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# CANYON FERRY RESERVOIR RISK ASSESSMENT: THE POTENTIAL IMPACTS OF INTRODUCTION OF FIVE NON-NATIVE SPECIES

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January, 1992

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*INTRODUCTION*

This review was commissioned by the Montana Department of Fish, Wildlife, and Parks to determine the potential impacts of introducing one of five new fish species into Canyon Ferry Reservoir. Considerable interest has been expressed by the angling public for a new fish species in Canyon Ferry to broaden fishing opportunities in that water. The purpose of this review is to evaluate five candidate species to determine if they would be likely to thrive in the environment of Canyon Ferry, if they would naturally reproduce, and what the risks of introduction would be to the existing species in Canyon Ferry and the downstream waters.

The five species reviewed in this report are: smallmouth bass, largemouth bass, northern pike, chinook salmon, and kokanee. The assumption is made that a maximum of one new species would be selected for introduction. Therefore, no analysis of the potential interactions between the five species has been undertaken.

The report includes a summary of the habitat characteristics found in Canyon Ferry Reservoir and the Missouri River between Toston Dam and Canyon Ferry. It also includes a summary of the life history of each candidate species, the characteristics of the sport fishery in other waters, a literature review on species interactions, and a summary of the potential outcome of introduction into Canyon Ferry.

*THE HABITAT CHARACTERISTICS OF CANYON FERRY AND THE SURROUNDING WATERS*

Canyon Ferry Dam is the first in a chain of three dams located on the upper Missouri River. Construction of the dam was completed in 1954 and the reservoir filled for the first time in 1955. The reservoir has a surface area of 35,200 acres and is about 25 miles in length and from 1.0 to 4.5 miles wide. The average depth of the reservoir is 58 feet, with a maximum depth of 160 feet near the dam. The usable capacity of Canyon Ferry Reservoir is 2,043,000 acre feet and dead storage capacity is 8,600 acre feet for a total storage of 2,219,000 acre feet. The penstock depth is at 91 ft at full pool and the river outlet depth is at 150 feet at full pool (U.S.G.S. 1989). The storage ratio (reservoir water volume divided by ave. annual water release) is approximately 0.53.

Temperature regime

Canyon Ferry Reservoir is at an elevation of 3,800.00 feet at full pool. The average July temperature is 66.8 F, based on 51 years of record (NOAA 1988). The number of frost free days is shown in Table 1.

Table 1: Number of days between frosts (NOAA 1988)

| Year | @ Dam | Townsend |
|---|---|---|
| 1973 | 111 | 114 |
| 1974 | 138 | 102 |
| 1975 | 127 | 117 |
| 1976 | 158 | 114 |
| 1977 | 118 | 103 |
| 1978 | 114 | 113 |
| 1979 | 126 | 115 |
| 1980 | 134 | 132 |
| 1981 | 149 | 140 |
| 1982 | 130 | 103 |
| 1983 | 128 | 114 |
| 1984 | 125 | 96 |
| 1985 | 138 | 86 |
| 1986 | 133 | 122 |
| 1987 | 173 | 106 |
| 1988 | 168 | 116 |
| Ave | 136 | 112 |

Data collected by Lere is summarized in Figure 1, showing mean surface water temperatures at three stations in Canyon Ferry in 1990. Water temperatures warm to 59°F around June 15, peak at about 73°F in August and have cooled to below 50°F by late October. Water in the upper reservoir (Silos station) tend to remain mixed during the sampling period due to shallow depths and exposure to wind action. In mid-reservoir (White Earth station), water tends to form a weak thermal structure beginning in May and ending in August. Thermoclines in mid-reservoir usually occur at depths ranging from 35 to 50 feet. Water in the lower reservoir (Cemetery station) tends to form a weak thermal structure from July through August at depths ranging from 50 to 60 feet (Lere 1991).

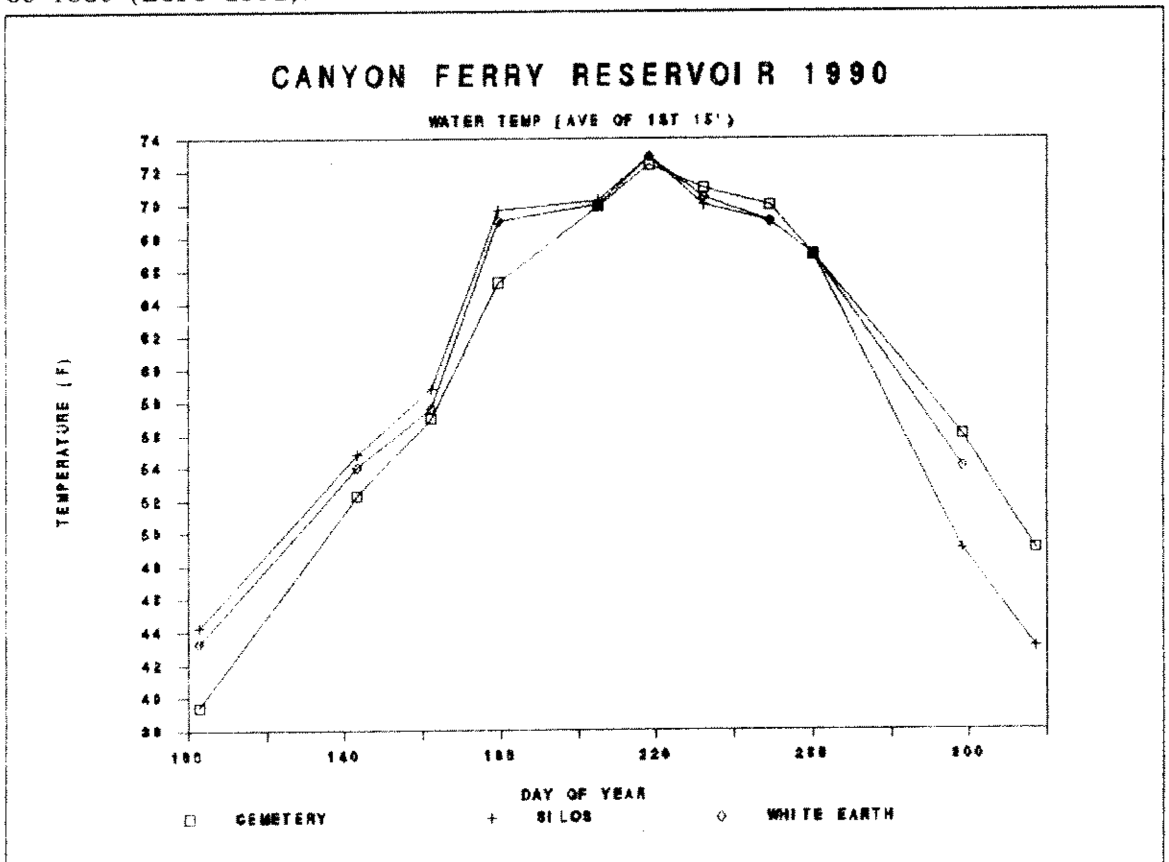



Figure 1 Surface water temperatures of Canyon Ferry Reservoir collected at three stations in 1990 (Lere 1991).

Water temperatures in the Missouri River at Toston Dam are presented in Figure 2. March water temperatures average about 39° F, warm to an average of 60° F in June, peak at an average of 67 - 68° F in July and August, and then begin cooling again. Figures located in Appendix A show the amount of year-to-year variation in monthly water temperatures over the last 10 years.

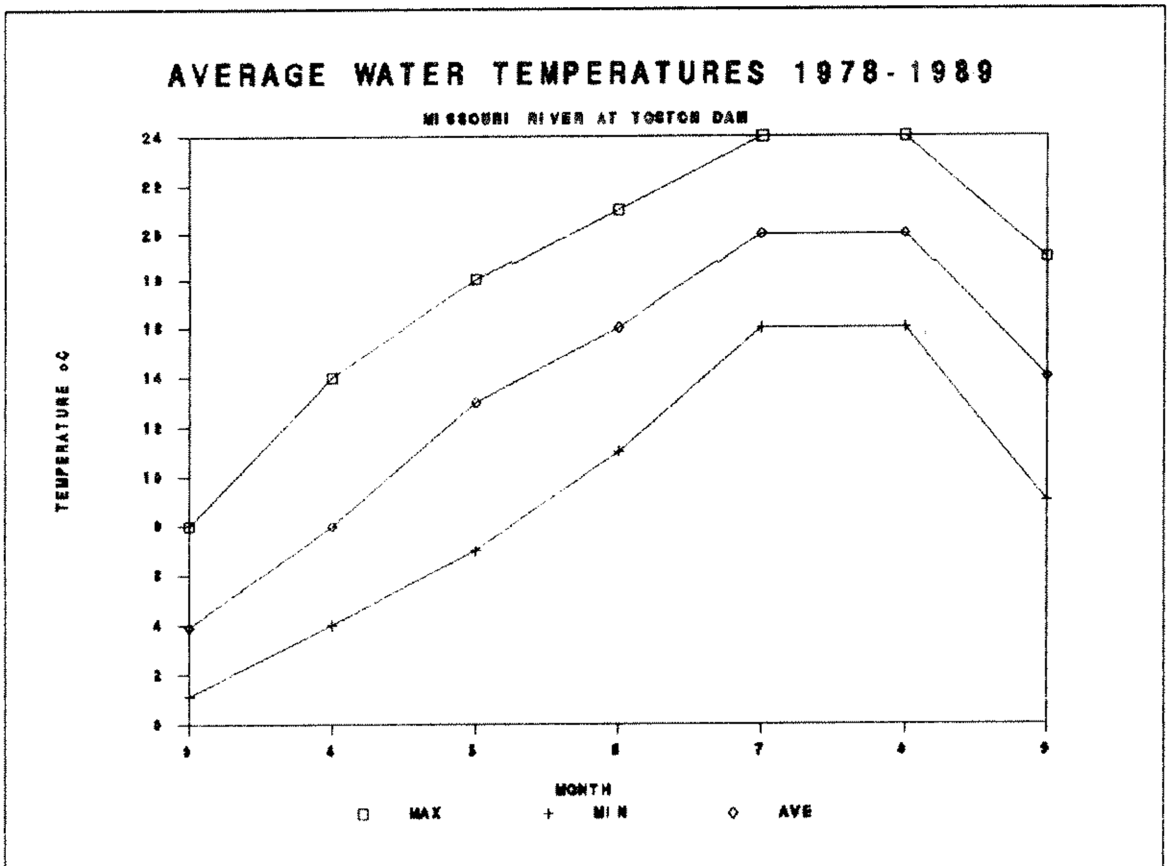



Figure 2 Maximum, minimum, and average water temperatures in the Missouri River at Toston Dam (USGS 1989).

## Flow regime, filling pattern

The Missouri River upstream of Canyon Ferry Reservoir has an average annual flow of 5,400 cfs (USGS 1989). The flow regime of the Missouri is typical of rivers in this region in that peak runoff usually occurs in May and June, with flows decreasing throughout the summer. The lowest flows typically occur in late summer when the river is drawn down for irrigation and in mid-winter when flows are naturally low. The highest flow ever recorded on the Missouri River at Toston is 32,000 cfs which occurred June 6, 1948. The lowest flow ever recorded was 450 cfs which occurred on July 31, 1989 and was the result of regulation i.e. diversion of water from the river.

Flows into Canyon Ferry are influenced by Toston Dam, 23 miles upstream from the reservoir. There are no barriers to fish movement between Toston Dam and Canyon Ferry Reservoir.

Based on the last 10 years of record, Canyon Ferry Reservoir is typically drawn down to it's minimum level in March, and then is refilled during the March - June period. The annual drawdown over the last 10 years has averaged 12 feet.

### Water chemistry

Summertime turbidity in the Missouri River at Toston averaged 11.34 NTUs during the 1980's. The maximum turbidity recorded by the USGS was 60 NTUs on May 5, 1981. Typical late summer turbidity readings are 2 - 5 NTUs.

Dissolved oxygen in the Missouri River at Toston rarely falls below 8.0 mg/l and 90% saturation. The average minimum DO (based on 9 years of record) is 8.7 mg/l. The Ph of the Missouri River at Toston ranges from 7.6 - 8.7, with the average pH being 8.17.

Summertime turbidity in Canyon Ferry Reservoir ranges from 4.0 - 100.0 (% trans.), with an average of 85.1, based on USEPA data collected in 1975. The pH levels in Canyon Ferry vary between 7.2 and 8.6, with the average being 8.1.

Dissolved oxygen in Canyon Ferry, measured near the dam, ranges from 0.6 mg/l to 11.6 mg/l, with an average of 7.6 mg/l. The percent saturation ranges from 5.3% to 100.0%. DO levels typically vary with depth, with surface waters being more oxygenated. Canyon Ferry is no exception, with lowest DO readings coming from a depth of 145 feet. The minimum DO at 27 feet (the approximate depth of the thermocline) was 4.0 mg/l, 39.2% saturation. During 1975, the minimum DO recorded in the surface water was 8.2 mg/l, 74.3% saturation.

## *SMALLMOUTH BASS*

### Review of life history of smallmouth bass

The smallmouth bass is native to the eastern and central United States and Canada. The species has been introduced across the United States and much of the world. Smallmouth are not native to Montana. The first known introduction occurred in Horseshoe Lake (near Bigfork) in 1914 (Brown 1971). Smallmouth bass are currently distributed in a variety of coolwater habitats across Montana, including Noxon Reservoir in western Montana and the Tongue River in southeastern Montana. The smallmouth is divided into two subspecies, the northern smallmouth Micropterus d. dolomieui and the Neosho smallmouth Micropterus d. velox (Hubbs and Bailey 1940). It is the northern smallmouth that is reviewed in this report.

Smallmouth bass are not currently known to exist in Canyon Ferry Reservoir.

#### Age and growth.

Smallmouth are generally a long lived species. Individuals to 15 years old have been reported (Scott and Crossman 1973). Smallmouths seem to live longer in the Pacific northwest than the mid-west, with a 13 year old smallmouth reported from the Snake River, Washington (Bennett et al 1983).

The approximate average size of smallmouth bass in Montana for each year of life is as follows: 1 year - 3 inches, 2 years - 6 inches, 3 years - 8.5 inches, 4 years - 10 inches, 5 years - 11 inches, 6 years - 12 inches, 10 years - 14 inches. It takes about 4 years for smallmouth to reach sexual maturity (Brown 1971).

**Spawning habits**

Smallmouth bass spawn mostly in May and June in Montana, with the timing closely linked to water temperature. Most spawning has been reported to occur at temperatures above 59° F. Some upstream spawning movement has been observed but this is apparently not mandatory. In the lower reaches of the Bighorn River, Montana there is evidence that smallmouth bass are migrating 2 - 3 miles upstream into very small tributary streams for spawning, in addition to spawning in the main river (Vaughn pers. comm. 1992). Nests are constructed by the male which fans out a shallow depression in sand, clean stone, or fine gravel, at depths of 1 - 21 feet, generally adjacent to a boulder or fallen log. The nest is defended by the male until the young disperse (Brown 1971, Bennett and Bennett 1991). Embryos incubate in 4 days at 59 - 65oF. Postlarval fish require about 8-11 days after hatching to swim-up from the nest (Turner and MacCrimmon 1970).

Nests are usually located in areas of slow current or current protected areas in streams, rivers, ponds, lakes, or reservoirs (Robbins and MacCrimmon 1974). Simonson and Swenson (1990) found that 80% of the smallmouth bass nest sites in the St. Croix River, Wisconsin were in sites characterized by large upstream obstructions that reduced current velocity near the nests. The rest of the nests were in pools.

**Food habits**

Food of young smallmouth bass is typically zooplankton, followed by insects, fish and crayfish. Adult smallmouth bass are highly dependent on larger food items, primarily fish and crayfish (Bennett and Bennett 1991).

In the Tongue River, Montana, smallmouth bass feed on small shorthead redhorse, flathead chubs, and stonecats. In the Tongue River Reservoir, older smallmouth bass feed on young perch, crappie, and other fishes (Clancy 1980).

In John Day Reservoir, Oregon, crustaceans were the most important food of smallmouth bass 2 - 4 inches long. The importance of crayfish decreased as predator size increased, with fish > 4 inches switching to fish as a major dietary component. Prickly sculpin were the most important prey of fish 9.8 - 15.7 inches long. Suckers were the most important food of smallmouth bass greater than 15.7 inches. Salmonids contributed 2 - 5% of the diet (Poe et al 1991).

In waters where there is an inadequate forage base the growth of smallmouth bass is depressed. Slow growth may result in low overwinter survival. For example, Bennett and Dunsmoor (1986) found that smallmouth bass in Brownlee Reservoir, Idaho fed primarily on Daphnia. Even bass over 7.9 inches were consuming large amounts of zooplankton on a seasonal basis.

Usually smallmouth bass switch to fish and crayfish by the time they are 2 - 2.4 inches. The result of the inadequate forage base was poor growth during the first year and low overwinter survival.

### Habitat requirements

Temperature is probably the most critical habitat variable. Temperature is especially important during two stages: from fertilization until the young leave the nest and over winter mortality (Bennett and Bennett 1991). Various standards have been proposed as a measure of temperature suitability for smallmouth bass. Hubert (1988) considered a growing season of 100 days or more as determinant of a successful bass population in Wyoming. Johnson et al (1977) found that smallmouth distribution into Ontario was limited to the north by the July mean temperature of 64° F or the mean annual frost-free period of 100 days.

Smallmouth bass are found in both lotic and lacustrine systems. Optimum lacustrine habitat consists of lakes with gravel, broken rock, and boulder substrates with adequate interstitial space. Mean depth of 30 - 33 feet is the most suitable, with deeper and shallower systems being less suitable. Turbidity to 30 JTUs is acceptable, but higher turbidities decreases suitability dramatically. Six parts per million dissolved oxygen is considered a minimum for maximum habitat suitability (Edwards et al 1983).

Stream dwelling smallmouth bass prefer gravel or rubble substrates and areas with abundant shade and cover (Carlander 1975, Paragamian 1976). They are often associated with log complexes in streams (Probst et al 1984). In the Mussellshell River, Montana smallmouth bass are concentrated in areas upstream and downstream of diversion dams. In the lower Bighorn River, Montana smallmouth bass are also found around diversion dams and in areas with heavy angular rock (Vaughn pers. comm. 1992).

Smallmouths prefer streams with moderate current. Edwards et al (1983) indicated that gradients from 0.08-0.46% were the optimum, and steeper or lesser gradients were less suitable for smallmouths. Pool depth of 3 - 16 feet is considered optimum habitat for smallmouths, with shallower pools decreasing dramatically in suitability and deeper pools decreasing gradually in suitability (Edwards et al 1983).

Growth of juvenile smallmouth bass is effected by dissolved oxygen levels less than 70% saturation (Bennett and Dunsmoor 1986).

### Common limiting factors

Temperature and turbidity are important limiting factors for extending the range of smallmouth bass. Water temperature is the single most important ecological factor limiting world distribution (Robbins and MacCrimmon 1974). Coutant (1975) reported the growth optimum temperature for smallmouth bass near 78.8° F. Turbidity has been important in limiting the establishment of introduced populations of smallmouths in many areas of the Rocky Mountains where turbidity is too high (Bennett and Bennett 1991).

Flooding has been reported to have a detrimental effect on the spawning success of nest building smallmouth bass in riverine environments (Funk and Fleener 1974).

Both large and smallmouth bass are known to exhibit large fluctuations in year class strength. These fluctuations result from small changes in survival during the earliest stages of life. The environmental factors most likely to increase the mortality of bass embryos and larvae are strong winds and low temperature (Eipper 1975).

## Characteristics of smallmouth bass fisheries in similar situations

### Mean annual and range of catch rates

Bennett and Bennett (1991) summarized the range of catch rates found in the literature on smallmouth bass. In general, catch rates in streams and rivers appear to be higher or similar to catch rates in lakes. In rivers, some of the lowest catch rates reported were from the Detroit River with rates from 0.0021 to 0.0062 fish/hr (Ryckman and Lockwood 1985). In Oregon, Dailey et al (1990) reported catch rates for the Umpqua and South Umpqua Rivers to be 0.8 to 1.2 fish/hr.

In lakes, catch rates range from 0.002 to 0.02 fish/hr in Lake Geneva, Wisconsin (Mraz 1960) to 0.27 - 0.28 fish/hr in Brownlee Reservoir, Idaho (Rohrer 1984).

### Sport fishery yields

In Montana, smallmouth bass provide some minor angling opportunities in the Mussellshell, Bighorn and Yellowstone Rivers. Statistics were not available, however in general smallmouth numbers in these rivers are too low to provide a significant fishery. In the Bighorn/Yellowstone system, smallmouth are usually caught incidentally by anglers fishing for sauger. In the Mussellshell River the smallmouth bass are concentrated around irrigation diversions and provide some angling opportunities to the few people who favor them (Vaughn pers. comm. 1992).

The range of yields reported in the literature range from 0.03 - 0.06 lb/acre in South Branch Lake, Maine (Bandolin 1973) to 8.7 lbs/acre in Courtois Creek, Missouri (Fleener 1975).

Funk and Fleener (1974) studied the impacts of stocking smallmouth bass on a Missouri Ozark stream. They reported a return to the creel of stocked smallmouth bass of 2.3%. Overall, stocking was found to be ineffective in increasing the catch of smallmouth bass. However, the effect of stocking was masked by an unusually large year class that was produced at the same time as the stocking program was initiated.

### Seasonal factors affecting the fishery

Based on the literature done by Bennett and Bennett (1991) it appears that the highest catch rates for smallmouth bass occur when water temperatures exceed 50° F. In general the highest catch rates occur during the spawning season. The fishing season generally extends from May to October, with little or no harvest occurring in the winter.

**Standing crops**

In general the standing crop of smallmouth bass tends to be higher in the southern portion of their range than the northern portion.

The abundance of smallmouth bass in John Day Reservoir, Oregon was found to be 34,954 (4.4 fish/acre) in 1985 and 1986 (Beamesderfer and Rieman 1991). This is far less than densities reported by Carlander (1977). The lowest density in his report is 39.5 fish/acre.

**Review of the literature on species interactions, concentrating on potential interactions with the existing sport fish species (trout, yellow perch, walleye, and kokanee).**

**Predation risk**

In Brownlee Reservoir, Idaho, planted rainbow trout were found to account for 40% of the fish consumed by smallmouth bass during the fall of 1985 (Bennett and Dunsmoor 1986).

In John Day Reservoir, Oregon, smallmouth bass were found to be a minor predator on out-migrating juvenile salmonids, consuming 4% by number overall. Juvenile salmonids appeared in smallmouth bass diets only in July and August probably because there was habitat overlap at that time of year with subyearling chinook salmon (Poe et al 1991).

Forney (1972) reported that young yellow perch were consumed by smallmouth bass. He found that high perch densities and warmer water temperatures contributed to an increase in growth increments of Age 1 and older smallmouth bass. However, he found a negative relationship between perch abundance and growth of young-of-the-year bass that suggested possible competition.

Smallmouth bass were not found to be a major predator on salmonids in Little Goose Reservoir, Washington. The frequency of occurrence in the diet was about 2%, although the estimate should be considered to be conservative due to the small sample size (Bennett et al 1983). Upstream of Little Goose Reservoir on the lower Snake River, salmonids comprised 26% of the food items in the spring (Bennett and Shrier 1986).

In Lower Granite Reservoir in the spring of 1987 salmonids contributed the most to the overall total weight of food items of smallmouth bass. Of the bass with salmonids in their stomachs, chinook salmon averaged 1.75/bass stomach (Bennett et al 1983).

There is no literature documenting smallmouth bass preying heavily on kokanee. However, it is certainly possible that smallmouth bass would prey on young-of-the-year kokanee, especially when the young are out-migrating from the tributaries.

Overall, when temperature conditions are suitable for smallmouth feeding ($> 50$ F) and sufficiently small salmonids are available, smallmouth bass will actively prey on salmonids.

**Competition risk**

In Canyon Ferry, young-of-the-year smallmouth bass would feed on zooplankton, as do the other fishes currently in the reservoir. Whether this competitive interaction would have an impact on the existing sport fishes is unknown.

No competitive interactions have been noticed between smallmouth bass and other species in the Bighorn/Yellowstone River system or in the Mussellshell River, Montana. This is probably because smallmouth bass numbers are very low in these systems. In the lower Bighorn River smallmouth co-exist with catfish, sauger, and ling. In the reaches of the Bighorn which contain trout, smallmouth bass are very rare due to temperature limitations (Vaughn pers. comm. 1992).

Smallmouth bass and trout co-exist in the Tongue River, Montana, however, there is significant habitat segregation between the two species. The upstream portion of the river, below Tongue River Dam, has cooler water temperatures and very few smallmouth bass. In the lower, warmer sections of the river temperatures are more favorable for smallmouth and less favorable for trout (Clancy pers. comm. 1992).

In Flaming Gorge Reservoir, Wyoming, smallmouth bass feed heavily on the littoral forage fishes. This is especially true if the young forage fishes inhabit the littoral zone. Smallmouth predation on Utah chub is having an impact on the other piscivores in the reservoir (Wengert pers. comm. 1991).

In Maine, attempts to stock rainbow trout in lakes containing smallmouth bass were largely unsuccessful. Biologists hypothesized that there was a competitive interaction between the two species, but the relationship was never proven (Walker pers. comm. 1991).

**Risk of spread of disease**

Bennett and Bennett (1991) reviewed the common diseases of the black basses. Most of these diseases do not cause harm either to fish or man, and most infect fish under intensive culture conditions or in eutrophic waters.

**Risk of spread of new species beyond the area of introduction (pioneering tendencies).**

The literature review by Bennett and Bennett (1991) indicates that smallmouth bass will pioneer into new territory, particularly in a downstream direction.

Smallmouth bass in the Tongue River, Montana exhibit a marked tendency to move long distances at two specific times of the year. In the spring, individuals larger than 12" moved upstream, some as far as 50 miles. This movement appears to be related to the nesting season. In September and October, smallmouth larger than 12" move downstream, primarily to a short reach of river with boulder substrate, resulting in a concentration of the fish in the fall (Clancy 1980).

## The effect of introducing smallmouth bass into Canyon Ferry Reservoir.

### The adequacy of the habitat for smallmouth bass

#### Spawning

Smallmouth bass prefer to spawn on sand, clean stone, or fine gravel, generally adjacent to a boulder or fallen log. This type of habitat is most common on the north end of Canyon Ferry Reservoir and in the Missouri River. However, water velocities in the river environment would limit spawning to pools and current protected areas.

As mentioned above, the critical environmental factors in determining year class strength in bass are wind and water temperature. Canyon Ferry has a reputation for being a windy place. High mortality rates of bass embryos and larvae could be expected in years when spring storms and high winds are common. Warm and calm conditions in the spring could result in strong year classes.

How common are cold spring storms in this area? Daily water temperature information was not available for Canyon Ferry Reservoir so it was not possible to assess the instability of spring water temperature conditions in the reservoir.

Daily water temperature data is available for the Missouri River at Toston. As can be seen from Figure 3, mean daily water temperatures exceed 59° F consistently after June 15, based on 10 years of data. However, as usual, there is year to year variation. As can be seen in Appendix B, water temperatures fluctuate above and below 59° F (15 C) almost every year. In some years, water temperatures only fluctuate below 59° F during the beginning of June and then they consistently stay above that level. In other years an extended warm period is interrupted by a cool period. In some years (2 of 12 reviewed), water temperatures will dip below 59° F in July for 2 - 3 days. It is this pattern that is likely to be most detrimental to bass spawning success.

Another factor which should be considered is water level fluctuations. Optimum conditions during the spawning and post-spawning time would consist of slowly rising or stable water levels. Therefore, the timing of spawning is a critical consideration. If it is assumed that spawning takes place in mid-June when water temperatures reach 59° F, then the critical period for water level fluctuations will be from the middle to the end of June. As can be seen in Figure 4, the typical situation in Canyon Ferry in June is rising water levels.

