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EFFECTS OF INTRODUCING SMALLMOUTH BASS INTO BEAR PAW LAKE

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Proposal

Proposed action

The proposed action is to introduce smallmouth bass (Micropterus dolomieui) into Bear Paw Lake.

Need for proposed action

At the present time, trout stocked into Bear Paw Lake show poor growth and survival. Consequently, the current management program is not satisfying the anglers who fish Bear Paw Lake. The reason for the poor trout fishery is believed to be competition for food with white suckers (Catostomus commersoni). It is hoped that smallmouth bass would prey on white suckers, thus reducing the white sucker population and improving the food supply for trout.

The objective of the proposed introduction is to provide a sustained yield of 11 - 13 inch trout from Bear Paw Lake.

It is also believed that smallmouth bass may provide a second sport fish in the reservoir, thus diversifying the available fishing opportunities. This would be a secondary benefit of the proposed introduction.

The study area for the purpose of this project is the area from Beaver Creek Dam upstream, as this is the portion of the drainage which has the potential to be impacted by the introduction of smallmouth bass into Bear Paw Lake. Smallmouth bass were introduced into Beaver Creek below Beaver Creek Dam in 1989 and 1991. Therefore, the introduction of smallmouth bass in Bear Paw Lake will not change the species present in the drainage below Beaver Creek Dam.

Background - Past and present fish management activities in Bear Paw Lake and the Beaver Creek drainage

Bear Paw Lake

Currently, Bear Paw Lake is stocked annually with catchable sized McBride strain (Yellowstone) cutthroat trout (Oncorhynchus clarki) and Arlee rainbow trout (Oncorhynchus mykiss). Eagle Lake rainbow trout have been stocked in the past (Gilge 1991).

In recent years, summer fishing pressure has exceeded 140 angler days per surface acre. Fishing pressure and harvest becomes excessive when acceptable size fish are readily available. A creel reduction from 10 to 5 fish was imposed in 1987 to distribute the catch under such conditions. Fishing pressure has declined dramatically since 1988 due to the small size and poor condition of the trout (Gilge 1991).

Beaver Creek Reservoir

Beaver Creek Reservoir is intensively managed with a variety of species. In the early 1980's, largemouth bass (Micropterus salmoides) were introduced to help curb excessive sucker populations and provide an additional sportfish. Although bass reproduction was documented, largemouth bass have not contributed significantly to the fishery. Soon after the bass introductions were made, northern pike (Esox lucius) appeared from an illegal introduction. The pike population increased steadily and peaked in 1987 (Needham and Gilge 1991).

Yellow perch (Perca flavescens) appeared in the reservoir in 1986. Reproductive success of this species has varied over the last few years (Needham and Gilge 1991).

Walleye (Stizostedion vitreum) were stocked in 1987 due to local demand. The walleye management plan included three consecutive years of stocking followed by two non-stocking years to evaluate natural reproduction. An introductory plant of walleye was made in the spring of 1987 with 50,000 fry. This was followed by a fall plant of 322 marked fingerlings. A plant of 100,000 fry was made in 1988 along with 193 marked fingerlings. In 1989, 300,000 fry and 802 fingerlings were stocked. No walleye stocking occurred in 1990 (Needham and Gilge 1991).

During fall 1991 gill netting, eleven walleye were captured averaging 13.2 inches and 0.86 lbs. Natural reproduction of walleye has yet to be documented (Needham and Gilge 1991).

Yellow perch and spottail shiners currently provide most of the forage base as juvenile sucker numbers have declined steadily since 1986 (Needham and Gilge 1991).

Beaver Creek

Beaver Creek is currently managed as a wild trout fishery, although hatchery trout from the reservoirs also enter the stream. Rainbow, brook (Salvelinus fontinalis), brown (Salmo trutta), and cutthroat trout are found in the stream. The target catch rate for trout in Beaver Creek is 0.5 fish/hr (Gilge 1989). An opening day creel census has been conducted since 1988. With one exception, catch rates have far exceeded the target. In 1988 catch rates ranged from 1.14 trout/hr (section 01 - below the Beaver Creek Dam) to 4.27 trout/hr (section 03 - above Bear Paw Lake). In 1989 and 1990 catch rates remained high, however pressure was very low. Local anglers are not fishing this stream because of the (correct) impression that trout numbers are low (Gilge 1990).

Trout populations were impacted by the 1988 drought. Numbers in 1989 were the lowest of any other year measured. In addition, every fish was heavily infected with "black-spot" disease, although the condition of the fish seemed fair to good (Gilge 1990).

Affected Physical Environment and Environmental Concerns

Description of the reservoir and the Beaver Creek drainage

Bear Paw Lake is located on Beaver Creek in Hill County Park, approximately 21 mi south of Havre, Montana (Figure 1). The reservoir is 45 acres in size and was constructed in 1958 to provide recreation. The dam is owned and operated by the Montana Department of Fish, Wildlife, and Parks within Beaver Creek Park, a Hill County park.

Beaver Creek is the main drainage of the Bear Paw Mountains, which range in elevation from 2500 to 6000 ft. The stream flows through Beaver Creek Park, a 10,000 acre County park, and intersects with the Milk River near Havre (Hitchcock 1988).

The mean annual precipitation in the area is 12.6 inches, half of which occurs between May and August (NOAA 1981). The average number of frost free days is 138. Winters are cold with sub-zero temperatures common. Summer air temperatures are warm but seldom hot (less than 95 F). The warmest months are July and August, with a mean air temperature of 68°F and 67 F, respectively. The mean annual air temperature is 42 F (NOAA 1981).

