CUMULATIVE EFFECTS OF HUMAN ACTIVITIES ON BULL TROUT (Salvelinus confluentus) IN THE UPPER FLATHEAD DRAINAGE, MONTANA

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ABSTRACT: We reviewed the potential cumulative effects of human activities on bull trout in the Flathead Lake and River system of northwest Montana. Bull trout are the largest fish native to the Flathead drainage, attaining a length of up to one meter and a weight of 10 kg. This species migrates from Flathead Lake up to 250 km upstream to spawn in cold headwater tributaries with groundwater upwelling and clean gravels. Spawning and rearing habitats are limited and vulnerable to damage by deposition of fine sediments. Potential threats to bull trout habitat and populations include timber harvest, road building, mining, residential and agricultural development, hydropower construction and operation, harvest of fish by anglers, and non-native fish species. Management and mitigation options include application of best management practices and riparian guidelines for logging, habitat protection and improvement, improved fish passage to blocked areas, fishing regulations and integrative management of fish populations. Because of reduction in habitat, continued potential for habitat degradation, and limited options for management, the bull trout population is vulnerable and should be closely monitored to detect signs of decline.
KEY TERMS: Migratory bull trout; spawning and rearing habitat; land management; sediment deposition; hydropower development; fisheries management and mitigation options.

INTRODUCTION

The bull trout is the largest fish native to the Flathead drainage, attaining a length of up to one meter and a weight of up to 10 kg. The bull trout of inland waters is a separate species from the smaller, coastal Dolly Varden (Cavender, 1978). Most bull trout in the Flathead system are migratory, growing to maturity in Flathead Lake and migrating up to 250 km through the river system and into tributaries to spawn (Fraley and Shepard, 1989, Fraley, 1989). Juvenile fish remain in tributaries from one to three years before migrating to the lake. Most bull trout in the North and Middle forks of the Flathead River mature in Flathead Lake.

Bull trout spawn in September and October, selecting low-gradient mountain streams with cold, clean water, beds of clean gravel, and areas of upwelling groundwater necessary for successful egg incubation (Fraley and Shepard, 1989). Hiding cover such as logs and undercut banks is required for adult spawners. These strict requirements make good spawning and incubatioon habitat limited and valuable.

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Suitable habitat for rearing juvenile bull trout is also limited. Young bull trout require cold-water tributaries with good cover (rocks and woody debris) and relatively little streambed sediment. Most juvenile bull trout are found in Flathead tributaries with average summer afternoon temperatures below 15° C.

Considerable research and management activities have been directed toward bull trout in the Flathead Basin (Fraley and Shepard, 1989). In cooperation with the USDA Forest Service, the Montana Department of Fish, Wildlife and Parks (MDFWP) has monitored effects of timber management on spawning and rearing habitat and fish populations in the upper drainage (Weaver and Fraley, 1988, Shepard et. al., 1984, USDA Forest Service, 1988). Monitoring activities have been coordinated with the Flathead Basin Commission's water quality monitoring program (Flathead Basin Commission, 1988). The trophy fishery for bull trout has been controlled by strict catch limits and by closing major spawning tributaries to angling.

Bull trout are listed as a Class B Species of Special Concern by MDFWP, which means they occur in limited habitat and numbers in Montana. The Flathead bull trout are one of the more significant populations in North America and their elimination would mean at least a moderate loss to the gene pool of the species (Holton, 1980). Bull trout are very sensitive to environmental disturbance. In this paper we examine the potential cumulative effects on bull trout caused by limited spawning and rearing habitat, the effects of land management activities, and increasing human population in the basin. We also consider measures to protect and enhance the bull trout population in the upper Flathead drainage.

STUDY AREA

The Flathead Lake and River system is a headwater drainage of the Columbia River Basin (Figure 1). Flathead Lake has a surface area of 476 km^2 and a mean depth of over 30 m. The Flathead River enters the north end of the lake. The South, Middle and North forks drain areas of the Great Bear and Bob Marshall wilderness, Glacier National park and managed Flathead National Forest Lands. The upper North Fork drains southern British Columbia. The Swan River enters Flathead Lake near the mouth of the Flathead River. More than half of Flathead Lake and the lower river system are within the Confederated Salish and Kootenai Indian Reservation.