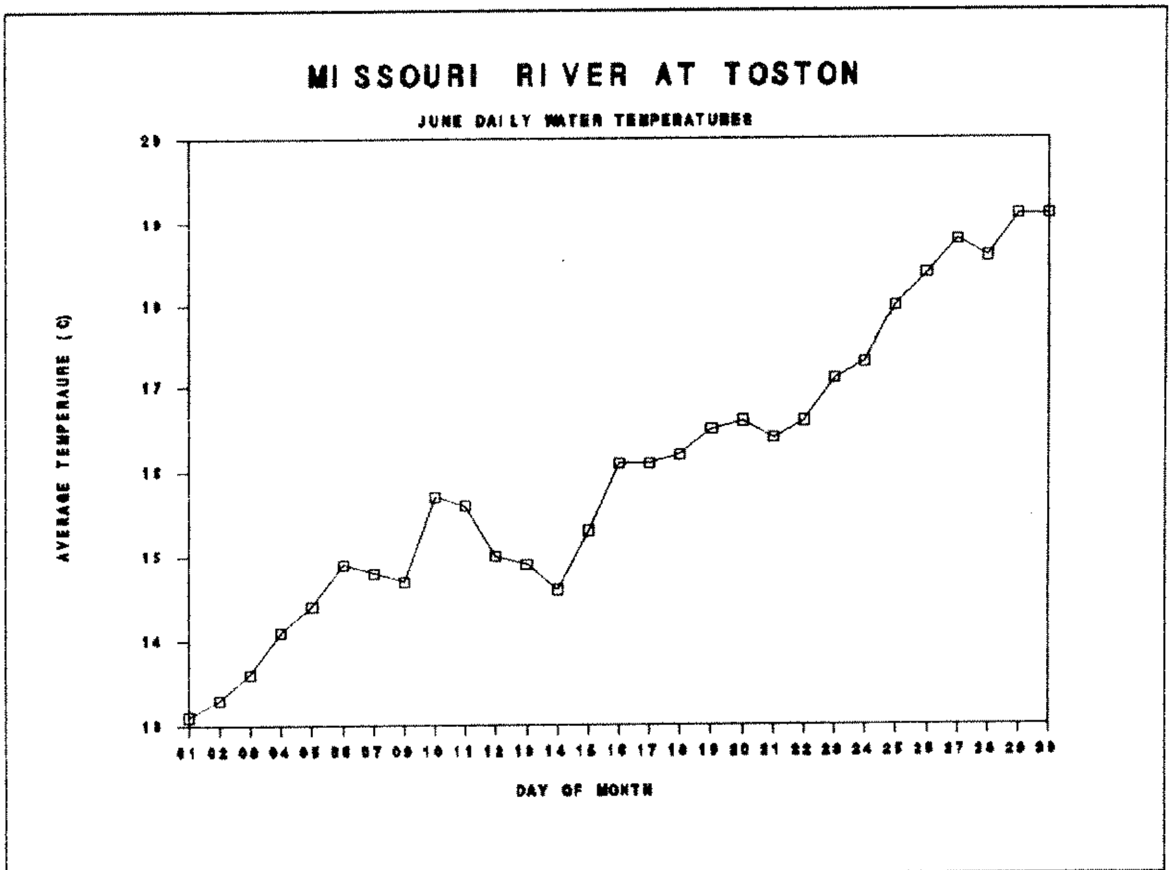



Figure 3 Average daily water temperatures in June, based on 10 years of record (USGS 1989).

However, if spawning should be delayed into July by colder than average temperatures, then the bass would be developing in a period of declining water levels. Over the last 11 years, water surface elevations have declined an average of 2 feet from the end of June until the end of July (Figure 4). This results in a habitat suitability of 0.0 based on the Edwards et al (1983) model.

However, there is considerable year to year variation. In the last eleven years, there have been two years when Canyon Ferry water levels were steady between June and July - in 1982 and 1986 (Figures 5 and 6). In 1981 and 1989 water levels fell a relatively modest amount during July. During these years water levels would be unlikely to impact bass spawning success even if spawning were delayed until July. However, in years like 1979, 1980, 1985, and 1987, spawning success would quite likely be impacted by falling water levels.

In the Missouri River at Toston, peak flows typically occur during June and decline in July. This flow pattern could have a detrimental impact on smallmouth spawning in two ways. First, smallmouth nests could be exposed by falling water levels after spawning. Second, water velocities would be very high during spawning season limiting the number of suitable spawning

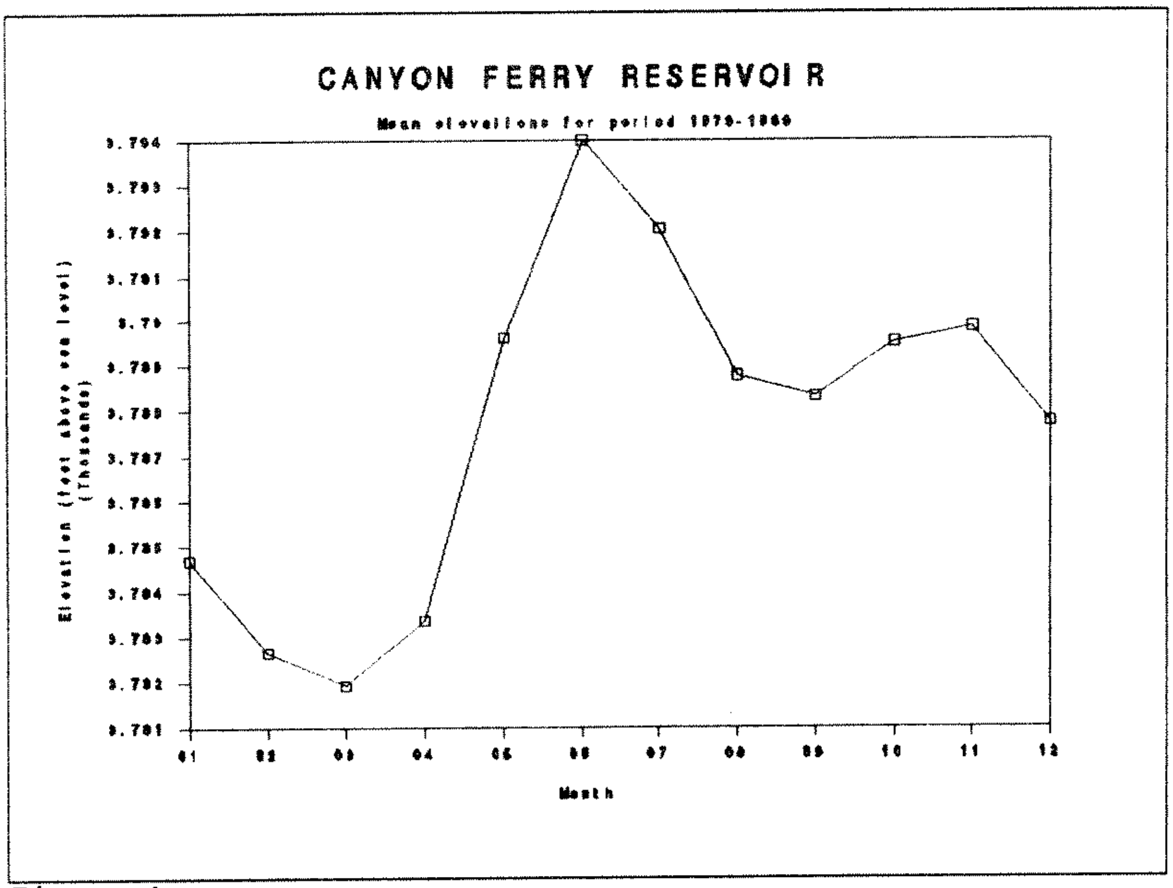



Figure 4

locations.

In summary, smallmouth bass spawning success would likely vary widely from year to year - as in common in many systems. From a practical standpoint, it would be difficult to manage a hatchery program that would only stock the reservoir during years with low recruitment. A decision would probably have to be made to either stock annually or not at all, based on the average or typical natural recruitment.

Rearing

Most spawning activity takes place at temperatures above 59° F. Surface water temperatures typically reach this level in Canyon Ferry and the Missouri River during early to mid-June (Figures 1 and 2). Eggs incubate in 4 days at 59-65° F (Turner and MacCrimmon 1970). Postlarval fish require about 8 - 11 days after hatching to swim-up from the nest (Bennett and Bennett 1991). Consequently, it could be expected that in an average year the young of the year would enter the reservoir in late June or early July.

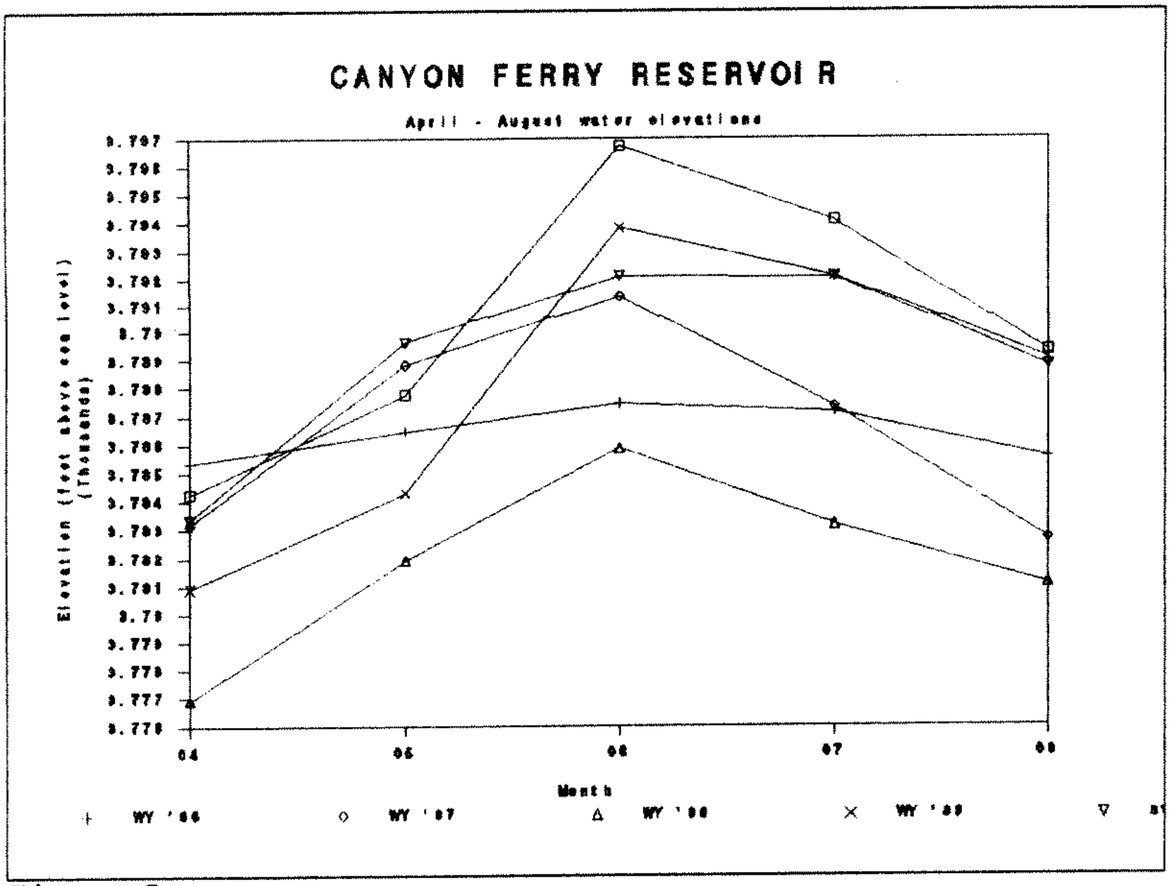



Figure 5

Canyon Ferry Reservoir has moderately high levels of zooplankton (Lere 1991). It appears that there are adequate levels of zooplankton to support young of the year smallmouth bass.

Adult

The climatological data collected at Canyon Ferry Dam and Toston Dam indicate an average frost free period in excess of 100 days, indicating that the climate is sufficiently warm to support smallmouth bass. However, there is considerable year to year variation and it should be noted that in some years the frost free period was less than 100 days at Townsend. The frost free season near Canyon Ferry Dam is considerably longer than it is upstream near Townsend.

Another measure of temperature suitability for smallmouth bass is a July mean air temperature of 64° F (Johnson et al 1977). The July mean air temperature at Townsend, Montana is 66.8° F, indicating suitable temperatures for smallmouth bass.

In their analysis of habitat suitability for smallmouth bass in western Montana Bennett and Bennett (1991) considered 70° F to be the preferred

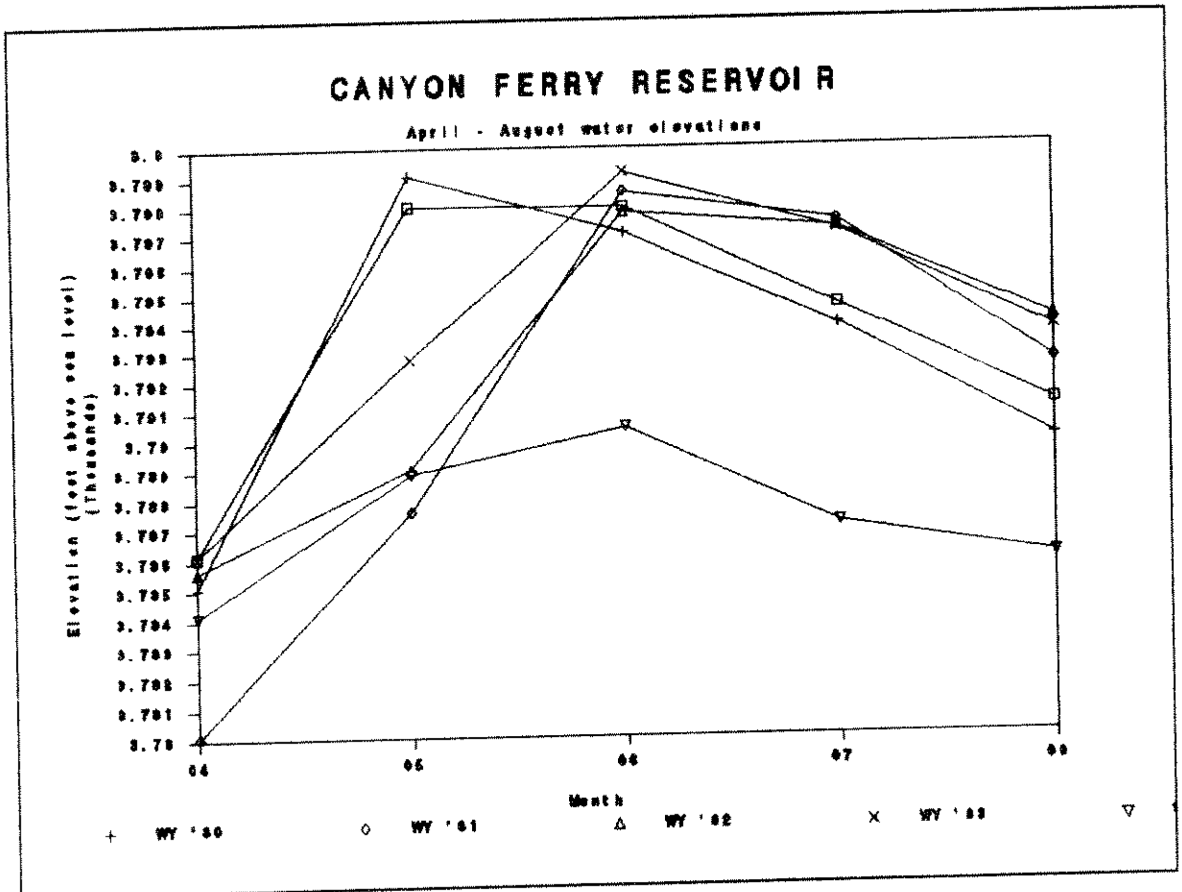



Figure 6

temperature for smallmouth. Using this criteria, Canyon Ferry seems to be suitable, although not optimal, habitat for smallmouth bass. Based on 1990 data, Canyon Ferry warmed to 70° F by late June and stayed at that temperature or above until early September (Figure 1). This is comparable to the temperature regime of the South Umpqua River near Roseburg, Oregon. This river system supports a population of smallmouth bass with good growth rates (Bennett and Bennett 1991).

Figures 7, 8, and 9, show the portions of the reservoir with water temperatures at or above 70° F during 1990. During the late-summer period, the approximately upper 20 - 30 feet of the reservoir was at or above 70° F. Near the north end of the reservoir, at the Cemetery station, the water is relatively deep (120 - 130 feet), so 30 feet represents a relatively small proportion of the total water column. The south end of the reservoir is shallower and shows less thermal stratification. Therefore, a higher proportion of the water column would be available to smallmouth bass.

Water temperatures in the Missouri River above Canyon Ferry also appear to be marginal for smallmouth bass based on the criteria in Edwards et al (1983). (The Edwards et al 1983 report gives suitability index graphs for smallmouth bass based on a number of key variables. For each variable,

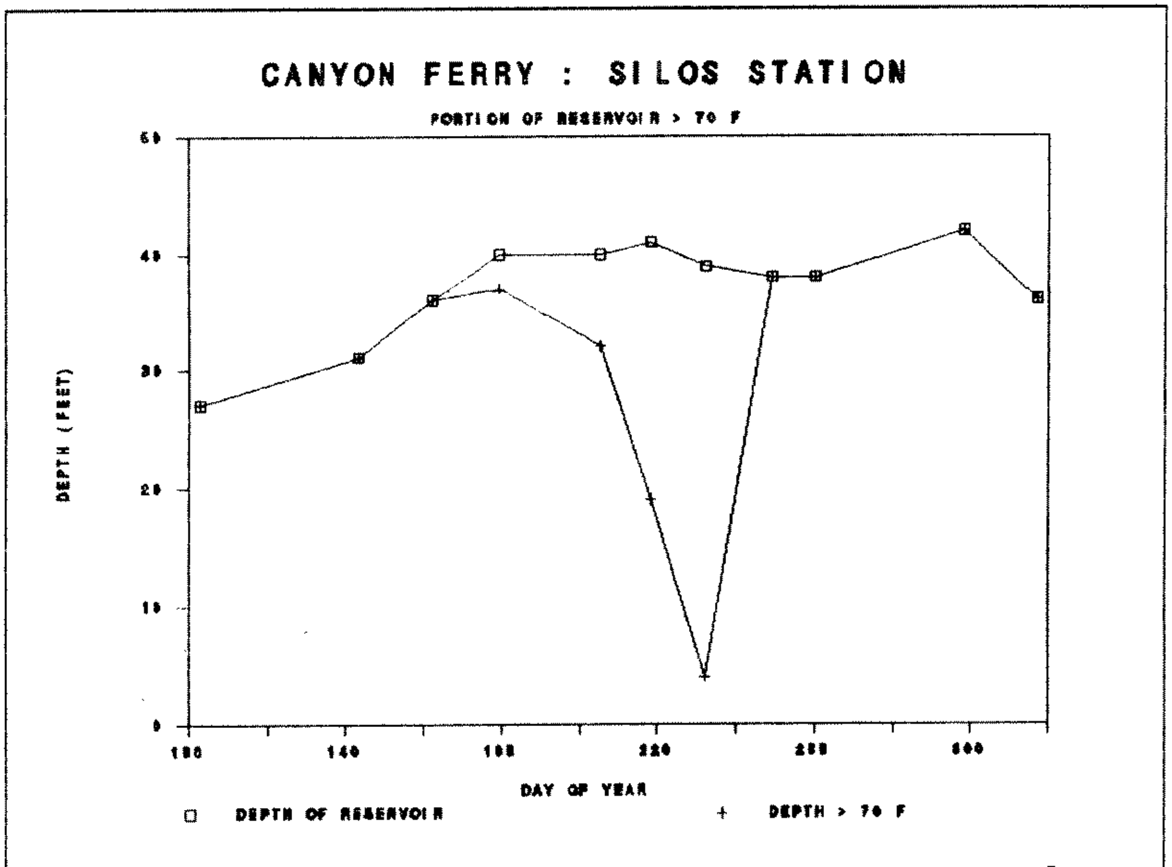


Figure 7 Shaded portion is area of the reservoir > $70^{\circ}$ F

suitability is described as ranging from 0.0 to 1.0 with 0.0 being totally unsuitable and 1.0 being completely suitable). The average June water temperature in the Missouri River at Toston is approximately 59 - 61° F, giving this reach of river a suitability of 1.0 for smallmouth bass embryo survival. Water temperatures during the growing season range from an average of 59 to 68° F (Figure 2). These temperatures are clearly cooler than optimum and would have to be considered marginally suitable (habitat suitability from 0.4 to 0.8). However, maximum water temperatures during July and August can rise as high as 75° F, which is in the optimum range for smallmouth bass (Figure 2).

Smallmouth bass prefer a gravel and broken rock substrate (Edwards et al 1983). The dominant substrate in Canyon Ferry Reservoir is silt and sand, which has a suitability of 0.2. However, some significant areas of gravel substrate do exist in the north half of the reservoir (Lere pers. comm. 1991). The Missouri River has significant gravel areas as well. These gravel areas would have a suitability of 1.0.

Maximum habitat suitability for smallmouth bass occurs at an average depth of 33 feet. Canyon Ferry has an average depth of 58 feet, giving it a habitat suitability rating of approximately 0.6. However, since the southern end of the reservoir is considerably shallower than the north end, the habitat

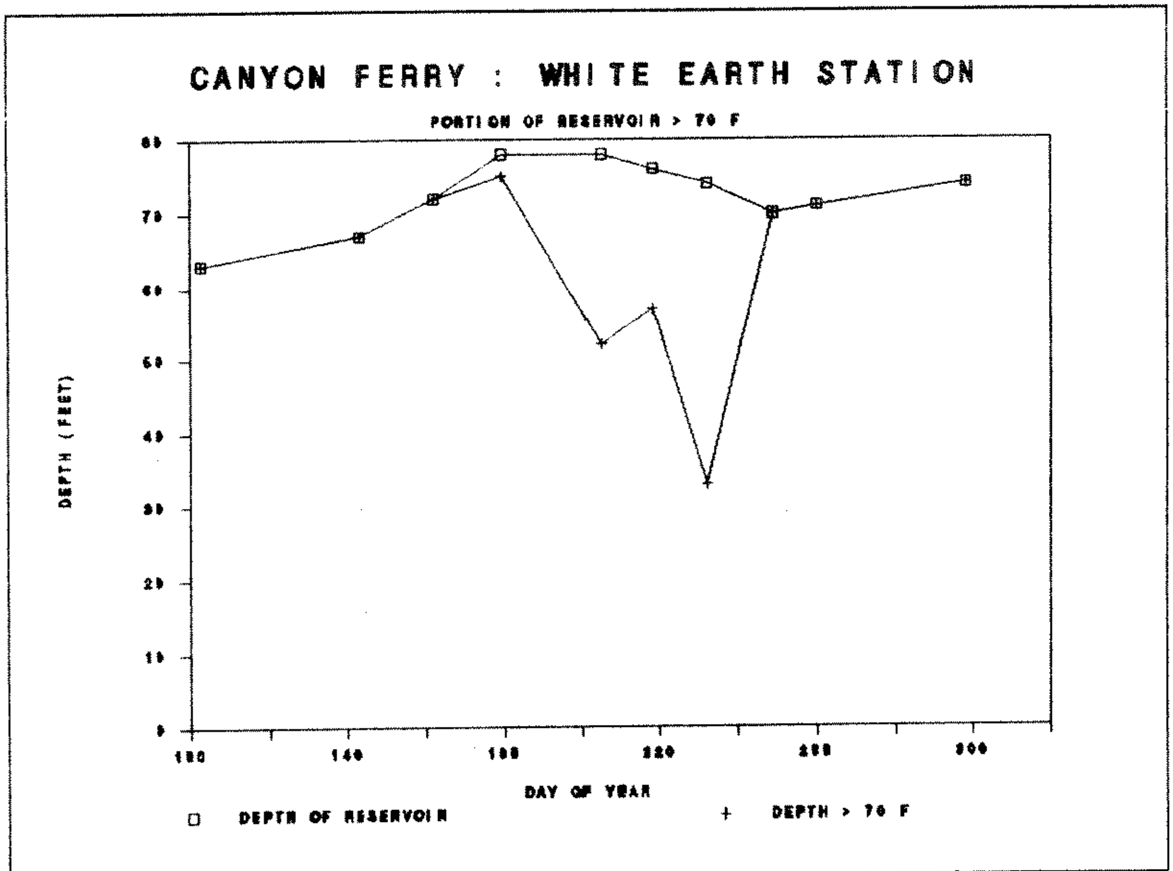



Figure 8 Shaded portion is area of reservoir > 70$^0$ F

suitability will vary. Water depth at the Silos sampling station is close to optimum, while the depth at the Cemetery station has a suitability of < 0.5. The White Earth Station is intermediate between the two.

The gradient of the Missouri River between Toston and Canyon Ferry Reservoir is 6.7 feet/mile. Based on the Edwards et al (1983) model, this gradient corresponds to a habitat suitability of 1.0.

The average pH, the maximum turbidity, and the minimum dissolved oxygen of both the Missouri River at Toston and Canyon Ferry Reservoir are at levels fully suitable (suitability of 1.0) for smallmouth bass (Edwards et al 1983).

There really is not enough information available to determine the adequacy of the forage base for adult smallmouth bass. In order for smallmouth bass to sustain high growth rates they need either to switch to a fish and crayfish diet at a young age. The abundance of crayfish in Canyon Ferry is unknown. If smallmouth are not feeding on crayfish they would likely feed on stocked rainbow trout, yellow perch, and the smaller non-game species.

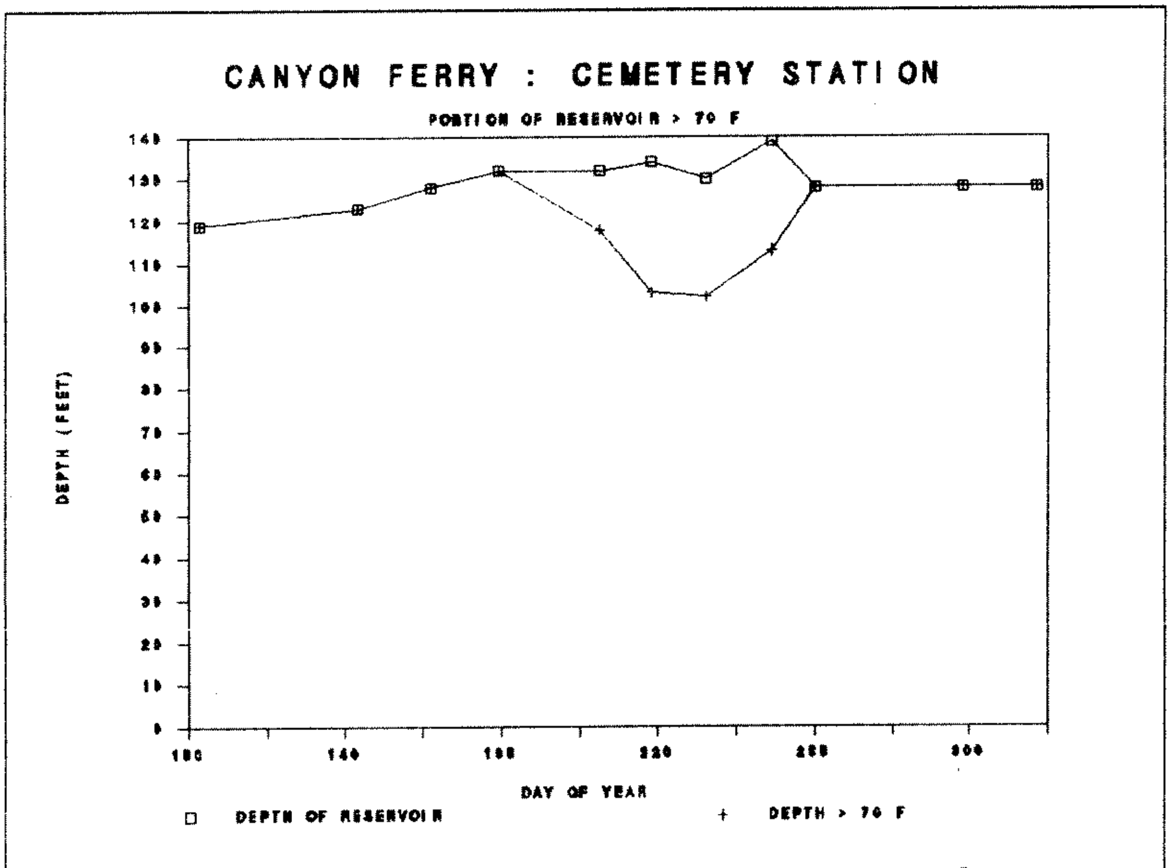



Figure 9 Shaded portion is area of reservoir > 70°F

**Interactions with existing species**

Competition

Canyon Ferry Reservoir has relatively few piscivores at the present time. However, there is a potential for smallmouth bass predation on Utah chub and other forage fishes to impact brown trout.

The greatest potential for competitive interactions is between young-of-the year smallmouth bass and other plankton feeders. Given the relatively high numbers of zooplankton in the reservoir, and the short period of time smallmouth bass make significant use of plankton, the risks of detrimental impacts seem low.

