available for Canyon Ferry (2001 to 2014), Holter (1996 to 2014), and Tiber (2001 to 2014) reservoirs, and Lake Francis (2001 to 2014). Average angler Walleye catch rates ranged from 0.27 fish per hour at Canyon Ferry Reservoir to 0.46 fish per hour at Holter Reservoir, and angler Walleye catch rates for a single year ranged up to 1.4 fish per hour (Holter Reservoir in 2008). A catch rate of 0.3 fish per hour is generally considered adequate for a good quality Walleye fishery (Colby et al. 1979), although reported catch rates range up to 1.5 fish per hour (Hansen et al. 2000). Variability in angler catch rates generally occurred without any clear relationship to Walleye abundance as indicated by gill-net catch rates or Walleye relative weight.

Angling pressure (number of angler days per year) was highest at Canyon Ferry Reservoir, followed by Fort Peck and Holter reservoirs, and was substantially lower at the other six reservoirs. Angling pressure appeared to be correlated with Walleye gill-net abundance at Fresno Reservoir and possibly at Fort Peck Reservoir. However, there was no apparent relationship between angling pressure and Walleye gill-net abundance at the other reservoirs. The average of the percent of anglers specifically targeting Walleyes ranged from 30% at Holter Reservoir to 87% at Nelson Reservoir, and was higher than 50% at Bighorn Lake, Fort Peck, Fresno, Tiber, and Lake Francis. The percent of anglers specifically targeting Walleyes was fairly stable across time at established Walleye fisheries such as Fort Peck, Tiber, and Nelson reservoirs. However, at the newly-established Canyon Ferry fishery, the percentage of anglers specifically targeting Walleyes increased from 10% in 1997 to over 50% in 2007.

CASE HISTORIES OF WALLEYE INTRODUCTIONS

The information presented in the Walleye Ecology section of this report indicated that substantial differences in the habitat preferences of salmonids, centrarchids, and Walleyes exist. When Walleyes naturally inhabit the same lakes as salmonids or centrarchids, they occupy different habitats than these other fishes based on temperature, light intensity, and food preferences. However, in waters with introduced Walleye populations, lack of habitat diversity, lack of thermal stratification, and overlap in habitat use between prey fish and Walleyes may preclude habitat and resource partitioning and lead to strong biological interactions such as competition and predation between Walleyes and the rest of the fish assemblage.

Case histories of Walleye-salmonid, Walleye-centrarchid, and Walleye-Yellow Perch interactions were sought and reviewed here in an attempt to document actual experiences. Examples of situations where Walleyes 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 resistant to introducing a major predator such as Walleyes into good trout fishing waters. Given the high recreational values generally attributed to productive salmonid fisheries, many management agencies in the West have decided not to take the chance of disturbing these fisheries through the introduction of Walleyes. Here, we present two case studies of Walleye-salmonid interactions (North Platte River reservoirs and John Day Reservoir), one case study with Walleye-salmonid and Walleye-Yellow Perch interactions (Canyon Ferry Reservoir), and one case study with Walleye-centrarchid and Walleye-Yellow Perch interactions (Escanaba Lake).

North Platte River Reservoirs, Wyoming

The best-documented case of the effects of the introduction of Walleyes into reservoir trout fisheries comes from the lower North Platte River of Wyoming (McMillan 1984; McMahon and Bennett 1996; Marwitz and Hubert 1997; Mavrakis and Yule 1998; Yule et al. 2000; Gerrity 2009; Hahn 2013). The lower North Platte River system includes six main-stem reservoirs named, from upstream to downstream, Seminoe, Kortes, Pathfinder, Gray Reef, Alcova, and Glendo reservoirs. Kortes and Gray Reef reservoirs are small, lack significant fisheries (Mavrakis and Yule 1998) and will not be addressed in this case history. From 1958 to 1981, 2.2 to 4.4 million fingerling Rainbow Trout were stocked annually into Seminoe, Pathfinder, and Alcova reservoirs, and high quality Rainbow Trout fisheries were established (Mavrakis and Yule 1998; Yule et al. 2000).

In 1961, Walleyes were first documented in Seminoe Reservoir. It is not clear how Walleyes got into the reservoir system. They may have been planted illegally, accessed the system from Colorado, or escaped from Como Bluff Fish Hatchery and accessed Seminoe Reservoir via Rock Creek and the Medicine Bow River (Mavrakis and Yule 1998). Discharges over reservoir spillways allowed Walleyes to colonize Pathfinder reservoir in 1976 and Alcova Reservoir in 1985 (Mavrakis and Yule 1983).

Prior to the establishment of Walleyes, Seminoe Reservoir was primarily a put-grow-and-take Rainbow Trout fishery (McMahon and Bennett 1996; Mavrakis and Yule 1998). Walleyes became well established in parts of the reservoir by 1968 (Mavrakis and Yule 1998). Initial high Walleye survival and fast growth occurred and Walleyes quickly depleted populations of native minnows, suckers, darters, and stocked Rainbow Trout fingerlings (Yule et al. 2000). Rainbow trout fingerlings (3 to 4 inches) were heavily preyed upon, probably because the lack of thermal stratification in Seminoe Reservoir precluded spatial separation of the two species based on temperature preferences. In the early 1970s, most of the 500,000 annually-stocked Rainbow Trout fingerlings were consumed by Walleyes within a few weeks after planting (McMillan 1984; McMahon and Bennett 1996). By 1973, a popular Walleye fishery developed with Walleyes averaging 17.7 inches (McMahon and Bennett 1996) and in 1974 over 20,000 Walleyes were harvested by anglers (Mavrakis and Yule 1998). However, Walleyes depleted the prey base, and Walleye abundance, growth, and condition declined, cannibalism increased, and Walleye recruitment failed. By 1978, fewer than 7,000 Walleyes were harvested and angler catch rate of Rainbow Trout was very low at 0.05 fish per hour (Mavrakis and Yule 1996).

A segment of the Seminoe Reservoir Walleye population travels upstream from the reservoir to spawn (McMillan 1984). Some of the Walleyes return to the reservoir after spawning while others remained in the river until the autumn. The effects of the Walleyes on Rainbow and Brown Trout populations in the river above Seminoe reservoir were not examined. Limited stomach analysis of Walleyes showed that they preyed on trout in the river, but the rate or frequency was unknown (McMillan 1984).

Fishery managers responded by stocking alternative prey species including Emerald Shiners, Spottail Shiners, and Gizzard Shad *Dorosoma cepedianum*. The Gizzard Shad plants were initially successful with Brown Trout and Walleyes using the shad extensively. Gizzard Shad were also found in the stomachs of Rainbow Trout as well. However, the Gizzard Shad did not survive over winter, therefore annual plants of Gizzard Shad were required. The Emerald Shiner plants were initially thought to be unsuccessful, probably because the abundant Walleyes preyed upon the introduced spawning stock and progeny (McMillan 1984). Subsequently however, biologists found that a reproducing population of Emerald Shiners had developed from the introduction.

Managers also experimented with dispersed stocking of Rainbow Trout, stocking of different strains of Rainbow Trout, and beginning in 1978, stocking larger (7 to 8 inch) Rainbow Trout, and later stocking 8-inch and larger catchable trout. In 1984, both Walleye and Rainbow Trout harvest increased, and by 1996 Walleye harvest was over 20,000 fish and Rainbow Trout harvest was over 45,000 fish. Managers have since refined harvest regulations from a creel limit of 20 Walleyes to a limit of 6 Walleyes. Stocking practices were refined to stocking 9-inch catchable Rainbow Trout in the autumn, which nearly doubled the angler return compared to spring-stocked Rainbow Trout in Seminoe and Alcova reservoirs (Yule et al. 2000). Autumn stocking may allow trout to avoid predation because Walleyes may prefer the smaller prey that is available during autumn such as age-0 Spottail Shiners, or because Walleye metabolism, food consumption, and consequently predation on trout declines in autumn (Yule et al. 2000).

Moreover, autumn-stocked Rainbow Trout grow a minimum of 2 inches by April of the following year which further reduces their vulnerability to Walleye predation. Pond feeding trials examining the influence of Walleyes and Rainbow Trout sizes on Walleye predation rates suggested that at 9 inches, Rainbow Trout were invulnerable to predation by 19 to 21 inch Walleyes; most Walleyes in Seminoe were smaller than 21 inches (Yule et al. 2000).

Although stocking larger trout may help avoid predation by Walleyes, it requires significant changes in hatchery operations and greatly increases costs. For example, as Walleyes expanded their distribution through Seminoe, Pathfinder, and Alcova reservoirs and the management shifted from planting fingerling to subcatchable and then catchable trout, the number and pounds of trout that managers requested from hatcheries changed. In 1974, managers requested 2.5 million fingerling trout weighing 29,000 pounds whereas in 1992 managers requested 390,000 catchable trout weighing 130,000 pounds. It takes about 1 year to produce a catchable trout compared to 4 months for a fingerling. Producing larger fish also requires more hatchery space, and the cost of transporting these larger fish is much greater (J. McMillan; WGFD, personal communication). Hatchery production can be strained by increased demand for larger trout (Mavrakis and Yule 1998).

A similar depletion of the Rainbow Trout fishery occurred at Pathfinder Reservoir as the Walleye population there became established (Mavrakis and Yule 1998). Walleyes were first captured in Pathfinder Reservoir in 1974 following a prolonged spill from Seminoe Reservoir in 1973. Although Walleyes were not known to reproduce in Pathfinder Reservoir, by 1981 most Walleyes exceeded 20 inches, and experimental gill-net catch rates of Cutthroat Trout and Rainbow Trout that were stocked as fingerlings dropped quickly during the period from 1979 to 1981. In 1982, subcatchable cutthroat trout were stocked, and in 1983 catchable trout were stocked. Switching to stocking larger trout appeared to be effective as evidenced by four-fold increases in experimental gill-net catch rates of trout by 1984 (Mavrakis and Yule 1998).

Alcova Reservoir near Casper, Wyoming, has historically been managed as a popular put-grow-and-take Rainbow Trout fishery, with the majority of anglers fishing from the bank, rather than in boats (Mavrakis and Yule 1998; Hahn 2013). The number of trout caught by anglers increased as trout stocking increased from the 1950s to the 1980s. Stocking 500,000 to 800,000 fingerling Rainbow Trout annually provided high angler catch rates. Angler trout catch rates in the late 1950s and 1960s averaged 0.63 fish per hour; in the mid-1980s, catch rates remained high at 0.76 Rainbow Trout per hour. Walleyes were rarely reported in Alcova Reservoir until an extended and uncontrolled spill from Pathfinder Reservoir in 1985. Walleyes apparently preyed heavily on stocked trout because the number of trout per purse seine haul dropped to 50 trout per haul in 1985 as compared to over 100 trout per haul in the 1970s and early 1980s. Rainbow trout angler catch rates dropped to 0.48 fish per hour in the mid-1990s and to as low as 0.07 fish per hour in 2009 (Hahn 2013).