Bull trout from Flathead Lake originally spawned in tributaries of all forks of the Flathead and the Swan River. Hungry Horse Dam was constructed in 1954 and blocked all migration into the South Fork Flathead River. Bigfork Dam was constructed in 1902 and has blocked most migration into the Swan River. Kerr Dam was constructed on the outlet of Flathead Lake in 1938 and blocked all upstream movement of bull trout from the lower Flathead and Clark Fork systems.

RESULTS AND DISCUSSION

Potential Threats to the Bull Trout Population

Timber harvest activities.—Major management activities on forested land in the drainage are timber harvest and associated road construction. In the Swan drainage, Shepard et al. (1984) and Leathe and Enk (1985) found a significant relationship ($r^2 = 0.56$, $P < .01$) between road development, stream gradient and stream substrate score, a transect method which estimates available clean or unembedded rearing

habitat in streams. Also, the percentage of stream substrate materials less than 6.35 mm in diameter was significantly correlated to road development and stream gradient ($r^2 = 0.49$, $P < .01$) (Leathe and Enk, 1985). These relationships indicate that road building associated with timber harvest can cause increased fine materials to be deposited in the streambed.

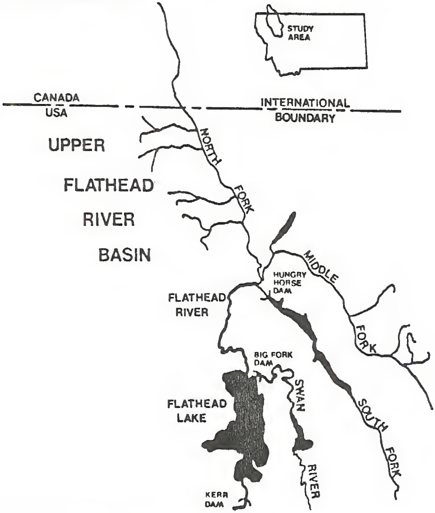

Figure 1. The Upper Flathead Drainage

Fine materials deposited in streambed gravels reduce survival to emergence of incubating bull trout embryos. Average survival to emergence of incubating bull trout embryos in Coal Creek (a tributary of the North Fork Flathead) fell from over 60 percent in gravels with 30 percent fine materials, to zero percent in gravels with 44 percent fine materials (Weaver and White, 1985). Clearly, excessive fine materials deposited in spawning areas could greatly reduce fry production.

Rearing habitat for juvenile bull trout in tributaries is also harmed by deposited sediments. Juvenile bull trout densities in tributaries of the Swan River were significantly correlated to the percentage of streambed materials less than 6.35 mm ($r^2 = 0.33$, $P < 0.01$) and substrate score ($r^2 = 0.40$, $P < 0.01$) (Shepard et al., 1984, Leathe and Enk, 1985). These findings indicate that land management activities that deliver fine materials to the stream could significantly reduce the instream habitat for juvenile bull trout.

Mining.--Mining and associated timber removal and road construction have the potential to eliminate bull trout stocks spawning in a particular tributary. A

recent case illustrating this potential threat was an International Joint Commission study on the proposed Cabin Creek coal mine in the Cabin and Howell creek drainages in Canada (International Joint Commission, 1988). As proposed, the open pit coal mine would eliminate ten percent of the migratory bull trout spawning stock in Flathead Lake because of the loss of Howell Creek as a spawning site (Biological Resources Committee, 1987). The spawning and rearing habitat in Howell Creek would be destroyed by increased toxic compounds of nitrogen in the groundwater, reduction of groundwater flow, sedimentation from land clearing, and stream channel changes. Mining activities could be especially damaging because bull trout require streams with a steady flow of groundwater for successful spawning and survival of incubating embryos.

Residential and agricultural development.--Over 73,000 people (1980 census) live in the Flathead Basin. As the population increases, more domestic sewage will enter the drainage. Increased agricultural use of fertilizer in the Flathead Valley could increase nutrient levels in the river. These factors could combine to lower water quality in Flathead Lake, where bull trout grow to maturity. Reduced water quality could favor more tolerant nongame fish and introduced fish species.