Predation

Smallmouth bass clearly will feed on salmonids if they are available. This is especially true if other food sources are in short supply. Before a decision is made to introduce bass in Canyon Ferry a survey of the available prey base, especially including crayfish, would be a wise idea. This survey should look at not only the numbers of each type of prey, but what their availability would be to predators. What habitats do the prey utilize at what times of day and season? Would these prey items actually be available to the predators during the predators feeding times?

Spread to other waters

It should be expected that smallmouth bass would move downstream and also upstream as far as Toston Dam.

## *LARGEMOUTH BASS*

### Review of the life history of largemouth bass

The largemouth bass is native to the eastern United States , excluding the northeastern U.S., and has been introduced throughout the United States (Robbins and MacCrimmon 1974). Although largemouth bass are not native to Montana, they have been stocked in a number of waters around the state, particularly in the Flathead drainage and in eastern Montana. Two subspecies are recognized, the northern subspecies, M. salmoides salmoides and the Florida subspecies, M.salmoides floridanus (Ramsey 1975). This report reviews the northern subspecies only.

Largemouth bass are already present in Canyon Ferry Reservoir in very low numbers do to drift from ponds in the Three Forks area, but they do not contribute to the sport fishery due to their scarcity.

#### Age and growth

The maximum known age of largemouth bass is 15 years, and the normal rate of growth for adult largemouth bass in southern waters is approximately 454 g per year (Stuber et. al. 1982). Bass in the northern portion of their range tend to live longer than in the southern portion of the range (Carlander 1973).

This species grows rather slowly in Montana because of the cold water temperatures. The approximate average length at each year of life is as follows: 1 year - 2 inches, 2 years - 4 inches, 3 years - 5.5 inches, 4 years - 7.5 inches, 5 years - 10 inches, 10 years - 14 inches. In Montana, the largemouth bass become sexually mature in 3 to 5 years (Brown 1971).

Growth rates are highly variable. A review of largemouth bass growth data from Idaho found that age at 7.9 inches (200 mm) ranged from 1.6 to 4.1 years, age at 11.8 inches (300 mm) ranged from 2.8 to 7.3 years, age at 15.7 inches (400 mm) ranged from 4.3 to 9.7 years (Dillon 1990).

#### Spawning habits

Spawning typically begins in the spring when water temperature reaches 60° F. Most spawning occurs between 66 and 68°F, although the absolute range of temperatures recorded is wider. Spawning activities start and stop with changes in the weather (Coutant 1975). In Kickinghorse and Ninepipes

Reservoirs, Montana, spawning seems to occur during the early June to mid-July time period (Hansen, pers. comm. 1991).

Incubation time ranges from 2 to 7 days, depending on water temperature (Kramer and Smith 1960, Badenhuizen 1969). Survival is highest when temperatures are around 68° F. Complete egg die off occurs at 50° F (Coutant 1975).

A gravel substrate is preferred for spawning, but they will nest on a wide variety of other substrates, including vegetation, roots, sand, mud, and cobble (Brown 1971). Nests are constructed by the male at water depths averaging 12 - 35 inches (Stuber at al 1982). Nests have been found as deep as 27 ft in a reservoir where depth increased during the spawning period (Miller and Kramer 1971). Bass prefer to spawn in areas of very low water velocity. Water velocities of 1.3 ft/sec may result in mortality of embryos (Dudley 1969), and Hardin and Bovee (1978) reported that water velocities > .3 ft/sec were avoided by the species.

The nest consists of a shallow depression about 1 foot in diameter, and is constructed by the male (Brown 1971). The male guards the nest until the young disperse or grow into the fingerling stage (Allan and Romero 1975). Although nests may be constructed almost anywhere on a lake, it is not unusual for them to be grouped on certain shorelines or in specific coves (Miller and Kramer 1971). These areas are usually warmest and provide protection from excess wind action which can destroy nests (Heidinger 1975).

Allan and Romero (1975) found that largemouth bass nests exposed to wind and wave action from expanses of open water were not productive. Nests so exposed produced no fry and disappeared between periods of observation. In addition to the losses caused by the physical impacts of wind and wave action, wind can result in the movement of colder water from the open basins into the exposed littoral areas where bass are spawning. A drop in water temperature of 4 to 6° F and wave action caused bass to display erratic spawning behavior, often abandoning their nests. This type of behavior occurred primarily when water temperatures were in the mid-60's. In addition, wave action resulted in shoreline erosion and bank sloughing resulting in the suffocation or burial of some nests (Allan and Romero 1975).

The common carp (Cyprinus carpio) has been observed to prey on bass nests (Allan and Romero 1975).

**Food habits**

The first food of young bass is zooplankton (primarily small crustaceans). They next eat insects and fingerling fishes, including each other. Adult bass eat fishes and crayfishes. In addition, many other organisms have been found in stomachs of bass. However, the digestive physiology of the bass limits the type of food it can utilize to flesh, as they lack the digestive enzymes necessary to digest vegetation (Heidinger 1975). In Kickinghorse and Ninepipes Reservoirs, Montana, the primary food items are crayfish, yellow perch, and pumpkinseeds. However, the relative importance of these food items varies between the two waters, with crayfish being more significant in Kickinghorse than in Ninepipes (Hansen, pers, comm. 1991).

Largemouth bass feed by swallowing the whole organism, thus limiting the size of prey that can be utilized. A bass can swallow a fish whose maximum depth is equal to the mouth width of the bass (Lawrence 1957). Thus only the large bass can utilize a forage population made up of large organisms. Adult bass often feed near vegetation within shallow areas. Their feeding intensity is bi-modal, with peaks in the early morning and late evening (Snow 1971, Olmstead 1974).

**Habitat requirements**

Lacustrine environments are the preferred habitat of largemouth bass (Scott and Crossman 1973). Optimal conditions are lakes with extensive shallow areas to support submergent vegetation, yet deep enough to successfully overwinter bass (Stuber et al 1982). In large lakes in the northern portion of their range largemouth bass are usually limited to weedy areas near shore and other shallows. Maraldo and MacCrimmon (1981) concluded that the size of natural populations of largemouth bass in preCambrian shield lakes is apparently limited by the extent of warm, weedy areas.

As largemouth bass grow older they move to deeper water, but are not found as deep as smallmouth bass (Carlander 1975).

Optimal cover for adult largemouths corresponds to 40 - 60 % of the pool or littoral area as too much cover may reduce prey availability (Saiki and Tash 1979). Optimal pools or littoral area for largemouth fry is assumed to have 40 to 80% cover (Stuber et al 1982).

Optimal riverine habitat for largemouth bass is characterized by large, slow moving rivers or pools of streams with soft bottoms, some aquatic vegetation, and relatively clear water (Scott and Crossman 1973). Optimal water velocities are $\leq$ .19 ft/sec, and velocities > .6 ft/sec are unsuitable (Hardin and Bovee 1978).

Growth of largemouth bass is reduced at dissolved oxygen levels < 8 mg/l, and a substantial reduction occurs below 4 mg/l (Stewart et al 1967). Levels below 1.0 mg/l are considered lethal (Moss and Scott 1961).

Increased water levels in reservoirs may reduce prey availability due to increased cover for prey species. Stable to decreased water levels concentrate prey, which increase feeding and growth rates of adult bass (Heman et al 1969). However, drawdowns during the spawning and incubation season often result in poor survival (Jester et al 1969). High water levels which flood near shore vegetation during the spawning and incubation period have been linked to strong year class productivity (Jenkins 1975, Rideout and Oatis 1975, Aggus and Elliot 1975).

In Ninepipes Reservoir, Montana, there seems to be a clear correlation between spring water levels and year class strength. For successful spawning, water levels need to be high enough to flood the emergent vegetation during the entire spawning and incubation period (Hansen, pers. comm. 1991). However, water levels are not as critical to spawning success in Kickinghorse Reservoir, Montana. Consequently, although stable high water levels are desired during the spawning season, the importance of this variable seems to vary between locations.

Standing crops of black basses (Micropterus sp.) are positively correlated with total dissolved solid levels of 100 - 350 ppm (Jenkins 1976).

Largemouth bass are considered intolerant of suspended solids and sediment. High levels of suspended solids may interfere with reproductive processes and reduce growth. Buck (1956) found that the greatest survival and growth occurred in ponds with suspended solids < 25 ppm. Growth was intermediate in ponds with suspended solids 25 - 100 ppm and lowest in ponds with suspended solids > 100 ppm.

The optimal pH range for largemouth bass is 6.5 - 8.5 (Stroud 1967). Largemouth bass can tolerate short term exposures to pH levels of 3.9 and 10.5 (Calabrese 1969).

The optimal temperature for adult largemouth bass is 80° F. Very little growth occurs below 59° F or above 97° F. (Coutant 1975, Carlander 1977). McCauley and Kilgour (1990) found that growth of largemouth bass was correlated to accumulated day-degrees over 50° F. They found that over half the variability in growth could be attributed to environmental temperature and that a minimum of 550 thermal growth units is required to maintain a viable largemouth bass population. (A thermal growth unit is day-degrees above 50° F in thousands).

A review of the available data in Idaho found that largemouth bass growth was most strongly correlated with conductivity and mean annual air temperature (Dillon 1990).

### Common limiting factors

The year class strength of largemouth bass is determined by events occurring within a few weeks after egg laying. The most common limiting factor during this period is water temperature and wind. Spawning success is greatest during intervals when the weather was stable. In addition, the amount of flooded shoreline vegetation can also strongly influence the survival of young bass (Summerfelt 1975, Aggus and Elliott 1975).

## Characteristics of largemouth bass fisheries in similar situations

### Mean annual and range of catch rates

Largemouth bass catch rates in Ninepipes Reservoir, Montana averaged 1.0 fish/hr during the summer. The average summer catch rate in Kickinghorse Reservoir for largemouth bass was 0.5 fish/hr (Evarts pers. comm. 1991).

Rieman (1982) studied largemouth bass fisheries on five lakes in northern Idaho. He found catch rates ranging from 0.14 fish/hr to 0.31 fish/hr.

Catch rates for tournament largemouth bass anglers in the Pend Oreille River system, Idaho was 0.154 fish/hr in May 1986 and 0.221 fish/hr in May 1988 (Barber et al 1989).

**Sport fishery yields**

The yield of largemouth bass from five lakes in northern Idaho were found to range from 0.35 lb/acre to 1.6 lb/acre. Estimates of total yield were positively related to fishing pressure (Rieman 1982).

The total catch of largemouth bass from the Pend Oreille River system, Idaho was 3,434 fish (Barber et al 1989).

In Quabbin Reservoir, Massachusetts 1,200 - 2,300 largemouth bass were harvested annually from 1954-1963. This is equivalent to .05 - .09 fish/acre (Rideout and Oatis 1975).

**Seasonal factors affecting the fishery**

Largemouth bass are reported to feed at temperatures in excess of 50° F (Coutant 1975). However, winter ice fisheries for largemouth bass do exist in Montana at Kickinghorse and Ninepipes Reservoirs, among other sites.

**Standing crops**

Bass population size and standing crop was estimated for three lakes in Idaho. Thompson Lake was estimated to have a population of 3,222 age two and older bass (95% C.I. 1,629 - 7,183). The standing crop was estimated to be 2.14 lb/acre. Medicine Lake was estimated to have 2,098 bass age two and older (95% C.I. 1,263-3,770), with 2.23 lb/acre. Fernan Lake was estimated to have 3,726 bass age two and older (95% C.I. 3,031 - 4,578), with 2.14 lb/acre (Rieman 1982).

The biomass of largemouth bass in Tadenac Lake, Ontario, was .35 lb/acre in 1975 and .19 lb/acre in 1976 for the entire lake. The biomass was 4.4 lb/acre (1975) and 2.3 lb/acre (1976) for the littoral habitat (Maraldo and MacCrimmon 1981).

Data on standing crops from 170 large reservoirs, mostly in the south, were reviewed by Jenkins (1975). The mean standing crop was 8.9 lbs/acre and the maximum was 52.8 lbs/acre. Carlander (1955) found an average standing crop of largemouth bass of 19.2 lbs/acre. Carlander's higher figure may be due to the inclusion of smaller water bodies.

**Review of the literature on species interactions, concentrating on potential interactions with the existing sport fish species (trout, yellow perch, walleye, and kokanee).**

**Competition risk**

It was difficult to locate information on species interactions between largemouth bass and the other species which exist in Canyon Ferry Reservoir. This is partially because not much work has been done on this subject in general, and partly because the species complex found in Canyon Ferry is not the "typical" largemouth bass species association. Robbins and MacCrimmon (1974) stated that there is little evidence that introductions of largemouth bass into larger bodies of open water have resulted in appreciable declines in population levels of native species

In Canyon Ferry Reservoir largemouth bass would likely be restricted to the littoral zone, particularly vegetated areas. They would be unlikely to establish significant populations in the river environment. This habitat restriction would likely limit their population size and distribution sufficiently to mitigate any adverse species interactions.

**Predation risk**

No information was available on this topic.

**Risk of spread of disease**

No information was located on this topic.

**Risk of spread of new species beyond the area of introduction (pioneering tendencies).**

Barber et al (1989) tagged largemouth bass in the Pend Oreille River, Idaho and found that the largest movements were 10.5 mi. downstream between April and July and 8.7 mi between May and August.

Winter (1977) studied the home range movements of largemouth bass in Minnesota and concluded that maximum home range size was .74 - 3.4 acres. The primary or utilized ranges were 0.8 - 1.0 acres. Bass were found to make excursions up to 7 days from their primary home ranges and then returned.

Dequine and Hall (1950) tagged 1616 Florida largemouth bass in six large connected lakes in Florida. The maximum distance traveled by largemouth bass was 12.5 mi. Most of the recaptures (84.1%) were collected from within 5 mi. of the point of release. A high percentage (39.6%) of the fish were recaptured within the 1 $mi^2$ area in which they were released. A considerable amount of movement between the most closely connected lakes was noticed.

Mesing and Wicker (1986) also documented largemouth bass movements away from their home ranges, primarily during spawning season. Homing was documented - 7 of the Florida largemouth bass which were displaced returned to their home ranges.

Moody (1960) recaptured one Florida largemouth bass 123 mi. downstream from the point of release. Another fish was captured 60 mi. upstream from the point of release. However, 61.9% of the recaptured fish were within 10 mi. of the point of release.

While it appears that bass utilize relatively small home ranges, it appears that largemouth bass do occasionally move moderately large distances.

## The effect of introducing largemouth bass into Canyon Ferry Reservoir

### The adequacy of the habitat for largemouth bass

#### Spawning

Spawning would occur in shallow littoral zone areas, especially areas with submerged vegetation. Spawning may be limited to particular coves, especially those that are sheltered from wind and wave action.

#### Rearing

Spawning activities would begin in mid-June when the water temperature in Canyon Ferry reaches 60° F. However, actual egg laying probably would not take place until water temperatures reached 66° F, at the end of June. The incubation time would probably be 2 - 3 days, meaning young would enter the reservoir beginning in early July. This schedule could vary depending on the weather conditions. A series of spring storms which bring wind and cool temperatures can interrupt spawning activities and delay the hatching of eggs.

The most common limiting factor for largemouth bass is mortality during the first few weeks of life. It is common for bass population to have wide swings in year class strength. It might be possible to lessen the fluctuations in population size through a hatchery stocking program.

The average water level fluctuation during the growing season is 6 feet (Figure 4). This corresponds to a fry suitability index rating of 0.95.

#### Adult

Largemouth bass prefer warm water temperatures, with the optimum temperature being 80° F. Canyon Ferry has a maximum summer water temperature of 70 - 72° F. The maximum weekly water temperatures during spawning would probably be about 66 - 68° F. Based on criteria established by Stuber et al (1982), Canyon Ferry has a suitability of 0.6-0.8 for water temperature. While clearly Canyon Ferry is cooler than optimum for largemouth bass, this water is still within the range for establishment of the species. Growth rates would be relatively slow at these temperatures.

Spawning temperatures are reached relatively late in the season at Canyon Ferry, resulting in a relatively short growing season. Smaller bass have higher over winter mortality rates than larger bass.

One important variable for largemouth bass is the percent bottom cover (aquatic vegetation) within pools, backwaters, or littoral areas during the summer. Quantitative data was not available for Canyon Ferry. If it is generously assumed that 10% of the littoral area has aquatic vegetation, logs, and debris, then the habitat suitability is <0.7 for adults and juveniles and <0.6 for fry.

The substrate composition of the littoral areas of Canyon Ferry is assumed to be primarily silt and clay. This substrate type has a suitability index of 0.8 for largemouth bass.

The average drop in elevation of Canyon Ferry between June 30 and July 31 is about 2 ft (Figure 4). This corresponds to a embryo suitability index rating of 0.9. The average water level fluctuation during the growing season is about 6 ft (Figure 4). This corresponds to an adult and juvenile suitability index rating of 1.0.

Both pH and dissolved oxygen levels are suitable for largemouth bass in Canyon Ferry. Criteria have also been established for salinity, total dissolved solids, and suspended solids. While no data was available for these variables, it seems unlikely that any of them would be unsuitable for largemouth bass.

The adequacy of the prey base is unknown at this time. Largemouth bass would be likely to feed on any small fish and crayfish that are available in the habitats the bass are utilizing. A crayfish survey would allow for a better assessment of the suitability of the prey base.

**Interactions with existing species**

Competition

Based on the assessments of Robbins and MacCrimmon (1974), there seems to be relatively little risk of harming the existing species complex by introducing largemouth bass.

Predation

No information was found on this topic.

Spread to other waters

While largemouth bass have been demonstrated to develop home ranges, they are also clearly capable of moving long distances both upstream and downstream. It should be assumed that largemouth bass would probably enter Hauser and Holter Reservoirs if they were introduced into Canyon Ferry. They would be unlikely to populate the Missouri River upstream of Canyon Ferry as they are not generally a riverine fish.

*NORTHERN PIKE*

## Review of the life history of northern pike

Northern pike are native to the northern part of Eurasia and North America as far south as Kansas. They are native to Montana in the Saskatchewan River drainage (Brown 1971). Their existence west of the continental divide in Montana is the result of an unauthorized plant into Lonepine Reservoir on the Flathead Indian Reservation. Northern pike are currently widely distributed in the warmer Montana waters.

Northern pike currently exist in Canyon Ferry Reservoir and the Missouri River upstream of Canyon Ferry in very low numbers. They do not contribute to the sport fishery due to their scarcity.

### Age and growth.

The approximate fork length of northern pike at each year of life in western Montana is reported to range as follows: 1 year - 7.5 - 13 inches, 2 years - 13 - 21 inches, 3 years - 15 - 25 inches, 4 years - 19 - 27 inches, 5 years - 24 - 31 inches, 6 years - 30 inches (Brown 1971, Jones 1990, DosSantos 1988). These growth rates are generally slower than those reported for the eastern United States and faster than those from Europe (Jones 1990).

Females are typically larger at age than males. In Montana, male pike are reported to become mature in 2 years and females in 3 years (Brown 1971).

### Spawning habits

Spawning usually occurs after the ice goes off at water temperatures of 46 to 54° F. Mature adults move from deeper water, where they over winter, into shallow flooded marshes or backwaters where they spawn. The fertilized eggs are adhesive and stick to vegetation and other substrates (Brown 1971). Priegel and Krohn (1975) found that egg densities were highest where dense mats of sedge and wild celery remains were present.

The absence of inundated vegetation can inhibit or delay spawning. Reservoir operations sometimes cause a loss of spawning sites, resulting in limited northern pike reproduction. In Lake Oahe, North and South Dakota, northern pike utilized newly flooded prairie grasslands as spawning habitat. However, since Oahe has reached full pool level, there has been a loss of shoreline vegetation and a resulting reduction in northern pike reproductive success (Conover 1986). However, northern pike do reproduce in Tiber Reservoir, Montana even though this reservoir fluctuates 10 - 20 ft and has a low amount of aquatic vegetation (Leathe pers. comm. 1992).

The eggs hatch in about 2 weeks (Brown 1971). Water temperatures and river flows have been found to be the most important factors influencing recruitment success (Franklin and Smith 1963).

**Food habits**

The young of northern pike are very precocious and feed avidly on most organisms small enough to swallow. Micro-crustaceans are important in their diet (Brown 1971). Priegel and Krohn (1975) reported that the principal food of northern pike up to 2 inches were Cladocera (especially Ceriodaphnia, Simocephalus, and Eurycerus), and Eucopepoda, and insects (especially Tendipedidae larvae).

After pike reach 3 or 4 inches in length, they feed almost exclusively on fish (Brown 1971). In the Lake Coeur d'Alene Lake system of Idaho, northern pike prey were found to vary seasonally and with local prey availability. Yellow perch, salmonids, and catastomids were more common prey items while brown bullhead and tench were least common (Bennett and Rich, 1990). In Horseshoe Lake, Minnesota, northern pike were found to consume yellow perch and panfish, with perch usually being the major portion of the diet (Anderson and Schupp 1986).

Reports of cannibalism are not uncommon in northern pike, although this usually accounts for a minor portion of their diet. They are ambush predators, preferring to lie in wait for their prey (Inskip 1982).

Adult northern pike in Wisconsin trout streams were found to eat primarily fish - 88% of their diet. Rainbow trout comprised 29% of the diet, brown trout 25%, and mottled sculpin 21%. Rainbow trout seemed to be selected for over brown trout as brown trout were far more abundant in the stream than rainbows. In addition, 9% of the brown trout examined had scars whereas 37% of the rainbow trout had scars. The preference for rainbows was attributed to the fact that rainbows tend to inhabit less sheltered sites, including open pools, and have a less wary nature (Hunt 1965).

Most researchers have found that northern pike prefer soft-rayed fusiform prey. Survival and growth of pike in waters dominated by centrarchids is poor (Conover 1986).

**Habitat requirements**

Northern pike are usually found in the bays of lakes and reservoirs and in marshes. In streams they are common in pools or backwaters where vegetation is present (Brown 1971). Larger pike occur more frequently in open water (Grimm 1981a) while smaller pike usually stay in the vegetation to avoid predation, especially cannibalism (Chapman and MacKay 1984b, Grimm 1981b). Pike are more often found over sand and rock rather than silt substrates (Chapman and Mackay 1984a).

Northern pike are a coolwater fish that show maximum growth at temperatures of about 68° F (Casselman 1978).

Jones (1990) researched the habitat variables and fishes in the sloughs of the Bitterroot River, Montana and found that pike occurred in only four of 41 sloughs examined. The most important habitat variables which predicted the presence of pike were maximum water depth, presence of Potomogeton natans, and vegetative area.

Bennett and Rich (1990) outfitted 21 northern pike with radio transmitters in the Coeur d'Alene Lake system in Idaho. From March to August pike were observed to use mostly shallow (<23 ft), vegetated habitats. Little use of pelagic or non-vegetated sites were observed.

### Common limiting factors

The availability of suitable spawning habitat is the factor which most often excludes northern pike from lakes, reservoirs, and slow moving rivers and which limits abundance where the species does occur. Young northern pike eventually disperse from spawning areas, but pike of all ages continue to frequent shallow areas with vegetation. Small pike are especially dependent on this habitat (Inskip 1982).

## Characteristics of northern pike fisheries in similar situations

### Mean annual and range of catch rates

A summer creel census conducted on Upper and Lower Lonepine Reservoirs and Rainbow\Dog Lake, Flathead Indian Reservation, Montana found northern pike catch rates ranging from 0.086 fish/hr in Upper Lonepine to 0.382 fish/hr in Lower Lonepine. Rainbow\Dog Lake was intermediate with a catch rate of 0.152 fish/hr (Evarts pers. comm. 1991).

The northern pike catch rate in Pishkun Reservoir, Montana from Memorial Day to Labor Day was 0.24 fish/hr in 1978 and 0.32 fish/hr in 1979 (Hill 1980).

The 1991 catch rate of northern pike in Tiber Reservoir, Montana was 0.07 fish/hr. Catch rates ranged from 0.03 fish/hr in late September to 0.22 in mid-July. In Lake Francis, Montana, the summer (April- September) northern pike catch rate was 0.107 fish/hr. In the winter the catch rate increased to 0.141 fish/hr (Leathe pers. comm. 1992).

Catch rates for northern pike in Murphy Flowage, Wisconsin ranged from 0.039 fish/hr before the lake was stocked with northern pike to 0.054 fish/hr after stocking. However, the catch rate in pounds declined from 0.088 lbs/hr to 0.070 lbs/hr (Snow 1974).

Catch rates for northern pike in Escanaba Lake, Wisconsin averaged 0.8 fish/hr over a 23 year period (Kempinger et al 1975).

### Sport fishery yields

In 1989 - 1990, northern pike constituted < 20% of the summer harvest and approximately 60% of the winter harvest from Lake Francis, Montana. However, since most of the fishing pressure is concentrated in the summer, northern pike make a relatively small overall contribution to the fishery.

About 22% of the total fishery yield from Lake Francis was northern pike (Leathe pers. comm. 1992).

Snow (1974) reported an average yield of 630 fish/yr in Murphy Flowage, Wisconsin in the years prior to stocking. In the four years after stocking, yields went from 774 fish/yr to 198 fish/yr.

The average annual harvest of northern pike from Escanaba Lake, Wisconsin, was 176 fish/year (54 fish/acre) (Kempinger 1975).

**Seasonal factors affecting the fishery**

In the lower Flathead River, Montana, catch rates for northern pike are highest in February and March, shortly after the ice melts (DosSantos pers. comm. 1991).

**Standing crops**

Snow (1974) reported densities of northern pike in unexploited lakes can run as high as 284/acre (Murphy Flowage, Wisconsin). However, he suggested that for best results, the total density of northern pike after stocking of large fingerlings (10 - 18") should not exceed 8 fish/acre. Some other reported densities of unexploited lakes are 62/acre in Morris Lake, Wisconsin, and 18/acre in Big Cedar Lake, Wisconsin (He and Kitchell 1990, Priegel and Krohn 1975).

Standing crops of northern pike in Escanaba Lake, Wisconsin (an exploited lake) ranged from 1 to 7 fish/acre (Kempinger et al 1975).

**Review of the literature on species interactions, concentrating on potential interactions with the existing sport fish species (trout, yellow perch, walleye, and kokanee).**

**Predation risk**

During the 1970's and 1980's, Rainbow/Dog Lake on the Flathead Indian Reservation, Montana was managed as a put-grow- and-take rainbow trout fishery. In the late 1980's, anglers began reporting catches of northern pike from this lake. A creel census was conducted during the summer of 1988, after the lake had been stocked with the usual number of rainbow trout. No rainbow trout were documented to have been caught by anglers during the creel census. The sport fishery was entirely composed of northern pike. Stocking of rainbows was then discontinued and now the lake is managed as a pike fishery (DosSantos pers. comm. 1991).

In the upper portion of the Flathead River basin, Montana, northern pike are currently found in 61 waters. Northern pike were not native to western Montana. In systems that are large and complex, there seems to be some potential for northern pike to co-exist with other fish species found in the drainage. However, problems have occurred in small systems or in areas where the entire habitat is suitable for northern pike (Vashro pers. comm. 1991).

When pike were introduced into Swan Lake, the largemouth bass disappeared and the yellow perch were greatly reduced in numbers (Vashro pers. comm. 1991).

In Lion Lake, northern pike, yellow perch, and largemouth bass were introduced by anglers in rapid order. The existing put-grow-and-take rainbow fishery greatly declined after these species were introduced. The lake is no longer stocked with rainbow trout (Vashro pers. comm. 1991).

Introductions of northern pike into Upper Stillwater Lake resulted in reduced numbers of yellow perch and westslope cutthroat trout (Vashro pers. comm. 1991).

Lagoni Lake used to be managed as a cutthroat trout fishery. Hatchery plantings of cutthroat trout used to yield fish up to 16 inches. After northern pike were introduced, they rapidly became stunted and the returns on the cutthroat plants dropped to nothing. The lake was rehabilitated at a cost of $5,000, and cutthroat were again stocked. Northern pike reappeared, the return of cutthroat trout again dropped to nothing, and the lake was eliminated from the planting program (Vashro pers. comm. 1991).

Jones (1990) found that pike had apparently eliminated all other species of fish except pumpkinseeds in two of the four sloughs in which they exist in the Bitterroot River, Montana.

In Tiber Reservoir, Montana, rainbow trout occasionally enter the reservoir from the upper river system. However, rainbows are rarely seen that are any less than 14" in length. Smaller trout are presumed to be preyed upon by northern pike and other predators. One 25 lb northern pike caught had a 16 1/2" rainbow in its stomach (Hill pers comm 1992).