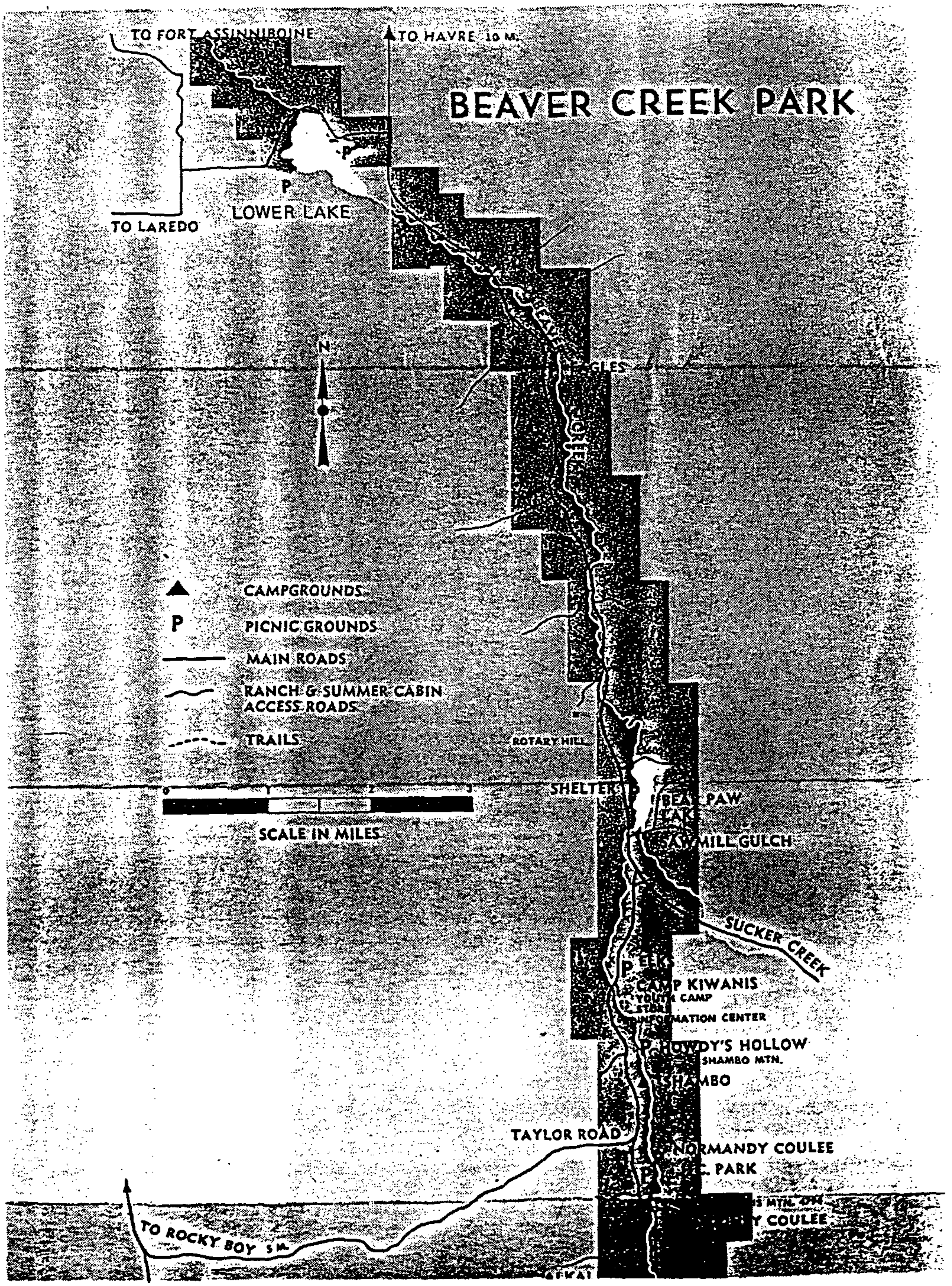
Bear Paw Lake

Bear Paw Lake is steeped sided, has a maximum depth of 55 ft., and stores 535 acre-feet of water at the normal pool (Christian, Spring, Sielbach, & Assoc. 1980). The shoreline is grassy, with some willows and cattails. The primary cover in the reservoir comes from submerged woody vegetation, remnants of brush that was flooded when the reservoir was constructed. There is very little other submerged vegetation. The reservoir experiences heavy algae blooms in the summer months (Gilge pers. comm. 1992).

In 1981, a prominent thermocline occurred at 20 ft in Bear Paw reservoir. Water temperature ranged from 50 F on the bottom to 68 F on the surface. Dissolved oxygen concentrations dropped below 5.0 mg/l at depths greater than 13 ft during August and September (Hitchcock 1988).

Operation of the reservoir was modified in 1982 to a hypolimnial release. This change in operation resulted in a near-isothermal reservoir throughout the summer. On July 7, 1982, water temperatures ranged from 64 F at the surface to 55 F at the bottom - the widest range of temperatures recorded that year. On August 17, temperatures ranged from 68 F on the surface to 63 F at the bottom. By September, surface water temperatures had dropped to 57°F. Except for mid-August, dissolved oxygen levels remained above 5 mg/l at all depths in 1982 (Hitchcock 1988).

igure 1 Map of area



Thermograph data collected in 1991 indicates slightly higher surface water temperatures in Bear Paw Lake. In that year, average daily water temperatures remained approximately at or above 70°F from early July to early September (Figure 2) (Gilge, unpublished data, 1991). Minimum daily water temperatures remained above 70°F from late July to early September, with one cooler period in early August (Figure 3). Temperature and dissolved oxygen conditions in the hypolimnion are unknown for 1991.

Beaver Creek Reservoir

Beaver Creek Reservoir is a 200 acre impoundment located 6 mi downstream from Bear Paw Lake. This reservoir has a maximum depth of 90 ft. It was constructed as a multi-purpose flood control, irrigation, and recreation project.

Beaver Creek

Immediately downstream of Bear Paw Lake, Beaver Creek has an average streambed gradient of 110 ft/mi and a mean width of 17 ft. Approximately 3.7 mi downstream of the dam the gradient and width decrease to an average of 40 ft/mi and 14 ft. In the section of Beaver Creek above Bear Paw Lake, the mean streambed gradient is 76 ft/mi, and the average width is 15.1 ft (Hitchcock 1988).

Due to differences in the underlying geology, the substrate of Beaver Creek changes above Bear Paw Lake. Downstream of Bear Paw Dam, the stream cuts through a thick bed of fine grained glacial moraine resulting in a silty substrate. Upstream of the reservoir, the substrate tends more to cobble and rubble sized materials (Hitchcock 1988).

From 1981 - 1983, flows in Beaver Creek ranged from 2.0 to 494 ft^3/s, with an average annual discharge of 10 - 15 ft^3/s. Low flows typically occur between August and February, while the largest discharge generally occurs from late April to mid-July (Hitchcock 1988).

The average maximum water temperature for August and September 1981 and 1982 was 63°F, 0.6 mi below Bear Paw Lake and 68 °F 3.2 mi downstream. The average maximum water temperature immediately upstream of Bear Paw Lake was 63°F for 1981 and 1982 (Hitchcock 1988).

Specific conductance ranges from 350 to 789 micro-mhos/cm with a mean value of 484 micro-mhos/cm at 52°F. The range of pH is 6.29 to 8.35. Dissolved oxygen levels are generally at saturation (Hitchcock 1988).

Riparian vegetation along the stream is generally thick and consists mostly of willow (Salix sp.), water birch (Betula fontinalis), red dogwood (Cornus stolonifera), wildrose (Rosa sp.), horizontal juniper (Juniperus sp.), and various grasses. In the area near and upstream of Bear Paw Lake yellow pine (Pinus jeffreyi) and aspen (Populus sp.) are also present. Beaver ponds are found along the length of the stream (Hitchcock 1988).

