POTENTIAL IMPACTS OF THE INTRODUCTION OF WALLEYE TO THE FISHERY OF CANYON FERRY RESERVOIR AND ADJACENT WATERS

Thomas E. McMahon

Biology Department/Fish and Wildlife Program

Montana State University

Bozeman, Montana

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I. Introduction

This report evaluates the potential impacts to existing fisheries in Canyon Ferry Reservoir and adjacent waters from the introduction of walleye. Walleye have been proposed for introduction into Canyon Ferry to increase and diversify angling opportunites and to control perceived rough fish problems (Easy 1990). Two factors have provided the impetus for this proposed introduction: one is the general increase in demand among anglers for expanding fishing opportunities for walleye in Montana and other western states, and second is the specific decline over the past several years in angler success of trout and yellow perch fishing in Canyon Ferry, one of the most popular and valuable fishing areas in the state.

In a recent assessment of the introduction of walleye beyond their current range in Montana, Colby and Hunter (1989) emphasized the need to evaluate proposed introductions of walleye on a case by case basis. Walleye introductions have created valued fisheries in eastern Montana and elsewhere, but as a top predator their introduction can have complex and varied effects on existing fisheries and on the entire aquatic community as a whole. Colby and Hunter also noted in their review that walleye introductions are especially controversial in western states due to their documented or perceived detrimental impact on salmonid fisheries. In recent years, introductions of nonnative fishes to increase angling opportunities have generally come under closer scrutiny by fishery biologists since numerous studies have illustrated that, in some cases, introductions carry risks that may outweigh short-term benefits (Rosen 1989; Moyle et al. 1986). Indeed, introducing a self-sustaining fish population is often irreversible (Werner 1986). Hence the need for a careful weighing of all potential benefits and risks.

This report attempts to answer three major questions surrounding walleye introduction into Canyon Ferry:

-Are walleye likely to develop a self-sustaining, fishable population in the Reservoir?

-What are the potential interactions between walleye and existing species and, in particular, what are the likely effects on existing trout and yellow perch fisheries?

-Are walleye likely to expand beyond the boundaries of Canyon Ferry Reservoir and, if so, what effect might this population expansion have on existing fisheries upstream and downstream?

To answer these questions, this report draws upon reviews of life history and limiting factors for walleye populations and case studies of walleye-trout and walleye-perch interactions, to anticipate likely fish community responses and evaluate benefits and risks associated with introducing walleye into the particular environmental conditions and fisheries present in Canyon Ferry and adjacent waters.

II. Physical and Biological Characteristics of Canyon Ferry

Physical Characteristics

a. General Description

Canyon Ferry Reservoir (Figure 1), the first major impoundment on the Missouri River, is operated by the Bureau of Reclamation for power production, flood control, irrigation, recreation, and as a municipal water source. The reservoir has been in full operation for the past 36 years. Toston Dam is located 23 miles above Canyon Ferry. The dam is a 26-foot high irrigation diversion structure that is a barrier to upstream migrating fish. Hauser and Holter Reservoirs lie about 3 and 30 miles downstream from Canyon Ferry. Downstream movement of fish from Canyon Ferry to Hauser and Holter Reservoirs has been documented during periods of high surface water releases from the reservoir (Rehwinkel 1986).

At full pool, Canyon Ferry has a surface area of 35,200 acres and a volume of about 2 million acre-feet. It is about 25 miles long and 1 to 4.5 miles wide. Canyon Ferry is a moderately deep reservoir, with an average depth of 58 feet and maximum depth near the dam of 160 feet. The upper, southern half of the reservoir is characterized by low relief, relatively shallow depth (< 50 feet), and gently sloping shorelines. It is frequently subject to strong winds, especially during the spring months. The lower, northern half is more protected and is characterized by cliffs and steeply sloping, rocky shorelines, particularly on the western shore. Depths tend to increase rapidly to > 60 feet a short distance from the shoreline. Submerged or emergent aquatic vegetation is generally lacking in the reservoir. The shoreline length of Canyon Ferry at full pool is 76 miles and the shoreline development factor, an index of the irregularity of the shore, is 2.9 (Rada 1974), reflecting a relatively uniform shoreline (1.0 is a circle) punctuated by a number of small coves and bays located near the mouths of tributary streams (Figure 1).

b. Reservoir Operation and Water Level Changes

Discharge from Canyon Ferry Dam occurs at various outlets: the radial gates near the top of the spillway (30 feet deep); power penstocks (94 feet); irrigation outlet (110 feet); and the river outlet (147 feet). The power penstocks are usually the main release point, except in spring and summer when additional releases are made from the spillway, irrigation, and river outlets (Rada 1974). Releases from the radial gates typically occur during June and July following peak river run-off. Radial gate spills have occurred in 25 of the past 36 years, with an average duration of 47 days (Rehwinkel 1986; Lere 1991 pers. comm.).

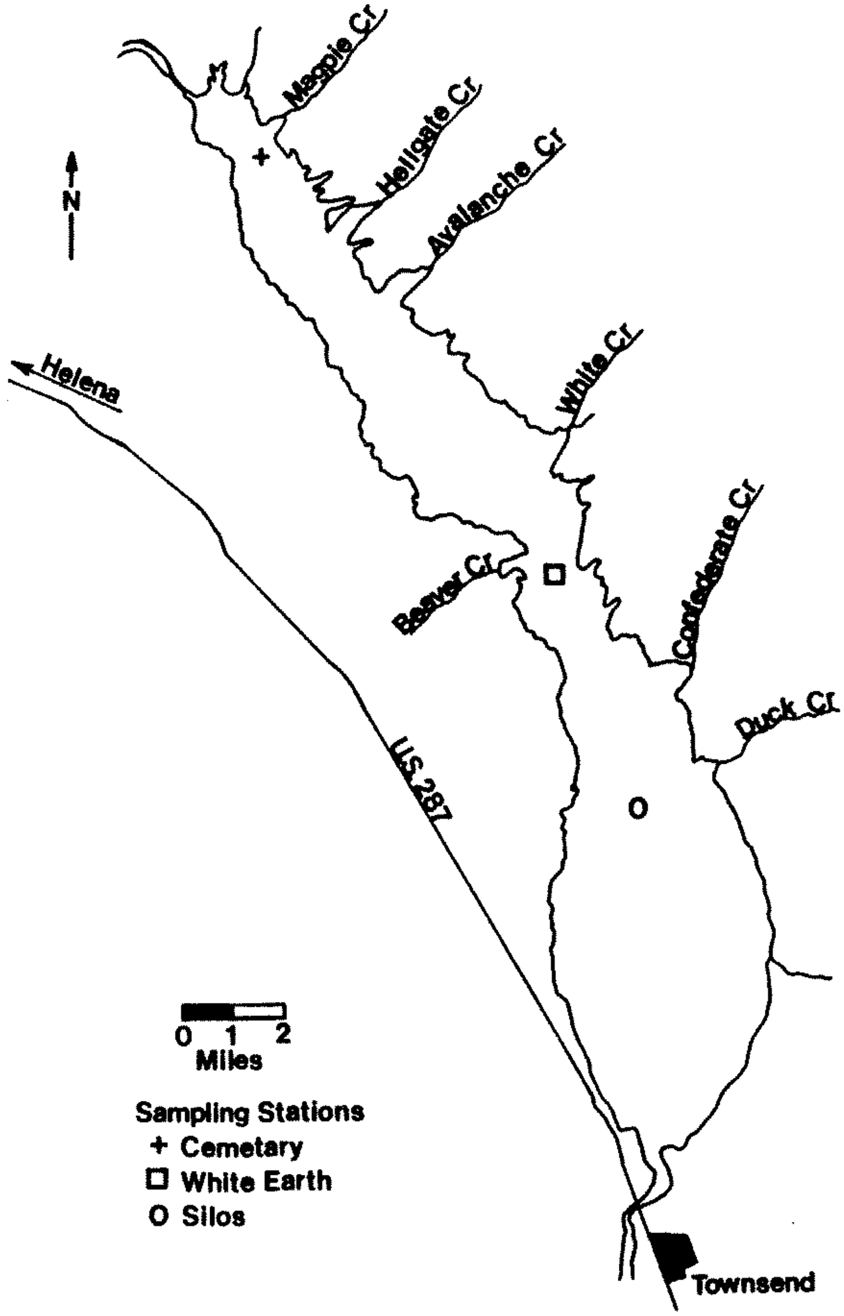
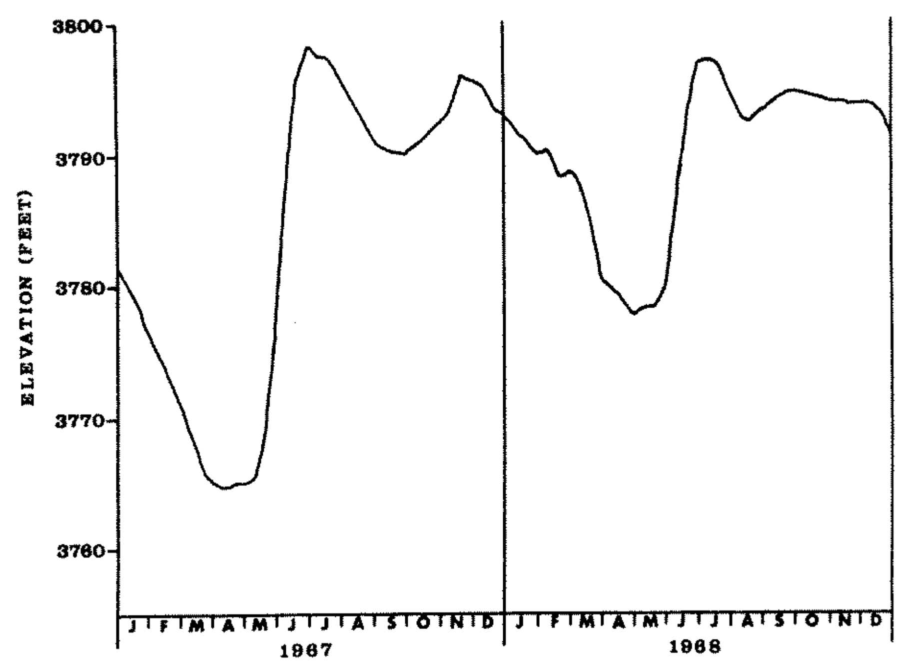


Figure 1. Map of Canyon Ferry Reservoir (from Lere 1991).

A typical pattern of seasonal water level changes in Canyon Ferry is shown in Figure 2. Rapid re-filling of the reservoir begins in early May with peak storage occurring in late June-early July, followed by a steady decrease (about 2 feet per month) during the summer period of high irrigation use (July-September). Decreases in reservoir volume continue throughout the fall and winter in preparation for storage of spring run-off. The retention time of water in the reservoir is about 140 days or 0.4 year. The storage ratio (reservoir water volume divided by average annual water release) averages 0.53. The annual water level fluctuation (drawdown) averages about 12 feet.