The Montana Department of Fish, Wildlife, and Parks has had some success stocking larger (6 - 8") rainbows in Pishkun Reservoir when northern pike numbers were low. However, when pike numbers increased, there was a high incidence of northern pike predation on rainbows. Due to the high incidence of predation and low return to the creel, hatchery stocking of rainbows in this water has been discontinued (Hill pers. comm. 1992).

When northern pike were introduced into Bolger Bog, Wisconsin, the result was a decline in the number of prey fishes and also changes in fish community structure. Emigration of prey fishes accounted for a rapid decline of total fish density and a change in community composition. The results of this study indicate that redbelly dace, fathead minnow, finescale dace, and brassy minnow are more vulnerable to predation by northern pike than bluegill, brook stickleback, creek chub, or golden shiner. The differences can be explained in terms of prey size and morphology. Bluegills and brook sticklebacks are spiny-rayed fishes. Northern pike usually prefer soft-rayed prey. In Bolger Bog, golden shiners and creek chub were larger than the other prey and may have escaped more efficiently from northern pike (He and Kitchell 1990).

In 1963, Murphy Flowage, Wisconsin was stocked with a high density of northern pike in an attempt to thin a population of stunted bluegills. Further research showed that the increased numbers of pike had no impact on bluegill growth or numbers. The author speculates that the lake was already at carrying capacity for space and so a large proportion of the pike introduced either died or migrated to other waters (Snow 1974).

In Horseshoe Lake, Minnesota, an increase in the northern pike population (created by hatchery stocking) was accompanied by a sharp decline in the yellow perch population, a decline in largemouth bass and walleye populations, an eventual explosion of bluegill, and changes in growth rates of bass, bluegill, pumpkinseed, perch, and walleye (Anderson and Schupp 1986).

It is hypothesized that predation by pike on perch that were recruiting to mature sizes caused the virtual collapse of the perch population. Northern pike, largemouth bass, and walleye were all major consumers of yellow perch in Horseshoe Lake, but pike probably had the greatest effect on perch abundance. Both walleye and bass prey on perch at life stages when there are large surpluses while pike feed on perch at life stages when surpluses may be less likely. There was no direct evidence of competition between pike and the other piscivores in terms of the amount of food consumed. Instead, it was the impact of pike predation on yellow perch sizes critical to recruitment of spawners that seemed to result in the reduction in the perch population (Anderson and Schupp 1986).

There are several cases known of pike gaining access to brown trout waters in the British Isles and completely eliminating the brown trout. This is true in spite of the fact that northern pike are native to the British Isles (Wheeler and Maitland 1973).

Mann (1985) reported that in a river in England only 9% of the prey taken by northern pike was trout. However, he felt that the northern pike removal program that was undertaken had a beneficial impact by reducing the number of trout that was needed to be stocked to produce a satisfactory fishery.

**Competition risk**

In Lake Francis, Montana, northern pike compete with walleyes for forage. An experiment is underway at Bynum Reservoir, Montana to see if walleyes will do better in the absence of northern pike, but results are not available as yet (Leathe pers. comm. 1992).

In Utah, northern pike are viewed as competitors with the endangered Colorado squawfish (Ptychocheilus lucius). Fishery workers on the Green River remove any pike they encounter to reduce this competitive interaction (Jones 1990).

**Risk of spread of disease**

Northern pike in the Bitterroot River system are hosts for a tapeworm. Jones (1990) reported that there was no positive identification of this tapeworm at the time of his work, but that it was believed to be Postodiplostomulum minimum, a common parasite of freshwater piscivorous fish. However, northern pike are also hosts to another tapeworm, Triaenopherus crassus. The adult tapeworm lives in the intestine of northern pike. The tapeworm eggs are released from the pike into the water, where they are taken up by a copepod, Cyclops bicuspidatus. When the infected copepod is eaten by a salmonid fish, the tapeworm larvae goes into the flesh and encysts, destroying their value as commercial or food fishes (Carl et al 1959). While the parasitized fish is harmless to man, the cysts make the flesh of the fish unsightly and unsalable (Davis 1953). Any salmonid which feeds on copepods would be vulnerable. Stream fishes might not be too likely to get the tapeworm, but reservoir fishes would be vulnerable, especially those that feed heavily on plankton (Sheldon pers. comm. 1991). This tapeworm is not known to exist in Montana waters, so it could be a serious problem if it was introduced here.

When northern pike were introduced into Murphy Flowage, Wisconsin, there was an outbreak of the disease Myxobolus, resulting in high mortality rates for both the wild and the stocked pike populations from disease (Snow 1974).

**Risk of spread of new species beyond the area of introduction (pioneering tendencies).**

In western Montana the first pike in western Montana was introduced illegally by an angler in Lonepine Reservoir in the 1950's. From there pike have spread downstream throughout the Little Bitterroot River system and into the lower Flathead River and Clark Fork River. Recently, pike have been found in the Bitterroot River. Pike are also found in the upper Flathead River and in warmer lakes in the upper Flathead drainage. The spread of pike into habitats upstream of Kerr Dam is clearly the result of illegal introductions by anglers. However, the spread of pike throughout the lower Flathead, Clark Fork, and Bitterroot drainages could have been the result of pike pioneering new habitats.

Pike are clearly capable of making long migrations. Pike in the Flathead River have been documented to travel as far as 45 miles one way to reach preferred spawning areas. A "typical" spawning migration for pike in the Flathead River is about 10 - 15 miles (DosSantos pers. comm. 1991).

It should be noted that although pike have spread across a broad area of western Montana, their existence is limited to specific habitat types, i.e. warmer waters, lakes, backwaters, and sloughs. Although pike have been in the lower Flathead River for several decades, they are not found in any of the major tributaries of that river other than the Little Bitterroot River. Similarly, pike are rarely found in the mainstem portions of the upper Flathead River (above Kerr Dam) even though they are common in the backwaters and sloughs connected to the river. Pike are almost never seen in Flathead Lake even though there is no physical barrier to prevent them from entering the lake. As mentioned previously, pike are only found in 4 of the 41 sloughs examined on the Bitterroot River.

A study of northern pike in Murphy Flowage, Wisconsin, found that the northern pike that were stocked into the lake moved extensively. Native pike moved only a limited amount. It appeared that downstream movement of stocked pike was density dependent. As the numbers of pike declined in Murphy Flowage, the numbers of pike moving downstream also declined (Snow 1974).

Carlander and Ridenhour (1955) found that northern pike moved to all parts of 3600 acre Clear Lake, Iowa within 6 months.

## The effect of introducing northern pike into Canyon Ferry Reservoir

### The adequacy of the habitat for northern pike

#### Spawning

Northern pike spawn in shallow, weedy areas. This type of habitat is not common in Canyon Ferry Reservoir, but where it exists it would be used by pike. In addition, northern pike can spawn in shallow, weedy sloughs and backwater areas of rivers. These areas are common in the five to ten miles of the Missouri River upstream of Canyon Ferry where they could be utilized by northern pike (Spoon pers. comm. 1991).

The suitability index criteria given in Inskip (1982) for northern pike spawning is the ratio of spawning habitat to summer area (area that is less than 3 ft deep and vegetated in the spring, divided by total midsummer area). There is not enough information available to calculate this ratio, however it is clear that the ratio would be very low in Canyon Ferry Reservoir. Based on this criteria, the suitability index for northern pike spawning might be between 0.0 - 0.2. However, the suitability of Canyon Ferry might be higher under certain circumstances. When there is several low water years that occur in sequence, there is heavy vegetation growth in the upper end of the reservoir in the delta area. In addition, in years when heavy rains occur in the spring the reservoir could rise high enough to flood shoreline vegetation (Peterman, pers. comm. 1991). In these circumstances there in an increased possibility of successful northern pike spawning.

The suitability criteria for the Missouri River above Canyon Ferry Reservoir would probably be higher given that vegetated sloughs and backwaters are common in this area. These slough areas are typically flooded in the spring when pike are spawning.

#### Rearing

Northern pike spawn when water temperatures are between 46 - 54° F. In Canyon Ferry Reservoir these water temperatures are reached in May. Incubation times are approximately two weeks in Montana.

Fry are usually adhesive and attach to vegetation while the yolk sac is being absorbed. Fry begin the emigrate from spawning sloughs when they are 2 - 3 inches long (Inskip 1982). The time required to grow to this size is variable, with times reported in the literature ranging from 10 - 24 days after hatching (Forney 1968, Franklin and Smith 1963). Emigration may be concentrated or prolonged and the speed of emigration may be controlled by environmental variables (Inskip 1982).

If it is assumed that spawning takes place in mid-May, incubation requires 2 weeks, and fry grow to 2 - 3 inches in another 2 weeks, then emigration into Canyon Ferry Reservoir would begin in mid-June.

Water levels are important during the embryo and fry stages. Canyon Ferry water levels are almost always either stable or increasing during May and June and so should not cause a problem for young pike.

As described above, suitable spawning habitat is not common in Canyon Ferry. Recruitment may be a limiting factor for northern pike populations. However, with limited shallow weed beds, Canyon Ferry may also have insufficient rearing habitat, in which case hatchery stocking would be of little benefit in creating a pike fishery.

Adult

Aggus and Bivin (1982) developed a relation which describes the harvest of northern pike as a function of growing season and outlet depth. This relation was developed by reviewing catch data and physical features for a number of reservoirs around the country.

Log(harvest of NP) = 3.7882 - 0.0177(growing season) - 0.8447log(outlet depth)

Based on this formula, and a growing season on 136 days at Canyon Ferry Dam (Table 1) and an outlet depth of 150 feet the expected harvest of northern pike would be 0.349 kg/ha/yr or .31 lbs/acre/yr or 10,958 lbs from the reservoir/yr. However, the accuracy of this model for predicting yield from Canyon Ferry Reservoir is unknown.

One of the habitat suitability criteria given by Inskip (1982) for northern pike is the percent of midsummer area with emergent or submerged aquatic vegetation or remains or terrestrial plants (bottom debris excluded). In order to have a maximum suitability of 1.0, between 30 - 70% of the water would have to be vegetated. If Canyon Ferry is $< 5\%$ vegetated in the summer, then the habitat suitability is $< 0.4$.

Water temperatures in Canyon Ferry appear to be suitable for northern pike. Inskip (1982) gives two temperature related suitability criteria - the number of days between frosts and the maximal weekly average temperature of the surface layer. In both cases, Canyon Ferry has a suitability index rating of 1.0.

The pH of Canyon Ferry is suitable for northern pike based on criteria in Inskip (1982).

Both yellow perch and rainbow trout are reported in the literature as common prey items for northern pike, although soft-rayed species are preferred. Large northern pike are also reported to feed on white suckers. It seems that habitat (lack of shallow weedy areas) is more likely to be limiting to northern pike than food is in Canyon Ferry.

**Interactions with the existing species**

Competition

Small northern pike will compete to some degree with yellow perch for food. However, impacts to yellow perch are more likely to be a result of predation by northern pike.

Brown trout in Canyon Ferry feed heavily on yellow perch and salmonids (Lere 1991). Northern pike would be competitors to brown trout for these species. Northern pike are capable of preying on yellow perch to the point of population collapse. This has a negative impact on the other species that rely on yellow perch as a prey base (Anderson and Schupp 1986). This would also have a negative impact on the existing yellow perch fishery.

Predation

There are numerous examples in the literature of northern pike having a profound impact on the fish community structure of lakes when they are introduced into a system. In Canyon Ferry, habitat limitations might keep pike numbers low enough that the impacts to other species might be minimal. In that case, however, the purpose of the introduction to provide more angling opportunities, would be lost.

Spread to other waters

Northern pike are clearly capable of passing downstream through small dams. It should be assumed that they can pass large dams as well and would be able to enter the Missouri River system below Canyon Ferry. Pike are clearly capable of swimming upstream in large rivers. It should be expected that they could move upstream as far as Toston Dam.

## *CHINOOK SALMON*

### Review of the life history of chinook salmon

Chinook salmon have the most diverse life history of any of the Pacific salmon. Among the four recognized races of chinook there is a diversity of many key life history features. This analysis assumes that chinook introduced into Canyon Ferry Reservoir would behave most similarly like landlocked chinook residing in other water bodies of a similar latitude. It is also assumed that fall chinook would be the strain introduced because this strain smolts at age 0+, as opposed to age 1+ for other chinook strains. This means the young spend less time in the hatchery and are therefore less expensive to produce.

Chinook are not native to Montana. They have been successfully planted in Ft. Peck Reservoir, where they produce a small recreational fishery which is entirely hatchery supported. Chinook salmon were planted in Canyon

Ferry Reservoir in small numbers in the past. They did not become established in Canyon Ferry and none currently exist in the reservoir.

**Age and growth.**

Chinook are the largest in size of the 5 species of Pacific salmon. The largest known weight is 126 lbs, with catches of fish from 13 to 51 lbs common in both the sport and commercial catch (Raleigh et al 1986). In Ft. Peck Reservoir, Montana, chinook become sexually mature at 3 to 4 years of age. They generally weigh 7 - 8 lbs at that time (Wiedenheft, pers. comm. 1991). In Lake Sakakawea, North Dakota, male chinook become sexually mature at age 1 and 2 and female are sexually mature at age 3 and 4 (Power pers. comm. 1991). In the Minnesota waters of Lake Superior, chinook spawners were predominantly age 3+, although a few did mature at age 2. The average length of spawning fall chinook was 29 inches (Close et al 1984).

The size of chinook entering the fishery is highly variable and dependent upon the forage base. In Lake Oahe, South Dakota, the average size of chinook caught dropped to 3 lbs. at a time when the forage base was low (Fielder pers. comm. 1991). In contrast, fish up to 42 lbs were caught in Lake Coeur d'Alene when they were first introduced (Horner pers. comm. 1991). In Lake Sakakawea, North Dakota average sizes have ranged from < 5 lbs to 18 lbs depending on food availability (Power pers. comm. 1991). The maximum size of chinook found in Ft. Peck has been 31 lbs to date (Wiedenheft pers. comm. 1991). In the Minnesota waters of Lake Superior, fall chinook captured by anglers averaged 24.3 inches and 5.6 lbs. (Close et al 1984).

**Spawning habits**

The time of spawning varies depending upon the race of salmon. In Ft. Peck Reservoir, chinook become ripe in late October - early November (although there is no natural reproduction due to the lack of spawning habitat) (Wiedenheft, pers. comm. 1991). When the Idaho Fish and Game Department first started stocking Lake Coeur d'Alene with chinook in 1982, they used Bonneville stock fall chinook. These fish spawned around the third week in September. More recently, Idaho has been stocking Lake Michigan stock which spawn later in the fall (Horner, pers. comm. 1991). South Dakota Fish and Game also used Michigan chinook stocks when they stocked Lake Oahe. In Oahe the spawning run is spread over the fall from mid-September to late November, with the peak in mid-October (Fielder, pers. comm. 1991).

The female builds a redd in gravel substrate ranging in size from 0.1 to 6 inches. The optimal size range for spawning gravel is estimated to be about .8 to 4 inches. The depth of water suitable for chinook spawning is $\geq$ 0.6 ft. in rivers with relatively stable flow regimes. The usable spawning and embryo incubation velocity range is about 0.6 to 3.77 ft/s with an optimal range of about 1.0 to 3.0 ft/s, dependent upon gravel permeability, average substrate size, and average size of spawning adult (Raleigh et al 1986).

For good survival of late summer and fall run chinook eggs, a period of incubation is needed of >2 but $\leq$ 3.5 weeks at temperatures between 40 - 55° F (Raleigh et al 1986).

The length of time from fertilization to hatching varies with water temperature, but requires roughly 900 to 1,000 thermal units (Seymour 1956). After hatching, the yolk sac fry typically spend several more weeks in the gravel prior to emergence.

**Food habits**

Rondorf et al (1990) studied the food habits of subyearling chinook salmon in the Columbia River. They found that caddisflies were the predominant food in riverine nursery habitats (64% by weight). Daphnia and terrestrial insects were more preferred in reservoir habitats. The shift in diet in the reservoirs was due primarily to the high availability of these food items.

Anadromous chinook salmon adults stop feeding when they enter a river to spawn and they die after spawning. Consequently, most of the literature on chinook food habits in freshwater environments deals exclusively with juvenile food requirements. However, some information on adult chinook food habits in freshwater is available from areas that have landlocked chinook.

In Ft. Peck Reservoir, Montana, chinook feed primarily on cisco (Wiedenheft pers. comm. 1991).In Lake Coeur d'Alene, Idaho, the primary forage for chinook is kokanee salmon. In fact, one of the purposes of the chinook introduction was to control an overabundant kokanee population (Horner pers. comm. 1991). In Lake Oahe, South Dakota and Lake Sakakawea, North Dakota, chinook feed primarily on rainbow smelt. Rainbow smelt populations tend to fluctuate considerably, resulting in fluctuations in the condition of the chinook. During periods of low numbers of rainbow smelt, chinook sizes fell to an average of 3 lbs in Lake Oahe and to < 5 lbs in Lake Sakakawea. Sizes have increased as the forage base has recovered. In Sakakawea, large chinook also feed on goldeye although this constitutes only about 1% of the total forage (Fielder pers. comm. 1991, Power, pers. comm. 1991).

In Cascade Reservoir, Idaho, where the chinook plant was unsuccessful, chinook did not feed significantly on yellow perch. It is assumed that if they had survived, they would have fed primarily on rainbow trout and coho. Yellow perch are primarily a littoral oriented species during most of their life and are therefore not generally available to a more pelagic species like chinook. When yellow perch are 2 to 3 months old they do have a brief pelagic phase in Cascade Reservoir. During that time they would be available to chinook. However, for 9 to 10 months a year, perch are not available to chinook (Anderson, pers. comm. 1991).

In Lake Michigan, small chinook feed on rainbow smelt and large chinook feed on alewife (Huffacher, pers. comm. 1991). In the Minnesota waters of Lake Superior, large chinook (averaging 27.4 inches) feed almost exclusively on smelt. Small chinook (averaging 16.9 inches) feed on smelt and opossum shrimp (Mysis relicta) is approximately equal portions (Close et al 1984).

In general, adult landlocked chinook seem to favor soft rayed, pelagic-type fishes as prey.

### Habitat requirements

Raleigh at al (1986) concluded that young-of-the-year chinook tend to select water velocities of 0 to 2.0 ft/s with an optimal range of 0 to < 1.3 ft/s at depths of $\geq$ 6 inches. Optimal size substrate for escape and winter cover is 4 to 16 inches in diameter. Most relatively silt free chinook streams with a 40 to 60% pool area will provide adequate juvenile habitat area. A temperature range of 32 - 75° F is adequate for chinook, with an optimal range of 54 - 64° C.

Some chinook introductions have been tried in coolwater reservoirs. In these situations, chinook distribution is limited by warm water temperatures. In Lake Sakakawea, North Dakota, chinook are limited to the parts of the reservoir that have summer water temperatures about 55° F to 59° F and 5 ppm dissolved oxygen (Power, pers. comm. 1991). Chinook were introduced into Cascade Reservoir, Idaho, but they never became established. Anderson, (pers. comm. 1991) believes that the reason is that the water quality in Cascade Reservoir is unsuitable for chinook due to warm water temperatures and the eutrophic character of the reservoir.

### Common limiting factors

In many systems no suitable spawning habitat exists for chinook and the fisheries is entirely supported with hatchery stock. An abundant forage base is also needed to establish a population of large chinook.

## Characteristics of chinook salmon fisheries in similar situations

Biologists in Idaho, North, and South Dakota commented that the chinook fishery in their states is a very specialized fishery. Anglers need large boats equipped with downriggers in order to catch chinook. Anglers in Lake Coeur d'Alene who utilize the chinook resource spend a lot of time learning how to fish for chinook (Horner pers. comm 1991, Fielder, pers. comm. 1991). In Lake Sakakawea, North Dakota, while about 90% of the harvest is caught with downriggers, there is a longline season in both the spring and fall. North Dakota also has a snagging season in October (Power pers. comm. 1991).

One social problem that has occurred in Idaho is that people want wild fish and not hatchery fish. The Idaho Fish and Game Department would like to build some barriers in the tributary streams to prevent chinook spawning because they are concerned about chinook overrunning their food supply. They do not have much angler support for this program. Chinook anglers are not, in general, supportive of Idaho's attempts to keep the chinook/kokanee fishery in balance (Horner pers. comm. 1991).

### Mean annual and range of catch rates

In Ft. Peck Reservoir, Montana the catch rate for chinook in the fall of 1990 was 0.05 fish/hr. The spring and summer catch rates are described as "very low" (Wiedenheft pers. comm 1991).

In Cascade Reservoir, Idaho, the catch rate on chinook during January 1985 was 0.02 fish/hr, compared to a total salmonid catch rate of 0.05 fish/hr (Partridge 1985).

In Chesterfield Reservoir, Idaho, catch rates averaged 0.03 fish/hr in 1984, with the highest catch rate (0.09 fish/hr) occurring during the July 21 to Aug 3 period. Chinook comprised 7% of the total angler harvest (Partridge 1990).

In Anderson Ranch Reservoir, Idaho, catch rates for fall chinook salmon averaged 0.01 fish/hr for boat anglers and 0.09 fish/ hr for shore anglers in 1985. Lake Coeur d'Alene had a fall chinook catch rate of .003 fish/hr in 1985 and .002 fish/hr in 1986 (Partridge 1988).

Chinook salmon have been stocked by the Wisconsin Department of Natural Resources in Lake Michigan since 1969. Since that time, catch rates have steadily increased. The highest catch rate recorded in the Wisconsin waters of Lake Michigan is about 0.09 fish/hr in 1985 (Hansen et al 1990).

In the Minnesota waters of Lake Superior, the highest observed seasonal catch rate for chinook was 0.008 fish/hr (Close et al 1984).

**Stocking rates and catch ratios**

Stocking rates in Lake Coeur d'Alene, Idaho, ranged from 2 fish/acre to 11.6 fish/acre between 1982 and 1986. The stocking rate in Cascade Reservoir, Idaho was 6.4 fish/acre and in Chesterfield Reservoir, Idaho the stocking rate has varied from 15.3 fish/acre to 111.7 fish/acre (Partridge 1988).

South Dakota stocks up to 1 million salmon/year in Lake Oahe although in some years this number has been adjusted downward to 250,000 to 500,000/year when there were too many salmon (Fielder pers. comm. 1991).

In Lake Michigan, the State of Wisconsin has stocked a total of 23 million chinook between 1969 and 1985. Prior to 1978 Wisconsin generally stocked less than 1 million fish/yr, but since 1978 they have stocked generally over 2 million fish/yr. This is equivalent to a stocking rate of ≤.5 fish/acre. Fingerling chinook salmon had the highest catch ratio for any of Wisconsin's stocked salmonids (12.9%) (Hansen et al 1990).

The catch ratio for chinook salmon in Minnesota's waters of Lake Superior averaged 0.23% from 1974 to 1979, with the maximum catch ratio being 0.33% (Close et al 1984).

**Sport fishery yields**

In Ft. Peck Reservoir, Montana, 187 chinook were taken during the fall 1990 creel survey. This survey was done during the season when chinook fishing was best and so represents most of the year's harvest (Wiedenheft pers. comm. 1991).

In Lake Oahe, South Dakota, the harvest of chinook has been as high as 30,000/year (Fielder pers. comm. 1991).

In the Wisconsin waters of Lake Michigan, catches of chinook salmon increased from 206 fish in 1969 to a peak of nearly 318,000 in 1983. Chinook is the dominant salmonid species harvested, comprising 35% of the total salmonid catch (Hansen et al 1990).

In Lake Sakakawea, North Dakota, the harvest of chinook currently averages about 5,000 fish/yr, although harvest has been as high as 15-20,000 fish/yr (Power, pers. comm. 1991).

In the Minnesota waters of Lake Superior, the total catch in 1983 was 3,479 fish, a 2.8 fold increase over the 1982 harvest. (Close et al 1984).

**Seasonal factors affecting the fishery**

In Ft. Peck Reservoir, Montana, chinook can not be caught from shore except in late October and early November. The rest of the year downriggers are needed to fish for chinook. Catch rates are very low during the spring and summer months (Wiedenheft pers. comm. 1991).

In Anderson Ranch Reservoir, Idaho, nearly 85% of the harvest by bank anglers and 50% of the boat angler harvest occurred in May in 1985 (Partridge 1988).

During the warm summer months, chinook are restricted to the cooler, deeper portions of Lake Sakakawea, North Dakota. Consequently, angling is limited to downriggers. However, in the spring and fall the chinook do move closer to shore and provide for a limited longline season. In October there is a snagging season (Power pers. comm. 1991).

In the Minnesota waters of Lake Superior fall creel census efforts were discontinued as the harvest of chinook in October and November was negligible (Close et al 1984).

**Standing crops**

No information was available on this topic.

**Review of the literature on species interactions, concentrating on potential interactions with the existing sport fish species (trout, yellow perch, walleye, and kokanee).**

**Predation risk**

In Idaho, chinook have only been successfully stocked in lakes which contain kokanee salmon. There is currently a concern in Idaho that chinook will overrun their food supply and depress kokanee numbers too much. This is particularly a concern in Lake Coeur d'Alene where the Idaho Fish and Game Department has lost control of chinook numbers due to unexpected wild reproduction. If chinook do outstrip their food supply, the result may be a small to non-existent kokanee population, with very small sized chinook (Horner pers. comm. 1991).

In Idaho, returns of chinook salmon from waters that do not have a pelagic forage fish such as kokanee have not been as successful in producing trophy-sized fish. The size of the chinook harvested from the Idaho lakes which lack the pelagic prey base has not been larger than the size of the rainbow trout and coho salmon normally caught in these waters. Cascade Reservoir is a good example of this problem. The fishery in this reservoir is mostly supported by a self-sustaining yellow perch population, and hatchery rainbow trout and coho salmon. Although some chinook were harvested by anglers during the years after stocking, the mean length of fish caught was 16 inches (Partridge 1985).

Chinook were introduced into Lost Valley Reservoir, Idaho, in an attempt to reduce numbers of yellow perch. Despite relatively high stocking rates (21 to 86 fish/acre), anglers reported few of these fall chinook in the harvest. During 1985, this reservoir was rehabilitated with rotenone. During this treatment 20 to 30 poor condition chinook were sampled ranging in size from 6.9" to 9.0" (Partridge 1988).

In Anderson Ranch Reservoir, Idaho, chinook were stocked too heavily, and wiped out the kokanee population. Maintaining the proper stocking rate seems to be key, even in situations where there is no natural reproduction. A stocking rate of 1 - 2 fish/acre seems to be about right (Horner pers. comm. 1991). It might be necessary to adjust this figure downward if other top predators were present in the system.

**Competition risk**

In Ft. Peck Reservoir, Montana, there is concern about having too many predators as chinook are very aggressive and do compete with other species (Wiedenheft pers. comm. 1991).

Young chinook, less than 4" total length, may compete for food with other planktivorous and insectivorous fishes. Research in Idaho has shown that the ideal size-at-release for chinook is 5.7" - 6.1" so that the chinook may feed on newly emerged kokanee, rather than competing with kokanee (Partridge 1988).

In Lake Oahe, South Dakota, there have not been any documented problems with species interactions since the introduction of chinook. Walleye and northern pike are the other significant game fish in that reservoir. They are spatially segregated from the chinook, with the coolwater species preferring the shallow, warmer parts of the lake and the chinook preferring the deep, coolwater areas. Although both walleye and chinook eat rainbow smelt, there hasn't been any change in walleye growth and numbers since the introduction of chinook. It should be noted that the chinook smolts are preyed upon heavily by walleye and other species when they are stocked into the lake. Chinook outgrow the predation risk when they reach yearling size (Fielder pers. comm. 1991).

In Lake Sakakawea, North Dakota, chinook prey upon rainbow smelt. The smelt are also the primary forage for most of the other game fishes in the lake such as walleye and sauger. However, no negative competitive interactions have been documented between chinook and the other game species (Power pers. comm. 1991).

**Risk of spread of disease**

The chinook stocked into Ft. Peck Reservoir came from Michigan. These fish tested disease free at the time. However, Michigan is currently experiencing severe problems with bacterial kidney disease (BKD), with up to 20,000 dead fish washing up on the shores of Lake Michigan. Consequently, eggs from Lake Michigan can no longer be imported into Montana (Peterson pers. comm. 1991).

In addition, all Columbia River chinook have BKD and IHN (Anderson, pers. comm. 1991, Peterson, pers.comm. 1991). Chinook from North and South Dakota are currently disease free, but they rarely have any extra eggs to send to other states. At the present time, there is concern about getting enough clean chinook eggs to stock into Ft. Peck Reservoir, much less beginning a stocking program in other lakes (Peterson, pers. comm. 1991).