FIGURE 2

AVERAGE WATER TEMPERTURE
BEAR PAW LAKE, 1991

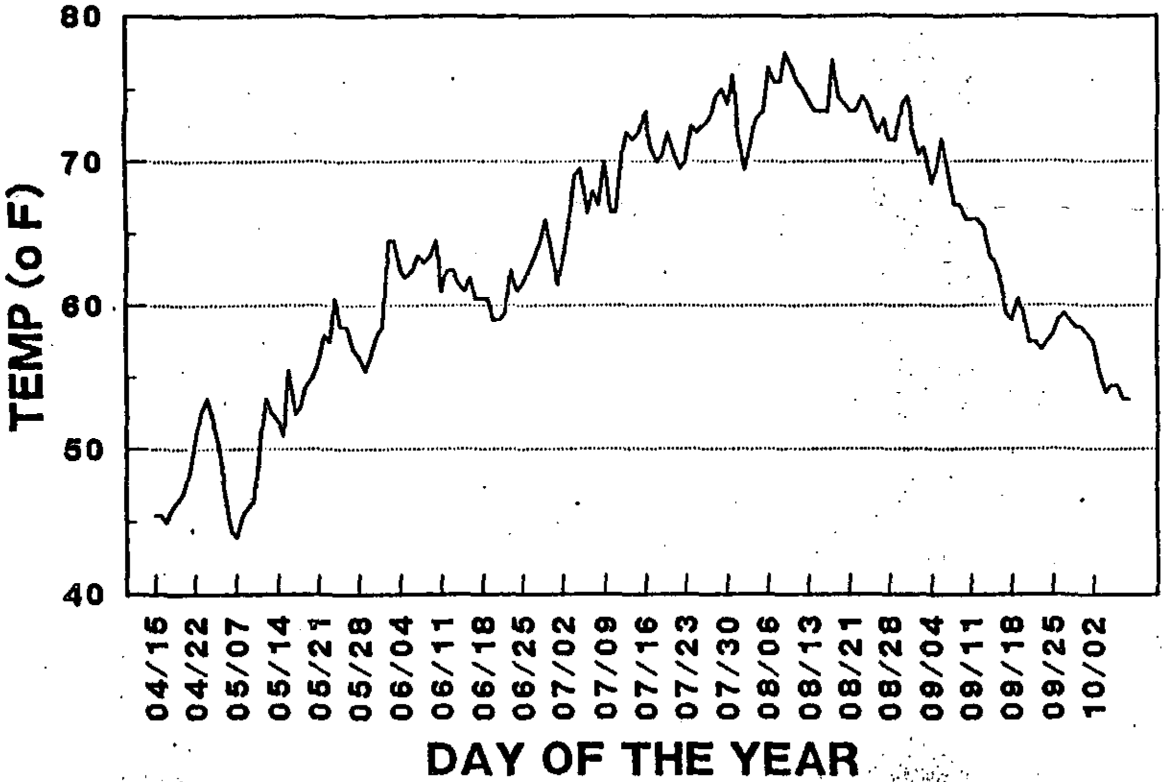
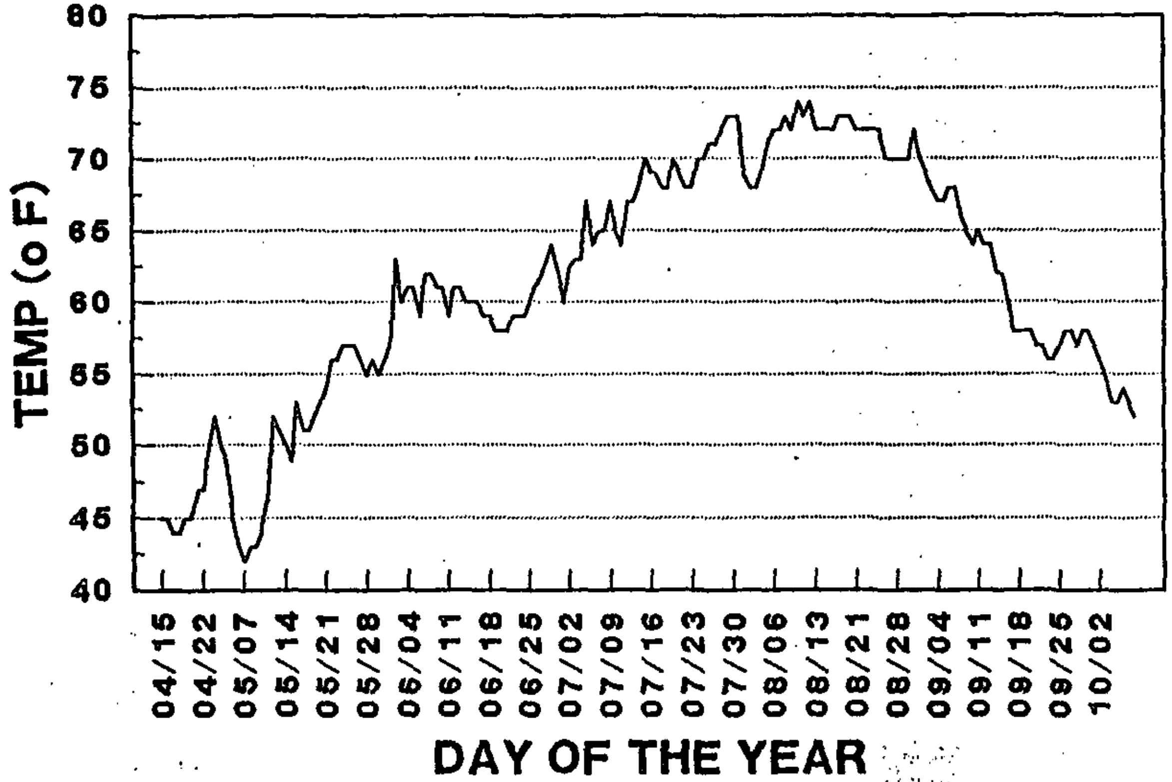


FIGURE 3

MINIMUM WATER TEMPERATURES
BEAR PAW LAKE, 1991



Description of the fish populations and associated food organisms

Bear Paw Lake

Bear Paw Lake contains fathead minnows(Pimephales promelas), brook trout, Yellowstone cutthroat trout, Arlee rainbow trout, mottled sculpins (Cottus bairdi), longnose dace (Rhinicthys cataractae), and white suckers (Gilge pers. comm. 1992).

Crayfish have become extremely abundant in recent years and may have an effect on food availability for trout (Gilge 1991). A population estimate conducted in the spring of 1992 found 21,577 ± 7,421 crayfish in Bear Paw Lake (80% confidence interval). The length range of crayfish in this estimate is 2.6" - 3.8" (tip of rostrum to tip of telson). The crayfish biomass estimate is 1,292 lbs, or 29 lbs/acre (Gilge pers. comm. 1992).

The population of Age II and older white suckers was estimated to be 72,737 ± 10,768 (80% confidence interval), or 1,616/acre in the spring of 1992. The biomass estimate is 13,992 lbs or 311 lbs/acre (Gilge pers. comm. 1992). In comparison, Olson (1963) found 19 adult suckers (> 14")/ acre and 43 lbs/acre in Many Point Lake, Minnesota. Schneider and Crowe (1980) reported 27 - 44 adult white suckers/acre (approximately 29 - 45 lbs/acre) Big Bear Lake, Michigan, in the early 1940's. These authors considered the abundance of suckers in these lakes to be high.