Figure 2. Typical seasonal pattern of water level changes in Canyon Ferry Reservoir (from Rada 1974).



c. Water Quality

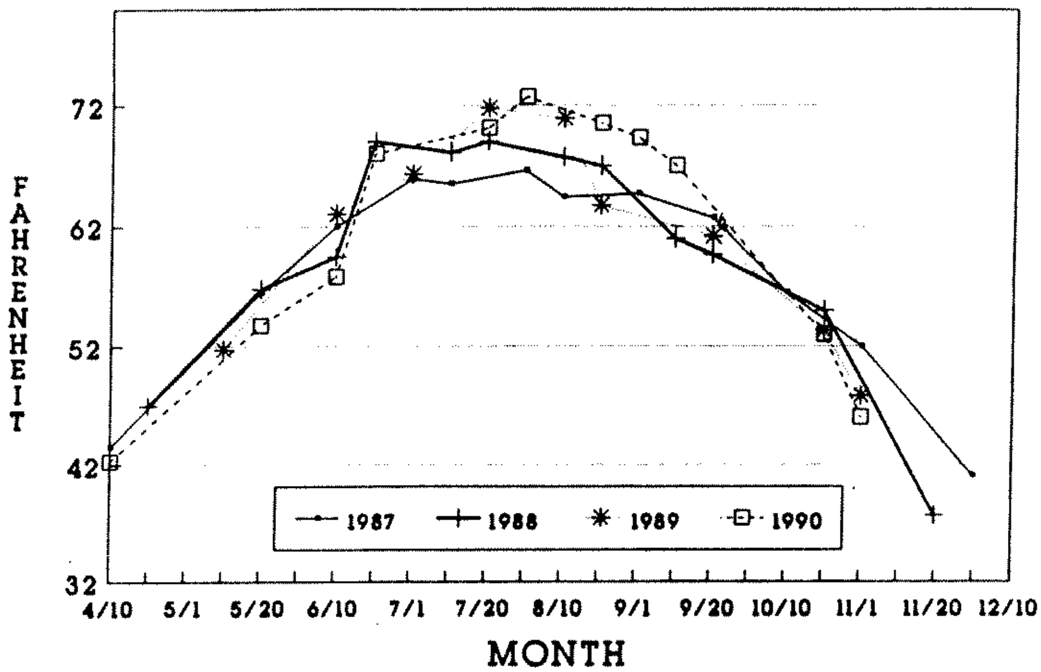
Canyon Ferry has moderately fertile and moderately clear water. A detailed limnological analysis of the reservoir in the early 1970s led Rada (1974) and Rada and Wright (1979) to classify Canyon Ferry as mesotrophic or of intermediate fertility on the scale between shallow, nutrient-rich, often turbid eutrophic waters and clear, deep, nutrient-poor oligotropic waters. A more recent study (Priscu 1986) found little change in nutrient levels and trophic status of the reservoir since that time.

Water transparency (Secchi disc depth) has averaged about 10 feet (range 9.8-11.2 feet) over the past four years. Transparency varies about two-threefold from the upper to lower reservoir, averaging 6, 10, and 15 feet in the upper (Silos), mid (White Earth), and lower (Cemetery) sections during the summer (Lere 1991).

A recent summary of water temperatures recorded at three stations in Canyon Ferry over the past four years is illustrated in Figure 3. Surface temperatures warm to 55 F by late May, peak near 70 in early August, and cool to below 50 F by late October. The combination of wind action and a deep reservoir outlet (94 feet at power penstock) results in a deep, weakly developed thermocline in Canyon Ferry. Water in the upper reservoir tends to remain mixed throughout the ice-free season (April-December) due to shallow depths and frequent winds. In the mid and lower reservoir, a weak thermocline is present from June through August at a depth range near 60 feet (Priscu 1987; Lere 1986, 1988, 1991).

Dissolved oxygen (DO) levels recorded for Canyon Ferry surface waters are excellent, with minimum values typically exceeding 7 mg/l (Priscu 1986; see summary by Thomas 1991). However, Rada (1974) reported that DO levels fell below 5 mg/l during summer at depths below the thermocline (60 feet). The pH levels in Canyon Ferry vary between 7 and 8.5 (Rada 1974).

Figure 3. Average surface water temperature (to 15 feet) of Canyon Ferry Reservoir, April-December, 1987-90 (from Lere 1991).

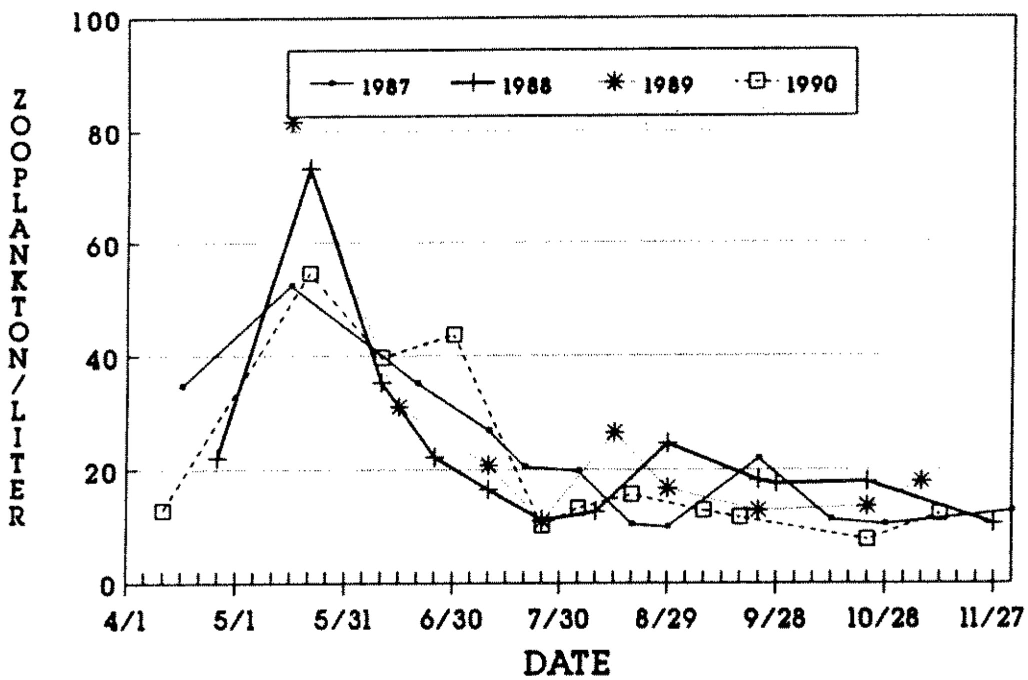


Biological Characteristics

a. Plankton Food Base

Canyon Ferry has a good population of plankton to support young and adult fish. From 1987-90, zooplankton densities averaged from 21-26 organisms per liter. Densities generally peak in mid-May at about 50 per liter, and remain at a relatively stable level of 20 per liter through the summer and fall months (Figure 4). Daphnia, the most important food item of rainbow trout and yellow perch, average about 8-10 per liter and range as high as 27-45 per liter at various times and locations in the resevoir during spring and summer months (Lere 1991). Plankton densities are sufficient to support growth of perch up to 9 inches (perch > 9 inches are primarily piscivorous; Bandow 1969) and trout larger than 18 inches in length.

Figure 4. Seasonal trends in average zooplankton densities in Canyon Ferry, 1987-90 (from Lere 1991).



b. Fish Populations

Sixteen species of fish are currently found in Canyon Ferry Reservoir (Bandow 1969; Lere 1991):

rainbow trout	golden shiner
brown trout	longnose dace
yellow perch	burbot
carp	bluegill
white sucker	largemouth bass
longnose sucker	mottled sculpin
mountain sucker	(kokanee)*
Utah chub	(channel catfish)*
flathead chub	walleye**

* stocked in 1960s but no populations established
** illegally introduced; 3 individuals captured over past 3 years (Lere 1991 pers. comm.)

Fish populations have been sampled in Canyon Ferry frequently over the past 36 years using gill nets. Rainbow trout, yellow perch, white sucker, carp, and brown trout comprise the bulk of the fish captured (Rehwinkel 1986; Lere 1991).

The relative abundance of fish captured in floating and sinking gill nets from 1986-1990 is shown in Table 1. Rainbow trout dominated the catch of floating nets in all years (Table 1A), but average catch per net has declined over this period from a high of 15 to a low of 5 trout per net (Lere 1991). Other species showed little change other than an increase in abundance of Utah chub, which still comprise < 5 % of the catch.

Yellow perch dominated the catch of sinking gill nets in 1986-88, followed closely by white sucker (Table 1B). Perch abundance declined by about half in 1989, but is showing evidence of recovery in 1990 (Table 1B) and 1991 (Lere 1991 pers. comm.).

Table 1. Percent composition by species for floating (A) and sinking (B) gill net catches in Canyon Ferry Reservoir from 1986-90 (from Lere 1991)

A. Floating gill nets

	1986		1987		1988		1989		1990	
SPECIES	SPRING	FALL	SPRING	FALL	SPRING	FALL	SPRING	FALL	SPRING	FALL
RB	91.3	90.8	70.2	90.2	59.0	76.3	51.4	73.9	63.8	82.3
LL	7.7	3.9	4.4	1.5	7.2	2.1	15.9	7.4	13.1	8.3
MWF	0	0	0	0	1.8	1.3	2.8	0	0	0
YP	1.0	0	0.4	0	14.0	0	0.9	0	0	0
LNSU	0	0.7	1.1	0	0.9	0	0	1.1	0.7	0
WSU	0	0	2.5	3.7	6.8	3.4	3.7	6.3	3.6	1.0
CARP	0	2.6	20.0	4.0	5.4	13.5	17.8	4.5	6.5	3.1
U.CHUB	0	2.0	1.4	0.6	4.9	3.4	7.5	6.8	12.3	5.2
TOTAL # CAUGHT	298	152	275	327	222	236	107	176	138	96
NUMBER OF NETS	13	18	13	18	13	18	13	18	15	18

B. Sinking gill nets

		1986		1987		1988		1989		1990	
RESERVOIR	SPECIES	SPRING	FALL	SPRING	FALL	SPRING	FALL	SPRING	FALL	SPRING	FALL
C. FERRY	RB		0.4		0.2		0.5		0.5		0.9
	LL		0.6		0.9		1.6		4.4		1.3
	MWF		0.2		0.2		0.8		1.1		0.9
	YP		59.7		59.5		52.6		20.8		32.1
	LNSU		2.7		1.2		0		0.5		0.9
	WSU		34.6		34.0		42.8		65.1		58.5
	CARP		0.8		2.1		1.1		7.1		1.3
	U. CHUB		1.0		1.2		0.3		0.5		2.7
	BURBOT		0		0.7		0.3		0		1.3
	# CAUGHT	0	489	0	429	0	367	0	183		224
	# OF NETS	0	3	0	3	0	3	0	3		3

RB= rainbow trout; LL= brown trout; MWF= mountain whitefish; YP= yellow perch; LNSU= longnose sucker; WSU= white sucker.

Canyon Ferry has a reputation as a rough fish lake (e.g, Heaton 1959), but fish abundance data derived from extensive bottom gill net sets made at various times from 1955-84 indicate that the relative abundance of suckers and carp has actually declined by half over the years, averaging 86% of the catch in the late 1950s and 43% in the early 1980s (Rehwinkel 1986). For comparison, suckers and carp comprise 70% or more of the catch of fish captured in bottom gill nets set in Hauser and Holter Reservoirs (Lere 1991).

c. Spawning, Habitat Use, and Food Habits

The majority of rainbow trout found in the reservoir have been primarily from annual plants of hatchery fish. A fall-running rainbow population, that migrated from Canyon Ferry upstream into the Missouri River below Townsend, was abundant in the 1970s (Fredenberg 1980) but is now rare (Rehwinkel 1986). Wild spring-spawning strains have recently been introduced (see next section) and limited spawning now occurs in Canyon Ferry tributaries and in tributaries to the Missouri River below Toston Dam (Lere 1988, 1991). Emigration of rainbow trout fry into Canyon Ferry occurs in late June-early July; there appears to be limited tributary rearing of rainbow fry due to dewatering. In summer, rainbow are found in the reservoir above the thermocline in water less than 80 feet deep.