**Risk of spread of new species beyond the area of introduction (pioneering tendencies).**

Chinook have strong pioneering tendencies. Chinook introduced into Ft. Peck Reservoir moved both upstream and downstream of the reservoir. One chinook was captured at the first dam upstream of Ft. Peck on the Missouri River near Great Falls (Wiedenheft, pers. comm. 1991). In Lake Oahe, South Dakota, a significant fishery has established itself in the tailrace. Salmon were never planted here, they moved through the dam (Fielder pers. comm. 1991).

When chinook were stocked in Lake Coeur d'Alene it was assumed that they would not reproduce because they are an anadromous fish. However, they have pioneered into the existing tributary habitat and reproduced. It is estimated that half the existing stock of chinook in Lake Coeur d'Alene is wild fish (Huffacher pers. comm. 1991). When the Idaho Fish and Game Department first introduced chinook into Coeur d'Alene, they used Bonneville stock. These fish spawn in the third week in September. At this time of the year some of the tributaries were unavailable to chinook due to a thermal block - that is, water temperatures were still too warm. Later, Idaho switched to Lake Michigan stock, which spawn later in the fall. This switch resulted in chinook pioneering into a greater number of tributaries because the thermal block no longer existed (Horner pers. comm. 1991).

In Lake Sakakawea, North Dakota, some immature age 1 chinook have been found at the upper end of the reservoir in seemingly unsuitable habitat. It is unknown if these fish are downstream migrants from Ft. Peck or upstream migrants from within Sakakawea (Power pers. comm. 1991).

## The effect of introducing chinook into Canyon Ferry Reservoir

### The adequacy of the habitat for chinook

#### Spawning

Spawning would occur in the Missouri River, below Toston Dam. Presumably, if the gravel in this reach of river is suitable for brown trout spawning then chinook could probably utilize it as well.

Chinook reproductive success in the Missouri River will depend on several variables, one of which is water temperature. The temperature suitability of the Missouri will depend in part on the timing of the spawning run. The timing of the spawning run will be determined by the strain of chinook stocked. Assuming that eggs are available from within Montana or the Dakotas, then the spawning run might be in October. Water temperatures in the Missouri River at Toston average about 46 - 48° F in October which would be suitable for chinook spawning.

#### Rearing

Juveniles out-migrate in the spring, primarily April - June (Raleigh et al 1986). Rearing habitat appears to be suitable for chinook in the Missouri River and Canyon Ferry Reservoir, based on a very limited amount of data.

#### Adult

Water temperatures at the surface of Canyon Ferry Reservoir in the summer commonly exceed 70° F. Based on the Lake Sakakawea example, chinook are limited to parts of the reservoir with water temperatures of about 55 - 59° F and 5 ppm dissolved oxygen. Assuming 1990 was a typical year, the only portion of Canyon Ferry that had water temperatures that cool were in the northern end of the reservoir, below a depth of about 85 feet.

At that depth, dissolved oxygen may be limiting. Based on water quality data collected in 1975, DO ranged from 2.2 to 9.4 mg/l at a depth of 60 feet. At a depth of 100 feet, minimum DO levels dropped to 1.8 mg/l. It seems clear that summer conditions in Canyon Ferry Reservoir may well be limiting for a cold water species like chinook.

The average pH levels in Canyon Ferry and the Missouri River are suitable for chinook. No other water chemistry criteria have been developed for landlocked chinook.

### Interactions with existing species

#### Competition

There is a risk that fall chinook and brown trout would compete for spawning habitat. There is a strong possibility of overlapping redds on the spawning beds due to the similar timing of the spawning runs.

Juvenile chinook would compete with all the insectivorous and planktivorous species in the reservoir and river. It is unknown whether juvenile chinook would be present in sufficient numbers to have an impact on other species.

Predation

Chinook salmon are a piscivorous fish. They have to prey on an existing fish species in order to be successful. They are a pelagic fish which prefers a pelagic prey. The most likely prey for chinook in Canyon Ferry are rainbow trout, Utah chub, and yellow perch (seasonally). In Idaho where chinook introductions have been attempted on a similar prey base the introduction was not a success as the chinook grew no faster or larger than the rainbow trout.

In general, it seems to be necessary to establish a successful, large chinook fishery there needs to be an abundant pelagic prey base. Such a prey base does not currently exist in Canyon Ferry.

Spread to other waters

Clearly, dams are not barriers to the downstream movement of chinook. There is a substantial risk that chinook would move downstream into Hauser Reservoir. Hauser currently has an abundant kokanee population which is providing a popular sport fishery. If chinook were to enter Hauser there is a risk that they would begin to prey heavily on the kokanee - perhaps too heavily. The consequences of such an introduction are beyond the scope of this report, but should be carefully considered before any introduction is attempted.

***KOKANEE***

Review of the life history of kokanee

Kokanee are native to coastal waters from Oregon to Alaska. They are not native to Montana. They were first introduced into Montana in 1914 into Flathead Lake. Kokanee currently exist in a number of lakes west of the continental divide, as well as a few east of the continental divide (Brown 1971). Kokanee have been planted in Canyon Ferry Reservoir in large numbers in the past. They did not become established in the reservoir, but they did move downstream into Hauser Reservoir. Hauser currently supports a popular kokanee fishery derived from this source.

Age and growth.

Growth rates and age at sexual maturity tend to vary in kokanee - not only between water bodies but also within a water over time. Because of the volatility of kokanee growth rates it is difficult to describe a typical pattern. Bjornn (1961) noted that there have been statistically significant differences in kokanee growth rates from one year to the other in the Priest Lakes, Idaho.

Age I+ kokanee in Hauser Reservoir, Montana are approximately 7" at the beginning of the growing season and are about 10" by the end of the growing season. Age II+ kokanee grow from about 12" to 17", and age III+ kokanee grow from 17" to 19 - 20" (Lere 1991).

**Spawning habits**

Most kokanee reach maturity in their fourth year in Montana. The spawning season is typically November and December in Montana. Kokanee congregate over loose rubble, gravel, or sand in tributary streams or along the borders of lakes. Redds are built by the female and are usually 2 to 4 square feet. Eggs develop in the gravel and take 110 days to hatch when the water temperature is 43° F. Fry emerge the following spring and enter the lake where they develop to maturity. All adult males and females die soon after spawning (Brown 1971).

Lakeshore spawning is generally limited to areas with groundwater flow into the lake (Decker-Hess pers. comm. 1991). Tributary spawning kokanee also tend to prefer spring influenced areas, although spring flow is not mandatory in riverine situations. Most (69%) of the kokanee spawning in the mainstem Flathead River, Montana occurred in areas influenced by groundwater springs (Beattie et al 1988).

In Oregon, most kokanee spawning takes place when water temperatures are between 43 and 48° F, although kokanee will spawn at temperatures of 50 F if no colder water is available (Fies, pers. comm. 1991). Kokanee require minimal egg incubation water temperatures in excess of 38° F for several days before the developing embryos can survive at temperatures below 38° F (Combs 1965). In Lake Granby, Colorado, the lack of natural reproduction has been attributed to cold water temperatures (Martinez and Wiltzius 1991).

The timing of spawning varies by location. In Oregon, kokanee spawn as early as Labor Day, whereas in Montana spawning is typically in late fall. It is not clear if the timing of spawning is determined by environmental conditions or genetics. For example, in Vallecito Reservoir, Colorado, kokanee spawn as early as mid-September. The origin of this strain of kokanee was Flathead Lake, where spawning occurs much later (Japhet pers. comm. 1991). However, Odell Lake, Oregon, contains two morphologically distinct races of kokanee. One race, thought to have originated from Kootenay Lake, British Columbia, spawns from mid-September to November. The other race originated in Flathead Lake, Montana and spawns from mid-October through December (Lindsay and Lewis 1978).

In Flaming Gorge Reservoir, Wyoming, kokanee used to spawn in some spring seeps that were the result of a leaking dam structure. Then the dam was repaired and the seeps no longer exist. Now kokanee have moved their spawning areas to the same types of places utilized by brown trout (Wengert pers. comm. 1991).

**Food habits**

Kokanee feed primarily on plankton. Micro-crustaceans are the most important item, but midges and other aquatic insects are frequently taken (Brown 1971).

In Flathead Lake, Montana, kokanee were strongly selective for Daphnia thorata and Epischura. Other species eaten included Cyclops, Bosmina, and Diaptomus. Diaptomus seemed to be most important in the winter and spring months, Daphnia thorata were most important in the summer (Beattie et al 1988).

In Dworshak Reservoir, Idaho, Daphnia and Cyclops were the most important kokanee food items in 1989, Daphnia was the prime food organism except in May when Daphnia fell below 4% of total zooplankton present (Mauser et al 1990).

When present, Daphnia galeata mendotae was the most preferred food item of all sizes of kokanee in Lake Granby, Colorado, usually outnumbering all other ingested organisms combined. Kokanee also appear to be highly selective for Daphnia pulex (Martinez and Wiltzius 1991).

In Elk Lake, Oregon, kokanee were reported to feed primarily on Chironomus, although they also eat Ephemeroptera, Ostracoda, and Hyalella (Chapman et al 1967).

In Lake Roosevelt, Washington, kokanee were strongly selective for Daphnia schodleri. Other foods included Leptodora kindtii, organic detritus, and walleye eggs (Peone 1990).

Kokanee fry fed extensively on Cyclops in Odell Lake, Oregon from late spring to mid-summer when Daphnia longispina became more abundant (Lindsay and Lewis 1978).

**Habitat requirements**

Kokanee reside in coldwater lakes and reservoirs and may also be found in streams adjacent to lakes during the spawning season.

Temperature is one of the most important factors determining the distribution of kokanee. The most favorable temperatures for young sockeye is the range from 41° F - 63° F. A general physiological optimum occurs in the vicinity of 59° F. In laboratory experiments, no sockeye growth took place at temperatures in excess of 73° F, despite excess food (Brett et al 1969).

Kokanee will move in response to temperature. In Elk Lake, Oregon, kokanee were found to move to deeper waters in August when the temperature of the upper 30 feet of the lake exceeds 65° F.

### Common limiting factors

It has been documented that kokanee salmon tend to decrease in size as their population increases in numbers. This trend has been well known for a long time (Foerster 1944). Rieman (1981) researched this trend in more detail in several north Idaho lakes. He found that growth of age 0+ and age 1+ kokanee was influenced by lake productivity and food availability but not by fish density. Growth of age 2+ and age 3+ kokanee was more influenced by fish density. Although he concluded that the influence of lake productivity on kokanee density is not clear, it is probable that the critical density increases as productivity increases.

In Anderson Ranch Reservoir, Idaho, kokanee numbers are rebounding from low levels in the 1980's. The causes for the decline in kokanee are hypothesized to be: 1) record high water years which could have reduced kokanee numbers through flushing the fry out of the reservoir during prolonged periods of spill and also reduced survival by reducing zooplankton densities, 2) release of fall chinook into the reservoir, and 3) the timing and size of the hatchery reared kokanee that were released (Partridge 1988).

The principle limiting factor for kokanee in Priest Lake, Idaho is lake trout predation, especially on the older age classes (Mauser et al 1988).

In Lake Granby, Colorado, the most significant variable determining mean spawner size is reservoir capacity on November 30. Low water levels in November result in higher survivorship and a corresponding small mean size of fish. It is hypothesized that lower water volumes allow the reservoir to warm more quickly in the spring resulting in a longer growing season. This variable seems to be even more important than competition with Mysis and predation by lake trout in determine kokanee population dynamics in this lake (Martinez and Wiltzius 1991).

In Odell Lake, Oregon, only one variable was found that showed a significant correlation to kokanee abundance and growth. The regression of year-class catch on mean density of Cyclops when these year classes were Age 0 was significant. It is believed that the density of Cyclops may be important to early summer survival (Lindsay and Lewis 1978).

## Characteristics of kokanee fisheries in similar situations

### Mean annual and range of catch rates

Summer catch rates for kokanee in Hauser Reservoir have ranged from 0.10 to 0.42 fish/hr. The overall summer catch rate over the last 5 years (1986 -1990) has been 0.22 fish/hr. Winter catch rates in Hauser Reservoir have averaged 0.20 fish/hr and have remained relatively constant during the three winters sampled. In Holter Reservoir, the summer catch rate for kokanee in 1990 was 0.11 fish/hr, the highest yet recorded (Lere 1991).

In Flathead Lake, Montana the winter catch rate for kokanee in 1984 was 4.42 fish/hr, in 1985 it was 3.2 fish/hr, and in 1986 it was 1.2 - 2.3 fish/hr

(McMullin 1984, Clancey 1985, Beattie n.d.). These high catch rates occurred when the lake was frozen over and the kokanee were congregated in specific bays well known to anglers. Summer catch rates in Flathead Lake ranged from 0.51 fish/hr to 2.12 fish/hr between 1978 and 1983 (Hanzel 1984).

In 1980, Lake Pend Oreille, Idaho had an average kokanee catch rate of 1.5 fish/hour. This was a decline from the average catch rate of 2.1 fish/hour in the time period from 1959 to 1980. Annual catch rates for kokanee in Pend Oreille have ranged as high as 3.5 fish/hour in 1964 (Ellis and Bowler 1981).

In Lake Coeur d'Alene, Idaho, the kokanee catch rate in 1979 was 2.04 fish/hr or 0.33 lb/angler hour (Rieman and Ward 1981).

In Priest Lake, Idaho, the average catch rate from the early 1950's to 1971 was 1.2 fish/hr. However, the population has declined since then and they are currently functionally extinct in this lake (Mauser et al 1988).

In Dworshak Reservoir, Idaho, anglers fishing specifically for kokanee harvested 1.25 fish/hr in a May-August sport fishery (Mauser et al 1990).

In Odell Lake, Oregon, catch rates varied between 0.17 - 0.68 fish/hr between 1965 and 1977 (Lindsay and Lewis 1978).

In Lake Roosevelt, Washington, 1988 kokanee catch rates ranged from 0.03 fish/hr (August) - 0.28 fish/hr (October). The yearly average was 0.11 fish/hr. In 1989 the kokanee catch rate ranged from 0.004 fish/hr in November to 0.07 fish/hr in October. the 1989 yearly average catch rate was 0.04 fish/hr (Peone et al 1990).

Catch rates in Loon Lake, Washington have ranged from 0.3 kokanee/hr from 1969 - 1973 to 4.4 kokanee/hr in 1984-1985 (Scholz et al 1988).

**Sport fishery yields**

The yield from Lake Pend Oreille, Idaho in 1980 was 50,642 lbs of kokanee, which is equivalent to 0.91 lb/acre (Ellis and Bowler 1981).

The yield of kokanee from Lake Coeur d'Alene in 1979 was 17.9 lb/acre and in 1980 yield was 17.66 lb/acre (Rieman and Ward 1981).

The yield from Priest Lake, Idaho averaged 64,200 fish from the 1950's through 1971. In 1978, 4,593 fish were harvested, and the population has been functionally extinct ever since (Mauser et al 1988).

Dworshak Reservoir, Idaho yielded 160,000 fish (247/acre) in 1989 (Mauser et al 1990).

The kokanee harvest from Lake Roosevelt, Washington, was 9,362 ± 3,873 in 1988 and was 11,906 ± 3,597 in 1989 (Peone et al 1990).

The harvest rate varies with the size of the kokanee. Larger kokanee are much more vulnerable to anglers than small kokanee. Data from Spirit

Lake, Idaho indicate that kokanee 10.6 inches long could be caught at 20 times the rate of kokanee 9.0 inches long (Rieman and Myers 1990). In some areas biologists are attempting to manage for a specific mean size kokanee spawner. The object is to provide a fish that is large enough to satisfy anglers but not so large it is vulnerable to overharvest (Martinez and Wiltzius 1991).

**Seasonal factors affecting the fishery**

Bjornn (1961) noted that catch rates for kokanee in Priest Lake, Idaho, were highest in the early summer and fall. As the epilimnion warms, the catch rate falls. Those anglers who fished near the thermocline during the mid-summer period had a higher success rate. When the surface waters cool in the fall, the catch rate rose to as high as 6 fish/boat/hr.

Winter kokanee fisheries can be very productive. In Lake Granby, Colorado it is common for more kokanee to be harvested in January during the snagging season than are taken by anglers from May - November (Martinez and Wiltzius 1991).

**Standing crops**

The standing crop of kokanee in north Idaho lakes was reported to be (Partridge 1988):

| | | |
|---|---|---|
| Anderson Ranch Reservoir | 452 | kokanee/acre |
| Lake Coeur d'Alene | 1,806 | kokanee/acre |
| Lake Pend Oreille | 642 | kokanee/acre |
| Spirit Lake | 2,441 | kokanee/acre |

5. Hatchery stocking and survival

The Idaho Department of Fish and Game stocks kokanee in several north Idaho lakes. In 1984, the following stocking rates were used (LaBolle 1986):

| | |
|---|---|
| Pend Oreille | 615 fish/acre |
| Spirit Lake | 1,072 fish/acre |
| Coeur d'Alene | 1,166 fish/acre |

Colorado uses a more conservative stocking rate. In Vallecito Reservoir, which has some natural reproduction, kokanee are stocked at a rate of 90 2" fry/acre. In other reservoirs with no natural reproduction, stocking rates are more typically 150 - 200/acre (Japhet pers. comm. 1991).

Fry survival was estimated to be 11.6% from July/Aug to Sept in Pend Oreille.

Review of the literature on species interactions, concentrating on potential interactions with the existing sport fish species (trout, yellow perch, walleye, and kokanee).

### Predation risk

Kokanee are primarily planktivorous so there is little risk of kokanee predation impacting the existing fish species. However, there is a risk that kokanee would be preyed upon to the point where the introduction might not be successful.

Brown trout will feed upon kokanee at some times of the year, although they usually utilize different habitats in reservoirs. In addition, yellow perch may feed on kokanee juveniles in the spring when they are entering the reservoir (Fies pers. comm. 1991).

The predator/prey balance with kokanee is notoriously difficult to manage. In systems with high reproductive potential, kokanee often become very abundant and stunted in size. In these situations, fisheries managers often encourage species that will prey on kokanee to keep kokanee numbers down and sizes up (see the section on chinook introductions in Idaho). When kokanee reproduction is low or predation on kokanee very high, kokanee populations can become extinct very rapidly. This has happened in numerous lakes that contain lake trout and Mysis shrimp.

### Competition risk

In Hauser Reservoir, just downstream from Canyon Ferry, a bloom of kokanee has coincided with a decline in numbers of brown and rainbow trout. Considerable concern has been expressed that the two occurrences are related. I contacted Colorado, Oregon, and Wyoming to see if those states had any experience with negative interactions between trout and kokanee.

Mauser at al (1988) hypothesized that competition between kokanee and westslope cutthroat trout may have caused an additional limitation on the kokanee fishery of Lake Coeur d'Alene, Idaho. Kokanee would be more likely to compete with smaller cutthroat. Larger cutthroat eat larger insects that are not eaten by kokanee.

In Oregon, where kokanee and trout co-exist in small lakes, there is some competition for food resources. However, this competition is much reduced or eliminated in larger lakes where the trout and kokanee tend to segregate into different habitats. In the larger lakes, (>4000 acres), kokanee tend to be more pelagic than the trout (Fortune pers. comm. 1991).

Several lakes in Oregon contain both kokanee and brown trout. These lakes contain early spawning kokanee, some of which spawn as early as Labor Day. The brown trout spawn later than the kokanee in these lakes. There is some superimposition of redds (brown trout on kokanee) in these systems, but the overall kokanee productivity is so high that the loss of some kokanee redds is viewed as beneficial (Fies pers. comm. 1991).

Vallecito and Lemon Reservoirs in Colorado contain kokanee, rainbow, and brown trout. No significant negative interactions have been reported. Brown trout do utilize kokanee for forage to a limited extent. Vallecito Reservoir has some natural reproduction in the tributary system. The brown trout and kokanee are spawning at the same time but there has been no problem of overlapping redds and both populations are holding up (Japhet pers. comm 1991).

Flaming Gorge Reservoir, Wyoming contains kokanee, brown, rainbow, and lake trout. While kokanee were first stocked in the reservoir in 1964, they did not become abundant until the 1980's after a large (one million fish) kokanee plant. Kokanee seem to be better able to utilize the small zooplankton than the Utah chubs, brown and rainbow trout. At the present time both the brown and rainbow trout are having a difficult time finding suitable forage in Flaming Gorge. The rainbows are suffering due to the large numbers of planktivorous fishes in the reservoir. The brown trout are not doing well due to the lack of small fish forage, especially Utah chubs. In this reservoir, kokanee seem to have had a negative interaction with brown and rainbow trout (Wengert pers. comm. 1991).

**Risk of spread of disease**

Kokanee in Hauser Reservoir have Frunculosus, a bacterial infection. However, trout in the upper Missouri River drainage are already infected with this bacteria so there is not a concern about introducing a new disease into Canyon Ferry. This disease is not currently causing any serious problems in the Missouri system (Peterson pers. comm. 1991).

In the fall of 1991, a substantial kokanee and brown trout fish kill occurred in Trout Creek, a tributary of Hauser Reservoir. The kill was determined to be caused by a fungus infection, Saprolegnia. While it is normal for spawning fish to suffer from fungus infections, they are rarely fatal. This particular infection was more severe than usual. The factors that caused the fish to be in a weakened condition, and therefore susceptible to the fungus, are unknown. Concern has been expressed that having large numbers of kokanee using the same spawning beds as brown trout could be increasing the incidence of fungus in brown trout. The significance of this fungus and the impact it may be having on brown trout is not known at this time (Peterson pers. comm. 1991).

**Risk of spread of new species beyond the area of introduction (pioneering tendencies)**

Kokanee became established in Hauser Reservoir through a plant which was made into Canyon Ferry Reservoir. Kokanee became established in Lake Koocanusa, Montana, through a release of hatchery fish that occurred in Canada. Kokanee are clearly capable of finding suitable spawning and rearing areas when they are introduced into new waters.

## The effect of introducing kokanee into Canyon Ferry Reservoir

### The adequacy of the habitat for kokanee

#### Spawning

Shoreline spawning kokanee require gravel and flows from springs for successful spawning. This type of habitat is rare in Canyon Ferry Reservoir. Consequently, no significant shoreline spawning could be expected. The most likely place for spawning to occur is in the Missouri River upstream of Canyon Ferry, particularly in spring influenced areas. At least two areas of the Missouri River below Toston have spring or groundwater inflow. In addition, Warm Springs Creek is considerably influenced by spring inflows. These are areas that attract trout spawners and would likely attract kokanee as well (Spoon pers. comm. 1991). Kokanee utilize the same spawning areas as brown trout in many areas when the two fishes co-exist so it seems reasonable to expect the same phenomenon in Canyon Ferry. Areas that are important brown trout spawning areas are likely to be suitable for kokanee as well.

Water temperatures in the Missouri River below Toston fall into the 43 - 48° F range in mid - late October. Water temperatures stay above 38° F until early to mid-November. Kokanee spawning later than mid-November may experience water temperatures too cold for egg incubation in some years.

#### Rearing

The timing of the outmigration of kokanee juveniles may depend on the strain of kokanee introduced into the reservoir. Most other areas of Montana which have kokanee have a late spawning strain which spawns in November and December and the young migrate to the lakes in the spring.

However, Oregon has eggs available of earlier spawning strains which would presumably move out of the tributaries earlier in the spring or in late winter if they continued to behave as they did in the lakes from which they originated. There are potential disease problems with these eggs as they are exposed to anadromous fish and could therefore be carrying unknown diseases.

There seem to be a wide variety of factors which influence kokanee population size in different lakes. It is difficult to predict whether stocking would be beneficial in Canyon Ferry. Kokanee have been stocked in large numbers in Canyon Ferry in the past without creating a kokanee fishery.

#### Adult

Aggus and Bivin (1982) developed a relation between harvest of kokanee in reservoirs and storage ratio and the growing season. Their formula is :

Harvest of kokanee = 8.771 + 2.682(storage ratio) - 4.682log(growing season)

Given that the storage ratio at Canyon Ferry is 0.53 and the growing season is 136 days at Canyon Ferry Dam, the expected harvest of kokanee would be 0.203 kg/ha/yr or 0.18 lbs/acre/yr or 6,359 lbs total from Canyon Ferry. The applicability of this model to Canyon Ferry Reservoir is unknown.

Surface temperatures in summer in Canyon Ferry are warmer than preferred for kokanee. Since it is known that kokanee avoid water temperatures in excess of 65° F, I plotted the depth of the 65° F isotherm in Figures 10, 11, 12. For approximately 80 days during 1990 the entire water column was warmer than 65° F at the Silos station. This indicated that kokanee would likely move out of the southern portion of the reservoir completely during the summer. At the White Earth station, there was approximately 30 days when almost the entire water column exceeded 65° F. At the Cemetery station, the lower 70 - 80 feet remained below 65° F for the entire year.

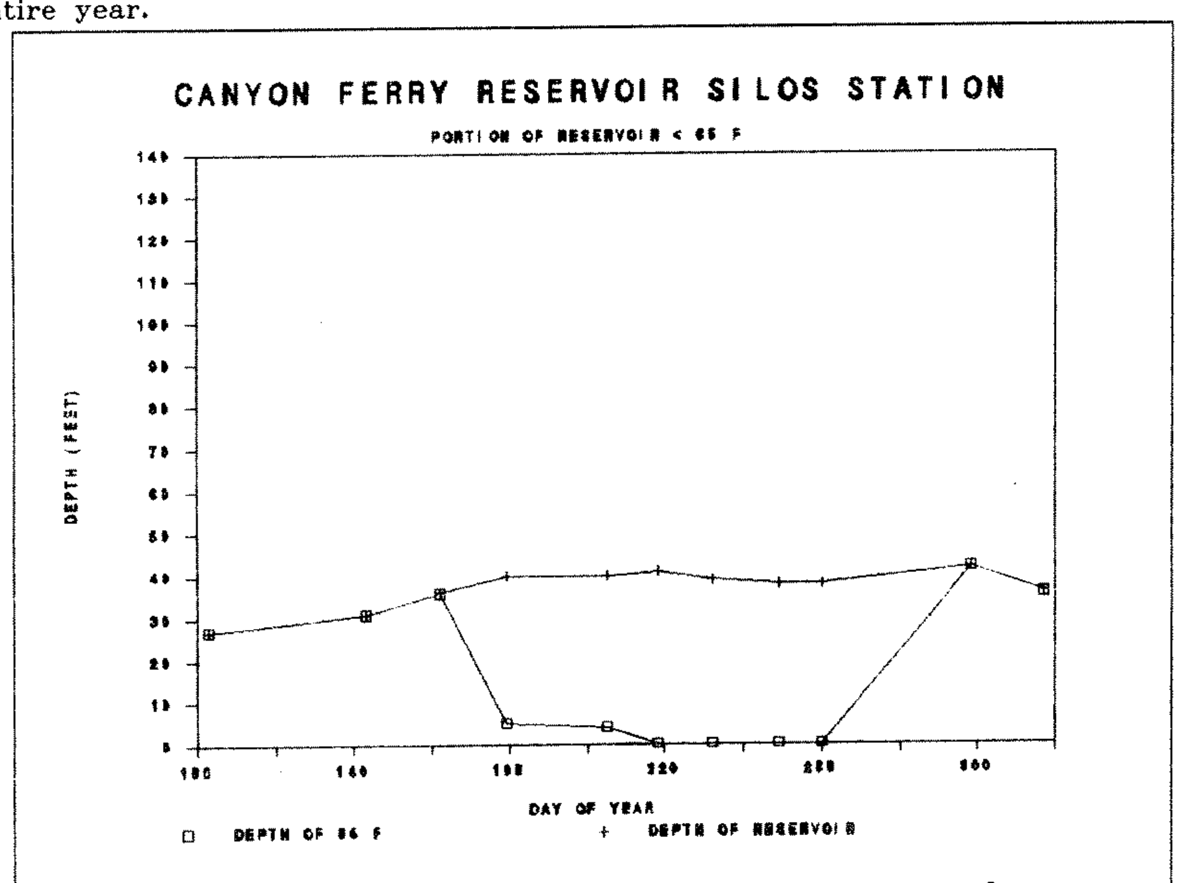



Figure 10 Shaded area is portion of reservoir $\leq$ 65°F

This temperature data indicates that kokanee would be restricted to a relatively small portion of the reservoir during the summer months. This leads to the next question - would kokanee be subjected to low levels of dissolved oxygen during the time they are restricted to the hypolimnion? Data retrieved from STORET indicates that sometime between 5/28/75 and 10/22/75, dissolved oxygen levels fell to 2.2 mg/l at a depth of 60 feet in Canyon Ferry.