Beaver Creek Reservoir

This reservoir contains a variety of cold, cool, and warmwater species including rainbow trout, northern pike, walleye, yellow perch, and largemouth bass. Since its initial filling in 1974, it has been managed as a trout fishery. Walleye were introduced in 1987 due to local demand. Yellow perch and northern pike were introduced illegally between 1982 and 1987 (Gilge 1991).

Other species in Beaver Creek Reservoir include spottail shiner (Notropis hudsonius) (introduced in 1987), emerald shiner (Notropis atherinoides), Iowa darter (Etheostoma exile), and silvery minnow (Hybognathus nuchalis) (Gilge pers. comm. 1992).

Beaver Creek

Fifteen species of fish are found in Beaver Creek. The most common is the white sucker with an estimated abundance of 1,168 fish/mi and a biomass of 179 lb/mi in 1981 and 1982. White suckers are found in all sections of the stream, mountain suckers (Catostomus platyrhynchus) and longnose suckers (Catostomus catostomus) are found only below Bear Paw Lake. Suckers are far more numerous than salmonids in all sections of the stream below Bear Paw Lake. Above Bear Paw Lake, the ratio of trout to suckers is 2.61 to 1 (Hitchcock 1988).

Rainbow trout are found in all sections of the stream and they are the most common game fish (Hitchcock 1988). Brook, brown, and cutthroat trout are also found in Beaver Creek above Beaver Creek Reservoir, although brown and cutthroat trout are relatively rare.

Northern pike and largemouth bass have been found in Beaver Creek upstream of Beaver Creek Reservoir. Other species of fish found in this section of Beaver Creek include brassy minnow (Hybognathus hankinsoni), silvery minnow, northern redbelly dace (Phoxinus eos), brook stickleback (Culaea inconstans), and lake chub (Couesius plumbeus) (Gilge pers. comm. 1992).

Smallmouth bass were introduced into Beaver Creek downstream of Beaver Creek Reservoir in 1989 and 1991 at the rate of 5,000, 1.5" - 2" fish/year. An electrofishing survey done in the spring of 1992 failed to locate any of these fish (Gilge pers. comm. 1992).

Potential value of controlling suckers

The sucker population of Bear Paw Lake is believed to be detrimental to trout by competing with trout for food. Is there direct evidence for competition between white suckers and trout? Have sucker control projects been successful in other areas in improving sport fish populations?

Holey et al (1979) reviewed the literature on sucker removal projects and concluded that there is poor evidence that suckers are harmful to sport fishes. However, since that review, some new research has been published which suggests that there is in fact competition between suckers and sport fish.

Magnan (1988) conducted a quantitative survey of 26 oligotrophic Quebec lakes and found that the presence of creek chub (Semotilus atromaculatus) or white sucker had an impact on brook trout populations. Evidence for competitive interactions among these species was provided by the observation that 1) the mean annual yield of brook trout was significantly reduced when they lived sympatrically with these species, 2) brook trout shifted their food habits from benthic organisms to zooplankton in the presence of creek chub and/or white sucker, and 3) the length of the gill rakers of brook trout was significantly higher in lakes containing chubs or suckers. The presence of white sucker reduced by almost half the yield of brook trout. Although brook trout increased their consumption of zooplankton in the presence of white sucker, the brook trout numbers were so reduced as to have little or no impact on zooplankton populations.

Tremblay and Magnan (1991) found that brook trout shifted their spatial distribution and/or their feeding habits in the presence of white sucker and that these interactions vary according to the size of the fish. Small sympatric brook trout abandon the littoral zone for the entire summer, whereas small allopatric trout merely reduce their use of the littoral zone only in the late summer. Small allopatric brook trout fed mainly on zoobenthos throughout the summer whereas small sympatric ones shifted their diet from zoobenthos to zooplankton in July and August. Large sympatric trout shifted their spatial distribution and diet sooner than small ones.

Hayes et al (1992) found that the strongest evidence for competition between white suckers and yellow perch was the shift in adult yellow perch diet observed in a lake where white suckers removed. After the removal of white suckers, the proportion of zooplankton in the yellow perch diet (by weight) dropped from 70% to 1%. During the same period, the mean number of chironomid larvae in the adult yellow perch diet increased 81-fold. In addition, the removal of white suckers resulted in an increase in the abundance of prey items utilized by yellow perch. In addition, adult yellow perch shifted their habitat use (towards the bottom of the lake) after sucker removal. These changes were statistically significant when compared to a control lake where white suckers were not removed.

While this information indicates that suckers compete with brook trout and yellow perch for food resources, the question remains as to the effectiveness of sucker removal projects in improving recreational fisheries. Schneider and Crowe (1980) found that yellow perch and rock bass clearly benefited from sucker removal, but largemouth and smallmouth bass clearly did not. They found that the increased production of yellow perch and rock bass was accomplished more by increased recruitment than by increased growth of individuals. There was also a three year lag before a large improvement in fishing began. They stated that sucker trapping projects are only likely to be effective under certain conditions. In complex fish communities and fertile environments, the potential benefits are likely to be greatly diluted.

Despite the changes in yellow perch food habits, habitat use, and feeding rate after white sucker removal in Douglas Lake, Michigan, the magnitude of the growth response was relatively small and not immediate (Hayes et al 1992).

Johnson (1977) concluded that removal of white suckers from lakes with limited fish species diversity appears to benefit percid populations. In this study of a Minnesota lake, yellow perch increased about 15-fold and walleye increased about one-third after removal of white suckers.

Overall, it appears that sucker removal projects are most successful in lakes where suckers comprise a large percentage of the total fish biomass, where a large portion of the sucker population can be removed, and where the fish species diversity is small. Holey et al (1979) stated that the most successful removal projects will be those in which all non-sport fish are removed (usually by chemical means) and sport fish are stocked.

It should be noted that all of the above studies were done on lakes where suckers were removed mechanically or chemically. No literature has been located where a predator has been stocked to reduce sucker populations. In addition, most of these studies were done on lakes with percid sport fishes. Both chemical and mechanical (trapping) methods have already been tried at Bear Paw Lake. The results of those efforts are summarized below.

Other sucker control measures

Chemical treatment

Chemical treatment of Bear Paw Lake has been tried on two previous occasions during the 1980's. These efforts were successful in reducing the sucker population and in increasing trout growth in the reservoir for a time. However, within a few years the sucker population rebounded and trout growth again declined to an unacceptable level.

Unfortunately, this management strategy has some major problems. Chemical treatment kills all the fish, including the desirable ones. The trout fishery is lost for one year. The lake is drawn down to its minimum pool level prior to chemical treatment. As the water level drops, steep banks composed of saturated soils are exposed. These banks tend to slough, resulting in sedimentation in the reservoir and the stream downstream. In addition, the creek downstream is dewatered for a time, resulting in high mortality of fishes downstream. Finally, chemical treatment is expensive - $4,000 - $5,000 - and the benefits are temporary.

Trapping

Olson (1963) used traps to reduce the size of the sucker population in Many Point Lake, Minnesota by 34%. This effort was not considered to be successful in reducing inter-specific competition with other species. The removal was offset by increased growth, recruitment, and survival of the remaining sucker species.