Brown trout spawn from late September-November in tributaries to the reservoir and Missouri River, and in a three mile section of the River below Toston Dam (Rehwinkel 1986). Rearing of brown trout is thought to occur primarily in Canyon Ferry. Fry migrate to the reservoir in late April at temperatures above 40 F (Lere 1988). The size of the brown trout population is unknown, but an estimated several thousand fish spawn in the Toston Dam area alone (Rehwinkel 1986).

Yellow perch spawn along the Canyon Ferry shoreline during late April to mid May at temperatures of 45-57 F (Bandow 1969). Young-of-the-year occur in large schools near the surface over shoals in various parts of the reservoir. As summer progresses, they move nearer the bottom and into deeper water. Bandow (1969) reported that all sizes of perch were most abundant at 10-30 foot depths along the shoreline during summer, but showed no obvious depth selection during the winter.

As noted, rainbow trout and yellow perch are primarily planktivorous in Canyon Ferry (Bandow 1969; Lere 1988). Fish (rainbow trout and perch) comprise over 85% of the dietary volume for brown trout in Canyon Ferry, with a majority of fish consumed recently stocked hatchery fish (Lere 1991). Data are not available on food habits of other species.

d. Sport Fisheries in Canyon Ferry and Adjacent Waters

Canyon Ferry has been managed as a rainbow trout fishery since the 1950s. It has historically been one of the state's premier trout fisheries (Rehwinkel and Wells 1984; Rehwinkel 1986). Catch rates for rainbow in the 1970s averaged about 0.5 trout per hour with fish averaging about 18 inches and 2+ pounds (Rehwinkel 1986). Rainbow catch rates declined in the 1980s, averaging 0.2 fish per hour since 1985 (range 0.14-0.28), despite annual stocking of about 900,000 fish (Table 2). Angler use days paralleled declining angler catch rates, decreasing from 118,000 in 1982-83 to 65,771 in 1984-85 (Rehwinkel 1986). Lower catch rates were also reflected by a decline in abundance of rainbow trout in gill net samples (see previous section).

Declining catch and abundance of hatchery plants was attributed to high loss rates of trout due to flushing during radial gate spills and to the poor survival of consecutive trout plants. To bolster trout populations, MDFWP began introducing DeSmet and Eagle Lake strains in order to establish a wild, self-sustaining population with a longer life span than the Arlee strain hatchery trout (Table 2).

Table 2. Numbers and strain of rainbow trout stocked in Canyon Ferry Reservoir, 1983-90 (Rehwinkel 1986, Lere 1991)

Year	Total	Arlee	DeSmet	Eagle Lake
1983	659,056	418,498	240,558	-
1984	1,015,124	312,198	702,926	-
1985	691,966	434,237	257,729	-
1986	1,097,739	1,035,639	62,100	-
1987	975,989	724,686	-	251,303
1988	1,023,145	766,045	135,513	121,587
1989	982,158	852,158	-	130,000
1990	671,054	-	196,431	474,623
avg	889,529			

Yellow perch provide an excellent winter ice fishery in Canyon Ferry. The winter fishery in Canyon Ferry provides an estimated 30,000 angler use days, making it the most popular winter fishery in the state (Vincent 1991 pers. comm.). Catch rates of 1.9-3.7 perch per hour averaging 8-9 inches in length were recorded in 1985-88 (Lere 1991). Catch rates have decreased by more than half, to 0.9 per hour, in the past two years. Lere (1991) speculated that low spring water levels and windy, cool spring weather contributed to lower perch recruitment.

Other species in Canyon Ferry comprise only a small portion of total angler catch. Brown trout, for example, form < 2 % of the harvest (Lere 1991).

Current management objectives for Canyon Ferry are to provide: 1) a stable trout fishery with a catch rate of 0.3 fish per hour; and 2) a winter perch fishery having an angler catch rate of 2 fish per hour with an average size of 8.5 inches and a total annual harvest of 300,000 fish. Management is directed at increasing limited tributary spawning habitat, monitoring success of wild and hatchery trout plants, determining loss rates of trout from reservoir flushing, and examining factors affecting survival and growth of perch populations (Lere 1991).

Many of the free flowing sections of the Missouri River above and below Canyon Ferry have been designated Class I or 'blue ribbon' streams due to the wild, trophy-sized brown and/or rainbow trout fisheries. These sections include the 23 miles of river above Canyon Ferry (Toston Dam to the reservoir), and a total of 39 miles of river below the reservoir (Canyon Ferry Dam to Hauser Reservoir; Hauser Dam to Holter Reservoir; below Holter Reservoir).

Hauser Reservoir supports a thriving kokanee salmon fishery as well as a rainbow trout and yellow perch fishery. Kokanee and perch populations are self-sustaining, while the rainbow population is maintained primarily from annual plants of hatchery fish. A very small self-sustaining walleye population in Hauser has been supplementally stocked with about 5,000 walleye fry per year since 1989 to provide enhanced fishing opportunities (Lere 1991 pers. comm.). Composition of angler harvest at Hauser in 1990 was 44.2% kokanee, 33.8% perch, and 21.2% rainbow (Lere 1991).

Holter Reservoir supports a good perch and rainbow trout fishery, comprising 58.5 and 28.5% of the angler harvest in 1990 (Lere 1991). Kokanee populations in Holter are expanding rapidly, following the pattern shown in Hauser Reservoir, comprising 12.5% of angler harvest in 1991. A self-sustaining walleye population is also present in Holter. This population was established from progeny of fish planted in nearby Lake Helena in the early 1950s. Population size is small and stable (about 3% of fish in gill net sets made over the past 5 years). Recruitment appears rather low as most walleye collected are relatively large and old, averaging 19-21 inches, 2.7-4.0 pounds, and 5 years of age. Low recruitment is thought to be due to high flushing losses of fry (water retention time is only 17 days). Walleye comprise less than 1% of the fish caught by anglers in Holter Reservoir (Lere 1991).

III. Are Walleye Likely to Develop a Self-Sustaining, Fishable Population in Canyon Ferry?

a. Potential for Reproduction

Evaluating the potential for walleye to develop reproducing or self-sustaining populations in Canyon Ferry is key to assessing the overall risks and benefits of their introduction. On the plus side, self-sustaining populations may require little subsequent effort and costs to maintain. On the minus side, a self-sustaining population limits the ability of fishery managers to manipulate population size and thus to control potentially undesirable effects of the introduction. With a non-reproducing population, stocking can be discontinued or curtailed if negative effects of the species on the system turn out to be more serious than anticipated.

Spawning substrate, temperature regime, water level fluctuation, reservoir water retention time, and plankton availability are the most important factors limiting reproductive success of walleye (see reviews by Kendall 1978; Colby et al. 1979; McMahon et al. 1984; Colby and Hunter 1989). Many Midwest reservoirs, for example, must be stocked to maintain walleye populations due to suboptimal temperatures and/or a lack of spawning habitat (Momot et al. 1977).

The first approach used to assess the probability of walleye reproduction was to compare the requirements for each of these 'reproductive' factors with the conditions present in Canyon Ferry. The results from this comparison, shown in Table 3, indicate that conditions generally are highly favorable for development of a reproducing walleye population in Canyon Ferry Reservoir.

Table 3. Comparison of habitat conditions in Canyon Ferry with requirements for successful walleye reproduction.

Factor	Requirements	Conditions present in Canyon Ferry?
Spawning habitat	Rocky, silt-free shorelines; rocky areas with slow-moderate current in rivers, tributary streams, and tailwaters	Yes
Temperature regime	Rising temperatures of 44-48 F in April (spawning) and 48-59 F in May (incubation)	Yes
Water level fluctuation	Spring water levels maintained over spawning locations	Yes
Water retention time/ storage ratio	Water releases from spillway limited during May-July; storage ration > 1.0, retention time > 0.7 year	No
Plankton availability	Moderate-high abundance of zooplankton (especially Daphnia) during early fry stage (mid May-July)	Yes

Spawning habitat, in particular, appears highly suitable and readily available in Canyon Ferry and in the Missouri River above the reservoir. There is abundant rocky shoreline near the dam and, as discussed, especially along the western shore of the lower half of the reservoir. Windy conditions in the spring would keep these areas wave-washed and silt-free during incubation. Walleye in many reservoir systems are known to migrate upstream to spawn in rocky sections of tailwaters below dams (Elrod et al. 1987; Nelson and Walburg 1977; McMillan 1984). This type of habitat is present in a number of locations in the Missouri River below Toston Dam (Spoon 1991 pers. comm.). Walleye are also known to spawn over shallow gravel bars in very small streams, particularly when other types of spawning habitat are limited (Nelson and Walburg 1977; Corbett and Powles 1986). This type of habitat is also available in tributaries to Canyon Ferry (e.g., Confederate Creek, Beaver Creek) and to the Missouri River below Toston Dam (Marsh Creek, Warm Springs Creek). Based on the development of spawning runs after their introduction in other reservoirs (e.g., Seminoe, WY- McMillan 1984), it is likely that the majority of spawning by walleye would be split evenly between the reservoir and the Toston Dam tailwater, with additional, limited spawning occurring in small tributaries.

Close synchrony of plankton blooms with hatching of fry are critical for successful reproduction of walleye (Koenst and Smith 1976; Noble 1986). Spawning of walleye typically occurs when temperatures rise to 44-48 F in the spring. In Canyon Ferry, temperatures in this range occur in most years during the last two weeks of April (Figure 3). Based on the duration of incubation after spawning (e.g., 14-21 days at 46-58 F; Ney 1978), fry are likely to hatch and move into the open waters of the reservoir around the last two weeks of May, which coincides with the time plankton abundance is peaking (Figure 4). Reproductive success would likely be reduced during years of cool, windy spring weather (Busch et al. 1975), a not infrequent occurrence at Canyon Ferry. Fry subsist on zooplankton for about the next 60 days (Colby et al. 1979), or the end of July in Canyon Ferry. Plankton availability appears good throughout this time period.

Rising water levels during spawning (Figure 2) also appear favorable for successful walleye reproduction (McMahon et al. 1984). However, it is likely that losses of fry from surface water releases from the radial gates may reduce recruitment in some years, since the timing and duration of surface spills coincide with the time recently-hatched fry would inhabit surface waters. Walleye fry are quite susceptible to flushing during rapid water drawdown, especially from surface discharges. For example, Walburg (1971) reported that fry loss rates were much greater in years when water releases from Lewis and Clark Reservoir were made at the 10 foot versus the 100 foot outlet. Large losses of walleye downstream have resulted in reduced population sizes and year-class strengths in reservoirs (Groen and Schroeder 1978). Similarly, the retention time (0.4 year) and storage ratio (0.53) of water in Canyon Ferry are less than the optimum values listed in the literature for successful recruitment of young walleye to the population (optimum is > 0.7 year for retention time, Johnson et al. 1988; > 1 year for storage ratio, Willis and Stephen 1987).