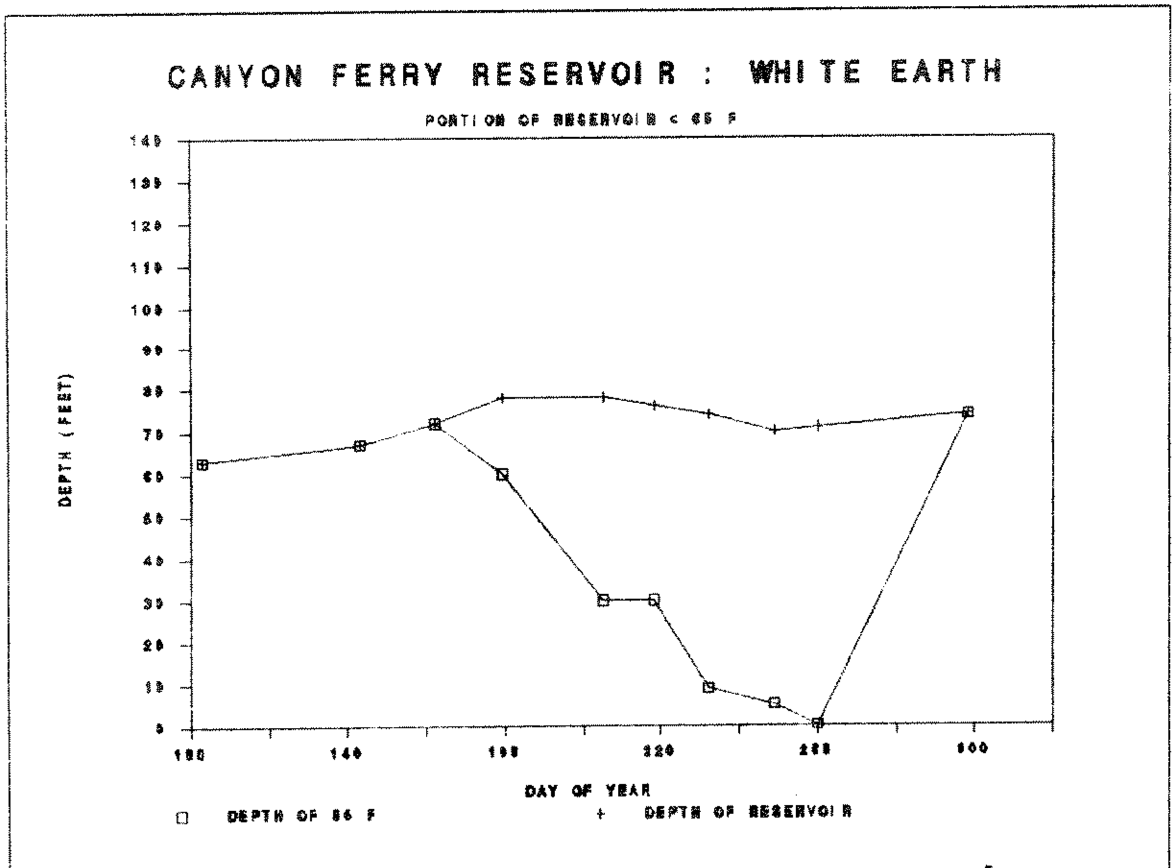



Figure 11 Shaded area is portion of reservoir $\leq$ 65°F

The minimum percent saturation of DO during this time was 19.8%. Between a depth of 60 - 145 feet, DO levels drop even more to a low of 0.6 mg/l and 5.3% saturation. These are potentially highly stressful (lethal?) conditions for kokanee.

Would the prey base in Canyon Ferry be adequate to support kokanee? The average zooplankton density in Canyon Ferry Reservoir between 1987 - 1990 was 23.1 organisms/liter. This is slightly higher than the average density of zooplankton in Hauser Reservoir during this same time period (21.7 organisms/liter) (Lere 1991). Hauser Reservoir currently supports a sizeable and growing kokanee population. It seems reasonable to assume that if the zooplankton densities in Hauser are sufficient to support a good kokanee fishery, then Canyon Ferry should have sufficient zooplankton as well.

The zooplankton community is dominated by Daphnia, Cyclops, and Diaptomus in Canyon Ferry (Lere 1991). Daphnia and Cyclops are some of the preferred food items for kokanee. It seems unlikely that kokanee would be food limited in Canyon Ferry.

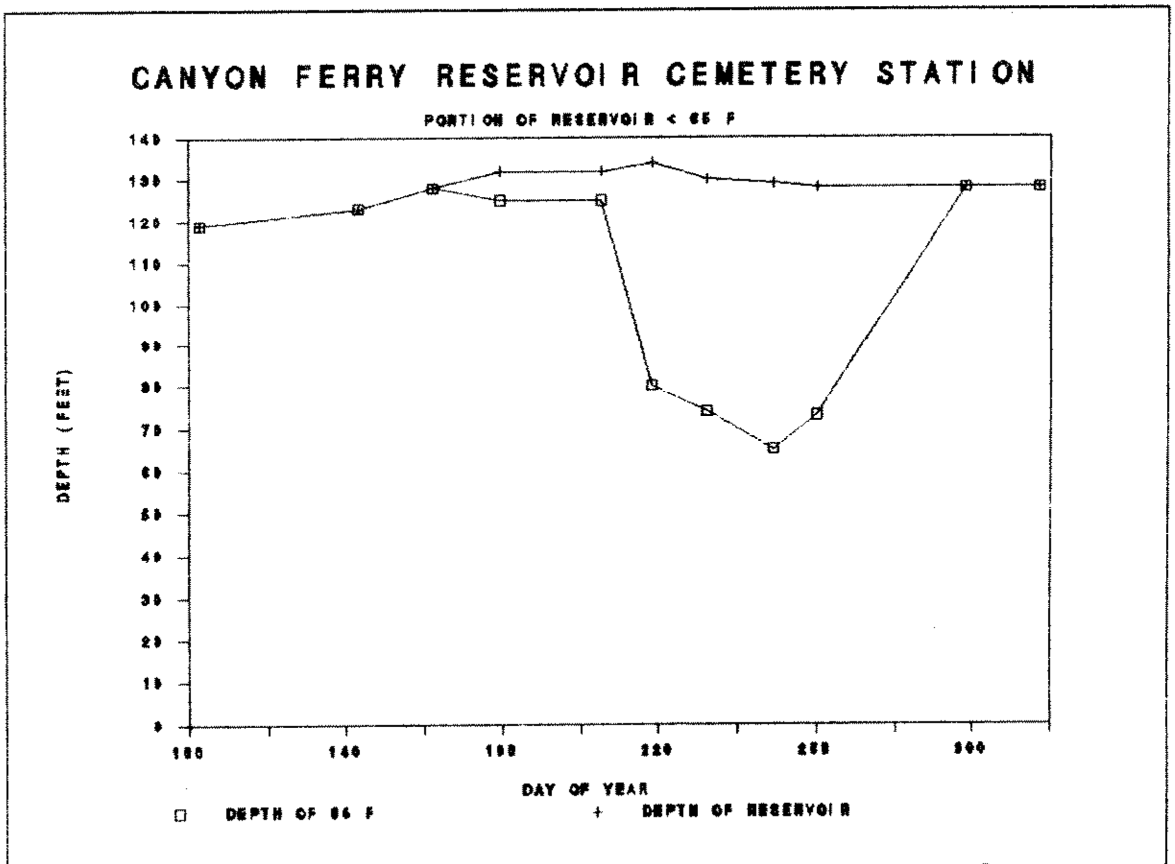



Figure 12 Shaded area is portion of reservoir $\leq$ 65°F

**Interactions with the existing species**

Competition

Daphnia is the most important food item in the diet of rainbow trout and yellow perch in Canyon Ferry Reservoir. Daphnia is also likely to be the most important food item of kokanee if they are introduced into Canyon Ferry. While many biologists I spoke with report no negative interactions between kokanee and trout, the potential certainly exists. In some waters rainbow trout are primarily piscivorous in which case there would be minimal competition with kokanee. However, in Canyon Ferry the rainbow trout are planktivorous, increasing the likelihood of negative impacts. Kokanee appear to be competing with rainbow trout for food and space in Hauser Reservoir. In addition, kokanee are competing with brown trout for spawning sites (Lere pers. comm. 1991).

Predation

Kokanee would not significantly prey on other fish species.

Spread to other waters

Kokanee already exist in abundance in Hauser Reservoir, immediately downstream from Canyon Ferry. Therefore, there is little risk of having any significant impact in a downstream direction unless the kokanee introduced into Canyon Ferry were of a different strain than the one currently residing in Hauser.

Kokanee would migrate upstream in the Missouri River during the spawning season. Kokanee die after spawning so there would not be adult kokanee in the Missouri River after the spawning season was complete. The young-of-the-year would outmigrate to the reservoir in the spring after hatching.

## *SUMMARY AND RECOMMENDATIONS*

The questions this report has tried to address are: 1) If any of these species were introduced into Canyon Ferry Reservoir would they flourish and provide a new sport fishery? and 2) What are the risks to the existing species? This is a summary of my findings on these questions.

### Smallmouth bass

#### Spawning habitat

Smallmouth bass prefer to spawn on sand, clean stone, or fine gravel in areas with little or no current. This type of habitat exists most commonly on the north end of Canyon Ferry Reservoir. (See pages 10, 15 - 22 ).

#### Rearing habitat

One potential limiting factor is spring weather conditions. Cold, windy, spring storms result in high mortality rates of juveniles and eggs. It should be expected that year class strength will vary widely depending on the spring weather. (See pages 11, 15 - 22).

#### Adult habitat

Smallmouth bass would likely be restricted in distribution to the rocky, shallower portions of the reservoir and to slow velocity areas in the Missouri River. Most of the suitable smallmouth habitat in the reservoir is located in the north end of the lake. Unfortunately, this portion of the reservoir is deeper than smallmouth prefer, however the shallow rocky places would be suitable habitat.

The Missouri River may be too cold for smallmouth bass. Average temperatures during the summer rarely reach the 70° F that smallmouth bass prefer. Temperature constraints would probably limit smallmouth numbers in the river system.

Before an introduction of smallmouth is undertaken I recommend that a survey of the reservoir substrate be done to determine quantitatively the amount of suitable smallmouth habitat. This would help determine if smallmouth would ever become abundant enough to provide a significant fishery.

If smallmouth are being seriously considered then a survey of crayfish populations is warranted. If crayfish are abundant in Canyon Ferry then there is a higher probability that the introduction would be a success and a lower probability of negative competitive interactions. (See pages 11, 15 - 22).

**Competition**

The risks of introduction are competitive interactions between young smallmouth and other planktivores, especially rainbow trout, yellow perch. In addition, smallmouth predation on the forage base could impact the other piscivores in the reservoir, such as brown trout (See page 14, 22).

**Predation**

Smallmouth bass will feed on yellow perch and rainbow trout. In some systems, significant smallmouth bass predation on salmonids has been documented (See pages 13, 22).

**Movement upstream and downstream**

It should be expected that smallmouth bass would move downstream and also potentially upstream as far as Toston Dam (See page 14).

**Status of the fishery**

If smallmouth bass were planted in Canyon Ferry and they found the habitat suitable, they would likely provide a fishery from May - October. Since smallmouth bass prefer relatively shallow water, anglers would not need deep water fishing gear. Most of the smallmouth fishing would be concentrated along the rocky shorelines in the northern end of the reservoir (See pages 12 - 13).

**Disease**

No significant disease risks were identified (See page 14).

Largemouth bass

### Spawning habitat

Largemouth bass construct nests in shallow water on a wide variety of substrates. The commonly seem to select warm, sheltered locations for spawning. Spawning habitat is unlikely to be limiting in Canyon Ferry Reservoir (See pages 23, 29 - 30).

### Rearing habitat

Largemouth bass are similar to smallmouth bass in their susceptibility to extreme fluctuations in year class strength due to variable early life history mortality rates. Spring weather conditions appear to be the most significant variable determining young-of-the-year survival. In years when high winds and cool temperatures occur during the spawning and incubation period, high mortality rates can be expected (See pages 25, 29 - 30).

### Adult habitat

Largemouth bass differ from smallmouth bass in that they prefer warmer water temperatures, shallower weedy habitats, and gravel, silt, or clay substrates. Canyon Ferry seems to be less than optimal habitat for largemouth bass, but it seems possible for a population to become established if there are enough shallow vegetated areas. Before any investment is made in establishing largemouth bass, a habitat survey is recommended to evaluated the quantity and quality of available habitat. In addition, a survey of the crayfish population would help to determine if Canyon Ferry has a suitable prey base (See pages 25, 29 - 30).

### Competition

Largemouth bass feed on zooplankton when young, and insects, fishes and crayfish when older. Given that Canyon Ferry appears to be habitat limited for largemouth bass, the risks to the existing species appear relatively small (See page 28).

### Predation

Based on minimal data, there seems to be relatively little risk to the existing species posed by largemouth bass introduction (See page 28).

### Movement upstream and downstream

Largemouth bass are not generally found in riverine environments, except in backwaters and sloughs where water velocities are low. Consequently while they may move into the Missouri River system, they would be limited to specific habitat types. Largemouth bass are capable of moving moderately long distances and would some fish would probably move into Hauser and Holter Reservoir (See page 28).

**Status of the fishery**

Largemouth bass are primarily caught when water temperatures exceed 50° F. However, winter ice fisheries do exist in other locations in Montana. Catch rates can be very high (1.0 fish/ hr), but it is impossible to predict catch rates that might occur in Canyon Ferry. Most of the fishing would take place in shallow, warmer parts of the reservoir, particularly in areas with flooded vegetation (See pages 26 - 27).

<u>Northern pike</u>

**Spawning habitat**

Northern pike may be habitat limited in Canyon Ferry due to the lack of shallow weedy areas in which to spawn and find cover. Most of the suitable spawning habitat exists in the backwater areas of the Missouri River (See page 31).

**Rearing habitat**

Young northern pike rear in the same areas where they were spawned until they are 2 - 3 inches long. See the discussion on spawning habitat above and pages 32 - 33.

**Adult habitat**

If northern pike are strongly desired then a survey of the shallow waters in Canyon Ferry is recommended. It may be that there are localized areas that would be suitable habitat for pike. In addition, it might be possible to undertake some vegetative manipulation to create more pike habitat (See page 32, 38 - 40).

**Competition**

The risk of pike competing with other species in Canyon Ferry is relatively low compared to the predation risk. However, pike predation on the forage fishes could impact brown trout (See page 36, 40).

**Predation**

The risks of pike introduction are high. If pike are successful in Canyon Ferry they would prey heavily on the existing species, including rainbow trout and yellow perch. There is a possibility that habitat limitations (lack of vegetated areas) would keep pike numbers low enough that the impact would be minimized. In that case however, pike would not be providing a significant recreational fishery (See page 34, 40).

**Movement upstream and downstream**

There are risks to the downstream reservoirs. If pike are introduced into Canyon Ferry they would almost certainly move downstream and could pose a threat to the existing fisheries in Hauser and Holter Reservoirs. Pike are capable of long migrations in river systems and would almost certainly be found in the backwater areas of the Missouri River as far upstream as Toston Dam (See page 37).

### Status of the fishery

Northern pike catch rates in Montana range from 0.07 to 0.38 fish/hr. Catch rates may be highest in the early spring (See page 33 - 34).

### Disease

Several disease risks associated with northern pike have been identified (See pages 36 - 37).

## Chinook salmon

### Spawning habitat

Chinook would be likely to spawn in the Missouri River at the same times and places as brown trout. This could result in superimposition of redds with negative consequences to one or both species (See page 41).

### Rearing habitat

Juveniles outmigrate from the river system soon after hatching in the spring. No information was found to indicate that there would be a shortage of rearing habitat in the Missouri River or Canyon Ferry Reservoir (See pages 43, 48).

### Adult habitat

Mid-summer water temperatures in Canyon Ferry would limit chinook to the deeper portions of the reservoir near the dam. Based on limited data collected in 1975, dissolved oxygen levels may be unsuitable for chinook in the deeper waters. If chinook are seriously considered, more temperature and DO data should be reviewed to determine the suitability of the summer habitat (See pages 43, 48).

### Competition

Chinook would compete with the other piscivores in Canyon Ferry for food. However, the risks to the existing recreational fisheries seems to be mostly related to predation (See pages 46, 48 - 49).

### Predation

The risks of introducing chinook are significant. Chinook are a large, pelagic predator which requires an abundant pelagic forage base in order to thrive. The most likely forage for chinook in Canyon Ferry is hatchery stocked rainbow trout. Yellow perch might also be utilized seasonally. However, introductions of chinook in reservoirs in Idaho with a similar species assembledge were not successful, so chinook may fail to grow to trophy size in Canyon Ferry. (See pages 45, 48 - 49).

**Movement upstream and downstream**

Chinook would migrate downstream through Canyon Ferry dam and enter the Hauser/Holter system. Hauser currently supports a popular kokanee fishery. Kokanee is a favorite prey item of chinook. Unless the Hauser kokanee population begins to overpopulate and stunt, then a large efficient kokanee predator might not be a desirable addition to the reservoir.

Chinook would migrate upstream in the Missouri River as far as Toston Dam during the spawning season (See page 46).

**Status of the fishery**

In the large, warm reservoirs where chinook have been stocked, the fishing season occurs primarily in the fall. During the warmer months the fish are in deep water and can only be caught with downriggers. Catch rates tend to be low for chinook. It is a fishery that appeals to anglers interested in catching a trophy-type fish (See pages 43 - 45).

**Disease**

Another limiting factor for chinook is the availability of disease-free eggs. The Great Lakes was the source of eggs in the past, however, they are no longer disease free. At the present time there is a severe shortage of disease free chinook eggs to supply the reservoirs where chinook are already established (See page 47).

<u>Kokanee</u>

**Spawning habitat**

Kokanee would be likely to spawn in the Missouri River, particularly in areas with groundwater inflow. From the information available, it appears that there would be natural reproduction of kokanee in the Canyon Ferry system (See page 50).

**Rearing habitat**

There appears to be suitable habitat in the river system to incubate kokanee eggs until the spring when the juveniles hatch and outmigrate to the reservoir. No clear habitat problems for juvenile kokanee were documented in Canyon Ferry Reservoir (See pages 51, 57 - 60).

**Adult habitat**

Kokanee are likely to experience the same problems with mid-summer water temperatures and dissolved oxygen levels as chinook. More research is needed to determine if kokanee could survive the summer conditions in Canyon Ferry.

The prey base in Canyon Ferry appears to be adequate for kokanee (see pages 51, 57 - 60).

**Competition**

The risks of introducing kokanee are the risk of competitive interactions with planktivorous rainbow trout (and to a lesser extent yellow perch) and the risk of negative interactions with brown trout. The rainbows and browns in Hauser Reservoir seem to be suffering some ill effects from kokanee, but it is unknown at this time if kokanee are really the cause of the problems or what the mechanism is for the problems. I strongly recommend that more research be done on these interactions in Hauser Reservoir before kokanee are introduced into Canyon Ferry (See pages 55, 60).

**Predation**

Kokanee feed primarily on zooplankton so there are no significant predation problems (See page 55, 60).

**Status of fishery**

In areas where kokanee have become well established they provide a popular, harvest-oriented fishery with relatively high catch rates. While the fishing quality varies throughout the year, it is a year round fishery. During the warm season, successful kokanee anglers are usually equipped with boats and trolling equipment. Minimal gear is needed during the ice fishery (See pages 52 - 54).

**Disease**

In Hauser Reservoir, kokanee may be increasing the incidence of Saprolegnia in brown trout. No other serious disease problems have been identified (See page 56).

## *LITERATURE CITED*

Aggus, L.R. and G.V. Elliott. 1975. Effects of cover and food on year class strength of largemouth bass. in H. Clepper, ed. Black Bass Biology and Management. Sport Fishing Institute, Washington, D.C. 534 p.

Aggus, L.R. and W.M. Bivin. 1982. Habitat suitability index models: regression models based on harvest of coolwater and coldwater fishes in reservoirs. U.S. Dept. Int. Fish. Wildl. Serv. FWS/OBS-82/10.25. 38 p.

Allan, R.C. and J. Romero. 1975. Underwater observations of largemouth bass spawning and survival in Lake Mead. in H. Clepper, ed. Black Bass Biology and Management. Sport Fishing Institute, Washington, D.C. 534 p.

Anderson, D. 1991. personal communication. Idaho Department of Fish and Game, McCall, Idaho.

Anderson, D.W. and D.H. Schupp. 1986. Fish community responses to northern pike stocking in Horseshoe Lake, Minnesota. Minnesota Department of Natural Resources Investigational Report 397.

Badenhuizen, T.R. 1969. Effect of incubation temperature on mortality of embryos of the largemouth bass. M.S. Thesis, Cornell Univ. Ithaca, New York. 88 p. cited in: Stuber, R. J., G. Gebhart, and O.E. Maughan. 1982. Habitat suitability index models: largemouth bass. U.S. Dept. Int. Fish Wildl. Serv. FSW/OBS-82/10.16. 32 p.

Bandolin, L.A. 1973. Population dynamics and angler use of smallmouth bass in South Branch Lake, Maine. M.S. Thesis. University of Maine, Orono. cited in Bennett, D.H. and K. M. Bennett. 1991. Effects of smallmouth bass introductions of smallmouth bass (Micropterus dolomieui) into waters of the Clark Fork, Flathead, and Kootenai drainages of western Montana. presented to : Montana Department of Fish, Wildlife, and Parks and the Confederated Salish and Kootenai Tribes.

Barber, M.R., R.A. Willms, A.T. Scholz, L.O. Clark, B.L. Renberg, K. O'Laughlin, K.L. Woodward, and R.D. Heaton. 1989. Assessment of the fisheries improvement opportunities on the Pend Oreille River. 1988 Annual Report. Upper Columbia United Tribes. Prepared for Bonneville Power Administration, Portland, Oregon. Project No. 88-66. Agreement No. DE-179-88BP39339.

Beamesderfer, R.C. and B.E. Rieman. 1991. Abundance and distribution of northern squawfish, walleyes, and smallmouth bass in John Day Reservoir, Columbia River. Trans. Am. Fish. Soc. 120:439-447.

Beattie, W. n.d. memo to Jim Vashro. Montana Department of Fish, Wildlife, and Parks, Kalispell, Montana.

Beattie, W., P. Clancey, and R. Zubik. 1988. Effect of the operation of Kerr and Hungry Horse Dams on the reproductive success of kokanee in the Flathead system. Montana Dept. of Fish, Wildlife, and Parks. prepared for Bonneville Power Administration, Portland, OR. Project No. 81S-5, Contract No. DE-AI79-86BP39641.

Bennett, D.H. and F.C. Shrier. 1986. Effects of dredging and in-water disposal of fishes in Lower Granite Reservoir, Washington. Final Report. U.S. Army Corps of Engineers, Walla Walla, Washington. cited in Bennett, D.H. and K. M. Bennett. 1991. Effects of smallmouth bass introductions of smallmouth bass (Micropterus dolomieui) into waters of the Clark Fork, Flathead, and Kootenai drainages of western Montana. presented to : Montana Department of Fish, Wildlife, and Parks and the Confederated Salish and Kootenai Tribes.

Bennett, D.H., P.M. Bratovich, W. Knox, D. Palmer, and H.Hansel. 1983. Status of the warmwater fishery and potential of improving warmwater fish habitat in the Lower Snake Reservoirs. Final Report. U. S. Corps of Engineers, Walla Walla, Washington. cited in Bennett, D.H. and K. M. Bennett. 1991. Effects of smallmouth bass introductions of smallmouth bass (Micropterus dolomieui) into waters of the Clark Fork, Flathead, and Kootenai drainages of western Montana. presented to : Montana Department of Fish, Wildlife, and Parks and the Confederated Salish and Kootenai Tribes.

Bennett, D.H. and K. M. Bennett. 1991. Effects of smallmouth bass introductions of smallmouth bass (Micropterus dolomieui) into waters of the Clark Fork, Flathead, and Kootenai drainages of western Montana. presented to : Montana Department of Fish, Wildlife, and Parks and the Confederated Salish and Kootenai Tribes.

Bennett, D.H., P.M. Bratovich, W. Knox, D. Palmer, and H. Hansel 1983.Status of the warmwater fishery and the potential of improving warmwater fish habitat in the lower Snake Reservoirs. Final Report. U.S. Army Corps of Engineers, Walla Walla, Washington. cited in: Bennett, D.H. and K. M. Bennett. 1991. Effects of smallmouth bass introductions of smallmouth bass (Micropterus dolomieui) into waters of the Clark Fork, Flathead, and Kootenai drainages of western Montana. presented to : Montana Department of Fish, Wildlife, and Parks and the Confederated Salish and Kootenai Tribes.

Bennett, D.H. and B. Rich. 1990. Ecological significance of northern pike in the Coeur d'Alene Lake system, Idaho. Idaho Department of Fish and Game, Fisheries Management Investigations, Project F-17-R-13, Annual Progress Report, Boise, Idaho.

Bennett, D.H. and L.K. Dunsmoor. 1986. Brownlee Reservoir fish population dynamics, community structure, and fishery. Idaho Fish and Game, Job Completion Report Project F-73-R-8.

Bjornn, T.C. 1961. Harvest, age structure, and growth of game fish populations from Priest and Upper Priest Lakes. Trans. Am. Fish. Soc. 90:27-31.

Brett, J.R., J.E. Shelbourn, and C.T. Shoop. 1969. Growth rate and body composition of fingerling sockeye salmon in relation to temperature and body size. J. Fish. Res. Bd. Can. 26: 2363 - 2394.

Brown, C.J.D. 1971. Fishes of Montana. Big Sky Books, Bozeman, Montana. 207 p.

Buck, D.H. 1956. Effects of turbidity on fish and fishing. Trans. N. Am. Wildl. Conf. 21: 249-261.

Calabrese, A. 1969. Effect of acids and alkalies on survival of bluegills and largemouth bass. U.S. Bur Sport Fish. Wildl. Tech. Pap. 42. 10 p.

Carl, C.G., W.A. Clemens, and C.C. Lindsay. 1959. The Freshwater Fishes of British Columbia. British Columbia Provincial Museum. Handbook No. 5879-6+3

Carlander, K.D. 1977. Handbook of freshwater fishery biology, volume 2. Iowa State University Press, Ames.

Carlander, K.D. 1977. Handbook of freshwater fish biology. Vol. 2. Iowa State Univ. Press, Ames.

Carlander, K.D. and R. Ridenhour. 1955. Dispersal of stocked northern pike in Clear Lake, Iowa. Prog. Fish. Cult. 17:186-189.

Carlander, K.D. 1975. Community relations of bass, large natural lakes. in H. Clepper, ed. Black Bass Biology and Management. Sport Fishing Institute, Washington, D.C. 534 p.

Carlson, A.R. and J.G. Hale. 1972. Successful spawning of largemouth bass under laboratory conditions. Trans. Am. Fish. Soc. 101:539-542.

Casselman, J.M. 1978. Effects of environmental conditions on growth, survival, and exploitation of northern pike. AM. Fish. Soc. Spec. Pub. 11: 114-128.

Chapman, C.A. and W.C. Mackay. 1984a. Versatility of habitat use by a top aquatic predator, Esox lucius. J.Fish. Biol. 25:109-115.

Chapman, C.A. and W.C. Mackay. 1984b. Direct observations of habitat utilization by northern pike. Copeia. 1984: 255-258.

Chapman, D.W., H.J. Campbell, and J.D. Fortune, Jr. 1967. Summer distribution and food of kokanee and trout in Elk Lake, Oregon. Trans. Am. Fish. Soc. 96:308-312.

Clancey, P. 1985. memo to Jim Vashro. Montana Department of Fish, Wildlife, and Parks, Kalispell, Montana

Clancy, C.G. 1980. Vital statistics and instream flow requirements of fish in the MONTCO mine area of the Tongue River, Montana. Montana Department of Fish, Wildlife, and Parks Report. Submitted to MONTCO, April 1980.

Clancy, C.G. 1992. Personal communication. Montana Department of Fish, Wildlife, and Parks, Hamilton, Montana.

Close, T.L., S.E Colvin, and R.L. Hassinger. 1984. Chinook salmon in the Minnesota sport fishery of Lake Superior. Minnesota Department of Natural Resources, Investigational Report 380.

Close, T.E., S.E. Colvin, and R.L. Hassinger. 1984. Chinook salmon in the Minnesota sport fishery of Lake Superior. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Investigational Report 380, St. Paul.