Johnson (1977) also found that removal of large, mature suckers resulted in an approximately 17-fold increase in the population of young suckers.

When trapping efforts have been tried at Bear Paw Lake, a similar result has been noted. Sucker trapping was begun in 1989, with over 9,000 lbs of suckers removed. In 1990 and 1991 approximately 5,000 lbs of suckers were removed each year. The overall number of suckers caught in gill nets in those years has increased. The increase has been in the suckers < 10" - to over 750 in 1990 from less than 250 in 1988 (Figure 4). The average length of trout during these years has remained around 9" (Figure 5) (Gilge, unpublished data 1991).

Overall, trapping efforts are not considered to be effective because they are labor intensive and they are ineffective in removing suckers < 6" in length.

Other predators

There may be other predators that would be better than smallmouth bass to accomplish the desired goal. Some likely candidates are largemouth bass, northern pike, or walleye. All three of these fishes are present in Beaver Creek Reservoir downstream. It is difficult to predict the potential risks and benefits of these species without a thorough review. However, it should be noted that largemouth bass prefer slightly warmer water temperatures than

FIGURE 4

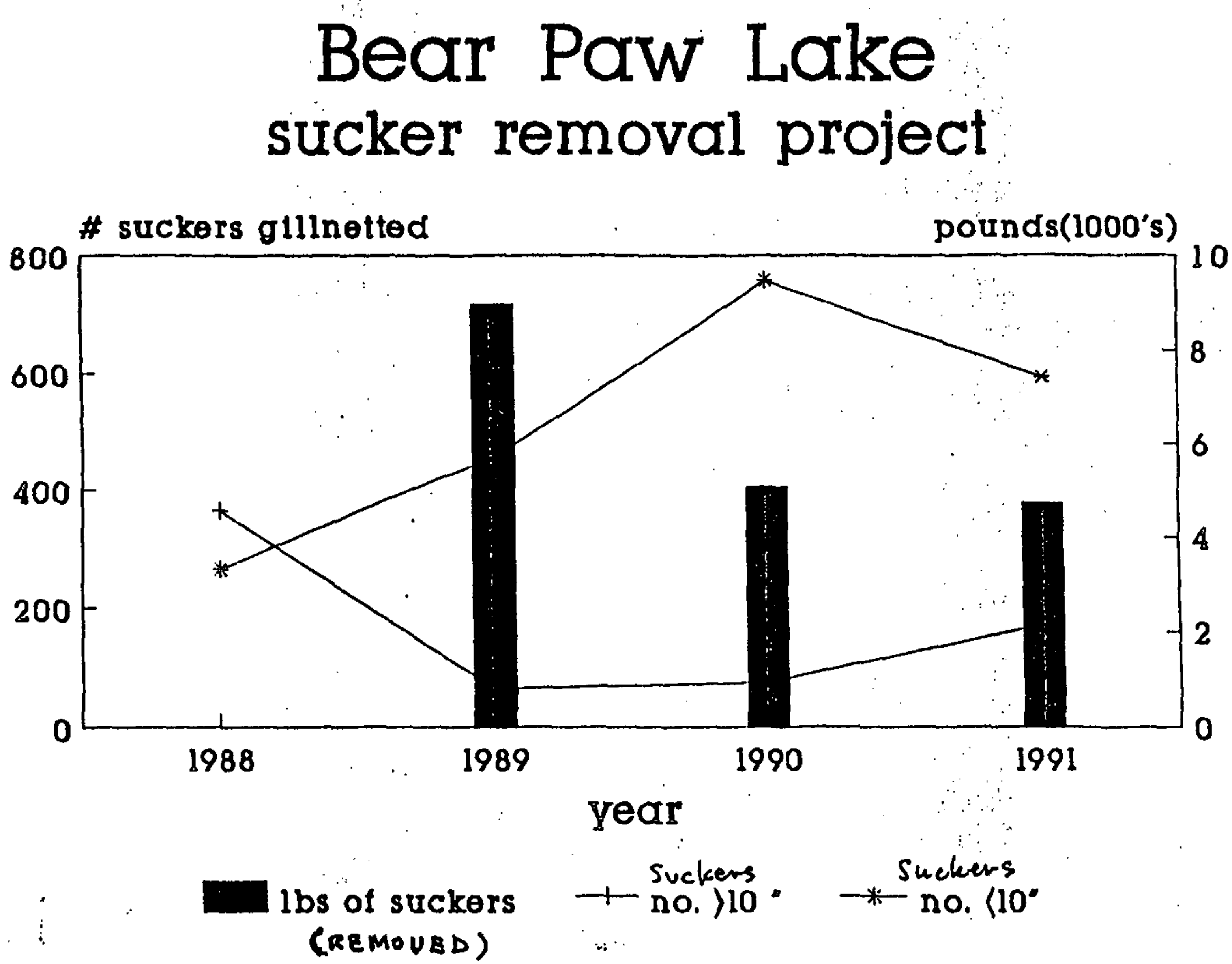
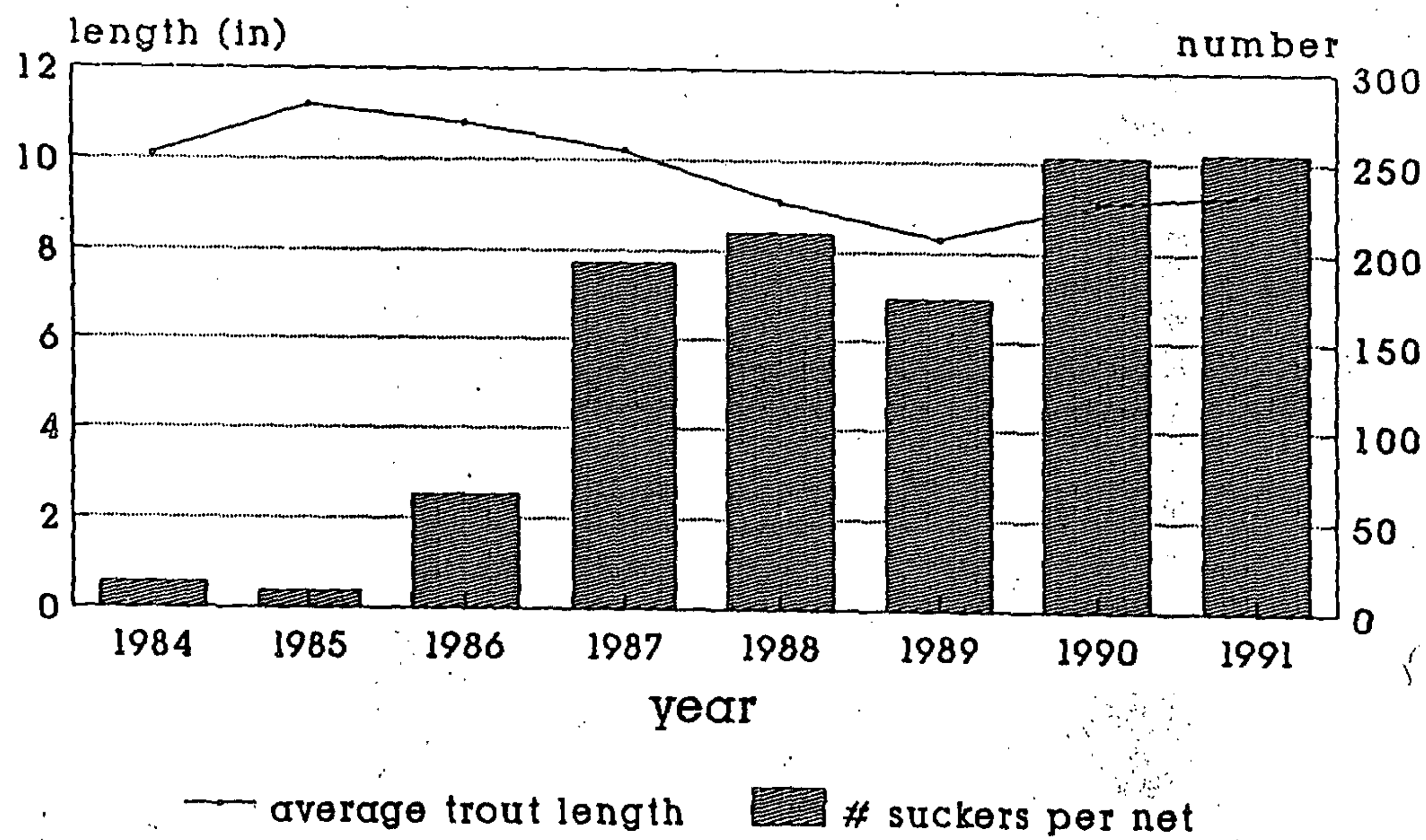