A second approach used to assess the probability of walleye reproduction in Canyon Ferry was to apply a walleye habitat model developed by Bennett and McArthur (1985). This model was specifically developed as a tool for predicting the success of establishing a reproducing population of walleye in a particular body of water. The model is based on data from the success or failure of walleye introductions in 542 lakes and reservoirs located throughout the U.S. Their analysis revealed that pH, maximum depth, reservoir surface area, and date of dam closure were the most important factors determining success. Sensitivity tests indicated that the model correctly classified success or failure in 73% of the reservoirs. Plugging values for each of these factors into the model (pH 6.8-8.8, maximum depth 160 feet, surface area 35,200 acres, date of dam closure 1955) resulted in the prediction that Canyon Ferry had a 75% probability of establishing a self-sustaining walleye population (Bennett 1991).

In summary, all available evidence leads to the conclusion that there is a high probability of walleye developing a self-sustaining population in Canyon Ferry Reservoir. Further, it is anticipated that there will be rather wide fluctuations in walleye reproductive success from year to year given the combination of variable spring weather and variable timing and duration of radial gate spills in the reservoir.

An additional consideration is the possiblity of stocking sterile walleye. This option offers greater management flexibility and control of walleye populations. Technology for production of sterile fish is progressing rapidly. Fish culturists now have the ability to produce triploid (three sets of chromosomes) and gynogenetic (all female) fish. The Aquacultural Laboratory at the University of Minnesota is currently evaluating walleye triploids, but crucial experiments to test for later sexual development have not as yet been completed (Malison 1991 pers. comm.). Development of gynogenetic walleye is in its infancy and questions about later sex reversal and development and overall performance in the wild remain unanswered (Malison ibid). Moreover, the option for using gynogenetic walleye in Canyon Ferry is not very viable given that some walleye have already been found in the reservoir. Present technology, then, has not developed to the point where hatchery production and introduction of sterile walleye is a feasible option.

A related question concerns the possible introduction of saugeye, a hybrid cross of male sauger and female walleye. Saugeye have been introduced into a number of reservoirs throughout the Midwest and Southeast (Lynch et al. 1982; Johnson et al. 1988). Two factors argue against their introduction into Canyon Ferry, however. First, though hybrid fish are often sterile, saugeye are not since backcrosses have been found to be fertile (Hearn 1986). Moreover, saugeye do best in tailwaters and turbid, fluctuating reservoirs with retention times of < 0.1 year (Johnson et al. 1988), conditions unlike those present in Canyon Ferry.

b. General Suitability of Canyon Ferry as Habitat for Juvenile and Adult Walleye

Walleye are most abundant in large, mesotrophic lakes and reservoirs characterized by cool temperatures, shallow-to-moderate depths, extensive littoral areas, moderate turbidities, clean rocky substrate, and abundant forage (Colby et al. 1979; Kitchell et al. 1977; McMahon et al. 1984; Colby and Hunter 1989). To assess how well Canyon Ferry meets these requirements, a limiting factors model developed by McMahon et al. (1984) was used to derive an overall 'habitat suitability index ' (HSI). This model is comprised of a list of factors known to affect how well a given water body could support a walleye population. Optimum values for each variable are then compared with the values present in a particular water body. The result is given by a number from 0 to 1, with 1 representing optimum and 0 unsuitable habitat for walleye.

Results from the application of this model, shown in Table 4, indicate that Canyon Ferry rates as 'good' habitat for walleye. Water quality factors (pH, temperature, and dissolved oxygen) and trophic status appear at or near optimum for walleye growth and survival. A depth contour map of Canyon Ferry (published by Townsend Chamber of Commerce) also reveals that the reservoir has a number of rocky shoals, point bars, and some shallow shoreline (littoral) areas (< 20 feet deep) favored as feeding and resting sites by walleye (Chevalier 1977; Sternberg 1986). However, Canyon Ferry is deeper than a lot of 'classic' walleye lakes, hence the amount of brush or boulder cover and shallow shoreline area is less than optimum.

Table 4. Habitat factors and their associated values for walleye habitat suitability in Canyon Ferry (from McMahon et al. 1984 and Colby and Hunter 1989). Sources for Canyon Ferry values can be found in the text. The overall Habitat Suitability Index, or HSI, is listed as the lowest Suitability Index. HSI are rated as 'excellent' (0.8-1.0), 'good' (0.5-0.7), 'fair' (0.2-0.4), and 'poor' (0.0-0.1) (McMahon et al. 1984).

Habitat Factor Index	Optimum Value	Value in Canyon Ferry	Suitability
Transparency	3-10 ft. Secchi depth	6-15 ft.	1.0 - 0.6
Abundance of forage fishes	high abundance	moderate	0.5 - 0.7
Percent littoral area (< 20 ft. deep)/ cover of boulders, brush, etc.	25-45%	15%*	0.6
pH	6-9	6.8-8.8	1.0
Dissolved oxygen above thermocline- summer	> 5 mg/l	> 7 mg/l	1.0
Mean weekly water temperature above thermocline- summer	64-77 F	66 F	1.0
Trophic status	mesotrophic	mesotrophic	1.0
			HSI = 0.5-0.7

(*estimate based on depth contour map)

Water transparency is also somewhat limiting to walleye habitat suitability in Canyon Ferry. Feeding of the light-sensitive walleye is highest in moderately turbid conditions or intermediate light conditions that maximize their ability to capture small prey fishes. These conditions are present in the shallow, turbid, windswept upper reservoir, but water transparency in the lower, deeper end is higher than what is considered optimum conditions for walleye feeding (Kitchell et al. 1977; Ryder 1977). In this section, transparency during the peak summer feeding and growing season for walleye averages greater than 15 feet deep (Lere 1991). Transparencies at or above this level reduce the time that walleye can feed, thereby limiting their overall growth and production. As Ryder (1977) noted, clearer lakes can produce many walleyes but the standing crop is substantially less. It is noteworthy that in lower Holter Reservoir, which has a transparency similar to that of the lower section of Canyon Ferry (Lere 1991), radiotagged walleye are often found during the day within turbid plumes associated with clay banks where they are thought to be feeding on yellow perch; they are relatively rare elsewhere in the reservoir (Binkley 1991 pers. comm.).

Given the overall good to excellent physical habitat available in Canyon Ferry, the availability of forage is probably the most important factor that would govern walleye population size. A large, stable base of forage fishes is needed to support a sizable population of walleye. Indeed, the principal limiting factor in reservoirs for predators is usually the availability of prey fish (Ney and Orth 1986). Fish are the mainstay of the walleye diet starting at a small size (1-2 inches) and an early age (by mid- to late summer of their first year), and remain so throughout their life (MacLean and Magnuson 1977; Swenson 1977; Colby et al. 1979). For a top predator such as the walleye, the forage base must be large because there is about a 80-90% energy loss associated with conversion of prey fish flesh to predator flesh. Thus, 50 pounds of prey fish would be needed to produce 5 pounds of walleye. The forage base must also be stable, since fluctuations in walleye growth and survival are directly related to the availabilty of prey fish (Kempinger and Carline 1977). Finally, the prey must be 'vulnerable', in other words, must be of a size and in a habitat in which walleye are able to capture them. The latter factor is particularly important after spawning in the spring when food demands are high but young-of-the-year fish are not yet large enough to eat, and during mid summer, when walleye fry switch from eating plankton to eating small fish (MacLean and Magnuson 1977; Ney and Orth 1986).

Quantitative estimates of the amount of forage present in Canyon Ferry are not available. However, yellow perch, suckers, and rainbow trout would likely provide most of the forage base in the reservoir, together comprising more than 90% of the total fish caught in gill nets (Table 1). All three species, especially yellow perch, are suitable prey for walleye (Forney 1980; McMillan 1984). The availability of forage for walleye was judged to be 'moderate' for two reasons. First, there appears to be rather large fluctuations in abundance of forage from year to year. For example, the abundance of small perch captured along the shoreline varied about 2- to 7-fold during 1987-1990 (Table 5). Similarly, the catch of yellow perch per sinking gill net set in the fall varied about 7.5-fold during 1986-90, from a low of 12.7 to a high of 97.3 perch per net (Table 1B). Second, the lack of extensive shallow shoreline area in Canyon Ferry indirectly precludes the establishment of large populations of littoral forage fishes such as young perch, minnows, and young suckers.

Table 5. Total catch and catch per tow of fish caught during shoreline seining (100 x 4 foot, 0.25 inch-mesh net) of Canyon Ferry. Data from Lere (1991 pers. comm.).

Date	no. of tows	Total catch	YP	WS/LS	Chub	Rbt	Mwf	Mean catch/tow (yellow perch)
8/31/87	6	1,647	1,299	343	3	1	1	217
7/30/90	38	15,338	15,338	*	-	-	-	404
8/12/91	30	44,710	44,710	*	-	-	-	1,490

YP = yellow perch, WS/LS = white and longnose sucker, Chub = unidentified chub species, Rbt = rainbow trout, Mwf = mountain whitefish

(*numbers not counted; abundant in tows made in shallow, stagnant coves)

A further consideration concerns the question of how well the forage base of Canyon Ferry could be maintained after walleye were introduced. This question is an important one since dramatic declines in forage fishes have been observed in a number of lakes and reservoirs following population expansion by walleye (McMillan 1984; Colby et al. 1987; Colby and Hunter 1989; Shepard 1991). Tiber Reservoir in Montana (Colby and Hunter 1989), Seminoe, Pathfinder, Keyhole, and Glendo Reservoirs in Wyoming (McMillan 1984; Wichers 1981, 1986; Wichers 1991 pers. comm.), and Salmon Creek Falls Reservoir in Idaho (Partridge 1988), are among the waters where such a pattern has been observed.

Evaluating the likely response of the perch population in Canyon Ferry is pivotal since perch are the most abundant and favored prey fish available in the reservoir. Several factors suggest that yellow perch populations could not support walleye predation for more than a few years. First, the age and size structure of the population indicates that the population would be highly vulnerable to predation. The perch population in Canyon Ferry consists of long-lived, relatively slow growing individuals (Bandow 1969). Adult perch, for example, do not reach the size favored by anglers (9-11 inches) until they are 7+ years of age (Figure 5). Young perch in Canyon Ferry grow about two inches a year (Bandow 1969), and do not reach the length of 6 inches- the size at which they become too large for walleye to eat (Colby et al. 1987), until their third year. By contrast, perch reach this critical size at the end of their second year in more productive systems (Bandow 1969; Fraser 1978; Forney 1980). Thus perch in Canyon Ferry would have an additional year of vulnerability to predation by walleye. Colby et al. (1987) noted that slow growth rates in perch increase the time perch are vulnerable to predation thereby limiting their recruitment to larger size classes. It is also important to note here that growth of perch in Canyon Ferry continues throughout life, resulting in good numbers of larger fish (Figure 6). The perch population of Canyon Ferry is not characterized by large numbers of small, stunted individuals as found in many perch populations. In stunted perch populations, the introduction of a predator can lead to greater growth of both the predator and perch populations via 'thinning' of prey numbers (Anderson 1976). However, such density dependent growth does not appear to be the case for the perch population in Canyon Ferry.

Figure 5. Length at age for Canyon Ferry yellow perch (from Bandow 1969). (Note-captures of young perch during shoreline seining over the past few years corroborate the growth rates of young perch that Bandow found in Canyon Ferry in the late 1960s. Young-of-the-year perch averaged about 2 inches and yearling perch about 4 inches in August of their first and second year, respectively; Lere 1991 pers. comm.).