Combs, B.D. 1965. Effect of temperature on development of salmon eggs. The Prog. Fish-Culturist. 27:134-137.

Conover, M.C. 1986. Stocking coolwater species to meet management needs. in R.H. Stroud, ed. Fish Culture in Fisheries Management. American Fisheries Society, Bethesda, Maryland. 481 p.

Coutant, C.C. 1975. Responses of bass to natural and artificial temperature regimes. in H. Clepper, ed. Black Bass Biology and Management. Sport Fishing Institute, Washington, D.C. 534 p.

Dailey, K., R. Perkins, and J. Johnson. 1990. Umpqua River smallmouth bass investigation 1987 - 1988. Mimeo report, Oregon Department of Fish and Wildlife, Portland. cited in Bennett, D.H. and K. M. Bennett. 1991. Effects of smallmouth bass introductions of smallmouth bass (Micropterus dolomieui) into waters of the Clark Fork, Flathead, and Kootenai drainages of western Montana. presented to : Montana Department of Fish, Wildlife, and Parks and the Confederated Salish and Kootenai Tribes.

Davis, H.S. 1953. Culture and Disease of Game Fishes. Univ. of Cal. Press, Berkeley. 332 p.

Decker-Hess, J. 1991. Personal communication. Montana Department of Fish, Wildlife, and Parks, Kalispell, Montana.

Dequine, J.F. and C.E. Hall, Jr. 1950. Results of some tagging studies of the Florida largemouth bass (Micropterus salmoides Floridanus). Trans. Am. Fish. Soc. 79:155-166.

Dillon, J.C. 1990. Largemouth bass forage investigations. Idaho Department of Fish and Game, Project F-73-R-12, Job Performance Report, Boise.

DosSantos, J. M. 1991. Personnel communication. Confederated Salish and Kootenai Tribes, Pablo, Montana.

DosSantos, J.M., J.E. Darling, and P.D. Cross. 1988. Lower Flathead System fisheries study: Main River and tributaries., Vol. II. Confederated Salish and Kootenai Tribes, prepared for the Bonneville Power Administration, Portland, Oregon.

Dudley, R.G. 1969. Survival of largemouth bass embryos at low dissolved oxygen concentrations. M.S. Thesis, Cornell Univ., Ithaca, New York. 61 p. cited in: Stuber, R. J., G. Gebhart, and O.E. Maughan. 1982. Habitat suitability index models: largemouth bass. U.S. Dept. Int. Fish Wildl. Serv. FWS/OBS-82/10.16. 32 p.

Edwards, E. A., G. Gebhart, and O,E, Maughan. 1983. Habitat suitability information: smallmouth bass. U.S. Dept. of Int. Fish and Wildl. Serv. FWS/OBS-82/10.36.

Eipper, A. W. 1975. Environmental influences on the mortality of bass embryos and larvae. in Black Bass Biology and Management. Stroud and Clepper, eds. Sport Fishing Institute, Washington, D.C.

Ellis, V. and B. Bowler. 1981. Pend Oreille Lake creel census. Idaho Department of Fish and Game. Job Perf. Report Project F-73-R-3.

Evarts, L.E. 1991. Personal communication. Confederated Salish and Kootenai Tribes, Pablo, Montana.

Fielder, D. 1991. personal communication, South Dakota Fish and Game Department.

Fies, T. 1991. Personal communication. Oregon Department of Fish and Game, Bend, Oregon.

Fleener, G.G. 1975. Harvest of smallmouth bass and associated species in Courtois Creek. in Black Bass Biology and Management. Stroud and Clepper, eds. Sport Fishing Institute, Washington, D.C.

Foerster,R.E. 1944. The relation of lake population density to size of young sockeye salmon, Oncorhynchus nerka. J. Fish Res. Bd. Can. 6:267-280.

Forney, J.L. 1968. Production of young northern pike in a regulated marsh. N.Y. Fish Game J. 15:143-154.

Forney, J.L. 1972. Biology and management of smallmouth bass in Oneida Lake, New York. New York Fish and Game Journal 19:132-154.

Fortune, John. 1991. Personal communication, Oregon Department of Fish and Game, Klamath Falls, Oregon.

Franklin, D.R. and L.L. Smith. 1963. Early life history of the northern pike Esox lucius L. Copeia 1960:143-144.

Funk, J.L. and G.G. Fleener. 1974. The fishery of a Missouri Ozark stream, Big Piney River, and the effects of stocking fingerling smallmouth bass. Trans. Am. Fish. Soc. 103:757 - 771.

Grimm, M.P. 1981a. The composition of northern pike (Esox lucius) populations in four shallow waters in the Netherlands with special reference to factors influencing 0+ pike biomass. Fish Manage. 12:61-76. cited in Jones, T.S. 1990. Floodplain distribution of fishes of the Bitterroot River, with emphasis on introduced populations of northern pike. M.S. Thesis, University of Montana, Missoula, Montana.

Grimm, M.P. 1981b. Interspecific predation as a principal factor controlling the biomass of northern pike (Esox lucius). Fish. Manage. 12:77-79. cited in Jones, T.S. 1990. Floodplain distribution of fishes of the Bitterroot River, with emphasis on introduced populations of northern pike. M.S. Thesis, University of Montana, Missoula, Montana.

Hansen, B. 1991. personal communication, Confederated Salish and Kootenai Tribes, Pablo, Montana.

Hansen, M.J., P.T. Schultz, B.A. Lasee. 1990. Changes in Wisconsin's Lake Michigan Salmonid Sport Fishery, 1969-1985. N. A. J. Fish Manage. 10:442-457.

Hanzel, D.A. 1984. Lake fisheries inventory. Montana Department of Fish, Wildlife, and Parks, Job Completion Report Project No. F-33-R-18.

Hardin, T. and K. Bovee. 1978. Largemouth bass. Instream flow group. U.S. Fish and Wildl. Serv., Western Energy and Land Use Team, Ft. Collins, CO. unpublished data. cited in: Stuber, R. J., G. Gebhart, and O.E. Maughan. 1982. Habitat suitability index models: largemouth bass. U.S. Dept. Int. Fish Wildl. Serv. FWS/OBS-82/10.16. 32 p.

He, X. and J.F. Kitchell. 1990. Direct and indirect effects of predation on a fish community: a whole lake experiment. Trans. Am. Fish. Soc. 119:825-835.

Heidinger, R.C. 1975. Life history and biology of the largemouth bass. in H. Clepper, ed. Black Bass Biology and Management. Sport Fishing Institute, Washington, D.C. 534 p.

Heman, M.L. R.S. Campbell, and L.C. Redmond. 1969. Manipulation of fish populations through reservoir drawdown. Trans. Am. Fish. Soc. 98:293-304.

Hill, B. 1980. Montana Department of Fish, Wildlife, and Parks, Job Progress Report F-5-R-29 I-a.

Hill, B. 1992. Personal communication. Montana Department of Fish, Wildlife, and Parks, Choteau, Montana.

Horner, N. 1991. personal communication. Idaho Fish and Game Department, Coeur d'Alene, Idaho.

Hubbs, C.L. and R.M. Bailey. 1940. A revision of the black basses (Micropterus and Huro) with descriptions of four new forms. Univ. Mich. Museum Zool. Misc. Publ. No. 48. 51 p. cited in: Coble, D.W. 1975. Smallmouth bass. in H. Clepper, ed. Black Bass Biology and Management. Sport Fishing Institute, Washington, D.C. 534 p.

Hubert, W.A. 1988. Altitude as the determinant of distribution of largemouth bass and smallmouth bass in Wyoming. N.A.J. Fish Manage. 8:386-387.

Huffacher, S. 1991. personal communication. Idaho Department of Fish and Game, Boise, Idaho.

Hunt, R.L. 1965. Food of northern pike in a Wisconsin trout stream. Trans. Am. Fish. Soc. 94:95-97.

Inskip, P.D. 1982. Habitat suitability index models: northern pike. U.S. Dept. Int., Fish Wildl. Serv. FWS/OBS-82/10.17. 40 p.

Japhet, M. 1991. Personnel communication. Colorado Division of Wildlife, Denver, Colorado.

Jenkins, R.M. 1975. Black bass crops and species associations in reservoirs. in H. Clepper, ed. Black Bass Biology and Management. Sport Fishing Institute, Washington, D.C. 534 p.

Jenkins, R.M. 1976. Prediction of fish production in Oklahoma reservoirs on the basis of environmental variables. Ann. Oklahoma Sc. 5:11-20.

Jester, D.B., T.M. Moody, C. Sanchez Jr., and D.E. Jennings. 1969. A study of game fish reproduction and rough fish problems in Elephant Butte Reservoir. New Mexico Job Compl. Rep. Fed. Aid Proj. F-22R-9, Job F-1. 73 p. cited in: Carlander, K.D. 1977. Handbook of freshwater fish biology. Vol. 2. Iowa State Univ. Press, Ames.

Johnson, M.G., J.H. Leach, C.K. Minns, and C.H. Oliver. 1977. Limnological characteristics of Ontario lakes in relation to associations of walleye (Stizostedion vitreum vitreum), northern pike (Esox lucius), lake trout (Salvelinus namaycush), and smallmouth bass (Micropterus dolomieui). J. Fish. Res. Bd. Can. 34: 1592-1601.

Jones, T.S. 1990. Floodplain distribution of fishes of the Bitterroot River, with emphasis on introduced populations of northern pike. M.S. Thesis, University of Montana, Missoula, Montana.

Kempinger, J.J., W.S. Churchill, G.R. Priegel, and L,M, Christenson. 1975. Estimate of abundance of the fish population of Escanaba Lake, Wisconsin, 1946-1969. Wisconsin Dept. Nat. Res. Tech. Bull. 84.

Kramer, R.H. and L.L. Smith, Jr. 1963. First year growth of the largemouth bass, and some related ecological factors. Trans. Am. Fish. Soc. 89:222-233.

LaBolle, L. 1986. Enhancement of kokanee on Priest and Pend Oreille Lakes. Idaho Department of Fish and Game, Job Performance Report, Project F-73-R-7.

Lawrence, J.M. 1957. Estimated sizes of various forage fishes largemouth bass can swallow. Proc. 11th Annual Conf. Southeast Assoc. Game Fish Comm. 220 - 225.

Leathe, S. 1992. Personal communication. Montana Department of Fish, Wildlife, and Parks, Great Falls, Montana.

Lere, M.E. 1991. Personnel communication. Montana Department of Fish, Wildlife, and Parks, Helena, Montana.

Lere, M.E. 1991. Canyon Ferry, Hauser, Holter Reservoirs Study. Montana Department of Fish, Wildlife, and Parks. Job Progress Report, F-46-R-1-II-f.

Lindsay, R.B. and S.L. Lewis. 1978. Lake and reservoir investigations (Kokanee ecology). Oregon Department of Fish and Wildlife. Job Final Report, Project F-71-R.

Mann, R.H.K. 1985. A pike management strategy for a trout fishery. J. Fish. Biol. 27 (Supplement A): 227-234.

Maraldo, D.C. and H.R. MacCrimmon. 1981. Reproduction, distribution, and population size of largemouth bass in an oligotrophic preCambrian shield lake. Canadian Field-Nat. 95:298-306.

Martinez, P. 1991. Personnel communication. Colorado Division of Wildlife, Ft. Collins, Colorado.

Martinez, P.J. and W.J. Wiltzius. 1991. Kokanee fishery studies. Colorado Division of Wildlife, Job Final Report, Project F-79.

Mauser, G.R., D.A. Cannamela, and R.D. Downing. 1990. Dworshak Dam impact assessment and fishery investigation. Project 87-99, Annual Report, Boise, Idaho.

Mauser, G.R., R.W. Vogelsang, and C.L. Smith. 1988. Enhancement of trout in large north Idaho lakes. Idaho Fish and Game, Study Completion Report Project F-73-R-10.

McCauley, R.W. and D.M. Kilgour. 1990. Effect of air temperature on growth of largemouth bass in North America. Trans. Am. Fish. Soc. 119:276-281.

McMullin, S. 1984. memo to Jim Vashro. Montana Department of Fish, Wildlife, and Parks, Kalispell, Montana.

Mesing, C.L. and A.M. Wicker. 1986. Home range, spawning migrations, and homing of radio-tagged Florida largemouth bass in two central Florida lakes. Trans. Am. Fish. Soc. 115: 286 - 295.

Miller, K.D. and R.H. Kramer. 1971. Spawning and early life history of largemouth bass (Micropterus salmoides) in Lake Powell. in G.E. Hall. Reservoir Fisheries and Limnology. Am Fish. Soc. Spec. Pub. 8.

Moody, H.L. 1960. Recaptures of the adult largemouth bass from the St. John's River, Florida. Trans. Am. Fish. Soc. 89:295-300.

Moss, D.D. and D.C. Scott. 1961. Dissolved oxygen requirements of three species of fish. Trans. Am. Fish. Soc. 90:377-393.

Mraz, D. 1960. Preliminary report on the Lake Geneva smallmouth bass studies (1958 - 1959). Research Report 1. Wisconsin Conservation Department, Madison. cited in Bennett, D.H. and K. M. Bennett. 1991. Effects of smallmouth bass introductions of smallmouth bass (Micropterus dolomieui) into waters of the Clark Fork, Flathead, and Kootenai drainages of western Montana. presented to : Montana Department of Fish, Wildlife, and Parks and the Confederated Salish and Kootenai Tribes.

Mraz, D. 1964. Observations on large and smallmouth bass nesting and early life history. Wisconsin Conserv. Dept. Res. Rep. 11 (Fisheries). 13 p.

National Oceanic and Atmospheric Administration. 1973 - 1988. Climatological Data Montana. National Environmental Satellite Data and Information Service, National Climatic Center, Asheville, North Carolina. ISSN 0145-0395.

Olmstead, L.L. 1974. The ecology of largemouth bass and spotted bass in Lake Fort Smith, Arkansas. Ph.D. Dissertation, Univ. Arkansas, Fayetteville, AR. 133 p. cited in: Stuber, R. J., G. Gebhart, and O.E. Maughan. 1982. Habitat suitability index models: largemouth bass. U.S. Dept. Int. Fish Wildl. Serv. FSW/OBS-82/10.16. 32 p.

Paragamian, V.L. 1976. Population characteristics on northern pike in the Plover River, Wisconsin. Prog. Fish-Cult. 38:160-163.

Partridge, F.E. 1985. Evaluation of fall chinook introductions. Idaho Fish and Game, Job Performance Report, Project F-73-R-7.

Partridge, F.E. 1988. Alternate species for lake and reservoir fisheries. Idaho Dept of Fish and Game, Job Perf. Rept. Project F-73-R-10.

Partridge, F.E. 1988. Evaluation of fall chinook introductions. Idaho Fish and Game Department. Job Completion Report, F-73-R-9.

Peone, T.L., A.T. Scholz, J.R. Griffith, S. Graves, M.G. Thather, Jr. 1990. Lake Roosevelt fisheries monitoring program. Upper Columbia United Tribes. Prepared for Bonneville Power Administration, Portland, Oregon. Project No. 88-63. Contract No. DE-8179-88BP91819.

Peterson, J. 1991. Personal communication, Montana Department of Fish, Wildlife, and Parks, Great Falls, Montana.

Poe, T.P., H.C. Hansel, S. Vigg, D.E. Palmer, and L.A. Prendergast. 1991. Feeding of predaceous fishes on out-migrating juvenile salmonids in John Day Reservoir, Columbia River. Trans. Am. Fish. Soc. 120:405-420.

Power, G. 1991. personal communication. North Dakota Fish and Game Department, Bismarck, North Dakota.

Priegel, G.R. and D.C. Krohn. 1975. Characteristics of a northern pike spawning population. Wisconsin Department of Natural Resources Technical Bulletin 86.

Probst, W.E., C.F. Rabeni, W.G. Covington, and R.E. Marteney. 1984. Resource use by stream dwelling rockbass and smallmouth bass. Trans. Am. Fish. Soc. 113:283-294.

Raleigh, R.F., W.J. Miller, P.C.Nelson. 1986. Habitat suitability index models and instream flow suitability curves: chinook salmon. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.122). 64 p.

Ramsey, J.S. 1975. Taxonomic history and systematic relationships among species of Micropterus. in Clepper, H., ed. Black Bass Biology and Management. Sport Fish Instit., Washington, D.C.

Rideout, S.G. and P.H. Oatis 1975. Population dynamics of smallmouth bass and largemouth bass in Quabbin Reservoir.in Clepper, H., ed. Black Bass Biology and Management. Sport Fish Instit., Washington, D.C.

Rieman, B.E. 1981. Kokanee-zooplankton interactions and descriptions of carrying capacity. Idaho Fish and Game Department. Job Progress Report Project F-73-R-3.

Rieman, B.E. 1982. Largemouth bass investigations. Idaho Fish and Game. Job Progress Report Project F-73-R-4.

Rieman, B.E. and Meyers. 1990. Status and analysis of salmonid fisheries: kokanee population dynamics. Idaho Department of Fish and Game. Job Performance Report, Project F-73-R-12.

Rieman, B.E. and B. Ward. 1981. Coeur d'Alene Lake creel census. Idaho Fish and Game Department. Job Progress Report Project F-73-R-3.

Robbins, W.H. and H.R. MacCrimmon. 1974. The blackbass in America and overseas. Publ. Div., Biomanagement and Research Enterprises, Ontario. 196 p. cited in: Stuber, R.J., G. Gebhart, and O.E. Maughan. 1982. Habitat suitability index models: largemouth bass. U.S. Dept. Int. Fish Wildl. Serv. FSW/OBS-82/10.16. 32 p.

Rohrer, R.L. 1984. Brownlee Reservoir fish population dynamics, community structure, and the fishery. Idaho Department of Fish and Game. Job Performance Report, Project F-73-R-6.

Rondorf, D.W., G.A. Gray, and R.B. Fairley. 1990. Feeding ecology of subyearling chinook salmon in riverine and reservoir habitats of the Columbia River. Trans. Am. Fish Soc. 119:16-24.

Ryckman, J.R. and R.N. Lockwood. 1985. On-site creel surveys in Michigan 1975 - 1982. Fisheries Research Report 1922, F-35-R, Michigan Department of Natural Resources, Lansing. cited in Bennett, D.H. and K. M. Bennett. 1991. Effects of smallmouth bass introductions of smallmouth bass (Micropterus dolomieui) into waters of the Clark Fork, Flathead, and Kootenai drainages of western Montana. presented to : Montana Department of Fish, Wildlife, and Parks and the Confederated Salish and Kootenai Tribes.

Saiki, M.K. and J.C. Tash. 1979. Use of cover and dispersal of crayfish to reduce predation by largemouth bass. in D. L. Johnson and R.A. Stein, eds. Response of fish habitat structure in standing water. N. Central Div. Am. Fish. Soc. Spec. Pub 6. cited in: Stuber, R. J., G. Gebhart, and O.E. Maughan. 1982. Habitat suitability index models: largemouth bass. U.S. Dept. Int. Fish Wildl. Serv. FWS/OBS-82/10.16. 32 p.

Scholz, A.T., K.O. Laughlin, T. Peone, J. Uehara, T. Kleist, and J. Hisata. 1988. Environmental factors affecting kokanee salmon in Deer and Loon Lake, Stevens County, Washington. Final Report submitted to Deer and Loon Lake property owners association, and Washington Department of Wildlife. Eastern Washington University, Department of Biology, Cheney, Washington. 167 p. cited in Peone, T.L., A.T. Scholz, J.R. Griffith, S. Graves, M.G. Thather, Jr. 1990. Lake Roosevelt fisheries monitoring program. Upper Columbia United Tribes. Prepared for Bonneville Power Administration, Portland, Oregon. Project No. 88-63. Contract No. DE-8179-88BP91819.

Scott, W.B. and E.J. Crossman. 1973. Freshwater Fishes of Canada. Fish. Res. Bd. Can. Bull. 184.

Seymour, A.H. 1956. Effects of temperature upon young chinook salmon. Ph.D. Dissertation, Univ. of Washington, Seattle. 127 p. cited in: Raleigh, R.F., W.J. Miller, P.C.Nelson. 1986. Habitat suitability index models and instream flow suitability curves: chinook salmon. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.122). 64 p.

Simonson, T.D. and W.A. Swenson. 1990. Critical stream velocities for young-of-the-year smallmouth bass in relation to habitat use. Trans. Am. Fish. Soc. 119:902-909.

Snow, H.E. 1971. Harvest and feeding habits of largemouth bass in Murphy Flowage, Wisconsin. Wisc. Dept. Nat. Resource Tech. Bull. 50. 25 p.

Snow, H.E. 1974. Effects of stocking northern pike in Murphy Flowage. Wisconsin Department of Natural Resources Technical Bulletin 79.

Spoon, R. 1991. Personal communication. Montana Department of Fish, Wildlife, and Parks, Townsend, Montana.

Stein, R.A. 1979. Behavioral response of prey to fish predators. in H. Clepper, ed. Predator - Prey Systems in Fisheries Management. Sport Fishing Institute, Washington, D.C.

Stewart, N.E., D.L. Shumway, and P. Doudoroff. 1967. Influence of oxygen concentration on the growth of juvenile largemouth bass. J. Fish. Res. Bd. Can. 24:475-494.

Stroud, R.H. 1967. Water quality criteria to protect aquatic life: a summary. Am. Fish. Soc. Spec. Publ. 4:33-37.

Stuber, R. J., G. Gebhart, and O.E. Maughan. 1982. Habitat suitability index models: largemouth bass. U.S. Dept. Int. Fish Wildl. Serv. FSW/OBS-82/10.16. 32 p.

Summerfelt, R.C. 1975. Relationship between weather and year class strength of largemouth bass. in Clepper, H., ed. Black Bass Biology and Management. Sport Fish Instit., Washington, D.C.

Turner, G.E. and H.R. MacCrimmon. 1970. Reproduction and growth of smallmouth bass, *Micropterus dolomieui*, in Precambrian lake. J. of Fish. Res. Bd. Can. 27:395-400.

U.S. Geological Survey. 1978-1989. Water Resources Data for Montana, Surface Water Records. U.S. Dept. of Interior.

Vashro, J. 1991. Personal communication. Montana Department of Fish, Wildlife, and Parks, Kalispell, Montana.

Vaughn, M. 1992. Personal communication. Montana Department of Fish, Wildlife, and Parks, Billings, Montana.

Walker, P. 1991. Personal communication, Colorado Division of Wildlife, Denver, Colorado.

Wengert, B. 1991. Personal communication. Wyoming Department of Game and Fish, Green River, Wyoming.

Wheeler, A. and P.S. Maitland. 1973. The scarcer freshwater fishes of the British Isles. I. Introduced species. J. Fish. Biol. 5:49-68.

Wiedenheft, W. 1991. personal communication. Montana Department of Fish, Wildlife, and Parks, Ft. Peck, Montana.

Winter, J.D. 1977. Summer home range movement and habitat use by four largemouth bass in Mary Lake, Minnesota. Trans. Am. Fish. Soc. 106:323-330.

APPENDIX A

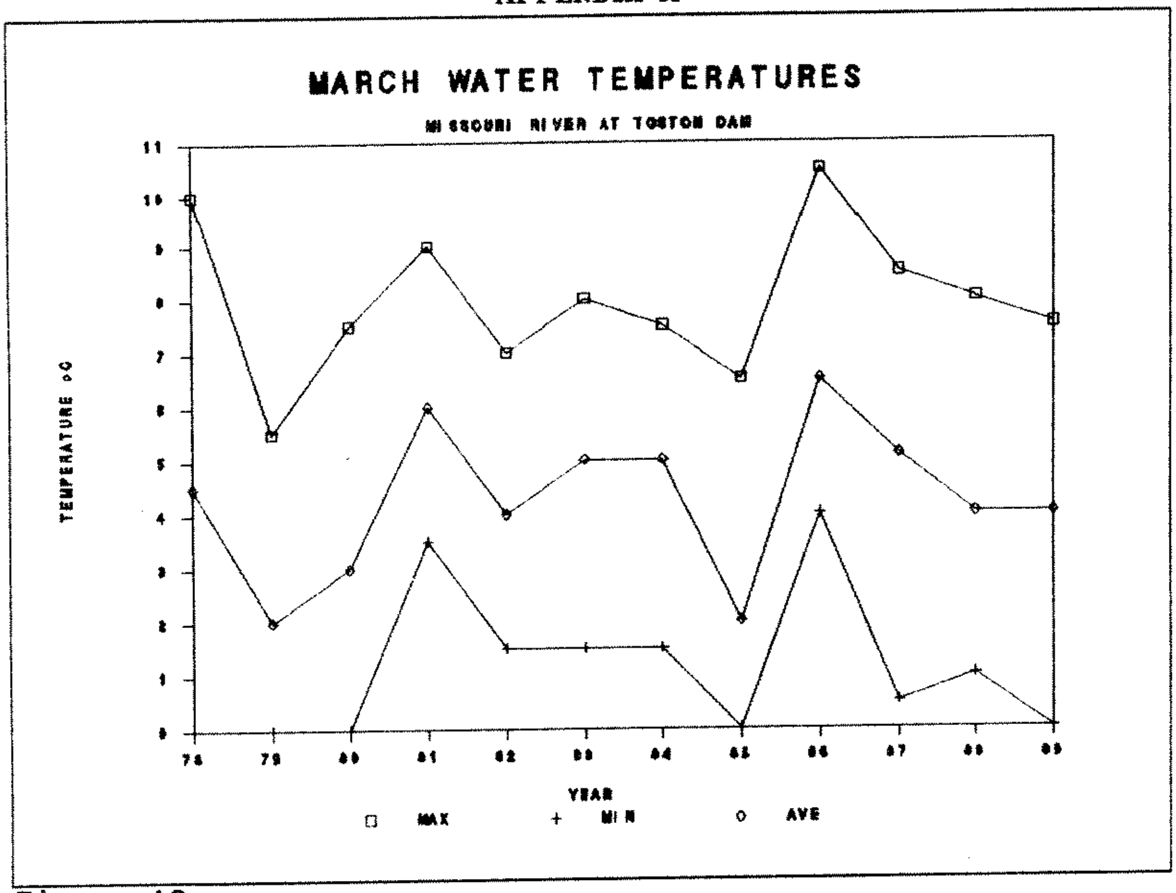



Figure 13

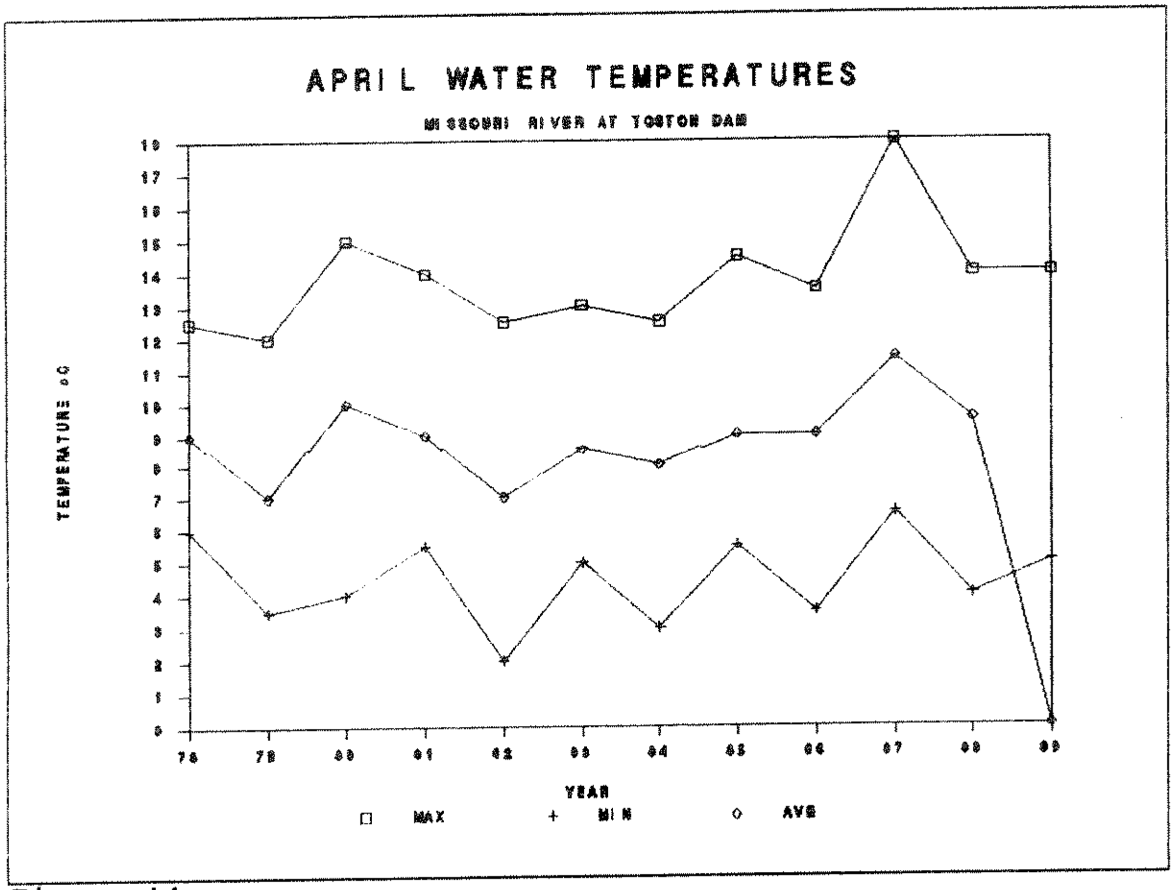
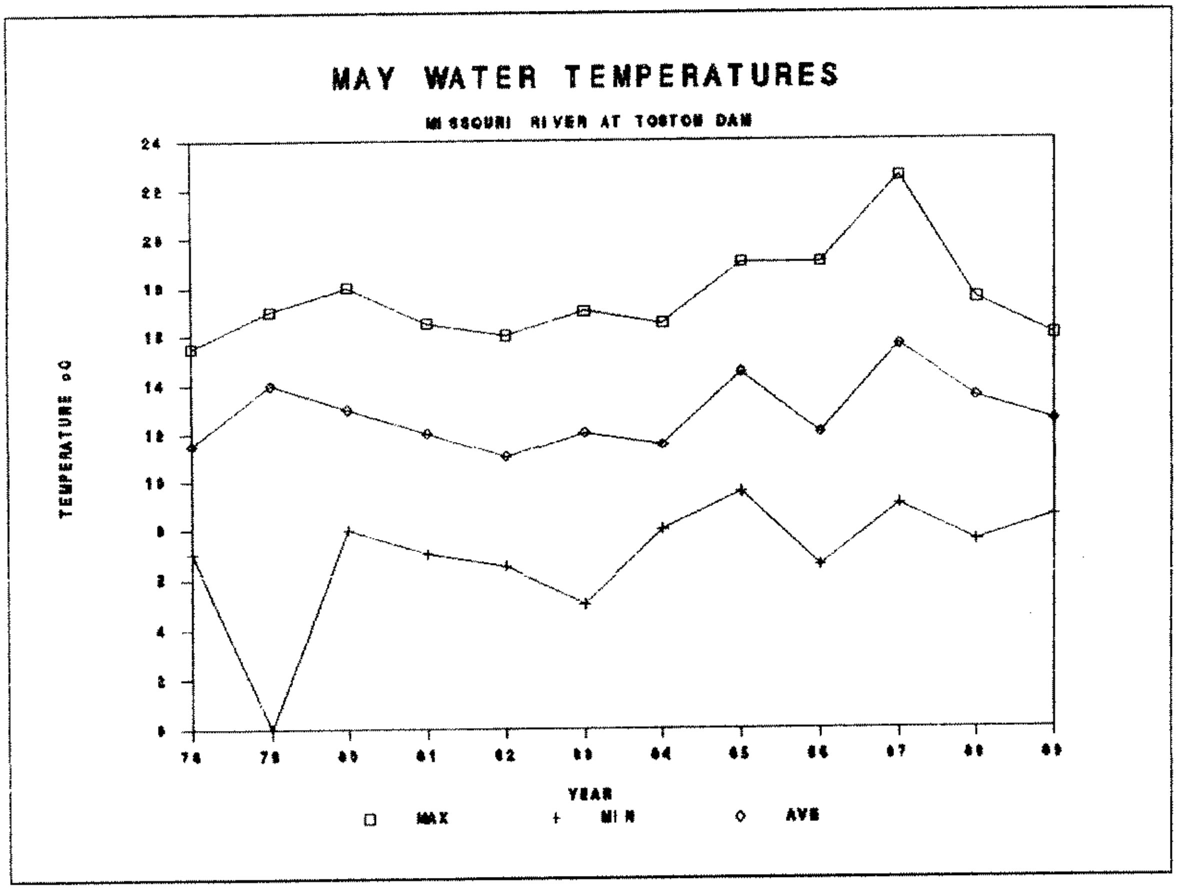