As predation of Rainbow Trout by Walleyes increased, managers responded by stocking 50,000 subcatchable Rainbow Trout in 1985 and 95,000 9-inch Rainbow Trout in 1997 (Hahn 2013). However, Walleye predation continued to increase and trout catch rates dropped to less than 0.20 fish per hour. The Walleye population in the 1990s and early 2000s was composed of modest numbers of large individuals, and no evidence of natural reproduction existed. Trout stocking was increased again to 95,000 to 130,000 9-inch Rainbow Trout in 2009 to 2012, but the trout catch rate remained below management objectives.

Maintaining trout catch rates in Alcova Reservoir through stocking in the face of Walleye predation may be possible, but is extremely expensive, and may result in increased recruitment of Walleyes (Hahn 2013). Managers have concluded that two options now exist for managing the Alcova Reservoir recreational fishery (Hahn 2013). The first is to reduce trout stocking rates, stock an alternate forage fish, manage a Walleye fishery, and use trout to provide some diversity in catch. However, this would be unpopular because over 95% of anglers at Alcova target trout and many are bank anglers; Walleyes are difficult to catch from the bank. The second option is to attempt to manage Walleye predation through increased angler harvest of Walleyes (Hahn 2013). For the time being, Wyoming has chosen the latter option; Walleye creel limits on Alcova Reservoir in 2015 are 12 fish per day (twice the statewide limit) and there is no limit on Walleyes taken with a spear gun.

Glendo Reservoir was managed as a trout fishery in the 1950s (Gerrity 2009). However, Glendo Reservoir is farther downstream and warmer than Seminoe, Pathfinder, and Alcova reservoirs and faces challenges in maintaining a trout fishery because of water temperatures, reservoir operations, competition from Yellow Perch and nongame fish species, and predation by Walleyes that were stocked in 1972 (A. Conder, WGFD, personal communication). Attempts to maintain the trout fishery following Walleye stocking by planting larger trout failed, and by 1981, WGFD abandoned efforts to provide a trout fishery and began to manage Glendo Reservoir as a Walleye fishery with Yellow Perch, Black Crappies, and White Crappies *Pomoxis annularis* as Walleye forage and to provide more diverse angling opportunities (Gerrity 2009). As of 2001, Glendo Reservoir provided good Walleye angling with a catch rate of 0.61 fish per hour, and as of 2007, WGFD Walleye gill-net catch rates were over three times higher in Glendo than in Seminoe, Alcova, and Pathfinder reservoirs (Gerrity 2009).

In summary, it appears that elevation and longitudinal (upstream to downstream) position of the reservoirs along the Platte River influenced the physical conditions (i.e., temperature), the suitability of each reservoir for trout and Walleyes, and the success of continuing to provide quality trout fisheries. Prior to the establishment of Walleye populations, high-quality trout fisheries existed in all of the reservoirs except Glendo Reservoir, which may have been too warm and low to support a quality trout fishery. As Walleyes became established and spread through this series of reservoirs, existing trout fisheries crashed because of predation by Walleyes. Walleye relative weight was positively associated with stocking densities of trout in Seminoe, Pathfinder, and Alcova reservoirs (Marwitz and Hubert 1997). Fishery managers responded with a variety of management tools, including stocking trout at different sizes, locations within reservoirs, and times of the year, stocking alternative forage fish, and attempting to manage Walleye abundance and size structure with angling regulations. The success of these strategies varied from upstream to downstream, with the highest success in the upstream reservoirs where physical conditions favor trout over Walleyes and the lowest in downstream reservoirs where physical conditions favor Walleyes over trout (A. Conder, WGFD, personal communication). The addition of Walleyes as a top predator increased the complexity, difficulty, and success of managing high-quality recreational trout fisheries in Wyoming's Platte River reservoirs.

John Day Reservoir, Columbia River

Pacific salmon abundances in the Columbia River basin have declined dramatically from historic levels; these declines have been attributed primarily to dams and associated hydropower development (Rieman et al. 1991). However, predation on outmigrating juvenile salmonids by piscivorous fish (native Northern Pikeminnow *Ptychocheilus oregonensis*, and introduced Walleyes, Smallmouth Bass, and Channel Catfish) in reservoirs and riverine reaches of the Columbia River was hypothesized to be influential as well (Beamesderfer and Rieman 1991; Poe et al. 1991; Rieman et al. 1991; Vigg et al. 1991).

The U.S. Fish and Wildlife Service (USFWS) conducted a four-year (1983 to 1986) investigation of the predation of juvenile salmonids by resident fish in John Day Reservoir. The USFWS was interested in determining the extent of juvenile salmonid mortality in reservoirs that could be attributed to predation. Chinook Salmon smolts moving downstream to the ocean from their freshwater rearing grounds were of primary interest. Northern Pikeminnow, Walleyes, Smallmouth Bass, and Channel Catfish were abundant in John Day Reservoir (Poe 1988).

The USFWS concluded that Northern Pikeminnow, Walleyes, Smallmouth Bass, and Channel Catfish consumed an average of 9 to 19% of the estimated juvenile salmonids that entered John Day Reservoir. The Northern Pikeminnow was the dominant predator; this species accounted for 77% of the total loss of juvenile salmonids to predators in the reservoir. Walleyes were the second-most important predator of juvenile salmonids, accounting for 13% of the total loss (Rieman et al. 1991). Most of the predation by Northern Pikeminnow occurred in the headwaters of John Day Reservoir in the afterbay of the upstream McNary Dam. However, Walleyes had the highest consumption rates in the main pool of the reservoir (Vigg et al. 1991).

Salmonids and other fish were the most important food items for smaller Walleyes, but salmonids decreased in importance with increases in Walleye size (Poe et al. 1991). The proportion of the ration of Walleyes less than 12 inches in length made up by juvenile salmonids was 27 to 60%, whereas Sand Rollers *Percopsis transmontana* and suckers were more important food items for larger Walleyes (Poe et al. 1991). The variation of importance of major food items with Walleye length was probably related to the size of the prey item relative to that of the predator. In this case study of predation in a reservoir and regulated river system, the native Northern Pikeminnow were the most important predator of salmonids, however introduced Walleyes were also important salmonid predators (Rieman et al. 1991).

Escanaba Lake, Wisconsin

Escanaba Lake is a 294-acre mesotrophic to eutrophic lake in Wisconsin with an irregular shoreline and bottom contours, islands and rocky shoals, and an entirely forested watershed (Nate et al. 2011). The present-day fish assemblage includes 24 species, which were all probably native except Walleyes and Northern Pike, which were stocked as fry in the 1930s and early 1940s. In 1946, Escanaba Lake was designated as an experimental lake with a compulsory creel census, and length, weight, and age data are collected on all harvested fish.

Walleyes entered the recreational harvest in about 1948, and Walleye harvest has varied erratically from less than 1,000 fish per year to nearly 6,000 fish per year with generally lower Walleye harvest and density since 1992 (Greg Sass, Wisconsin Department of Natural Resources, unpublished data; Nate et al. 2011). In 2003, a 28-inch minimum length limit was imposed on Walleyes, but age-0 Walleye and adult Walleye density remained low from 2003 to 2007 (Nate et al. 2011). Northern Pike harvest peaked at 935 fish in 1958, and harvest varied erratically until 1979, when Northern Pike harvest declined and remained at less than 100 fish per year.

The establishment of Walleyes and Northern Pike significantly affected the sport fish assemblage composition (Kempinger and Carline 1977). Smallmouth Bass and Largemouth Bass were the two primary gamefish harvested in 1946, but the harvest of both species declined to less than 10 fish per year by the mid-1960s (Greg Sass, Wisconsin Department of Natural Resources, unpublished data) after Walleyes and Northern Pike became established. Heavy predation of Smallmouth Bass by Walleyes commonly led to greatly reduced bass populations in other northern Wisconsin lakes during the 1940s after Walleyes were stocked (Kempinger and Carline 1977). The harvest of panfish, including Yellow Perch, Bluegill *Lepomis macrochirus*, Pumpkinseed *Lepomis gibbosus*, Black Crappies, and Rock Bass *Ambloplites rupestris* also crashed in the mid-1960s, likely due to predation by Walleyes. Smallmouth Bass have again entered the harvest in 2000s as Walleye densities declined.

In some lakes where predators dominate the biomass, Walleyes are abundant and slow growing. However, in Escanaba Lake, Walleye growth rates remained fairly constant despite large variations in the densities of prey. Reduced prey abundances affected Northern Pike growth rates more than those of Walleye, perhaps because Walleyes were better able to exploit alternate food resources than were Northern Pike (Kempinger and Carline 1977). This case history again demonstrates the effect that introduced Walleyes can have not only on the forage base, but on other predators as well. In this case, Smallmouth Bass, Largemouth Bass, and Northern Pike declined as Walleyes reduced the forage fish biomass.

Canyon Ferry Reservoir

Canyon Ferry Reservoir is a 35,200-acre reservoir located on the Missouri River near Helena, Montana (McMahon 1992; Roberts et al. 2010). Canyon Ferry Dam and Reservoir are operated by the U.S. Bureau of Reclamation for power production, flood control, irrigation, recreation, and as a municipal water source. Canyon Ferry has been in full operation since 1956. The upper, southern half of the reservoir is relatively shallow (< 50 feet) with gently sloping shorelines, and often windy conditions. The lower, northern half is deeper and more protected with cliffs and steeply sloping, rocky shorelines, particularly on the western shore. The combination of windy conditions and a deep outlet (94 feet at power penstock) results in a deep, weakly developed thermocline in Canyon Ferry Reservoir (Roberts et al. 2010). Submerged or emergent vegetation is almost totally absent in the reservoir (McMahon 1992).

Prior to the illegal introduction of Walleyes, Canyon Ferry Reservoir was managed primarily as a Rainbow Trout and Yellow Perch fishery, with Burbot also present (Roberts et al. 2010). Brown Trout have provided an important trophy component to the fishery in the past, but low numbers of Brown Trout have resulted in low catch rates in Canyon Ferry Reservoir and the Missouri River upstream to Toston Dam since the mid-1990s. Other game fish species, including Smallmouth Bass, Largemouth Bass, Bluegill, and Northern Pike are present but are not abundant enough to provide significant sport fishing opportunities. Non-game species in this system are abundant, but not particularly diverse. The three primary nongame species are Common Carp, White Sucker, and Longnose Sucker *Catostomus catostomus* (Roberts et al. 2010).

The Rainbow Trout population in Canyon Ferry Reservoir has been maintained since 1955 by stocking of 250,000 to 1.2 million hatchery fish each year because natural recruitment is not sufficient to meet the demand of the fishing public (Roberts et al. 2010). In past years, MFWP has adjusted the stocking of Canyon Ferry Reservoir several times in an attempt to enhance the

Rainbow Trout population by stocking different numbers, sizes, and strains of Rainbow Trout and with different methods of dispersing them into the reservoir (Roberts et al. 2010).

Walleyes were first detected in the reservoir in the late 1980s and large year classes of Walleyes were naturally produced in 1996 and 1997. The establishment of a reproducing Walleye population conforms to McMahon's (1992) assessment that spawning habitat, temperature regime, water levels, reservoir retention time, and plankton availability in Canyon Ferry Reservoir are all suitable for successful Walleye reproduction. Prior to the establishment of large numbers of Walleyes, numbers (Figure 57) and angler catch rates (Figure 58) of Rainbow Trout fluctuated primarily because of variable success of MFWP's stocking program. After increased stocking rates of fingerlings during the mid-1990s significantly increased Rainbow Trout abundance, the population trend remained relatively stable at about 10 Rainbow Trout per net throughout the late-1990s (Figure 57).