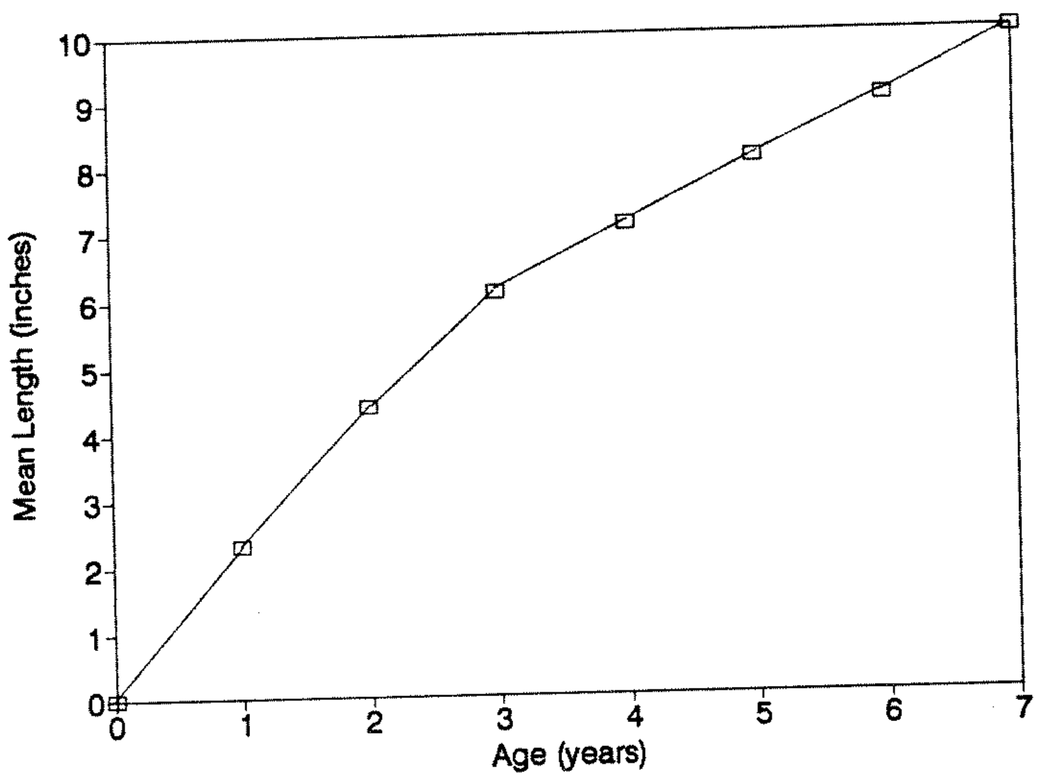
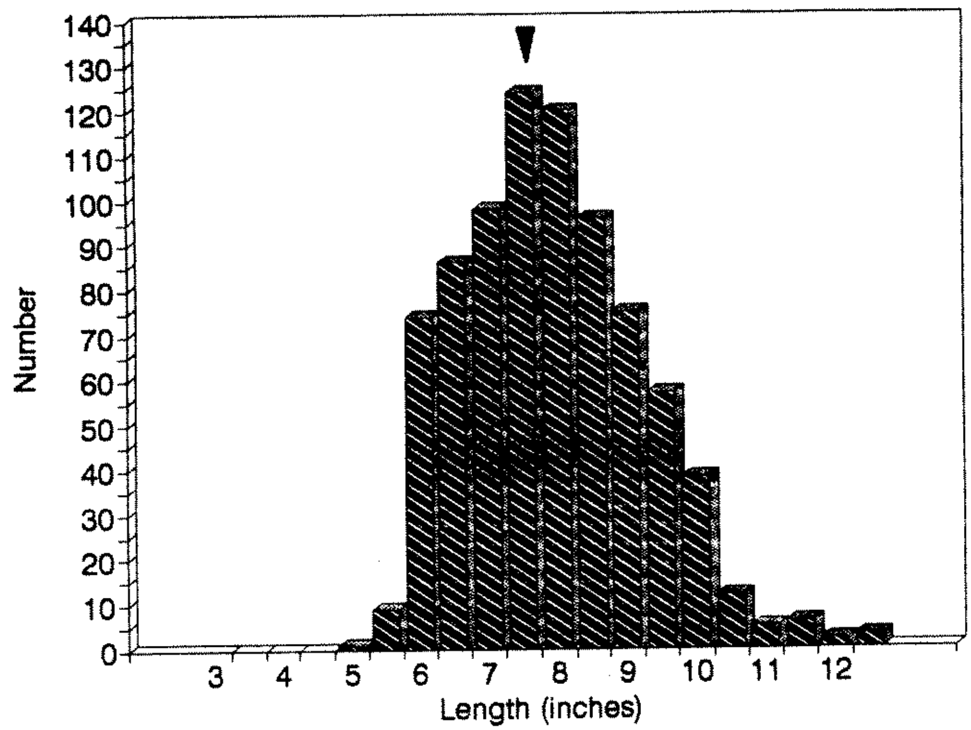


Figure 6. Length-frequency distribution of Canyon Ferry perch caught in gill nets, 1987-91. Arrow indicates average length. Total number sampled was 807 (from Lere 1991 unpub. data).



It also likely that larger perch would compete with walleye for prey fish. Bandow (1969) found that the diet of large (9-11 inch) perch in Canyon Ferry was comprised primarily of small fish, particularly young perch. In the face of high predation by walleye, young perch abundance would probably decline, thus reducing an 'energy-rich' prey source for larger perch and reducing their growth. A substantial decline in the number of larger, more fecund perch has been observed after the introduction of a top predator, resulting in lower reproductive output and lower recruitment of perch to larger sizes (Colby et al. 1987).

Another factor affecting perch vulnerability to walleye predation is the lack of a substantial prey refuge in Canyon Ferry. Stable predator-prey interactions require that prey have a particular behavior or morphological feature or have access to habitat that reduces predation risk; large numbers of efficient predators like walleye are otherwise able to nearly eliminate their prey (e.g., McMillan 1984; Colby et al. 1987). For littoral prey fishes like perch, association with vegetation or other cover can greatly reduce predation risk (Werner et al. 1983). For example, Swenson (1977) found five times greater perch densities in vegetation compared to substrates lacking cover in a lake containing walleye. The large reduction in the crappie population after the introduction of walleye into Boyd Reservoir, Colorado, was attributed to the lack of shoreline vegetation as cover for young crappie (Puttmann and Weber 1980). Canyon Ferry is generally lacking in rooted aquatic vegetation, and access to flooded vegetation and brush is reduced as water levels decline over the summer.

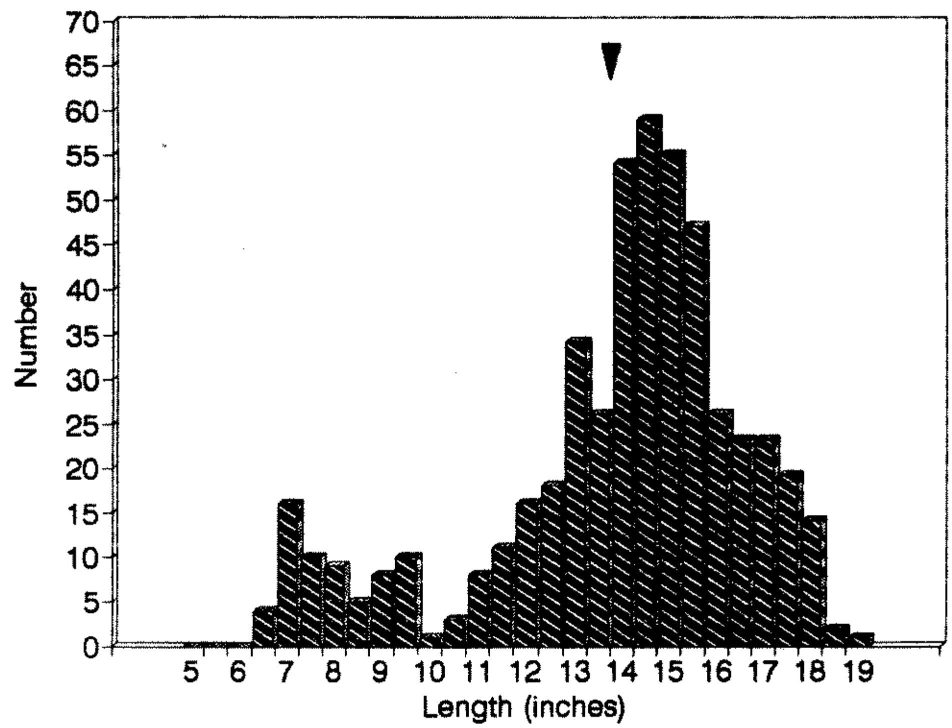
One alternative to the above scenario is that reproduction by a pool of large, invulnerable-sized perch would provide sufficient forage for a stable prey base for walleye (Forney 1980). Although this scenario is unlikely for reasons outlined above, if this were to occur it would be questionable whether large perch could also sustain a productive fishery.

Another question concerns why the walleye-perch interaction in Canyon Ferry would be unstable. At first glance this seems contradictory given that these two species are part of a 'coevolved trophic assemblage' in lakes in their native range, often coexisting at a high abundance of both species. Two factors likely account for this apparent contradiction. First, water level fluctuations in Canyon Ferry and other reservoirs often create less than favorable conditions for perch reproduction and recruitment, often resulting in rather wide fluctuations in their abundance from year to year. Furthermore, the lack of cover in reservoirs due to summer drawdown in water levels, makes perch highly vulnerable to nearly complete loss from walleye predation, particularly during years of poor reproductive success and/or low water levels. For example, minimal recruitment of perch into larger size classes was observed after sizable populations of walleye developed in Salmon Creek Falls Reservoir, Idaho (Partridge 1988) and Glendo Reservoir, Wyoming (Anon. 1990; Wichers 1991 pers.

comm.), even during years when young-of-the-year perch were abundant. In reservoirs, therefore, the combination of wide variations in prey fish abundance and a lack of adequate cover often results in walleye depleting their forage base.