Bear Paw Lake
sucker removal project
# suckers gillnetted
pounds(1000's)
800
600
400
200
0
10
8
6
4
2
0
1988
1989
1990
1991
year
lbs of suckers
(REMOVED)
Suckers
no. >10"
Suckers
no. <10"

FIGURE 5

Bear Paw Lake
Gillnet Results



smallmouth bass, and they prefer weed habitats. Smallmouth bass may be better suited to the environment of Bear Paw Lake than largemouth bass.

Northern pike and walleye are both highly predacious, piscivorous fish. The risk to the existing trout population would be higher with these species than with smallmouth bass.

Potential to establish a naturally reproducing population of 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.

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 - 65°F. 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). There is a positive, linear, relationship between prey size and size of smallmouth bass. Larger fish tend to add larger prey items to their diet, while continuing to feed on smaller items as well. They tend to be "feeding generalists", selecting prey based on size and abundance in the environment (Pflug and Pauley 1984).

Some investigators have found crayfish to be the most important food of smallmouth bass (Martin and Fry 1972, Serns and Hoff 1984) whereas others have found smallmouth bass to be more piscivorous (Hubert 1977, Applegate et al 1967, Livingston 1987). The abundance of prey to large part determines the food habits of smallmouth bass.

In Flaming Gorge Reservoir, Utah, smallmouth bass switched from a primarily fish diet to a primarily crayfish diet over a one year period. It was assumed by the authors that the change was due to an increase in crayfish numbers (Schmidt and Brayton 1982).

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 Lake Sammamish, Washington, sculpins (Cottus sp.) were the major prey item for Age I smallmouth bass, although juvenile salmon and crayfish were also eaten. Age II and III smallmouth bass fed mostly on sculpins, while age IV and V bass fed on crayfish and juvenile salmon. Other incidental prey items include zooplankton, smallmouth bass fry, squawfish, peamouth, and brook lamprey (Pflug and Pauley 1984).

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).

In Lake Sammamish, Washington, smallmouth bass were found to have an unmistakable habitat preference for gravel and cobble substrate with access to drop offs (Pflug and Pauley 1984).

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 affected 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).

<u>Potential for smallmouth bass to become established in Bear Paw Lake</u>

Spawning

For this introduction to be considered successful, it is not necessary that smallmouth establish a naturally reproducing population. If smallmouth do not reproduce in Bear Paw Lake then they will have to be restocked periodically with hatchery fish. This has the disadvantage of creating extra expense for the Department of Fish, Wildlife, and Parks. However, the advantage of this scenario is that if a problem with bass is encountered, stocking could be discontinued. Would smallmouth bass be likely to reproduce in this water?

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 more common in Bear Paw Lake and in upper Beaver Creek than in other areas of the drainage. However, water velocities in the stream 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. 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 data are available for Bear Paw Lake only for one year - 1991 and wind data was not available. In that year water temperatures remained at or above 59°F from the beginning of June to the middle of September. There was a cool period at the end of May when water temperatures declined (Figure 2). It is difficult to make judgements based on one year's data, but it appears there would be suitable water temperatures for spawning during at least some years.

Water level fluctuations are minimal in Bear Paw Lake so there is unlikely to any problem with dewatering of nests during the spawning and incubation season.

Rearing

Most spawning activity takes place at temperatures above 59°F. Surface water temperatures typically reach this level in Bear Paw Lake during early June (Figure 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 mid to late June.

Adult

Habitat suitability was partially determined through the use of habitat suitability information found in Edwards et al (1983). This report gives suitability index graphs for smallmouth bass based on a number of key variables. For each variable, suitability is described as ranging from 0.0 to 1.0 with 0.0 being totally unsuitable and 1.0 being optimal habitat.

Water temperature is one of the most critical variables determining smallmouth bass success. Average surface water temperature during the growing season (May - October) in Bear Paw Lake ranged from approximately 45°F to 75°F in 1991 (Figure 2). Water temperatures remained at or above 70°F from early July through the end of August in both Bear Paw Lake and Beaver Creek (below Bear Paw Lake) (Hitchcock 1988). Habitat suitability for temperature would therefore range from 0.1 to 1.0 throughout the growing season, but from July through August suitability would be from 0.9 - 1.0.

Average maximum water temperature in Beaver Creek above Bear Paw Lake was 63°F in 1981 and 1982. This corresponds to a maximum habitat suitability for this section of the stream of 0.7 (Edwards et al 1983).

The growing season in the Bear Paw Lake area exceeds 100 days per year, indicating that the climate is sufficiently warm to support smallmouth bass (Hubert 1988, Johnson et al 1977).

The stream gradient for Beaver Creek is generally too high for smallmouth bass. The average gradient above Bear Paw Lake is higher than the highest gradient listed in Edwards et al (1983) so it is difficult to predict an exact suitability, but suitability would clearly be less than 0.5 and possibly as low as 0.0. The lowest gradient reach of Beaver Creek (immediately above Beaver Creek Reservoir) has a habitat suitability of 0.5.