APRIL WATER TEMPERATURES
MISSOURI RIVER AT TOSTON DAM
TEMPERATURE oC
YEAR
MAX
MIN
AVG

Figure 14


MAY WATER TEMPERATURES
MISSOURI RIVER AT TOSTON DAM
TEMPERATURE oC
YEAR
MAX
MIN
AVE

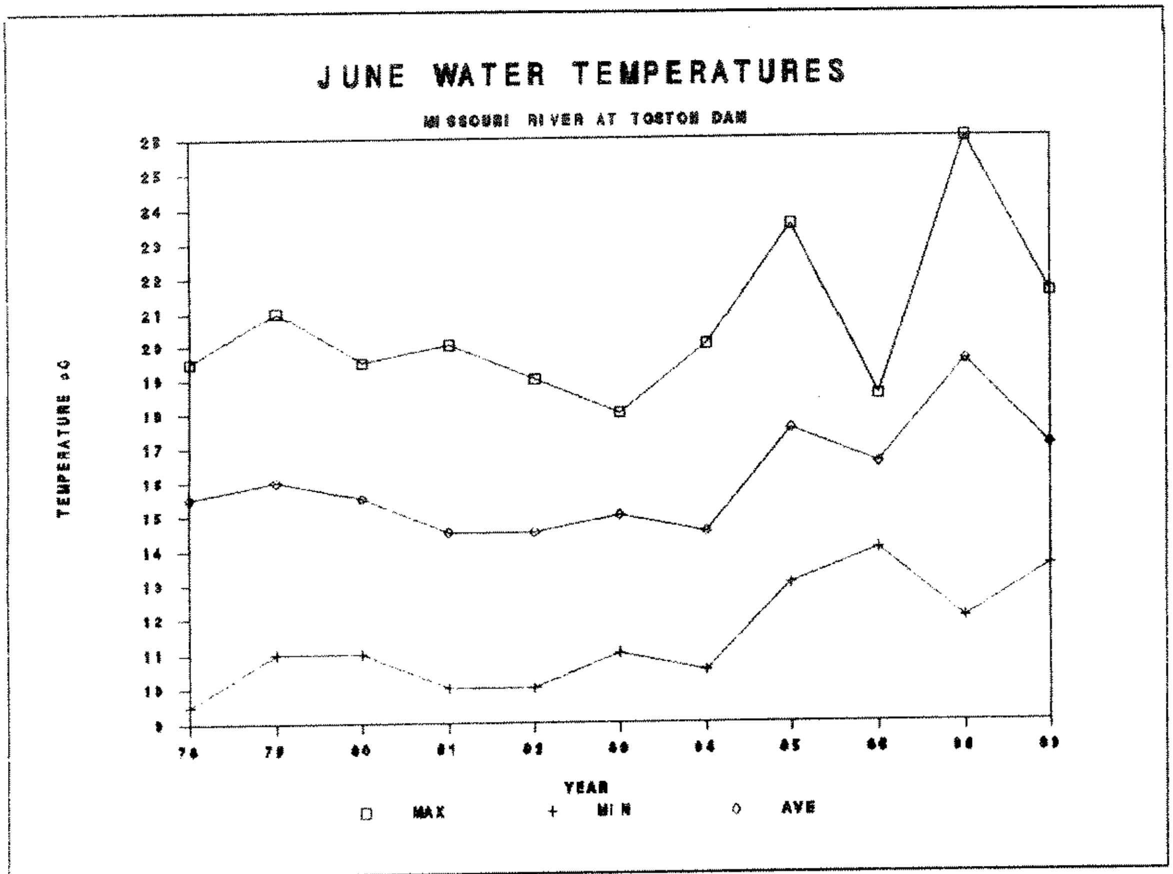

JUNE WATER TEMPERATURES
MISSOURI RIVER AT TOSTON DAM
TEMPERATURE °C
YEAR
MAX
MIN
AVE

Figure 16

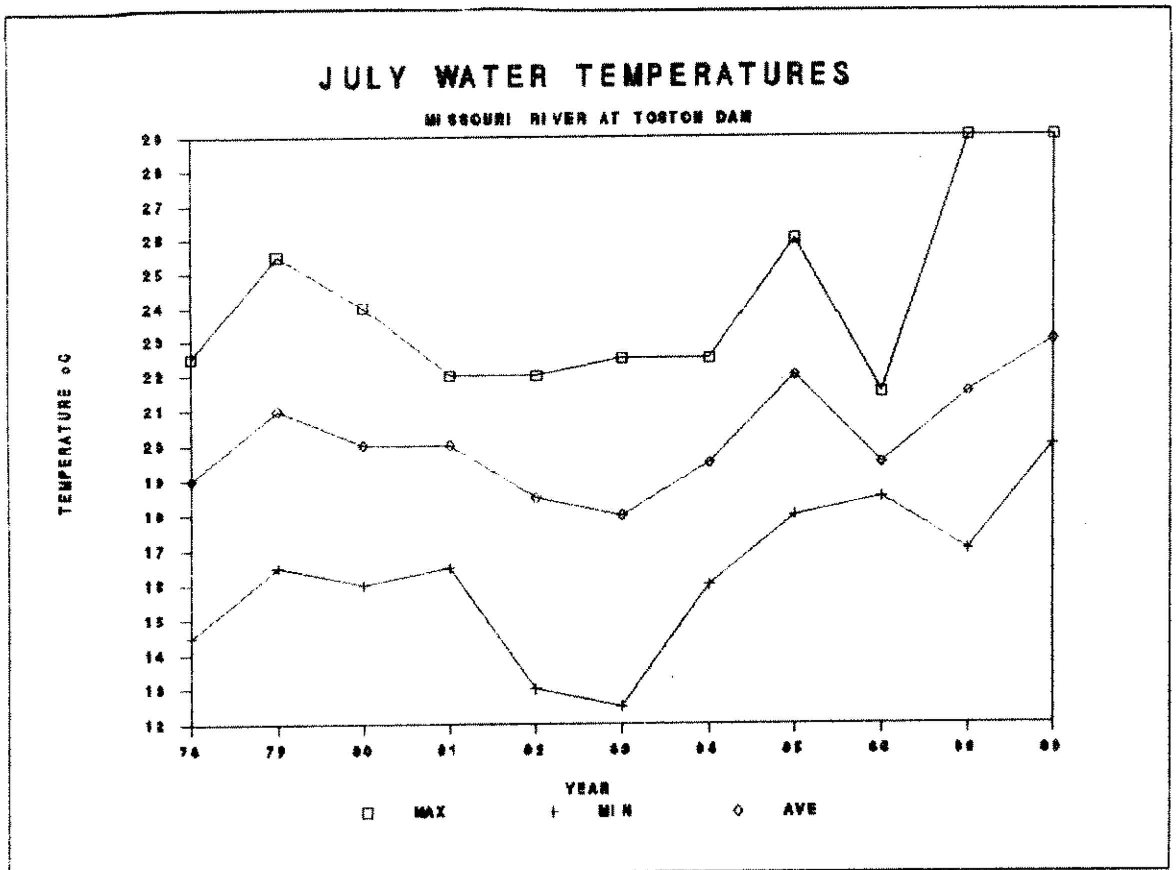
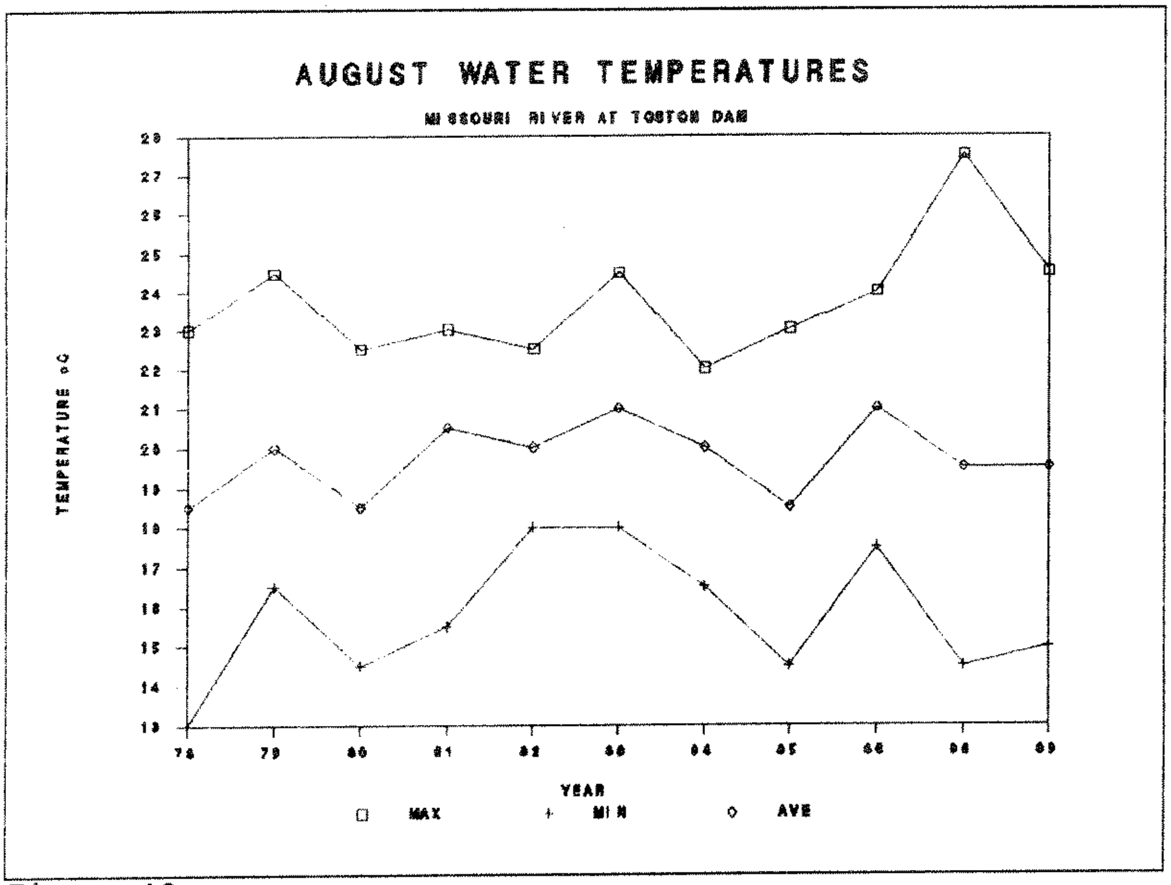

JULY WATER TEMPERATURES
MISSOURI RIVER AT TOSTON DAM
TEMPERATURE oC
YEAR
MAX
MIN
AVE

Figure 17


AUGUST WATER TEMPERATURES
MISSOURI RIVER AT TOSTON DAM
TEMPERATURE °C
YEAR
MAX
MIN
AVE
Figure 18

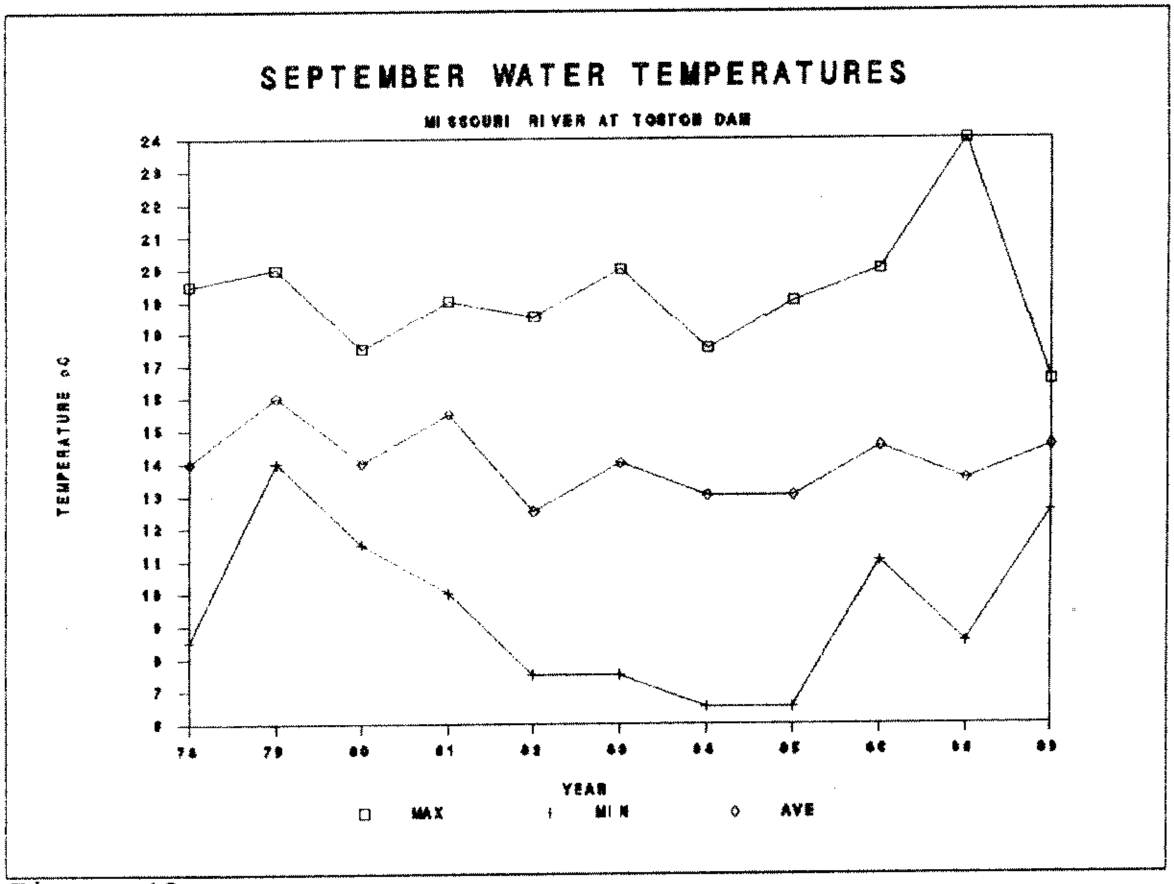

SEPTEMBER WATER TEMPERATURES
MISSOURI RIVER AT TOSTON DAM
TEMPERATURE oC
YEAR
MAX
MIN
AVE

Figure 19

## APPENDIX B

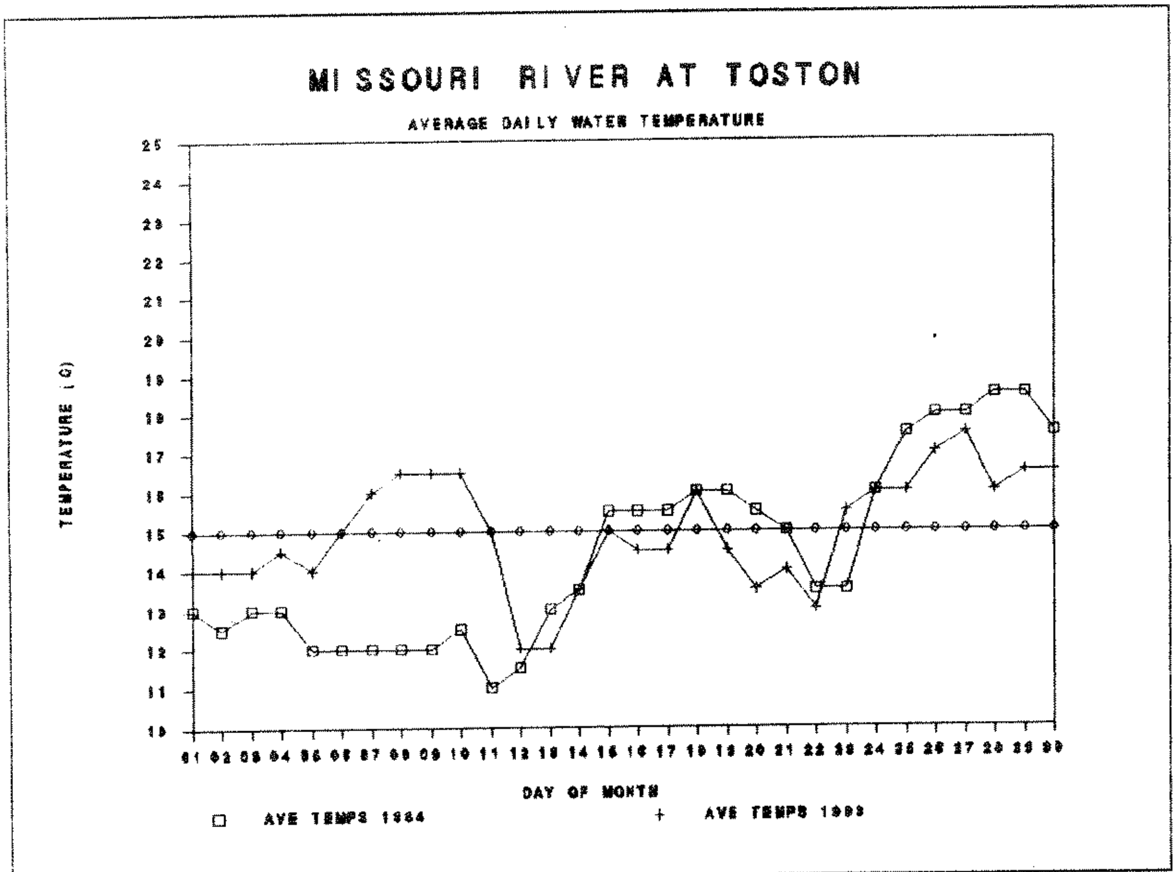



Figure 1

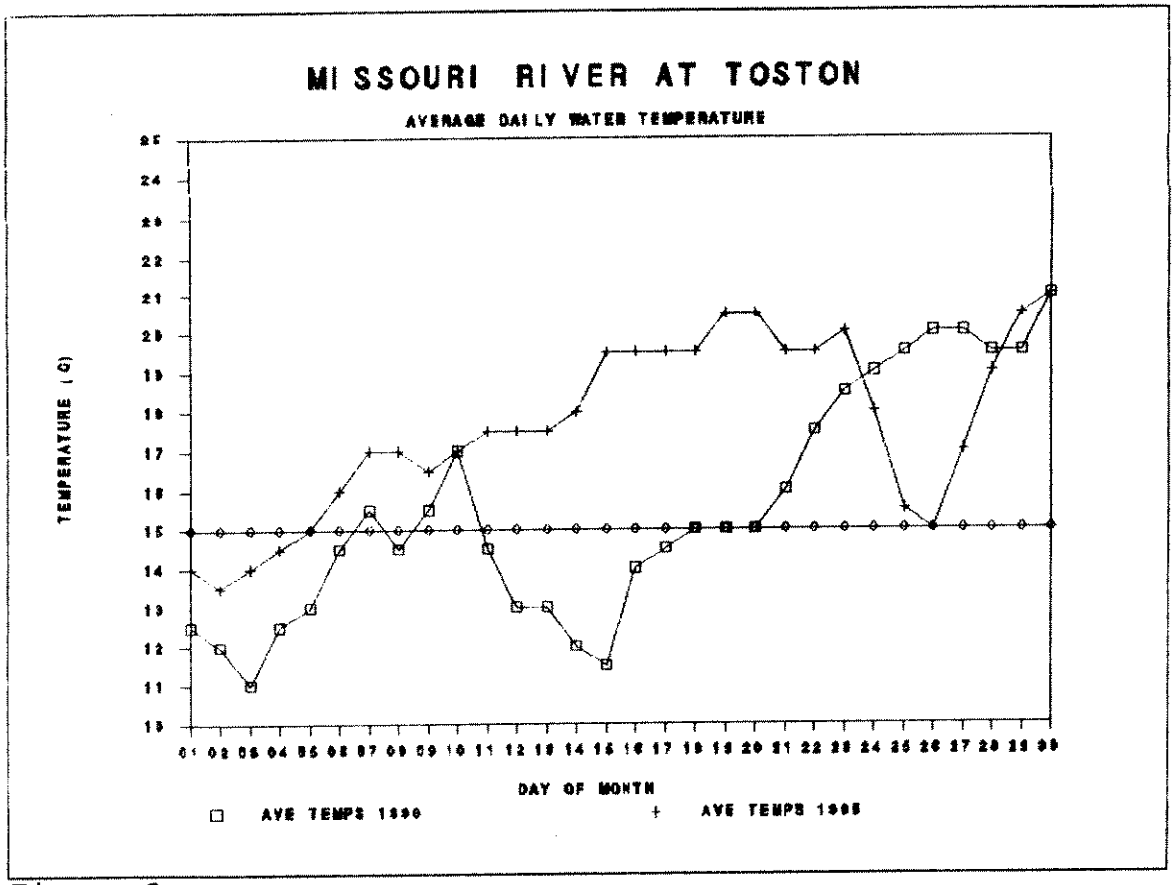

MISSOURI RIVER AT TOSTON
AVERAGE DAILY WATER TEMPERATURE
TEMPERATURE (C)
DAY OF MONTH
AVE TEMPS
AVE TEMPS

Figure 2

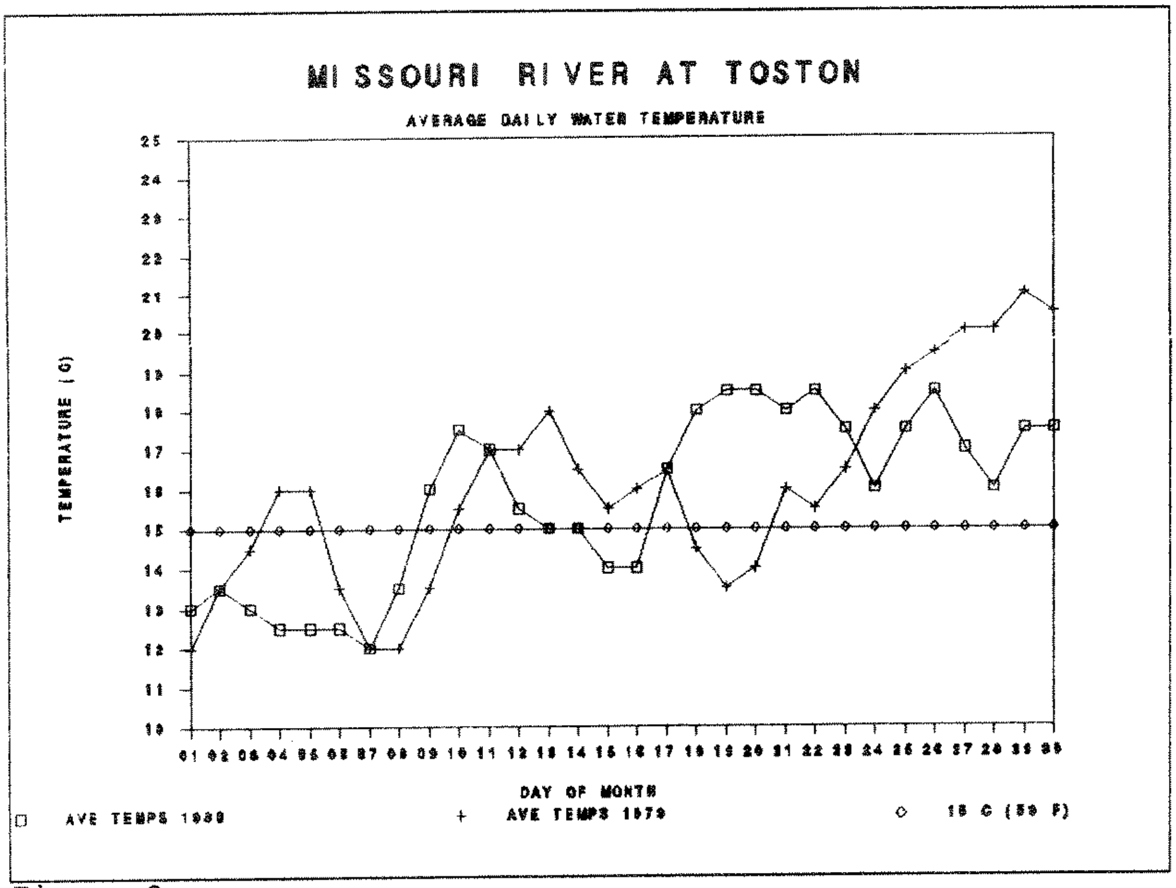

MISSOURI RIVER AT TOSTON
AVERAGE DAILY WATER TEMPERATURE
TEMPERATURE (C)
DAY OF MONTH
AVE TEMPS
AVE TEMPS

Figure 3