Although most land in the upper basin is public, some residential development exists and is ongoing along some tributaries used by spawning bull trout in the North and Middle Fork drainages. Domestic sewage from this development and stream channel changes caused by building in the floodplain (where most private land is located) could reduce habitat quality in some tributaries.

Hydropower development.--Hungry Horse and Bigfork dams have reduced by nearly 50 percent the spawning and rearing habitat available to bull trout in Flathead Lake (Figure 1). Loss of nearly half of the available stream habitat probably reduced the population of bull trout in Flathead Lake by a proportional amount. The construction of Hungry Horse Dam resulted in an estimated loss of 4,000 adult bull trout in Flathead Lake (Fraley et al., 1989). Current operations of Hungry Horse Dam, which affect flow and temperature, may be affecting bull trout rearing and movements in the Flathead River below the South Fork.

This major loss of spawning and rearing habitat is largely irreplaceable. Migratory bull trout must now rely on only half of their former habitat, making them more susceptible to environmental degradation in the remainder of the drainage. Loss of the South Fork and Swan River stocks could have reduced genetic diversity in the Flathead Lake population.

Harvest of bull trout by anglers.--Because of the restricted distribution of bull trout spawning in the Flathead Basin and the limited size of the annual spawning run, harvest of mature fish by anglers in both the lake and river could have a dramatic effect on the population. We estimate that only 3,000 to 5,000 bull trout from Flathead Lake escape harvest and successfully spawn in tributaries each year. Based on harvest and escapement figures in 1981, anglers may have taken up to 40 percent of the adult bull trout that entered the river system. Any increase in fishing pressure and harvest could reduce the spawning population, cause a loss of juvenile production, and reduce the population in Flathead Lake.

The segment of the population most vulnerable to overharvest is the upper river stocks. These fish can be seen in the clear headwater streams and must pass anglers along the river system to reach spawning areas. Mostly because of this vulnerability, MDFWP lowered the creel limit in the lake and river from two to one fish in 1982. A creel survey in 1987 in the North Fork estimated that harvest was only half that estimated in 1981, although spawning populations did not increase consistently after the limit was reduced. The British Columbia Ministry of the Environment reduced the creel limit to one fish in the Canadian portion of the North Fork in 1983.

Bull trout are protected from legal angling once they reach many of the tributaries in which they spawn. MDFWP closed most of the important spawning streams to angling in the early 1960s, and Glacier Park closed important streams within park boundaries in the 1970s. In 1983, the B.C. Ministry of the Environment closed to angling all North Fork tributaries in Canada used by spawning bull trout. Illegal harvest of bull trout in tributaries has long been recognized as a serious management problem. Large bull trout in small tributaries are easily snagged, and lack of enforcement personnel has made it difficult to reduce poaching in remote areas.

Introduction of non-native fish.—Bull trout coexist with 23 other species of fish in Flathead Lake, only ten of which are native. Introduced species, such as lake trout, may compete with bull trout for food and space and may prey on young bull trout entering Flathead Lake. Kokanee, yellow perch and lake whitefish, as food items, may provide an advantage for bull trout. In addition, brook trout occupy some tributary streams and could compete and interbreed with bull trout. It is not possible to estimate the overall effect on bull trout by these introduced fish species. Because of these concerns, MDFWP has adopted a policy of not planting non-native species where they will compete with native fish stocks in northwest Montana. The use of non-native fish in private ponds is similarly controlled. New fish species could be introduced only after completion of an environmental assessment showing no probable adverse effects.

Populations of non-native opossum shrimp (Mysis relicta) in Flathead Lake have increased greatly since they became established (from tributary drift) in 1981 (Beattie et al., 1988, Bukantis and Bukantis, 1987). These organisms eat Daphnia thorata, and they have contributed to the recent decline in zooplankton and kokanee in Flathead Lake. Young bull trout have been shown to eat Mysis in Idaho lakes, so bull trout in Flathead Lake may benefit by using Mysis as a food item. However, Mysis may also benefit the lake trout population which could have a negative effect on bull trout. Finally, Mysis could cause large-scale changes in the trophic structure of Flathead Lake that could affect bull trout.