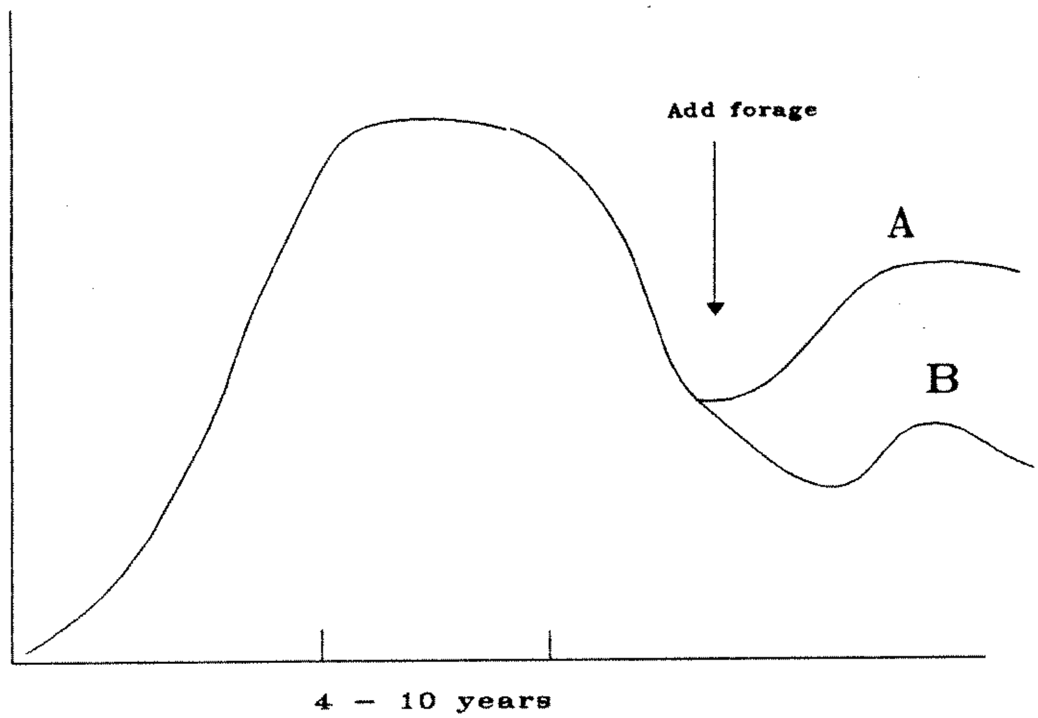
Finally, what about suckers and other rough fish as walleye forage? While suckers are usually of secondary importance as forage for walleye, walleye prey on young suckers to a significant degree when other forage is lacking (McMillan 1984). For example, in Cooney Reservoir, Montana, suckers less than 10 inches long declined from 42 to 9% of the total suckers caught in gill nets following introduction of walleye (Fredenberg and Poore 1987). Similarly, white suckers declined from an average of 51.5 to 27% of the total fish caught in gill nets in Tiber Reservoir, Montana, after walleye were introduced (Colby and Hunter 1989). While not a preferred forage, carp also can become an predominant part of the walleye diet when other forage is scarce (Wichers 1981; McMillan 1984). How constant a prey base suckers or carp would provide is questionable, however. As a general rule of thumb, walleye can feed on prey fish about half their size (Colby et al. 1979; McMillan 1984). But in Canyon Ferry, most white suckers are too large to be eaten by all but the largest walleye, as suckers average 13.7 inches in length with few less than 9 inches long (Figure 7). In both Seminoe and Tiber Reservoirs, heavy predation by walleye caused significant reductions in sucker populations to the degree that recruitment of small suckers was very low after a few years. Suckers that remained were larger, older individuals that were too large to be eaten by walleye. In both these situations the loss of an adequate forage base led to the introduction of supplemental forage in an attempt to increase survival and growth of walleye.

Figure 7. Length-frequency distribution of Canyon Ferry white sucker caught in gill nets, 1987-91. Arrow indicates average length. Total number sampled was 502 (from Lere 1991 unpub. data).



A probable sequence of walleye population growth over time after their introduction into Canyon Ferry is shown in Figure 8. This sequence was derived by David Bennett, professor of fisheries at the University of Idaho and an expert on reservoir fisheries management. Based on the response of walleye in similar systems, he speculated that walleye populations would expand rapidly to a high level within 4-10 years, with good fishing during this period. Given the questionable forage base present in Canyon Ferry, walleye would then start outstripping the food supply and fishing would decline. With declining sizes of walleye and increased angler dissatisfaction, the decision would have to be made to introduce additonal forage. From this point, two possible scenarios would develop. One (A) would be the development of a stable forage base and an increase in growth and survival of walleye. The other scenario (B) would be a brief pulse in the walleye population followed by a decline in recruitment after plankton became limiting from population expansion by the new forage fish.

Figure 8. Probable walleye population growth following their introduction into Canyon Ferry Reservoir (from Bennett 1991).



In summary, Canyon Ferry rates as good to excellent habitat for juvenile and adult walleye. Forage fishes are moderately abundant in the reservoir, but the ability of the forage base to sustain the significant biomass of walleye that is likely to develop is questionable.

c. Potential Population Size and Harvest

There is considerable variation in the size of the walleye populations that have developed in Montana reservoirs after their introduction. Holter Reservoir is an example of a low density population, with walleye generally comprising less than 5% of the total fish sampled in gill nets (Lere 1991). The other end of the spectrum is typified by Tiber Reservoir, where walleye are the dominant species, comprising 50-60% of the total fish population (Colby and Hunter 1989).

Based on the good to excellent habitat present, walleye population density would likely expand rapidly in Canyon Ferry after their introduction. Hence, population density and angler catch rates would likely compare to that observed at the 'high' end of the spectrum for Montana walleye fisheries as typified by Nelson and Tiber Reservoirs (Needham and Gilge 1985; Colby and Hunter 1989). Nelson Reservoir has angler catch rates of 0.27 walleye per hour and Tiber has walleye densities of about 5 fish per acre. Nationwide, harvest rates of 0.3 fish per hour are considered good walleye fisheries (Colby et al. 1987). In Wisconsin 'walleye country', the average density of walleye in 115 lakes with naturally reproducing populations was 4.8 fish per acre (Anon. 1991).

A regression model developed by Aggus and Morais (1979) was used to provide another estimate of potential walleye standing crop in Canyon Ferry. This model provides a rough approximation of expected walleye population abundance based on morphological and operational characteristics of reservoirs; biological characteristics such as adequacy of the forage base and species interactions are not incorporated. Walleye standing crop in 12 Midwestern reservoirs was found to be significantly correlated with reservoir storage ratio and the length of the growing season (number of frost-free days) by the equation: Standing crop of walleye (lbs/acre) = 227.7821 + 3.751 (storage ratio) - 100.9362 (log growing season). Plugging in values for these factors from Canyon Ferry (storage ratio = 0.53, growing season = 136 days, Thomas 1991) into the equation yielded an estimated standing crop of 14.4 lbs/acre. This would roughly correspond to a annual harvest of 4.3 lbs/acre, based on a typical angler exploitation rate for walleye of 30% (Colby et al. 1979; Needham and Gilge 1985). Colby and Hunter (1989) noted that a good walleye fishery yields about 1-4 lbs/acre/year.

Walleye are almost exclusively caught by boat anglers. Boat anglers in Nelson Reservoir, Montana, and Seminoe Reservoir, Wyoming, harvested 93% of all walleye caught (Needham and Gilge 1985; Peterson 1986).

IV. What are the Potential Interactions between Walleye and Existing Species in Canyon Ferry?

a. Risk of Transmission of Diseases and Parasites

Colby et al. (1979) found no reports of parasitic outbreaks causing significant mortalities among juveniles and adults in their substantive review of walleye life history. Walleye do not appear to harbor any unique parasites or diseases that would likely affect trout or other species in Canyon Ferry. Morever, it is likely that the yellow perch inhabiting Canyon Ferry harbor the same complement of diseases and parasites as do walleye since both species naturally co-exist in similar habitats. Proper handling of walleye eggs and fry in the hatchery before planting would further minimize the risk of disease transmission. In turn, there have been no reports of disease outbreaks in Canyon Ferry fishes that would adversely affect walleye.

b. Risk of Competition with Existing Species

It is likely that walleye would compete for forage with the other piscivores present in Canyon Ferry, namely, large yellow perch, brown trout, and burbot. Walleye populations can reduce growth and survival of other piscivores if their population becomes large enough to reduce the forage base (Colby et al. 1987), which is the expectation if they are introduced into Canyon Ferry. In Seminoe Reservoir, brown trout condition and abundance declined markedly after the expanding walleye population significantly reduced the abundance of forage, especially crayfish, the favored food of brown trout (McMillan 1984). As noted, intense competition between walleye and large perch for prey fish (young perch) would likely lead to reduced growth and recruitment to the perch population.

Another potential competitive bottleneck to consider is the early fry stage when walleye share the plankton food base with perch, trout, and other planktivorous fishes. In this case, walleye are at a competitive disadvantage if plankton availability is low since other fishes are more efficient at capturing zooplankton (Werner et al. 1983). However, plankton does not appear to be limiting in Canyon Ferry. As Thomas (1991) noted, nearby Hauser Reservoir supports a large population of planktivorous kokanee on a plankton base similar in density to Canyon Ferry's.

Spatial overlap of walleye and trout interactions can be minimal during summer in large, thermally stratified lakes due to different temperature (MacLean and Magnuson 1977). However, walleye and trout distribution would likely overlap to a great degree in Canyon Ferry given the lack of strong thermal stratification. Summer temperatures are generally favorable for both species in the open water and littoral areas of the reservoir. Rainbow trout are distributed throughout the upper 60-80 feet of the water column of Canyon Ferry during summer (Lere 1987). While trout and juvenile and adult walleye would not compete for forage in Canyon Ferry (Arlee, DeSmet, and Eagle Lake rainbow are all primarily planktivorous; Vincent 1991 pers. comm.), the lack of spatial segregation does increase the potential for predator-prey interactions (see walleye-trout interaction section below).

c. Risk of Predation on Existing Species

Walleye have broad preferences when it comes to eating prey fishes, generally preying on fishes in order of their relative abundance and availability in the environment (Colby et al. 1979; Knight et al. 1984). As noted, yellow perch, rainbow trout, and suckers would most likely form the major part of the walleye diet in Canyon

Ferry. Other forage fishes present would undoubtedly be utilized (e.g., Utah chub), but to a small degree due to their relatively low abundance.

The question of the adequacy of the forage base for supporting walleye was addressed in Section IIIb of this report. Corollary to this is the question of what effects walleye predation might have on existing sport fisheries. The effects of walleye predation on the trout and perch fisheries in Canyon Ferry are of particular interest and will be considered in detail in this section.

Walleye-trout interactions

As Colby and Hunter (1989) noted, reports of walleye preying on trout or salmon are not widespread in the literature. In their native range, lakes with both walleye and lake trout are relatively rare (Johnson et al. 1977). Moreover, where they are found together (large, deep, oligotrophic lakes), walleye predation on lake trout is generally minimal since walleye inhabit shallower, warmer bays and lake trout the colder, deeper, open water (MacLean and Magnuson 1977).

However, there is a growing body of information from western reservoirs where walleye have been introduced into situations traditionally managed as trout fisheries. The effects of walleye on existing trout fisheries run the gamut from major to minor impacts.

The best documented case of detrimental impacts of walleye predation on trout fisheries is from Seminoe Reservoir on the North Platte River system, Wyoming. Seminoe is a frequently cited case study since there is a well documented sequence of changes in fish populations for 30 years after walleye became established. The events at Seminoe are relevant to Canyon Ferry since the two reservoirs have a number of similar characteristics including size, trophic status, water transparency, temperature regime, and thermal stratification. The fish populations are roughly equivalent, although Seminoe lacks yellow perch (McMillan 1984). Like Canyon Ferry, Seminoe was managed as a productive put-grow-and-take rainbow trout fishery.

Table 6 summarizes the sequence of changes in Seminoe Reservoir fisheries following the introduction of walleye (see also Colby and Hunter 1989 for additional description). With the expansion of the walleye population, sharp reductions in the forage supply of native minnows and darters, crayfish, and suckers became evident. At the same time, predation on stocked rainbow fingerlings became severe enough to sharply curtail return of trout to the creel. As a result, various stocking strategies were implemented in an attempt to increase fingerling survival. Dispersed stocking of fingerlings was successful for a year or two, but the lack of alternate forage combined with a ever-growing walleye population made this success short-lived. Subsequently, walleye growth and condition declined, leading to the introduction of nonnative gizzard shad and emerald shiners to rebuild the forage base. The combination of an alternative forage base, decreased size of walleye, and the stocking of large, catchable trout (8-13.5 inches) that were relatively invulnerable to walleye predation, led to increased survival of trout plants. Today, Seminoe has an excellent trout fishery and a good fishery for small (12-16 inches) walleye. However, the costs associated with transporting and rearing larger trout are substantially greater (McMillan 1991). Additionally, the continuation of this combined fishery rests on the average size of walleye remaining less than 16 inches; larger sizes proportionally increase the size of stocked trout needed to avoid predation (McMillan 1984).