By 2000, Walleyes in the large year classes of 1996 and 1997 had grown large enough to effectively prey upon stocked Rainbow Trout fingerlings (Roberts et al. 2010). Rainbow Trout numbers declined accordingly (Figure 57). The average abundance of Rainbow Trout as indicated by standardized autumn gill-net surveys in the years following Walleye population expansion declined by 72% from 12.1 fish per net for 1986 to 2000 to 3.4 fish per net for 2001 to 2013 (Strainer 2013), which is below MFWP's management goal of a three-year running average gill-net catch of 5 to 6 Rainbow Trout per net in the autumn floating gill-net series (Roberts et al. 2010). However, catch rates of anglers targeting Rainbow Trout have largely been maintained following Walleye population expansion. The average summer catch rates of anglers targeting Rainbow Trout in the years before Walleye population expansion (1986 to 2000) increased 32% from 0.25 fish per hour to 0.33 fish per hour post-Walleye (2001 to 2013). Therefore, MFWP's management goal for Rainbow Trout angler catch rate, which is to maintain a three-year running average summer angler catch rate of 0.25 Rainbow Trout per hour is currently being met (Roberts et al. 2010). Despite this, the average winter catch rates for anglers targeting Rainbow Trout in the years before Walleye population expansion (1986 to 2000) decreased 19% from 0.37 fish per hour to 0.30 fish per hour post-Walleye (2001 to 2013; Figure 58).

Following Walleye population expansion, it became necessary to stock larger Rainbow Trout in the spring and autumn to reduce predation on stocked trout (Roberts et al. 2010). Stocking larger Rainbow Trout reduces predation by Walleyes because many of the Walleyes are not large enough to eat the larger (8-inch) stocked Rainbow Trout. Stocking in the autumn also reduces Walleye predation because of lower Walleye energy demands during cooler water temperatures. However, the larger trout increased hatchery costs 7-fold because of the increased hatchery space necessary to grow larger fish, increased food requirements, and increased transportation costs to haul additional loads of fish (Roberts et al. 2010). Although it is not fully understood why Rainbow Trout angler catch rates have been maintained despite apparent declines in Rainbow Trout abundance, stocking these larger Rainbow Trout is probably partially responsible for minimizing declines in Rainbow Trout angler catch rates post-Walleye (Figure 58).

Yellow perch have been one of the most abundant species of fish in Canyon Ferry Reservoir for the past fifty years (Roberts et al. 2010). However, the perch population has fluctuated extensively over time (Figure 57). These fluctuations are probably related to poor spawning and rearing habitat, variable spring weather conditions, and reservoir water levels that are believed to influence Yellow Perch spawning and rearing success. Moreover, the expansion of the Walleye population in the late 1990s resulted in reduced abundance of Yellow Perch in Canyon Ferry Reservoir (Figure 57). Yellow perch are a vulnerable prey species that is often selected by Walleyes over other prey species.

Trends in Yellow Perch abundance in Canyon Ferry Reservoir have been periodically monitored by MFWP since 1955. Catch of Yellow Perch per net pre-Walleye varied from a high of 79 per net in 1964 to a low of 10 per net in 1994. Following Walleye expansion in the late 1990s, catch of Yellow Perch per net has varied from a high of 47 per net in 1999 to a low of 0.5 per net in 2004 and 2005 (Figure 57). The average abundance of Yellow Perch in standardized sinking gill-net surveys in the years following Walleye population expansion declined by 75% from 21.7 fish per net during 1994 to 2000 to 5.5 fish per net during 2001 to 2013 (Figure 57; Strainer 2013). During 2001 to 2013, Yellow Perch gill-net catch rates were below MFWP's management goal of a three-year running average gill-net catch of 10 Yellow Perch per net (Figure 57; Roberts et al. 2010; Strainer 2013).

Yellow perch population trends are also monitored with summer beach seining that was initiated in 1991 to provide an index of annual Yellow Perch production. Reliability of beach seining for assessing annual production of perch is poor due to high variability, but it indicates that perch production can vary significantly from year to year and highlights years when Yellow Perch numbers contribute to higher levels of forage availability for Walleyes. Walleye predation appears to reduce the abundance of juvenile Yellow Perch. The average abundance of Yellow Perch (mostly juveniles) in summer beach seining surveys in the years following Walleye population expansion declined by 64% from 458.2 fish per net for 1991 to 2000 to 165.9 fish per net for 2001 to 2013 (Strainer 2013).

Based on data from a roving creel census that began in 1985, the number of anglers specifically seeking Yellow Perch on Canyon Ferry Reservoir during summer has been steadily declining, with an average of only 0.1% of all anglers targeting only perch from 2004 to 2008 (Roberts et al. 2010). Fishing for Yellow Perch is more popular in winter. During the winter of 2008, 37% of all anglers were specifically fishing for Yellow Perch. Winter catch rates of anglers targeting Yellow Perch were high pre-Walleye, with an average of 2.3 fish per hour in 1986 to 2000. Angler catch rates declined 52% to an average of 1.2 fish per hour in 2000 to 2008 (Figure 58). Winter angler catch rates of Yellow Perch have remained comparatively low since 2005, and were at a record low of 0.3 fish per hour in 2010 and 2011 (Figure 58). Yellow Perch winter catch rates are below MFWP's management goal of a three-year running average of 2.0 Yellow Perch per hour (Roberts et al. 2010).

Yellow Perch are now classified as game fish in Montana and are being managed as such in many waters (Roberts et al. 2010). In 2005, the Canyon Ferry Reservoir Yellow Perch daily and possession bag limits were reduced from 50 to 15 to counteract record low abundance in the reservoir. Additional ongoing management efforts included reducing the effects of reservoir operations on fishery resources and enhancing spawning and rearing success by providing additional lake bottom structure. For the past 14 years, thousands of recycled Christmas tree structures have been placed in the reservoir with the aid of several community and sportsman's groups. Yellow perch have been documented using the structures as spawning habitat, but whether these structures positively influence perch abundance is unknown (Roberts et al. 2010).

Walleyes were not present in Canyon Ferry biological samples from 1955 through 1988. The first Walleye was captured in 1989 during autumn netting to monitor Rainbow Trout. The Walleye population initially entered a phase of extremely rapid population growth that is characteristic of newly developing populations (McMahon 1992). In 1998, autumn gill-net catch of Walleyes reached a record high 10.4 Walleyes per net (Figure 57), but continued exponential growth was not realized. Relative abundance of Walleyes declined after the 1998 peak and has since fluctuated between 2.0 (2004) and 7.4 (2001) Walleyes per autumn gill net (Figure 57). During 2000 to 2013, abundance averaged 5.2 Walleyes per gill net (Figure 57).

Average length of Walleyes captured in gill nets generally increased from 1996 to 1999, and has declined from 2004 to 2014 (Figure 59). The initial increase in average length probably represents growth of the initial Walleye year classes, and subsequent declines in average length indicate successful Walleye reproduction with smaller fish entering the population. Adult Walleye size classes are divided into six categories by fisheries managers to characterize the size structure of the population: Sub-stock (< 10 inches), Stock (10 to 14.9 inches), Quality (15 to 19.9 inches), Preferred (20 to 24.9 inches), Memorable (25 to 29.9 inches), and Trophy (> 30 inches). Numbers of smaller Walleyes were high, and numbers of larger Walleyes were low in

1996 to 1997 (Figure 60). Larger Walleyes were generally more abundant from 1998 to 2006, and smaller Walleyes have been more abundant since 2007 (Figure 60).

Relative weight (the weight of an individual fish compared to an expected standard weight of a fish of the same length) of Walleyes generally declined from 1996 to 2014 (Figure 59). The decline occurred in all size classes of adult Walleyes (Figure 61). The decline in relative weight was probably caused by a declining food base for Walleyes, namely Yellow Perch and stocked fingerling Rainbow Trout.

Walleye diet analyses have been conducted since 1994 because forage diversity and supply are thought to be critical for sustaining quality Walleye populations. Yellow Perch and suckers made up most of the diet of Walleyes when the population first developed in Canyon Ferry. Yellow Perch are still a significant component of the Walleye diet, with perch comprising 85% of the diet by weight in 2013. Suckers currently contribute little to the Walleye diet, making up only 0.3% of the diet in 2008 and 0% in 2013. White Sucker abundance has declined steadily since 1996 (Figure 62) and White Suckers <12 inches long have become very rare in the gill-net catch (Strainer 2013), probably as a result of Walleye predation. White Sucker abundance remains well below MFWP's management goal of 15 White Suckers per net. Trout also made up a large percentage of the Walleye diet in the past, with trout making up over 70% of the diet in some years. However, since stocking of 8-inch Rainbow Trout began in the early 2000s, the number of trout in Walleye diets has decreased. For example, no trout were found in 2013 Walleye diet samples.

Gill-net catch rates of Burbot have declined since the establishment of Walleyes (Figure 63; Strainer 2013). Catch rates of winter anglers targeting Burbot have also declined substantially from over 1.0 Burbot per hour in 1996 and 1997 to < 0.2 Burbot per hour in 1996 and 1997 in 2011 and 2012. However, little is known about overall Burbot population trends in Canyon Ferry Reservoir because gill nets are not very effective at capturing Burbot. Walleyes are known to consume Burbot (Scott and Crossman 1973), so the Burbot population may have been reduced by Walleye predation. However, because Burbot also consume fish such as Yellow Perch (Scott and Crossman 1973), Burbot may be negatively affected by competition with Walleyes for a limited fish forage base. Conversely, downstream in Hauser and Holter Reservoirs, Burbot populations have increased, despite record high Walleye abundance and record low Yellow Perch abundance (Hauser only). In Canyon Ferry, Burbot remain below MFWP's management goal of 0.4 Burbot per net.

Angling pressure at Canyon Ferry typically ranks near the top of the statewide angling pressure survey, averaging about 102,555 angler days from 1999 to 2013 (Figure 64). Angling pressure peaked at 133,200 angler days in 2009. About one third of the angling pressure at Canyon Ferry (an average of 35,000 angler days) occurs during the relatively short ice-fishing season in January, February, and early March. The percent of all anglers that are specifically targeting Walleyes has steadily increased from about 10% in 1997 to about 50% since 2007 (Figure 65). This increase does not appear to be related to Walleye net catch rates, but rather probably reflects increased awareness among the angling public about the Walleye fishery in Canyon Ferry. An angler satisfaction survey completed during the 2007 license year indicated a general lack of satisfaction with the current fishery in Canyon Ferry Reservoir. On a scale of 1 to 5 where 1 = poor and 5 = excellent, satisfaction was rated as 1 by 33.2% of anglers, 2 by 26.7%, 3 by 27.0%, 4 by 8.2%, and 5 by 4.7% (Roberts et al. 2010).