Dissolved oxygen levels vary with depth and by year in Bear Paw Lake. For optimum suitability, smallmouth bass require dissolved oxygen levels of at least 6 ppm (Edwards et al 1983). In 1982, dissolved oxygen levels remained above 5 ppm throughout the reservoir during July and September. Only in the month of August were there anoxic conditions at depths below 18 ft. In 1981, dissolved oxygen levels were low during August and September at depths below 12 - 15 feet. It is clear that, depending on the conditions of the year and the operation of the dam, smallmouth bass are going to be stressed by low oxygen levels for some or all of the summer. They could be restricted to the top 12 - 15 feet of the reservoir for as long as two months.

Substrate in the reservoir and upstream is primarily gravel and cobble. This substrate has a suitability of 1.0 for smallmouth bass. Beaver Creek below the reservoir has a silt/sand substrate, which has a suitability of 0.2 (Edwards et al 1983).

Other water quality parameters (conductivity, pH) seem to be generally suitable for smallmouth bass in both the stream and reservoir.

There is no quantitative data available on the percent of the reservoir which contains cover. However, it is known that there are a large number of dead trees and bushes in the reservoir. If these trees and bushes cover 25% - 50% of the reservoir this would be considered optimum for smallmouth bass.

The average depth of the reservoir is not known. However, the maximum depth is 55 ft and the banks are steep. The average depth may be in the range 30 ft, which is optimum for smallmouth bass (Edwards et al 1983). Pool depth in Beaver Creek is also unknown. However, given the size of the stream, pools are probably less than 3 ft deep in most locations above Bear Paw Lake. Suitability for smallmouth bass drops off rapidly when pools are less than 3 ft deep.

There is no information on zooplankton or insect densities in the reservoir so it is difficult to predict if there is adequate forage for young of the year smallmouth bass. However, there is clearly adequate forage for juvenile and adult smallmouth, given the high numbers of crayfish and small white suckers which live in the reservoir.

Summary

Based on the 1991 data, water temperatures in Bear Paw Lake and in Beaver Creek below the reservoir appear to be warm enough to support smallmouth bass. Water temperatures in Beaver Creek above the reservoir are cooler than optimal.

The substrate of the reservoir and upper Beaver Creek is suitable for smallmouth bass while substrate in lower Beaver Creek is siltier than what smallmouth prefer.

The amount of cover in Bear Paw Lake is not known with certainty, but there appears to be a large amount of dead brush which may be excellent cover for smallmouth. The average depth of the reservoir is also unknown, but appears to be in the suitable range, and possibly near optimum.

The gradient of Beaver Creek is higher than what is preferred by smallmouth bass. The pool depth is not known for certain, but is probably shallower than the preferred pool depth.

The food supply is abundant for smallmouth bass. If bass were to be introduced, they would be the only predacious fish above Bear Paw Dam.

Potential for negative interactions with trout populations in Bear Paw Lake and Beaver Creek

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).

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).

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

Competition risk

In Bear Paw Lake, 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.

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 reducing the numbers of chub, thus reducing the forage available for other piscivores in the reservoir (Wengert pers. comm. 1991). However, given that there are no other piscivores currently inhabiting Bear Paw Lake, the risk of negative competitive interactions between adult smallmouth bass and other fishes in the reservoir is minimal.

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).

Smallmouth bass were introduced into Lake Opeongo, Ontario sometime prior to 1928. There was a small brook trout fishery in that lake before the introduction of bass. This species is now taken only very rarely. It is difficult to assess if bass are responsible for the decline of brook trout, or what the mechanism might be (Martin and Fry 1972).

There is no evidence the smallmouth bass has had any appreciable effect on lake trout or whitefishes in Lake Opeongo. No lake trout or whitefish or their eggs have ever been found in bass stomachs. The smallmouth do feed on insects and perch, important forage for trout and whitefish, but only to a limited extent. The spatial separation of these species for much of the year and the size and variety of habitat available in Lake Opeongo probably mitigate against any direct or indirect conflict between bass and many of the colder water species (Martin and Fry 1972).

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 spawning 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).

Summary of risks to salmonids in the Bear Paw Lake/Beaver Creek System

It should be assumed that smallmouth bass, if planted into Bear Paw Lake, will pioneer both upstream and downstream. The risk to the hatchery stocked salmonids is relatively small because these fish are stocked at a catchable size. Only the very largest smallmouths would be able to prey on the catchable trout. If smallmouth reproduce in the system, there could be a competitive interaction between young smallmouth and trout for zooplankton and insects. However, smallmouth begin feeding on larger foods (crayfish and fish) at a fairly small size. Competition would likely be limited to a relatively brief period in the spring and early summer when the young smallmouth are still feeding on insects and zooplankton.

Smallmouth bass could prey on the small population of wild trout which occurs in the drainage. However, the data indicate that smallmouth bass select their prey on the basis of size and abundance. In most areas, crayfish and other fishes are far more abundant than juvenile trout. The one possible exception is Beaver Creek upstream of Bear Paw Lake. This portion of the drainage supports a population of wild brook trout and is a popular sport fishery. There is a risk that smallmouth bass could become established in the stream and prey on juvenile brook trout, potentially impacting the sport fishery in this area.

Not enough information is available to estimate ecological impacts of the introduction of smallmouth bass on fishes in Beaver Creek Reservoir. That water body has numerous predators, most of which were introduced in the last decade. In addition, the overall species diversity is much higher than in the upstream areas.

Potential for reducing the abundance of sucker populations

For the purpose of this evaluation, the question of whether and to what degree smallmouth bass eat white suckers is critical. It is obvious from the above discussion that smallmouth bass are opportunistic in their eating habits. Given the fact that juvenile white suckers are often sold as bait to smallmouth bass anglers, it is clear that bass will eat white suckers (Scott and Crossman 1973). In fact, it was estimated in 1963 that 30 million sucker fingerlings were harvested and sold as bait in Minnesota. Small suckers have also been used as forage for predacious fishes, especially walleyes, in rearing ponds (Olson 1963).

Olson (1963) concluded sucker were of low forage value for fish in Many Point Lake, Minnesota. He examined 995 stomachs from 9 fish species but did not find suckers in a single stomach. He concluded suckers were able to avoid capture by predatory fish.

Within the Beaver Creek drainage, smallmouth bass fingerling were observed feeding on schools of white suckers within moments after being stocked. In another instance, young-of-the-year largemouth bass captured in Beaver Creek Reservoir all had ingested small suckers while adult bass had consumed numerous crayfish (Gilge, unpublished data 1992).

Summary and conclusions

Any introduction of a new species poses potential risks. In this situation, there are several risks. The most serious risk is that the smallmouth bass will have a detrimental impact on the trout species which are already in the drainage. If this were to happen, it would be directly counter to the objective of the project, which is to improve trout fishing.

The other risks are that the introduction simply will not work, i.e. the smallmouth bass will not survive in the drainage, or that smallmouth will not prey on white suckers. If the bass fail to become established in the drainage then no environmental harm has been done, although time and money will have been spent on a failed effort. If the bass do survive, but do not prey on white suckers, then the primary objective (improve trout fishing) will not have been met. However, there could be a secondary benefit of a new recreational fishery.