Table 6. Sequence of changes in walleye and trout populations, Seminoe Reservoir (from McMillan 1984; McMillan 1991).

Year	
1961	First appearance of walleye (WE).
1962-67	WE population small but expanding. No noticeable impact on forage supply. Diet of suckers, crayfish, native minnows, yoy carp, and darters. Annual stocking of 530,000 3-4 " rainbow trout (RBT).
1968	Continued expansion of WE population. Predation on stocked 3-4" fingerling RBT increases sharply. Diet now mostly small suckers and crayfish. Predation on small suckers results in shift to large, invulnerable sizes of suckers.
1973-75	Various stocking strategies implemented to increase survival of trout plants. Crayfish abundance declines sharply due to WE predation. Abundance (80% decline) and condition of brown trout follow suit due to prey shortage.
1976-77	Food supplies overrun. Sharp decline in WE growth and increase in cannibalism. Average length of WE decreases from 18" in 1973 to 13" in 1978; WE > 16" decline from 52 to 9% of adult population. Gains in RBT survival offset by WE population increase. Angler use declines.
1978	Gizzard shad added as WE forage.
1979	Trout of various sizes planted; only RBT > 13" survive to creel. Few WE > 18" in length.
1980	Emerald shiners planted as WE forage.
1984-90	Combined excellent trout and good fishery for small (12-16") WE after forage fish introduction and stocking of large catchable trout. WE 24% of angler harvest. Catch of 0.02-0.15 per hour for WE, 0.3 for RBT. Stocked RBT (200,000) provide 12.7% return to creel. Optimum trout stocking size 13.5".

The pattern of changes after walleye introduction shown in Table 6 has been repeated in a number of other cases. In Wyoming, heavy predation from introduced walleye led to stocking of larger trout or elimination of the trout fishery together in Pathfinder (McMillan 1984), Keyhole (Wichers 1981, 1986), Alcova (Anon. 1990), and Glendo Reservoirs (Anon. 1984, 1990). It is important to note that good populations of forage fishes existed in these reservoirs prior to the introduction of walleye. However, the forage base was not able to sustain heavy predation pressure in the presence of a large, self-sustaining walleye population. There was a series of prey depletions in each case, culminating in reduced walleye numbers, size, and condition (Table 6). Subsequently, additional forage species such as gizzard shad or spottail or emerald shiners were then introduced to bolster highly depleted prey fish populations.

Analyses of walleye stomachs reveal that walleye rapidly switch to trout fingerlings soon after stocking. In Glendo Reservoir, walleye switched from perch to rainbow trout when the choice was available (Anon.1984). In Seminoe Reservoir, McMillan (1984) found that most of the walleye predation on trout occured within the first few weeks after stocking. Several characteristics of planted trout make them susceptible to walleye predation. First, walleye prefer soft-rayed, fusiform species such as trout as prey when available (references in Conover 1986). Second, planted trout are especially susceptible given the normal practice of stocking large numbers of fingerling trout in the spring when walleye are feeding heavily. In addition, hatchery fish often lack well-developed predator avoidance behaviors (Olla and Davis 1989). In Seminoe, some early success was achieved in buffering predation on trout plants once an abundant, alternate prey species (shad) had become established (McMillan 1984). However, only stocking of large fish has been successful at maintaining the trout fishery over the longer term.

In Salmon Falls Creek Reservoir, Idaho, a mixed rainbow trout (30% of catch of game fish in gill nets) and walleye fishery (60% of catch) is maintained by stocking catchable trout of 10+ inches (Partridge 1988). Teeth marks on many of the trout point to the considerable predation pressure by walleye. Partridge (1991 pers. comm.) concluded that "you really have to work at it to maintain a trout fishery in the presence of (a significant population of) walleye."

In Boyd Reservoir, Colorado, walleye virtually eliminated the crappie fishery after their introduction in the 1970s (Puttmann and Weber 1980; Colby et al. 1987). Plants of large, broodstock rainbow now support a mixed walleye and trout fishery in the reservoir (Bergerson 1991 pers. comm.).

Detrimental impacts of walleye on existing trout or salmon populations have not been observed in all cases, however. In John Day Reservoir on the Columbia River, walleye consumption of migrating salmonid smolts is less significant than that by other predators in the system such as northern squawfish. Juvenile salmonids are the fourth most important food item in John Day, comprising 14% of the diet compared to suckers (40%), sand roller (17%), and sculpins (16%) (Beamesderfer and Nigro 1989). In Montana, walleye have had a minimal impact to date on trout fisheries in Bighorn, Hauser, Holter, and Dailey Reservoirs (Shepard 1991).

A common thread among all the reservoirs where walleye have had a minor impact on trout or salmon is the presence of a low density walleye population and an abundant, reliable supply of other small forage fish. Limited spawning habitat or high flushing rates in these systems keep densities low. Densities of walleye in John Day Reservoir, for example, average 0.4 fish per acre, with angler catch rates of 0.05 fish per hour. In Holter and Hauser Reservoirs, walleye comprise less than 3% of the total fish population (Lere 1991). By contrast, the situations where walleye have caused detrimental impacts on trout fisheries are all characterized by favorable environmental and forage conditions (over the short term), which have resulted in the development of a large, self sustaining population of walleye.

There is a lack of information on impacts of walleye introduction on wild- as opposed to planted- trout fisheries. Lake McConaughy, Nebraska, offers the only documented example analagous to the situation in Canyon Ferry. There, predation by a sizable, self sustaining walleye population has had a major impact on planted trout but a relatively minor effect on wild rainbow trout (Ellison 1991). Very poor returns from plants of catchable sized trout (7-12 inches) due to heavy predation by walleye and striped bass led to cessation of hatchery plants in the 1980s. The wild rainbow fishery has not been as affected since wild fish spawn and rear in tributary streams for a year, enter the reservoir in the early spring at a size of 8 inches, and quickly grow beyond the size vulnerable to predation by early June.

Wild trout in Canyon Ferry presently do not have the benefit of this predator refuge, however. Dewatering of tributary streams in the summer limits their use as rearing areas for trout fry. Rather, most brown and rainbow trout fry emigrate from natal streams soon after emergence (late April-early June for brown trout and late June through July for rainbow trout) at a size of about 1-2 inches (Lere 1990, 1991). Walleye appetites are especially strong during this post-spawning period. Alternate forage is often scarce at this time, too, since young-of-the-year perch have not yet grown large enough to be suitable prey for walleye adults (Ney and Orth 1986). These two factors would undoubtedly make wild trout fry and fingerlings in Canyon Ferry highly susceptible to predation by walleye.

Walleye-perch interactions

In Section IIIb it was concluded that given the age and size structure of the perch population, the lack of a prey refuge, and fluctuating environmental conditions, it is likely that walleye predation would reduce the numbers of fishable-size perch in Canyon Ferry. Sharp declines in perch fisheries have been reported in a number of western reservoirs following the development of a large, self-sustaining walleye population.

Tiber Reservoir, Montana, supported a yellow perch-trout fishery in the 1960s. During this period, perch were the most abundant game fish, comprising 59-78% of the total catch in gill net surveys of the reservoir. After establishment of walleye and pike populations in the early 1970s, perch became a relatively minor component of the fish population. In the 1976-78 period, perch abundance declined to a low of 4.2-9.7% of the gillnet catch, whereas walleye increased to 52.3-66.9%, and pike 9.7-17.2% (Colby and Hunter 1989). More recent surveys reveal that perch are still an important part of the walleye diet, but the abundance of young perch fluctuates widely from year to year dependent on reservoir water levels, and few large perch are now reported in the fishery (Hill and Wipperman 1985).

This reversal in perch-walleye abundance over time has also been observed in other western reservoirs. In Salmon Creek Falls Reservoir, Idaho, perch made up 80%, and walleye less than 1%, of the total numbers of game fish caught in gill nets in 1975, shortly after the introduction of walleye (Partridge 1988). Perch numbers declined as walleye numbers increased, and by 1987, perch made up only 8% of the game fish compared to 60% for walleye. State record walleye were caught here in the 1980s, but numbers and maximum sizes have since declined and repeated forage introductions have been made in an attempt to reduce the problem of limited forage. Larger perch have essentially disappeared from the fishery, despite some years of good perch reproduction (Partridge 1991 pers. comm.). A similar situation has been reported for Keyhole Resevoir, Wyoming, where walleye predation limited survival of perch beyond two years of age (Wichers 1981, 1986).

As mentioned, the fishery for crappie- a species similar in habitat and food habits of yellow perch- was rapidly reduced following the introduction of walleye into Boyd Reservoir, Colorado. Good angler harvests of walleye compensated for the reduced crappie harvest for a few years. But, the combined catch for walleye and crappie then declined by more than half, leading to a significant reduction in recreational hours (Puttmann and Weber 1980). A similar pattern was noted in Sanchez Reservoir, Colorado, where an excellent perch fishery was virtually eliminated following the introduction of walleye (Bergerson 1991 pers. comm.).

The history of the sport fishery at Glendo Reservoir, Wyoming, further illustrates the difficulty of sustaining a mixed walleye-perch fishery in fluctuating reservoirs. Walleye were introduced into the 12,365 acre reservoir following chemical treatment in 1972 to control an overpopulated, stunted perch population (Anon. 1984; McMillan 1984). By 1981, an excellent fishery for both perch and walleye had developed. Of the 72,926 fish harvested that year, 62% (44,272) were yellow perch and 29% were (21,000) were walleye, with angler catch rates for the respective species of 0.32 and 0.15 per hour. The success of this fishery was short-lived, however. Over the past decade, the number of perch has declined steadily to less than 3% of that caught in gillnets in the 1977-81 period (Table 7). Perch reproduction is variable, yet still substantial in some years, but there is a lack of recruitment to larger size classes (Anon. 1990). The flooding of shoreline vegetation in the spring by rising water levels provides favorable conditions for successful perch reproduction in most years, but drawdown in the summer months leaves young perch highly vulnerable to walleye predation. As a result, the large 9-11 inch perch that were abundant during the peak fishing years are virtually absent and the perch fishery has collapsed (Wichers 1991 pers. comm.). The size and condition of the walleye population in Glendo mirrored the decline in the perch forage base (Table 7), necessitating the introduction of shad and shiners as additional forage species (Anon. 1990).

Table 7. Catch of perch and walleye in gillnets, Glendo Reservoir, 1977-90. Expressed as number of fish per net-hour (from Anon. 1984, 1990).

	Perch	Walleye
1977	7.8	5.6
1980	9.2	3.7
1981	7.9	6.3
1987	5.5	3.3
1988	2.8	3.4
1989	0.2	0.9
1990	0.2	1.7

Unlike natural lakes where fishing is often good for both walleye and perch (e.g., Forney 1980), there are relatively few examples in western reservoirs where stable, productive fisheries exist for both species. As is the case with trout fisheries, impacts of walleye on a perch fishery are likely to be minor in reservoirs where walleye density remains relatively small. An example of this is Holter Reservoir, which supports a stable, mixed fishery for perch, trout, and walleye (see Section IIc). Two features of natural lakes that support high quality fisheries for both walleye and perch- and which are often absent in western reservoirs- are a productive, vegetated littoral zone that provides food and cover for perch populations, and a diverse prey base that can serve to buffer heavy predation on any single prey species (MacLean and Magnuson 1977; Forney 1980; Lyons and Magnuson 1987).