A risk assessment entitled “Potential Impacts of the Introduction of Walleye to the Fishery of Canyon Ferry Reservoir and Adjacent Waters” concluded that the possibility of increasing fishing opportunities with the introduction of a species such as Walleye is offset by the potential effects on other fish species (McMahon 1992). Walleye densities did not grow to proportions anticipated when the population first expanded in the late-1990s, but the reproductive potential in Canyon Ferry Reservoir is still very high. This assessment, along with numerous other sources of expertise, experience, and public input, provided the basis for management strategies centered on management of a multi-species sport fishery that includes Walleye.

In 1997, the reservoir was drawn down to near record low levels which reduced the quality of Walleye spawning habitat at the only documented spawning site. Concurrently, MFWP conducted an effort to remove mature Walleyes from spawning areas. About 40 million Walleye eggs were intercepted from 175 females prior to spawning. Despite this effort, Walleye catch rate was 4.0 yearlings per net in the autumn 1998 netting series, compared with 6.3 yearlings per net in the 1997 autumn netting series. Following unsuccessful Walleye removal efforts in 1997, MFWP recognized that Walleyes were going to be a significant component of the fishery and developed strategies to incorporate Walleye into the multi-species fishery (Roberts et al. 2010).

Results of intensive Walleye sampling conducted since 1994 confirm the concerns expressed in the 1992 risk assessment (McMahon 1992). A small spawning population in 1996 and 1997 produced very strong year classes that resulted in a well-established Walleye fishery at Canyon Ferry Reservoir. Yellow Perch abundance and angler catch rates have plummeted to historically low levels. Rainbow Trout abundance has apparently declined post-Walleye, but Rainbow Trout angler catch rates have been maintained, probably as a result of stocking larger Rainbow Trout. Why Rainbow Trout angler catch rates have not declined commensurate with apparent declines in Rainbow Trout abundance is not currently well understood. The abundance of forage fish, such as White Suckers, has also declined to historically low levels. Burbot population abundance may also have declined. Walleye population size structure is currently fairly balanced with fish of all size classes present, but the relative weight of all Walleye size classes has been declining moderately since the late 1990s. Walleye average length has also declined since the late 1990s. Walleye angler catch rates have increased since the late 1990s but have been somewhat irregular. Summer catch rates for anglers targeting Walleyes peaked at 0.49 Walleyes per hour in 2011, but declined to 0.35 in 2012 and 0.21 in 2013. Winter Walleye angler catch rates have been highly variable, peaking at 0.59 Walleyes per hour in 2003, but have been at essentially zero from 2008 to 2013. A catch rate of 0.30 Walleyes per hour is considered good in many parts of the United States and Canada (P. Colby, Ontario Ministry of Natural Resources, personal communication).

The primary concern at Canyon Ferry Reservoir is that Walleye reproductive potential is very high, which could lead to a high-density Walleye population that could deplete prey species, including sport fish such as Yellow Perch, Rainbow Trout, and Burbot. Further, if the forage base is depleted, Walleye growth may be diminished, which would negatively affect the quality of the existing Walleye fishery. Determination of Walleye densities that can be maintained without permanently depressing the prey populations is unknown and is still being studied. Because Walleye year class strengths vary naturally (Bozek et al. 2011), another extraordinary year class such as that produced in 1996 is likely to occur at some point in the future, and will have unknown effects on the overall Canyon Ferry Reservoir fishery.

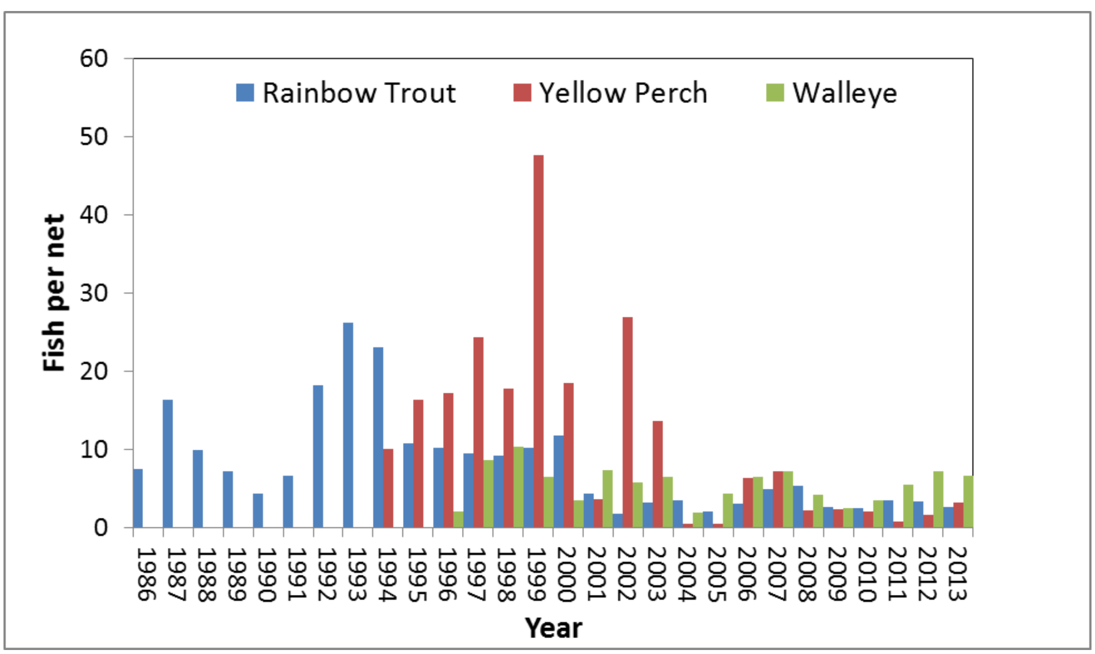

Figure 57. Catch rates of Rainbow Trout in spring horizontal floating gill nets from 1986 to 2013, Yellow Perch in the historic sinking gill-net series in 1994 to 2013, and Walleyes in the autumn Walleye gill-net series in 1996 to 2013 in Canyon Ferry Reservoir.

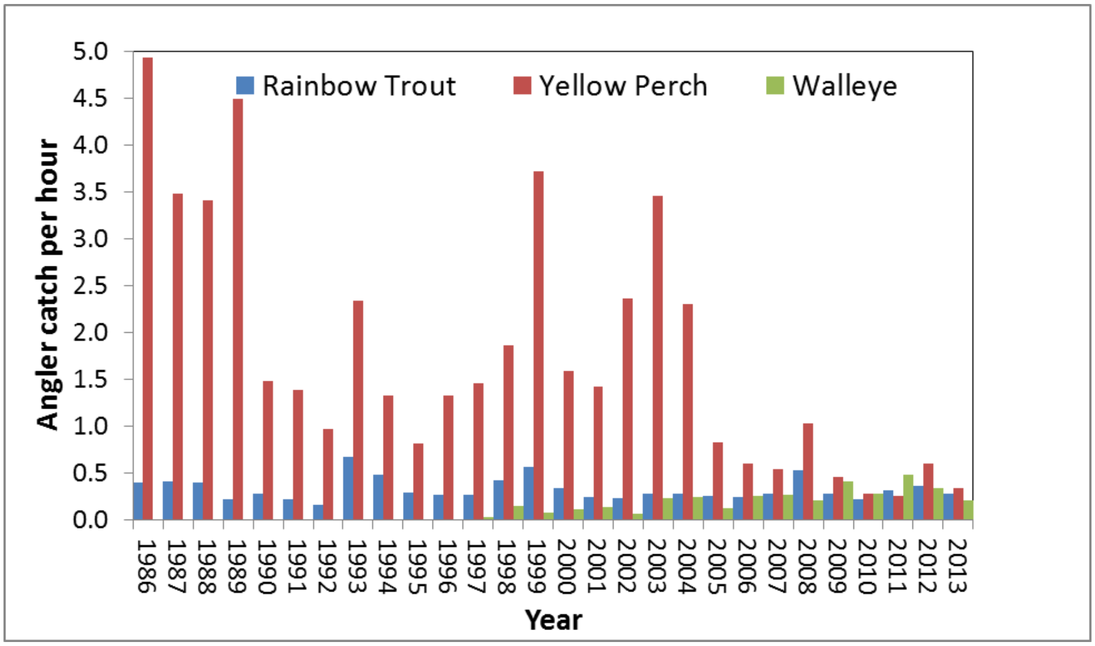

Figure 58. Catch rates of winter anglers targeting Rainbow Trout in 1986 to 2013, winter anglers targeting Yellow Perch in 1986 to 2013, and summer anglers targeting Walleyes in 1998 to 2013 in Canyon Ferry Reservoir.

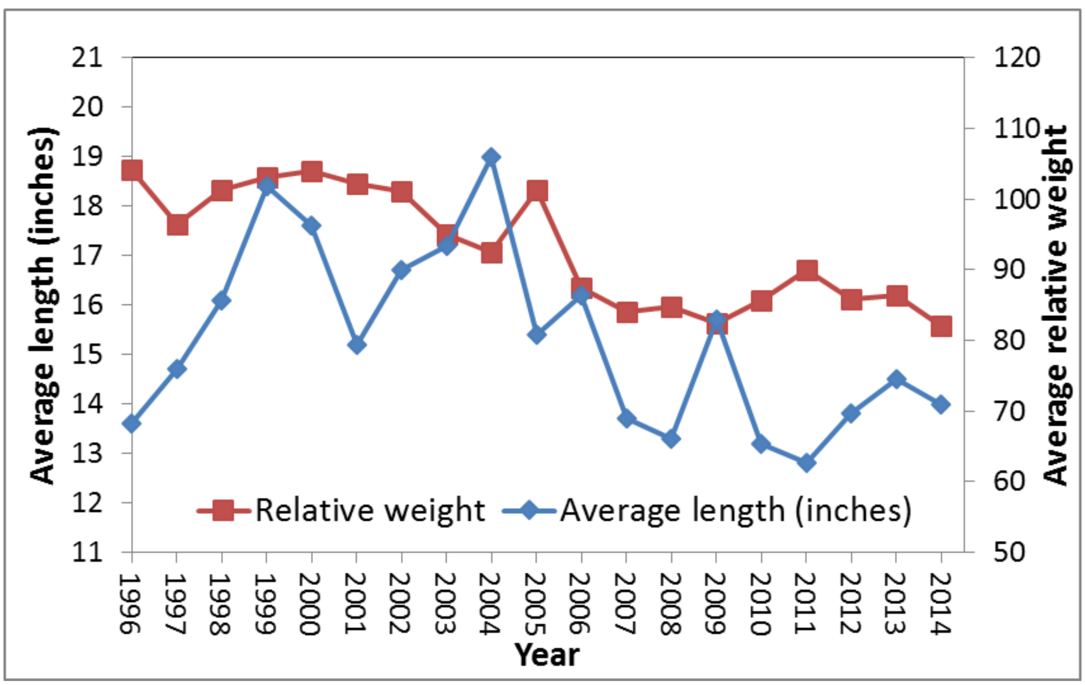

Figure 59. Walleye average length and relative weight from gill-net sets in Canyon Ferry Reservoir, 1996 to 2014.