In my opinion, there is a risk of negative interactions with the trout which are already present in the system. The risk of predation is very small in the reservoir because the trout in the reservoir are primarily of hatchery origin, and are stocked at catchable size. The risk of competitive interactions in the reservoir appear to be minor due to the very abundant smallmouth forage base. This is forage which is not being utilized by the trout.

Most of the potential for negative interactions between these two species appears to be in the stream environment above Bear Paw Lake. These trout are naturally reproducing so the young of the year would be susceptible to smallmouth bass predation. However, the stream environment is not optimal smallmouth bass habitat. The gradient is generally too high and temperatures too cool to be utilized to a large extent by smallmouth bass.

There is a high probability that smallmouth bass, if introduced, would survive and grow in Bear Paw Lake. They would also likely reproduce, at least in years with relatively warm and calm spring weather. The greatest problem they are likely to face in the reservoir environment is low oxygen levels in the late summer months.

Would smallmouth bass feed heavily on white suckers, reducing their numbers to a low level, and allowing trout to thrive? While suckers show up in the literature as one of the foods used by smallmouth bass, they are rarely the primary food. Given the abundance of crayfish in the reservoir, smallmouth bass may use this food source and leave the sucker food base unexploited. If this were to happen the result might be a smallmouth bass fishery in Bear Paw Lake, with no improvement in the trout fishery.

The remaining question is: what will happen if nothing is done to improve the fishing in Bear Paw Lake? The answer is not as simple as it may appear. It is very possible that local anglers, frustrated with the situation, would take matters into their own hands and stock Bear Paw Lake with a new species of fish. Given the recent history at Beaver Creek Reservoir, likely candidates for illegal introduction are northern pike and yellow perch. These introductions could be more risky than the introduction proposed here.

Overall, given the potential benefits, the lack of other management options, and the fact that there are no other *predacious fishes in this water*, I think the possible benefits of the introduction outweigh the risks.

LITERATURE CITED

Applegate, R.L., J.W. Mullan, and D.I. Morias. 1967. Food and growth of six centrarchids from shoreline areas of Bull Shoals Reservoir. Proc. SE Assoc. Fish and Game Comm. 20: 469-482. cited in Serns, S.L. and M.H. Hoff. 1984. Food habits of adult yellow perch and smallmouth bass in Nebish Lake, Wisconsin - with special reference to zooplankton density and composition. Tech. Bull. No. 149. Wisconsin Department of Natural Resources, Madison, Wisconsin.

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 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.

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.

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

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.

Christian, Spring, Sielbach, & Assoc. and Northern Testing Laboratories, Inc. 1980. Final Draft - Phase 1 inspection report, Bear Paw Lake Dam. MT-115. National Dam Safety Program. Prepared for Montana Department of Fish, Wildlife, and Parks, Helena, 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.

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.

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.

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.

Gilge, K. 1989. Northeast Montana Coldwater Ecosystem Investigations. Montana Department of Fish, Wildlife, and Parks. Job Progress Report, F-46-R-2.

Gilge, K. 1990. Northeast Montana coldwater ecosystem investigations. Montana Department of Fish, Wildlife, and Parks. Job Progress Report F-46-R-3.

Gilge, K. 1991. Northeast Montana coldwater ecosystem investigations. Montana Department of Fish, Wildlife, and Parks, Helena, Montana. Job Progress Report F-46-R-4, V-d.

Gilge, K. 1992. Personal communication. Montana Department of Fish, Wildlife, and Parks, Chinook, Montana.

Hayes, D.B. W.W. Taylor, and J.C. Schneider. 1992. Response of yellow perch and the benthic invertebrate community to a reduction in the abundance of white suckers. Trans. Am. Fish. Soc. 121:36-53.

Hitchcock, R.W.III. 1988. Limitations to a rainbow trout population in north-central Montana. Master of Science Thesis, Montana State University, Bozeman, Montana.

Holey, M., B. Hollender, M.Imhof, R. Jesien, R. Konopacky, M. Toneys, and D. Coble. 1979. Never give a sucker an even break. Fisheries 4: 2 - 6.

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. 1977. Comparative food habits of smallmouth bass and largemouth bass in Pickwick Reservoir. J. Ala. Acad. Sci. 48: 167 - 178. cited in Serns, S.L. and M.H. Hoff. 1984. Food habits of adult yellow perch and smallmouth bass in Nebish Lake, Wisconsin - with special reference to zooplankton density and composition. Tech. Bull. No. 149. Wisconsin Department of Natural Resources, Madison, Wisconsin.

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.

Johnson, F.H. 1977. Responses of walleye (Stizostedion vitreum vitreum) and yellow perch (Perca flavescens) populations to removal of white sucker (Catostomus commersoni) from a Minnesota lake, 1966. J.Fish. res. Bd. Can. 34: 1633-1642.

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.

Livingston, A.C. 1987. Habitat use and food habits of young of the year centrarchids in the Jack's Fork River. M.S. Thesis, University of Missouri, Columbia. 167 p.

Magnan, P. 1988. Interactions between brook charr, Salvelinus fontinalis, and nonsalmonid species: ecological shift, morphological shift, and their impact on zooplankton communities. Can. J. Fish. Aquat. Sci. 45: 999-1009.

Martin, N.V. and F.E.J. Fry. 1972. Lake Opeongo: Effects of exploitation and introductions on the salmonid community. J. Fish. Res. Bd. Can. 29:795-805.

Needham, R.G. and K.W. Gilge. 1991. Northeast Montana warmwater ecosystem investigations. Montana Department of Fish, Wildlife, and Parks, Helena, Montana. Job Progress Report F-46-R-4, V-e.

NOAA (National Oceanic and Atmospheric Administration). 1981. Local climatological data, annual summary with comparative data, 1980, Havre, Montana. Ashville, North Carolina.

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

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

Pflug, D.E. and G.B. Pauley. 1984. Biology of smallmouth bass in Lake Sammamish, Washington. Northwest Science 58: 118-130.

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.

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.

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.

Schmidt, B.R. and S. Brayton. 1982. Flaming Gorge Reservoir fisheries investigations. 1982 annual report. Publication no. 83-14. Utah Division of Wildlife Resources, Salt Lake City, Utah.

Schneider, J.C. and W.R. Crowe. 1980. Effect of sucker removal on fish and fishing at Big Bear Lake. Michigan Department of Natural Resources Fisheries Division. Fisheries Research Report No. 1887.

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

Serns, S.L. and M.H. Hoff. 1984. Food habits of adult yellow perch and smallmouth bass in Nebish Lake, Wisconsin - with special reference to zooplankton density and composition. Tech. Bull. No. 149. Wisconsin Department of Natural Resources, Madison, Wisconsin.

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.

Trembley, S. and P. Magnan. 1991. Interactions between two distantly related species, brook trout (Salvelinus fontinalis) and white sucker (Catostomus commersoni). Can. J. Fish. Aquat. Sci. 48:857-867.

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.

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.