In summary, a diverse body of evidence from a number of western reservoirs strongly suggests that it is unlikely that a productive yellow perch and wild or put-grow-and-take trout fishery could be maintained in Canyon Ferry in the presence of heavy walleye predation. Fishing would likely be good for all three species for several years after walleye were introduced, but the ability to sustain a productive fishery is highly questionable once the walleye population becomes large. A mixed walleye and trout fishery could be maintained by stocking large (8-13 inch) hatchery rainbows, but at significantly greater cost. Over the long term, depletion of the forage base, and associated declines in walleye growth and reproduction, would likely occur, necessitating a decision on whether to introduce additional prey species as forage for walleye.

V. What are the Potential Effects of Walleye on Fish Populations in Adjacent Waters?

Walleye are highly migratory and would be expected to extend their range into waters upstream and downstream from Canyon Ferry. In the North Platte River system, walleye extended their range throughout seven reservoirs and over 270 miles within 10 years after their discovery in Seminoe Reservoir (McMillan 1984). Similarly, walleye have now expanded their range over much of the Columbia River below Lake Roosevelt (Nigro 1991). Movement of walleye above Canyon Ferry would be limited to the 23-mile stretch of the Missouri River below Toston Dam. There are no known barriers to downstream movement to Hauser and Holter Reservoirs and beyond.

a. Risks to Threatened or Endangered Species

There are no known federally listed threatened or endangered species or state listed fish species of special concern in Canyon Ferry or adjacent waters that could potentially be affected by the introduction of walleye.

b. Risks to Upstream Fish Populations

The Missouri River between Canyon Ferry and Toston Dam supports a brown trout fishery during the fall spawning run (Rehwinkel 1986). Although the life history and habitat use of the trout in this area is not well known, the large size and condition of spawners and the relatively low density of young trout in the river, suggests that Canyon Ferry is the major rearing area for brown trout (Rehwinkel 1986; Spoon 1991 pers. comm.).

The tailwaters below Toston Dam would very likely be used by walleye for spawning (see Section IIIa). McMillan (1984) and Wichers (1991 pers. comm.) reported that large numbers of walleye moved into the North Platte River above Seminoe and Pathfinder Reservoirs in the spring when water temperatures warmed above 40 F. Most of the walleye moved downstream after spawning but a considerable portion remained in the river throughout the summer in deep pools, moving back down to the reservoir in the fall when temperatures declined to 50-55 F.

Spring and summer temperatures in the Missouri River at Toston Dam appear favorable for walleye. Water temperatures warm to > 40 F in early April, and summer temperatures are in the preferred range for walleye (70-72 F); temperatures fall to 50-55 F in mid- to late-September (Rehwinkel 1986). There also appears to be good walleye habitat in the 10-mile section of the river above Canyon Ferry. This low gradient, braided section has the slow current and deep (3-10 feet) pools (Spoon 1991 pers. comm.) characteristic of 'classic' walleye rivers (Kitchell et al. 1977; McMahon et al. 1984).

There is very little information on walleye-trout interactions in river systems. The blue ribbon rainbow and brown trout fishery in the rivers above Seminoe and Pathfinder Reservoirs declined after walleye were introduced, but the exact causes of this decline are unknown (Wichers 1991 pers. comm.). Significant walleye densities in the North Platte have been observed during summer surveys- up to 113-220 walleye per mile or 20% of the total game fish (Anon. 1988). Walleye predation on trout is thought to be significant in some sections, but the extent and overall effect of this is unknown.

Competition and predation by walleye on brown trout would likely have a negative impact on the brown trout fishery. As noted (Section IVb and c), brown trout numbers and growth would likely decrease when walleye numbers became large enough to reduce the forage base of prey fishes in Canyon Ferry. The probable use by walleye of the deep pools in the river would also facilitate predation on brown trout fry as they migrate downstream to the reservoir in the late spring. The combination of these two factors would likely further depress an already low brown trout population. Brown trout numbers in the Missouri River below Toston Dam are currently considerably less than that reported in the early 1980s probably as a result of the recent drought (Spoon 1991 pers. comm.).

c. Risks to Downstream Fish Populations

Hauser Reservoir supports a mixed kokanee, rainbow trout, perch, and limited walleye fishery, while Holter Reservoir supports a mixed perch, rainbow trout, and limited walleye fishery. Thirty-nine miles of the free-flowing Missouri River above and below Hauser and Holter Reservoirs are designated as blue ribbon trout streams.

Walleye have been present in both Hauser and Holter Reservoirs for a number of years. The populations are self sustaining, but densities are low, especially in Hauser, where supplemental stocking of fry has taken place since 1989. There has been no apparent impact of walleye on other sport fishes in either reservoir. Food and spawning habitat is abundant in both reservoirs, but low water retention times appear to limit recruitment of walleye beyond the fry stage. Also, the low densities of walleye combined with good densities of perch probably serve as a buffer to reduce predation on rainbow trout and kokanee (Lere 1991 pers. comm.).

Downstream movement of walleye during periods of surface spills over Canyon Ferry Dam would undoubtedly increase the abundance of walleye in Hauser and Holter. Although fry are most susceptible to downstream displacement, direct losses of juvenile and adult walleye have also been observed during periods of high reservoir water releases (McMillan 1984; Willis and Stephen 1987). It is these latter losses that have the most potential to impact downstream fish populations in Hauser and Holter. Willis and Stephen (1987) found that planting of walleyes larger than those typically stocked increased the population density of walleye in Kansas reservoirs with low water retention times. In Alcova Reservoir, Wyoming, invasion of walleye from upstream Seminoe and Pathfinder Reservoirs has been significant enough to necessitate the planting of larger trout to circumvent heavy walleye predation, despite a lack of natural reproduction of walleye in the reservoir (Anon. 1988). Invasion of large numbers of juvenile and adult walleye from Canyon Ferry could thus pose a risk to downstream trout and perch fisheries in Hauser and Holter. The probable response of kokanee to walleye is difficult to evaluate due to the lack of published reports on walleye-kokanee interactions. Introductions of other predators to control kokanee populations have met with varied success (Thomas 1991).

Walleye are currently found in low numbers in the few, scattered deep pools that exist in the blue ribbon section of the Missouri River below Holter Dam (Liknes 1991 pers. comm.). These fish presumably are progeny of walleye from Holter Reservoir. Significant numbers of juvenile walleye have been observed on occasion in the river below Holter Dam, but there has been no corresponding increase in abundance of larger walleye in the river (Leathe 1991 pers. comm., Lere 1991 pers. comm.).

VI. Conclusions

a. Potential for Reproduction

1. Conditions are highly favorable for development of a self-sustaining walleye population in Canyon Ferry Reservoir. High quality spawning habitat is available along the western shore and near the dam, in the tailwaters below Toston Dam and, to a lesser extent, in tributaries to Canyon Ferry and the upper Missouri River.

2. Spawning of walleye would likely occur during the last two weeks of April. Entry of fry into the reservoir would occur at the end of May. The timing of entry would synchronize well with the timing of the Canyon Ferry plankton bloom.

3. Losses of walleye fry are likely to be substantial during years of surface water releases from Canyon Ferry. Surface water releases and variable spring weather are likely to contribute to wide fluctuations in annual walleye reproductive success.

4. The introduction of sterile walleye into Canyon Ferry is an attractive, but infeasible, option at this time. This may provide an important walleye management option in the future.

5. Canyon Ferry does not provide favorable conditions for the introduction of hybrid (nonsterile) saugeye.

b. Suitability of Canyon Ferry as Habitat for Juvenile and Adult Walleye

1. Canyon Ferry would provide good to excellent habitat for juvenile and adult walleye.

2. Forage fishes appear moderately abundant in Canyon Ferry, but the ability of the forage base to sustain a sizable walleye population is doubtful.

3. Yellow perch, suckers, and trout would provide most of the forage base for walleye in Canyon Ferry.

4. Perch would provide an unstable prey base for walleye. Wide fluctuations in perch availability would be expected given variable spring weather and reservoir water levels. Slow growth rates and the lack of brush and rooted aquatic vegetation as cover would make perch highly vulnerable to walleye predation.

5. Most suckers in Canyon Ferry are too large to be eaten by walleye. Heavy predation on small suckers would probably cause a further shift in the sucker

population to larger, invulnerable-sized individuals within a few years after the introduction of walleye.

c. Potential Harvest

1. Walleye population growth and angling success would likely be a 'boom and bust' situation as the walleye population first expanded rapidly then outstripped the forage base. Angling success during the 'boom' years is likely to be good- perhaps in the range of 0.3 fish per hour. It is anticipated that the sizes and numbers of walleye harvested would decline markedly as forage becomes limiting.

2. Fishing for walleye will be almost exclusively a boat fishery.

d. Potential interactions with other species

Transmission of diseases and parasites

1. There seems to be minimal risk of transmission of diseases and parasites to existing species in Canyon Ferry from walleye introduction given proper handling of walleye fry in the hatchery.

Competition

1. Walleye will likely reduce growth of other piscivores, namely large yellow perch and brown trout, as their populations become large enough to deplete the forage fish.

2. Plankton densities in Canyon Ferry appear high enough to limit competition for plankton between walleye fry and perch, rainbow trout, and other planktivorous

fishes in Canyon Ferry.

3. A high degree of spatial overlap between walleye and trout is expected given the lack of thermal stratification in Canyon Ferry during the summer months.

Predation

1. Walleye are unlikely to be compatible with maintenance of a productive yellow perch and wild or put-grow-and-take trout fishery in Canyon Ferry.

2. The size of wild and stocked fingerling trout make them highly vulnerable to walleye predation.

3. A mixed walleye-trout fishery could be established by stocking large (8-13 inch) hatchery trout, but at significantly greater cost.

4. Unlike natural lakes, a mixed walleye-perch fisheries would likely be difficult to sustain in a fluctuating reservoir like Canyon Ferry. Fishing for perch and walleye would likely be very good for a few years after the introduction of walleye. Over time, walleye predation would sharply reduce the numbers of large perch desired by anglers.

5. Introduction of additional forage would likely be necessary to sustain good walleye growth and survival following the anticipated depletion of the forage base.

e. Potential Impacts on Fish Populations in Adjacent Waters

1. Walleye would be expected to extend their range into waters upstream and downstream from Canyon Ferry.

2. There are no federally listed threatened or endangered species of state listed species of special concern that could potentially be affected by the introduction of walleye into Canyon Ferry.

3. The tailwaters below Toston Dam and the deep pools in the Missouri River above Canyon Ferry are favorable habitat for spawning and rearing of walleye.

4. Competition for food with brown trout in the reservoir, and predation on brown trout fry and fingerlings in the Missouri River and the reservoir, would likely have a negative impact on the trophy brown trout fishery in the Missouri River above Canyon Ferry. The combination of these factors would probably further depress an already low brown trout population.

5. Substantial downstream movement of walleye would be expected during years of water release over the Canyon Ferry Dam. Invasion of large numbers of juvenile and adult into Hauser and Holter Reservoir could pose a risk to existing kokanee, trout, and perch fisheries. Risks to trout in the blue ribbon section of the Missouri River below Holter Dam appear low given the apparent low suitability of habitat for walleye.

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