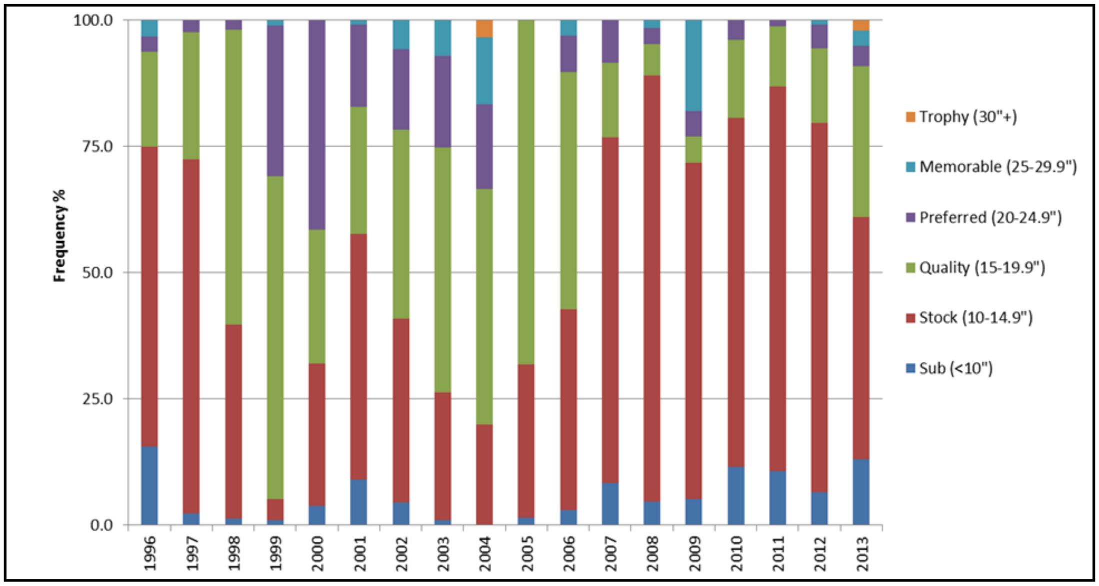

Figure 60. Relative Stock Density frequency (%) for Walleyes in 1996 to 2013 in Canyon Ferry Reservoir.

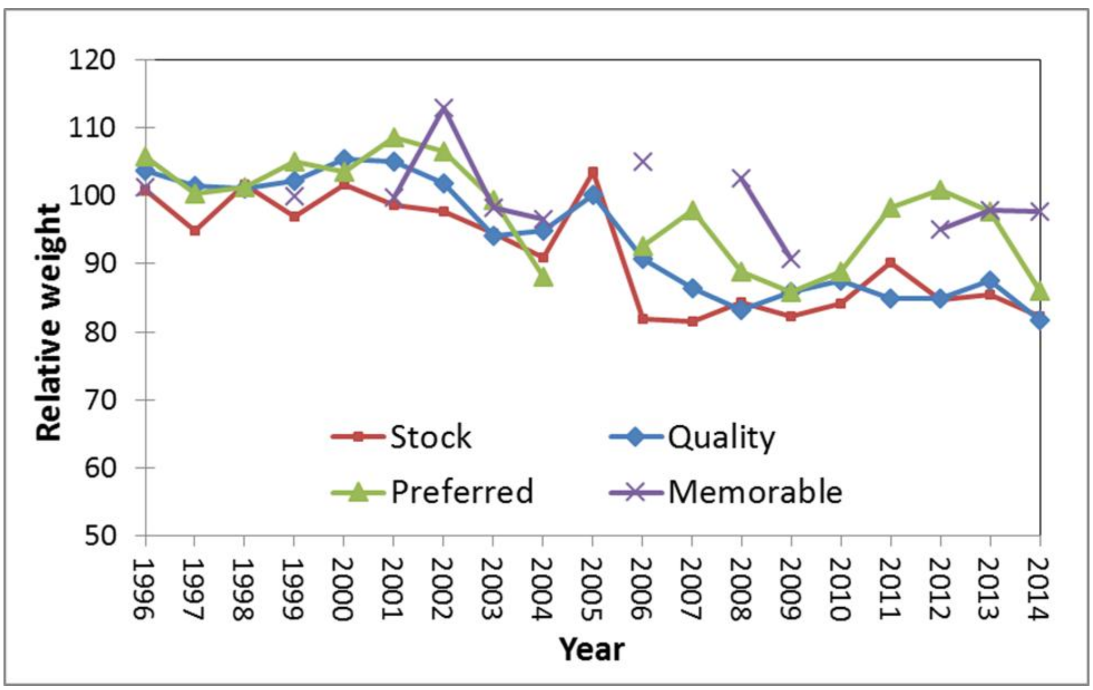

Figure 61. Relative weight of stock, quality, preferred, and memorable size Walleyes from gill nets in Canyon Ferry Reservoir, 1996 to 2014.

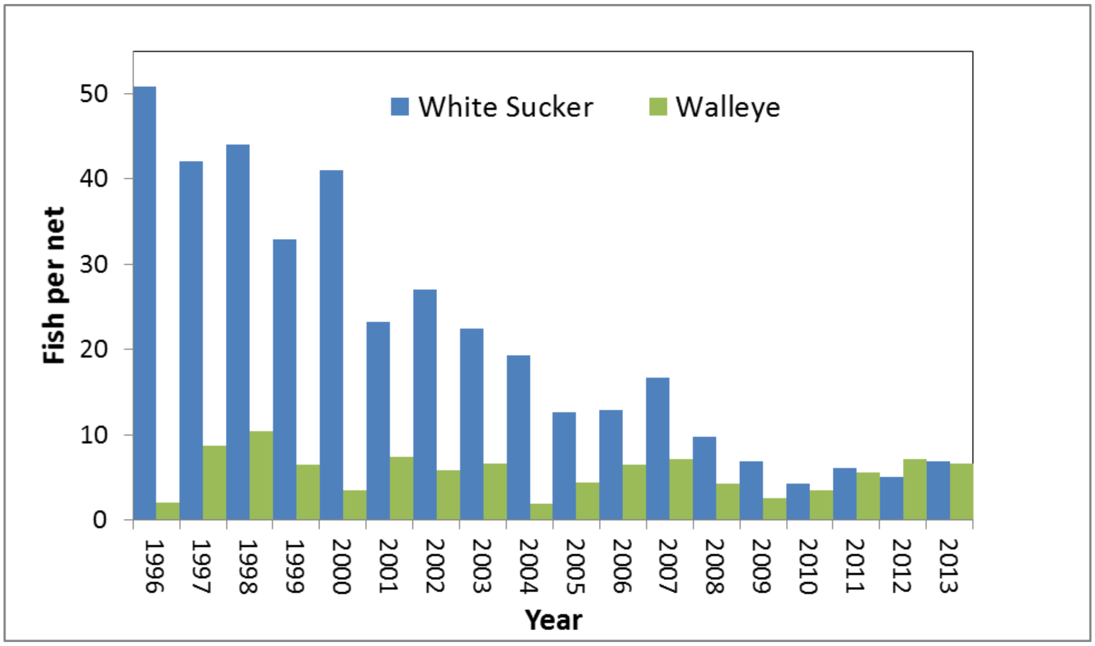

Figure 62. Catch rates of White Sucker in the historic sinking gill-net series and Walleyes in the autumn Walleye gill-net series in 1996 to 2013 in Canyon Ferry Reservoir.

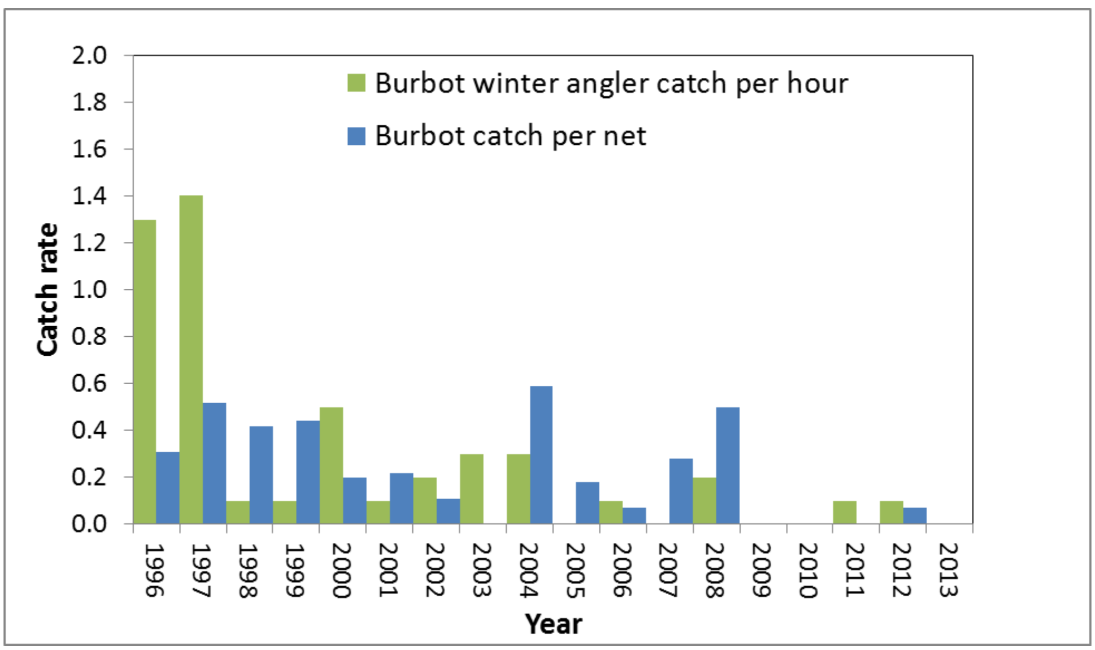

Figure 63. Catch rates of Burbot in the historic sinking gill-net series and winter angler catch of Burbot in 1996 to 2012 in Canyon Ferry Reservoir.

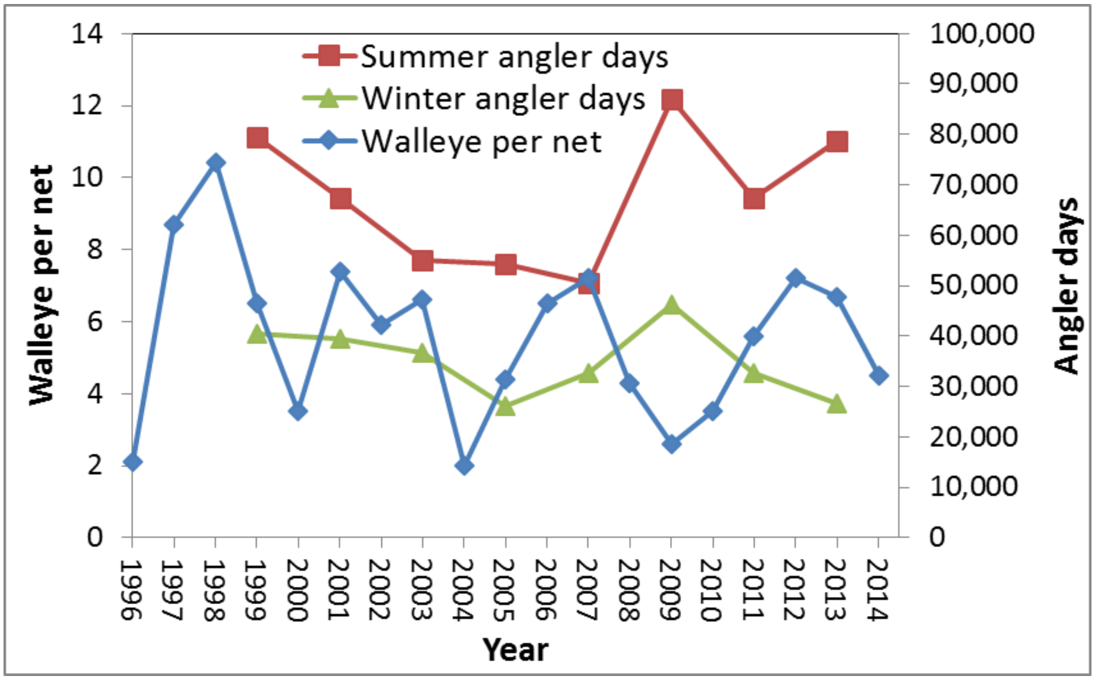

Figure 64. Walleye catch rates by gill-net sets and fishing pressure in summer and winter in Canyon Ferry Reservoir, 1996 to 2014.

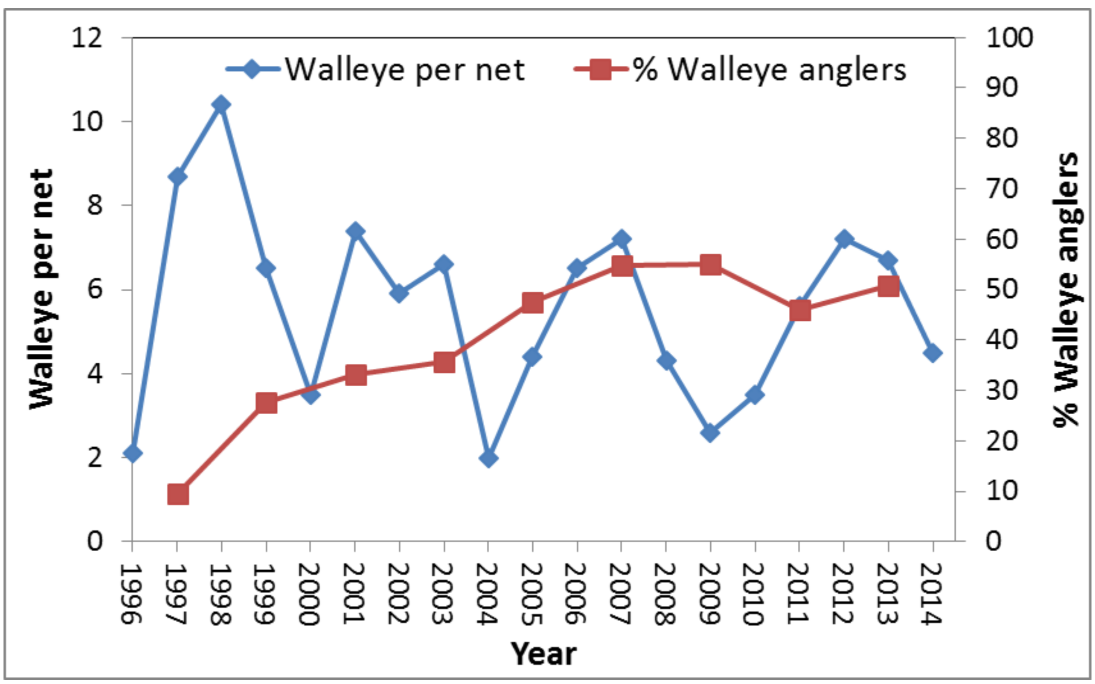

Figure 65. Walleye catch rates by gill-net sets and percent of anglers fishing for Walleyes in Canyon Ferry Reservoir, 1996 to 2014.

CHAPTER 2. FUTURE INTRODUCTIONS OF WALLEYE IN MONTANA

MFWP Fisheries Division

MANAGEMENT APPROACH AND PHILOSOPHY

Fish species have long been introduced to areas outside of their native range for recreational fisheries, food aquaculture, controlling undesirable aquatic species, and as ornamental species (Crossman 1991; Cambray 2003; Gozlan et al. 2010). In other cases, fish species have been introduced unintentionally through mechanisms such as escape from aquaculture facilities or removal of natural barriers. The introduction of fish species for recreational fishing was formerly viewed almost entirely favorably, because historically the societal value of recreational fishing was the primary consideration and the effects of introduced species on the conservation of biodiversity were not considered (Cambray 2003). Although most introductions were carried out with good intentions, evaluation of the full range of effects that could occur following an introduction was usually not adequate (Kohler and Courtnay, Jr. 1986). However, awareness of the negative effects of introduced fish species has increased in recent decades, and introduced fish species are now recognized as one of the largest global threats to fish conservation. Invasive species are probably the second greatest threat to fish conservation after habitat destruction, and one-third of all endangered and threatened fish species in the United States are listed at least in part because of threats posed by introduced species (Cambray 2003).

The introduction of any fish species is always a high-risk venture. The possibility of increasing fishing opportunities incurs a risk of affecting other fish species. Introduced fish species can affect fish assemblages through predation, competition, hybridization, habitat modification, and introduction of novel diseases (Gozlan et al. 2010). Walleye in particular have been shown to have negative effects on recreational fisheries, even those based on other introduced species (Kempinger and Carline 1977; McMahon and Bennett 1986; Kerr and Grant 2000; Yule et al. 2000). Even introductions that are often considered long-term successes, such as the introductions of Brown Trout and Rainbow Trout to Montana and other areas where they are not native, have their downsides. The Brown Trout is now a popular mainstay of trout fishing in the United States, but has caused declines in native trout populations including Golden Trout *Oncorhynchus aguabonita*, Gila Trout *Oncorhynchus gilae*, and Bull Trout *Salvelinus confluentus* (Rosen 1989; Cambray 2003). The introduction of Rainbow Trout throughout the West has been partially responsible for the decline of native Cutthroat Trout species through competition and interbreeding.

The introduction of Walleye can be viewed in much the same way as Brown Trout and Rainbow Trout. Many fishing opportunities for Walleyes have developed over the past half century, but there have also been impacts to other fish species. The benefits to anglers from Montana's major Walleye fisheries are many. Walleyes are currently found in 118 waters across the state, and 26 of these are actively managed through stocking while 24 reservoirs or river sections are managed through exceptions to standard fishing regulations. Geographically, these waters are spread throughout the Missouri and Yellowstone river drainages, ranging from Fort Peck Reservoir in the northeast to Tongue River Reservoir in the southeast, Tiber Reservoir in the north-central and Dailey Lake in the south-central parts of the state. Through MFWP's Fishing Access Site Program, there are 65 sites that provide access for the public to rivers and reservoirs with Walleye populations.

Two of Montana's largest state-run hatcheries (Fort Peck and Miles City) devote most of their space to growing Walleyes to stock as fry and fingerlings. Many anglers actively seek Walleye angling opportunities, and on a statewide basis, over 9% of total effort (approximately 323,000 angler days) is directed specifically toward Walleyes. Much of this effort is directed at the popular Walleye fisheries profiled in the Status section of this report, where the percent of anglers seeking Walleyes ranges from 28-88%. Many of the statistics provided in the Status section describe desirable aspects of these fisheries. For instance, many of these waters provide for catch rates higher than 0.3/hour, a level often used to describe a "good" fishery. The average size of fish in nets is also notably good on Bighorn Lake (15-18 inches in the past 10 years), and Holter Reservoir has had very good relative weights (100 to over 110%) for fish in the preferred and memorable categories (20 inches and larger). Fishing regulations have even been tailored to try to create a trophy fishery at Canyon Ferry Reservoir. Aside from these measures of a successful Walleye fishery, there are also many waters where the Walleyes add enjoyment through the diversity they add to the angling experience. The most prominent of these is Fort Peck Reservoir where Walleyes join Northern Pike, Smallmouth Bass, Lake Trout and Chinook Salmon as game species.

Statistics such as catch rates and size of fish are incomplete measures of the overall effect on angling satisfaction in waters where Walleyes replace or suppress other game species. Canyon Ferry Reservoir is probably the most obvious example of this where the boom in Walleye fisheries has come at the expense of the Rainbow Trout and Yellow Perch fisheries. Another example is Noxon Rapids Reservoir, where illegally introduced Walleyes have the potential to impact the popular bass fishery as well as predate upon juvenile Bull Trout emigrating from natal tributaries.

Many of the financial costs associated with managing a Walleye fishery are not unlike those for any other game fish. Stocking will occur in certain waters where natural reproduction is not sufficient to maintain the population, and population monitoring and creel surveys will be conducted by biologists to assess the fishery and propose changes to fishing regulations, reservoir operations, etc. to ensure a desirable fishery. Because Walleyes are large predators, the management challenges will usually extend to the co-existing fisheries in those waters. The Case History section above describes many of these issues, from the standpoint of the interaction of Walleyes with different species groups (salmonids, centrarchids, Yellow Perch, Northern Pike). Fish managers have the responsibility to study case histories such as these in order to fully understand the potential outcome of any Walleye introduction.

TEN QUESTIONS THAT MUST BE ANSWERED BEFORE STOCKING WALLEYE

The American Fisheries Society recommended 10 questions that need to be answered before considering the introduction of a new species (Kohler and Courtenay 1986). It is informative here to consider the answers to the 10 questions as they apply to Montana's experience, and it should also help to clarify the position of MFWP and its hesitance to consider additional introductions.

1. **Is the need valid and are no native species available that could serve the stated need?** If no valid need exists, no reason exists to take the risk of the introduction. If a valid need exists, could the risk associated with introducing a species be avoided by using a native species to fill the stated need? In Montana, "need" as defined by Walleye anglers will typically include the desire for a fish with superior taste that can attain large size and can be managed at densities that allow for high catch rates (0.3 fish per hour). In addition, some Walleye anglers enjoy the challenge of catching a species that can sometimes be hard to catch. Native predatory game fish that might be substitutes for Walleye in larger lakes that currently do not have Walleye include Westslope Cutthroat Trout *Oncorhynchus clarki lewisi*, Yellowstone Cutthroat Trout *Oncorhynchus clarki bouvieri*, Redband Trout *Oncorhynchus mykiss gairdneri*, Bull Trout, Lake Trout, Northern Pike, Burbot, Channel Catfish, and Sauger. The cutthroat trout, Redband Trout, Bull Trout, and native Lake Trout are species of concern in Montana, and despite conservation efforts, are not currently present in many lakes in numbers that would allow for a generous harvest. Moreover, Bull Trout, Redband Trout, and native Lake Trout have small geographic native ranges, as does the Northern Pike in the Saint Mary River drainage (which also is not in MFWP jurisdiction). Burbot, Channel Catfish and Sauger are native to waters in eastern Montana (Burbot are also native to some western Montana waters) and currently occur in most reservoirs and rivers with Walleyes, but their catch rates by sport anglers in reservoirs is normally quite low and/or seasonal. Therefore, stocking these species to most western Montana waters would also constitute the introduction of a nonnative species. Sauger and Channel Catfish habitat is also typically more associated with moving waters and higher turbidity than

suitable Walleye habitat, so their use as sport fish in reservoirs is limited. Therefore, in general, there are probably no native species that can serve as acceptable substitutes to Walleye anglers.

2. **Is the proposed introduced species safe from overexploitation in its native range?** This question is not germane as the legal Walleye introductions in Montana have been made with fish obtained from hatcheries.

3. **Are safeguards adequate to guard against importation of disease or parasites?** As described in question 2, any Walleye introductions would come from hatcheries, where disease testing is a requirement for cultured fish. While this testing will minimize the risk of disease importation, it will always be a concern in Montana, particularly since both Fort Peck and Miles City hatcheries are on open water supplies.

4. **Would the proposed introduced species be limited to closed systems?** Introductions to a closed system will minimize the risk of expansion to other waters, while introductions to open waters will pose a variety of risks to other waterbodies depending on the local circumstances. All large waterbodies in Montana are in open systems, and in currently occupied waters, the Walleyes have no doubt moved both upstream and downstream over time. The impacts of this dispersal on other species has yet to be determined to be significant anywhere in Montana, although concern has been expressed by many anglers in the situation where Walleyes have dispersed downstream from Holter Reservoir into the rainbow/brown trout fishery in the Missouri River. Additional consideration should be given to whether the introduced fish could reach any other states, provinces, or tribal lands. This is a valid issue in Montana; many open systems west of the Continental Divide contain Bull Trout (a threatened species under the Endangered Species Act) and all waters drain to Idaho or Canada. East of the Continental Divide, hybridization of Saugers with introduced Walleyes is known to occur, but the risk of hybridization with Saugers is thought to be low. However, hybridization risk must be addressed in individual situations. In southwest Montana, considerable concern would surround the impacts to non-native salmonids that constitute the bulk of recreational angling in the heavily-used rivers, such as the Madison, Big Hole, Ruby, and Beaverhead rivers. Elsewhere east of the Continental Divide, many open systems also currently have Walleyes, and in those circumstances, there would be a concern that the new introduction would compound or exacerbate any deleterious impacts of Walleyes already present.

5. **Would the proposed introduced species be able to establish a self-sustaining population in the range of habitats that would be available?** MFWP believes that introductions which are not self-sustaining, i.e., can only be maintained by stocking, provide relatively low-risk

opportunities to manage Walleyes and is willing to consider developing such fisheries east of the Continental Divide. However, this will be done only after impacts on other species are deemed to be acceptable or insignificant (question 6), and that the risk of expansion and subsequent impacts to other fisheries is also acceptable (question 4).

6. **Would the proposed introduced species have only positive ecological impacts?** For example, what impact would Walleyes have on the existing fishery, especially threatened or endangered species or species of concern, other native species, other game species, and important forage species? In Montana, this question would be evaluated in any Environmental Assessment (EA) which proposes an introduction. The primary threatened or endangered species or species of concern include Bull Trout, Cutthroat Trout, Arctic Grayling *Thymallus arcticus*, and Redband Trout. Impacts on forage fish and their consequences for food web alterations must also be considered, especially focusing on impacts to forage species that other game fish are dependent upon, and game fish such as Yellow Perch and Rainbow Trout that can be affected by introduced Walleyes.
7. **Would all consequences of the proposed introduced species be beneficial to humans?** For example, would the economic benefit of a Walleye fishery exceed the economic benefit of existing trout or other recreational fisheries and what are the immediate and long-term impacts that Walleyes might have on previously existing angling opportunities. This question is very relevant for Montana, where most lakes and reservoirs currently without Walleyes have well-developed constituencies for salmonid stocking programs that would most likely be affected. For the most part then, the consequences for humans are going to be related to how Walleyes change the angling experience either through a change in angler effort or impact on anglers seeking species which Walleyes have impacted. A prime example of this is Canyon Ferry, where Walleye anglers have replaced many trout and perch anglers as catch rates for those species have declined. At the same time, angler pressure has not increased appreciably since Walleye numbers exploded in the mid-1990s.
8. **Is there a species synopsis and is it complete?** This question considers whether there is adequate data and published literature available to produce a synopsis of the species' ecology on which to base the evaluation of ecological impacts and human consequences. In the case of Walleye, this document is sufficient to serve this role.
9. **Does the species synopsis indicate desirability for introduction?** The species synopsis (as portrayed in the summaries in this report) indicates desirability from the standpoint that good angler catch rates and/or large average lengths or high relative weights can be developed and sustained on some Montana waterbodies to which Walleyes have been introduced. Catch rates for the nine reservoirs is only available for Canyon Ferry, Holter,

Tiber and Lake Francis, and they all ranged from 0.27-0.46 fish per hour, at times exceeding the 0.3 fish per hour benchmark for a good quality fishery (Colby et al 1979). Average lengths were generally smaller in Lake Francis, Cooney, Fresno and Tiber reservoirs than the other five. Companion to good quality fisheries is an angling public seeking these fish, and the fact that 9-10% of Montana anglers report that when they fish, Walleyes are the primary species they are fishing for, shows that the angling demand is robust. The presence of a large constituency with local chapters of organizations dedicated to Walleye fishing is consistent with these facts.

10. **Would benefits exceed risks?** For any new introduction, this would have to be evaluated through the MEPA Environmental Assessment process, and can only be assessed on a site-by-site situation, because each water has its own potential and unique circumstances. MFWP also has the responsibility to view the risk/benefit tradeoff in a broader context. If current Walleye angling opportunities are adequate to meet demand, then the benefits derived from any new introduction are relatively minor. Conversely, the risks are always present, and may actually increase as the range of Walleye increases. It is from this perspective that the balance between risks and benefits are considered.

Possible Introduction Scenarios

West of the Continental Divide

In August 1989, MFWP developed a policy (ID-6), which was adopted by the MFWP Commission that forbade the stocking of Walleyes into waters of the state west of the Continental Divide (Clark Fork, Flathead, and Kootenai drainages) and the Missouri River drainage upstream of Toston Dam. It further stated that management emphasis would be placed on waters where Walleyes already occurred as described in management plans.

This policy has remained unaltered since 1989, and has recently been manifested through the Montana Statewide Fisheries Management Plan 2013-2018. That plan described management direction for different fish species and waterbodies in each drainage of the state. The only drainage west of the Divide or upstream of Toston Dam that included Walleyes was Noxon Reservoir in the Lower Clark Fork River drainage, where the management direction for Walleyes was “Suppress illegally-introduced Walleyes from the reservoir as possible.” Currently, this is being implemented through the use of liberal angling regulations.

The primary reason MFWP remains committed to the Walleye stocking policy is out of concern for the potential impacts to native and endangered salmonids residing in the lakes where Walleyes could be stocked, or in waters to which Walleyes could disperse into after they are stocked. Moreover, for each new waterbody that Walleyes are introduced into, it becomes logistically easier to use fish from those waters as a "seed" for new illegal introductions.

Some anglers who live in western Montana have expressed frustration with this policy because it requires them to travel considerable distances to fish for Walleyes. MFWP has tried to mitigate for this by providing Walleye fisheries as far west as possible without violating the stocking policy. The closest Walleye fisheries to the Continental Divide include Canyon Ferry, Hauser and Holter Reservoirs just to the east of Helena. Farther north, Walleye fisheries are provided near the Rocky Mountain front in Tiber Reservoir and Lake Francis, the latter of which is only 140 miles from Kalispell.

East of the Continental Divide

Current policy, as described above, allows MFWP to consider the introduction of Walleyes East of the Continental Divide and downstream of Toston Dam, and since the release of the Colby/Hunter report in 1989, MFWP has introduced Walleyes into 12 new waters. At the time of this writing, MFWP is not proposing any new introductions, but if it does so in the future it will need to consider the benefits, risks and habitat suitability of any potential waterbody. The benefits and risks were described in the answers to the 10 questions above.

In addition, habitat suitability criteria specific to Walleye and Montana should also be addressed in any EAs for new Walleye introductions. The following criteria, described by Colby and Hunter (1989), are recommended:

- 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 Walleyes. In addition, shorter retention times limit thermal stratification of lakes and reservoirs, which increases the likelihood of Walleye predation on salmonids.
- If the proposed waterbody is a reservoir, water levels should be manageable and managed in such a way as to provide adequate forage fish reproduction.
- The waterbody should provide the habitat requirements for Walleye as described in Table 1 of this document.

WALLEYE AS AN ILLEGALLY INTRODUCED SPECIES

Some of the financial costs associated with managing Walleye fisheries have been mentioned, but what is often not recognized are the considerable costs of dealing with illegal Walleye introductions. Since MFWP has a finite budget, expenditures to deal with illegal introductions take away from resources available to manage legitimate fisheries. From an administrative standpoint, the approach that MFWP took toward Walleyes in Canyon Ferry Reservoir is emblematic of the decisions and challenges that the agency faces when any illegal introduction occurs. Issues that must be taken into account upon learning of an illegal introduction are characterized below along with some examples:

1) **Can the Walleyes be eradicated or suppressed? If so, how will that be done in a socially and politically acceptable way?** Efforts at Canyon Ferry Reservoir included suppression netting of spawning fish in the years before the population exploded. Some anglers expressed outrage over these efforts, and the media and politicians got involved. These influences played a role in the decision of MFWP to stop the suppression netting. The result was an approach that was less inflammatory--a liberal bag limit for anglers to try to keep Walleye numbers low. Efforts at Noxon Rapids Reservoir in the 1990s initially involved suppression netting, but changed to a monitoring phase when densities were found to be too low for suppression efforts to be effective. This dilemma—suppression being ineffective because densities are too low--is particularly frustrating for managers, because the most desirable time to combat an illegal introduction is before their densities become great enough that they impact the existing fishery and perhaps expand to other waters. The Walleye population in Noxon has grown considerably in recent years, and currently an assessment is ongoing to determine the likelihood of success if suppression efforts were to be resumed. This new assessment has also led to controversy, with MFWP receiving criticism that it was not proactive in its actions and/or not transparent in its intentions. These two examples are presented to show that responding to an illegal introduction is not simply a matter of logistics and budgetary capabilities, and that public sentiment may also influence the direction (and diminish the effectiveness) of response actions.
2) **If suppression or eradication is not feasible, decisions must be made on how Walleyes will be managed relative to existing fisheries and constituencies.** Roughly 15 years after MFWP attempted suppression efforts and instituted a liberal bag limit on Canyon Ferry Reservoir, it moved toward integrating Walleyes into the management plan for the reservoir. To do this, the agency worked with anglers to develop a more restrictive bag limit with protected size classes to create quality-sized fish. Because Canyon Ferry is a high-use fishery, considerable dialogue was required with the angling community to make this transition. This effort included two management planning efforts (in 2000 and 2010) that involved a facilitated advisory committee process. The lesson from this

effort is that changing management actions on a popular illegal fishery can involve considerable time and expense with an uncertain outcome.

3) **The financial costs to respond to illegal introductions**. Efforts to eradicate may last only a year or two but financial costs can be high due to manpower demands, while costs to suppress could be even higher because those efforts are typically long-term. Lastly a decision to manage the new fishery as a game fish is potentially the most expensive option of all, as extra effort may be needed to adaptively manage other game species and forage species the Walleyes may interact with.

4) **Equitability.** The simple fact that Walleyes might grow well and reach suitable abundance for angling in a lake to which they were illegally introduced does not justify the fact that the angling public as a whole was not consulted about this action. The dilemma for MFWP then becomes one of its obligation to follow the process it has developed for management of the existing fisheries and honor the commitment it has made to existing constituencies. To circumvent this process would be an abrogation of its stewardship responsibilities.

Part of the reason that there needs to be a sense of urgency in dealing with new illegal introductions is that with each new waterbody that Walleyes are introduced into, it becomes logistically easier for criminals to use fish from those waters as a source for new illegal introductions. A case in point is the finding in 2015 of Walleyes marked with the antibiotic tetracycline in Bynum Reservoir, where none had been planted by MFWP. The nearest source of similarly marked Walleyes is Lake Frances which is only 50 miles away and it therefore would have been easy and quick for a criminal to move fish from Frances to Bynum undetected.

Ironically, the year the Colby/Hunter report was released (1989), was the same year the illegal stocking of Walleyes into Canyon Ferry Reservoir was discovered. In the intervening 27 years since the original report, there have been 13 additional instances of illegal introductions of Walleyes—the most recent being Swan Lake in 2015. In order for MFWP to respond to these introductions, it has had to expend considerable resources to the detriment of other Fisheries Division needs.

Regardless of whether or not these illegal actions are the work of groups or lone individuals is irrelevant to the fact that they all occurred by person(s) not empowered by law to do so. In Montana statutes (MCA 87-1-201, 87-1-301) only MFWP and the Fish and Wildlife Commission has the authority to stock fish in public waters, acting as stewards of the resource for the people of Montana. These person(s) who stock illegally are making decisions on their own that affect a public resource and they do so assuming their desires are more important than other users of the resource. Moreover, these selfish person(s) cannot even claim to know if their actions meet the approval of other anglers. A case in point is the survey taken during the development of the Canyon Ferry Reservoir Fisheries Management Plan in 1992 which revealed that a majority (79.1%) of Walleyes Unlimited members supported the introduction of Walleyes into Canyon Ferry, but that support dropped to 58.3% if it was assumed that there was a high risk to existing rainbow trout, brown trout and yellow perch fisheries.

Beginning with the original Colby/Hunter report, MFWP has emphasized the use of educational efforts to stop illegal introductions, believing that prevention is ultimately the only solution. MFWP has used media outlets, printed materials, magazine articles, and face-to-face meetings to engage the public, anglers and lawmakers on the topic of illegal fish introductions. The primary message has been: 1) there are negative ecological consequences from illegal fish introductions; 2) law-abiding anglers are being denied their rightful opportunity to influence the management of these waters when illegal introductions occur; and 3) there are considerable costs associated with responding to these illegal introductions, and the money to pay for these efforts comes primarily from the sale of fishing licenses. The hope with these efforts is that it will sensitize the angling community to the issue and effectively create a self-policing culture where these illegal acts would be reported to authorities. More recently in 2014, MFWP has joined with statewide angling groups to sponsor a rewards program, where each group pledges a sum of money to be paid to informants who provide information leading to the conviction of someone responsible for the illegal introduction of a fish. There are few measures of the success of this approach, but illegal introductions continue nonetheless. MFWP would benefit from an evaluation of their approach to this issue, and also strive to develop a new dialogue with the public to create a greater societal disdain for individuals who “manage” and damage public resources without the public’s input.

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APPENDIX

Appendix Table 1. Characteristics of nine Montana reservoirs with managed Walleye fisheries.

Reservoir	Surface Area (acres)	Mean Depth (feet)	Max. Depth (feet)	Shoreline Length (miles)	Age (years)	Water Retention Time (days)	Surface Elevation (feet)	Annual Pool Fluctuation (feet)	Year closed
Canyon Ferry	35,200	58	164	76	52	140	3,797	12	1954
Holter	4,800	50	121	50	100	21	3,575	2	1918
Tiber	17,800	85	182	75	58	591	2,933	12	1956
Fort Peck	246,000		220	1,520	68		2,250	9	1940
Fresno	5,757	27	50	65	66	127	2,588	21	1939
Nelson	4,320	14	50	30	90	610	2,217	8	1915
Bighorn	12,598	237	474	195	39	164	3,640	25–30	1967
Cooney	768		65	8	76		4,244		1937
Lake Frances	5,500	19	45	16	104		3,815	8	1910

Appendix Table 2. Number of Walleye fry and fingerlings stocked, in millions, in six Montana reservoirs with stocked Walleye fisheries.

Reservoir	Size	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Fort Peck	Fry	23.1	51.4	27.1	43.1	29.1	24.1	26.6	23.8	30.8	22.8	35.5	16	15.6	45.6	28.6	5.4	17.8	9.5	14.7
	Fingerling	2.0	1.6	1.4	1.9	0.9	2.1	1.9	2.3	1.6	1.4	4.1	2.5	2.2	3.3	2.4	2.6	2.6	2.8	2.3
Fresno	Fry	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fingerling	0	0.01	0.1	0	0	0	0	0.1	0.1	0.1	0.2	0.1	0.1	0.09	0.1	0.04	0	0	0
Nelson	Fry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fingerling	0.02	0.01	0.02	0	0.02	0	0.02	0	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.05
Bighorn	Fry	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	0	0	0	0	0	0	0
	Fingerling	0.6	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.5	0.5	0.05*	0.1*	0.0006*	0.1*	0.07*	0.1
Cooney	Fry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fingerling	0.1	0.1	0.1	0.1	0.07	0.05	0.05	0.05	0.05	0.05	0	0	0	0	0	0	0	0	0
Lake Frances	Fry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fingerling	0	0.1	0.1	0	0.08	0	0.1	0	0.01	0	0.01	0	0.01	0	0.096	0	0.04	0	0.05

*Triploid (sterile) fingerlings

Appendix Table 3. Information on fisheries management sampling for nine Montana reservoirs with managed Walleye fisheries.

Reservoir	**Gear type**	**Mesh size (inches)**	**Net dimensions (L X W)**	**Time of year (month)**	**Standardized?**	**Purpose**
Canyon Ferry	Experimental Gill Net	0.75"–2.0"	125' X 6'	September	Yes	Determine Walleye relative abundance in relation to management goals
	Experimental Gill Net	0.75"–2.0"	125' X 6'	June and August	Yes	Historic sinking net series--performed periodically since 1955 and annually since 1994
	Sinking Gill Net	3.0"	100' X 6'	April–May	No	Spawn survey (discontinued)
	Merwin Traps	3/8"	8'x8'x10'	April–May	No	Monitor Spawning Walleye
	Beach Seine	0.25"	100' X 10'	August	Yes	Forage abundance
	Partial Creel Census			May–October and ice covered months	Yes	Determine angler catch rates and size of catch

Reservoir	Gear type	Mesh size (inches)	Net dimensions (L X W)	Time of year (month)	Standardized?	Purpose
Holter	Experimental Gill Net	0.75"–2.0"	125' X 6'	May	Yes	Species Trends/Abundance
	Experimental Gill Net	0.75"–2.0"	125' X 6'	October	Yes	Species Trends/Abundance
	Vertical Gill netting	0.5"–2.0"	6'x100'	June–September	Yes	Kokanee Abundance (discontinued)
	Trap Nets	1"	4'x6'	April–May	No	Tag Walleye
	Beach Seine	0.25"	100' X 10'	August	Yes	Forage Abundance
	Boat Electrofishing			May	No	Tag Walleye
	Partial Creel Census			May–October and ice covered months	Yes	Determine angler catch rates and size of catch

Reservoir	Gear type	Mesh size (inches)	Net dimensions (L X W)	Time of year (month)	Standardized?	Purpose
Tiber	Experimental Gill Net	0.75"–2.0"	125' X 6'	September	Yes	Monitor relative abundances and condition of Reservoir fisheries
	Vertical Gill net	0.37"–2.0"	100' X 10'	April–November	Yes	Monitor abundance and size structure of Cisco population
	Trap Nets	1.0"	4' X 6'	April	No	Monitor adult Walleye and Northern Pike populations
	Boat Electrofishing			April	No	Monitor and tag river-spawning Walleye
	Beach Seine	0.25"	100' X 10'	August	Yes	Forage abundance
	Zooplankton monitoring	0.155 mm	50' Tows	April–November	Yes	Monitor species composition and size distribution of zooplankton assemblage
	Partial Creel Census	Weekends		May–September	Yes	Determine angler catch rates and size of catch

Reservoir	**Gear type**	**Mesh size (inches)**	**Net dimensions (L X W)**	**Time of year (month)**	**Standardized?**	**Purpose**
Fort Peck	Experimental Gill Net	0.75",1",1.25", 1.5:, 2"	125'x6'	July and August	Yes	Historic sinking net series-performed almost annually since 1979 with some netting started in 1950's
	Vertical Gill net	.5"	6'x100'	September	Yes	Coldwater forage abundance
	Lake trout Netting	3",4",5"	300'x6'	November	No	Monitor spawning Lake Trout and egg collection
	Trap Nets	1"	4'x6'	April	No	Collection of Walleye and Northern Pike for annual egg-taking efforts
	Merwin Traps	3/8"	8'x8'x10'	April	No	Collection of Walleye and Northern Pike for annual egg-taking efforts
	Beach Seine	3/16"	100'x9'	August and September	Yes	Shoreline forage relative abundance

Reservoir	Gear type	Mesh size (inches)	Net dimensions (L X W)	Time of year (month)	Standardized?	Purpose
Fresno	Experimental Gill Net	0.75",1",1.25", 1.5:, 2"	125'x6'	End of September	Yes	Species Trends/Abundance
	Beach Seine	0.25	100x10	August	Yes	Forage abundance, reproduction of sport fishes
Nelson	Experimental Gill Net	0.75",1",1.25", 1.5:, 2"	125'x6'	end of September	Yes	Species Trends/Abundance
	Beach Seine	0.25	100x10	August	Yes	Forage abundance, reproduction of sport fishes
Bighorn	Experimental Gill Net - lower and upper Reservoir	0.75"–2.0"	125'X6'	Spring and Autumn	Yes	Monitor fish populations
	Boat Electrofishing			April–May	Yes	Monitor spawning Walleye and other fish populations

Reservoir	Gear type	Mesh size (inches)	Net dimensions (L X W)	Time of year (month)	Standardized?	Purpose
Cooney	Experimental Gill Nets (2 floating, 2 sinking)	1"–3"	125' X 6'	October	Yes (with additional nets some years)	Determine Rainbow Trout survival, Walleye numbers and size, and sucker number and size
	Boat Electrofishing			April	Yes (two standard transects and creek shocking for spawners)	Determine relative abundance of larger Walleye in Reservoir and fish tagging for growth evaluation
	Merwin Trap	0.25"	150'	April	No	Assess sucker population, tag Walleye, sample other fish species
Lake Frances	Experimental gill net	0.75"–2.0"	125' X 6'	September	Yes	Monitor relative abundances and condition of Reservoir fisheries
	Trap Nets	1.0"	4' X 6'	April	No	Monitor adult Walleye and Northern Pike populations
	Beach Seine	0.25"	100' X 10'	August	Yes	Forage abundance
	Partial Creel Census	Weekends		May–September	Yes	Determine angler catch rates and size of catch