Management and Mitigation Options

Management options that will prevent harmful effects, or mitigate existing effects on bull trout or their habitat include: 1) Application of Best Management Practices (BMP's) and riparian guidelines during timber harvest; 2) Stream habitat protection efforts; 3) improving fish passage to blocked areas; 4) special management designations such as wild and scenic and wilderness; 5) habitat enhancement in tributaries; and 6) Integrative Management of fish populations.

BMP's and riparian guidelines.—Application of BMP's greatly reduces damage to stream habitat during timber harvest operations (Environmental Quality Council, 1988). BMP guidelines address road planning and location, design, drainages from road surfaces, road construction, and maintenance. BMP's also include guidelines for timber harvesting, streamside management, slash treatment, stream crossings, winter logging, and hazardous substances.

In a recent BMP Audit, the Environmental Quality Council (1988) reports that the most commonly reported violations were inadequate road drainage facilities, inadequate erosion control from skidding, excessive logging disturbance in the streamside management zone, and improper management of logging slash. The Council listed various options, including a forest practices act, to promote the use of BMP's in Montana. Strict BMP application would reduce the delivery of sediments to important bull trout spawning and rearing areas.

The Flathead National Forest has included riparian guidelines for all management activities, including timber harvest, in their forest plan (USDA Forest Service, 1985). These guidelines apply to all classified riparian areas and serve to emphasize protection of fish and wildlife habitat. Specific management standards were also developed to protect important bull trout spawning and rearing habitat in the basin. These standards will be amended to reflect new information from ongoing research and monitoring efforts.

Streambed protection laws.--The county soil and water conservation districts are responsible for administering the Natural Streambed and Land Preservation Act, which is designed to protect stream habitat on private lands. The Montana Department of Fish, Wildlife and Parks cooperates with the conservation districts to inspect proposed projects which could affect a stream channel. MDFWP administers the Stream Protection Act, which is designed to protect stream channels on government land. Approximately 100 projects are reviewed each year. Efforts by MDFWP and the conservation district have been effective in protecting bull trout habitat in the basin.

Improved fish passage.--With modifications and/or redesign, the inoperative fish ladder at Bigfork Dam could allow bull trout access to 1813 km^2 of drainage area in the Swan system (Fraley et al., 1989). Tributaries in the Swan drainage where brook trout have become established could be chemically rehabilitated and planted with bull trout to establish migratory bull trout runs. Screens placed across the diversion channel at the damsite diversion channel would minimize mortality of juveniles and adults moving downstream.

Other opportunities for improving fish passage past natural and man-made barriers exist in the upper drainage. For example, bull trout spawned in Tunnel Creek in the Middle Fork drainage before road construction and a large culvert blocked the system to migratory fish.

Special management designations.--Special designations of river corridors and land areas are an option to protect stream habitat. Currently, over 1.5 million acres of the upper watershed lie in Glacier National Park and the Bob Marshall-Great Bear Wilderness complex. Also, much of the upper North and Middle Fork drainage is included in the wild and scenic rivers system. Many of the major spawning areas for bull trout in the Middle fork drainage already are protected by these designations. Further proposals for wilderness and wild and scenic designations could protect additional bull trout spawning and rearing habitat from degradation.

Habitat enhancement in tributaries.--The Flathead National Forest and MDFWP began an experimental habitat enhancement program on Coal Creek in 1988 (Weaver and Fraley, 1988). Workers felled trees into the stream channel at strategic areas to provide additional cover for juvenile bull trout rearing in several stream sections. Control sections were established to gauge the effect of the habitat treatments. These efforts should increase populations of young bull trout in these sections if rearing habitat is a limiting factor. If successful, these efforts could be expanded to more tributaries in the basin to increase rearing capacity and recruitment of young bull trout to Flathead Lake.

Integrative management of fish populations.--Managers could increase populations of bull trout in the Flathead Lake-River system by reducing non-native species, reducing angler harvest on bull trout and increasing limits on competing species, or by stocking hatchery-reared juvenile bull trout in tributaries or directly into the lake. Brook trout could be removed from some tributaries in the Swan and Middle Fork drainages to reduce competition with rearing bull trout. Removing brook trout from these tributaries also would reduce the chance of hybridization with bull trout.

In Flathead Lake, lake trout are a competitor with bull trout for food and space. Increased angling limits on lake trout could allow an increase in numbers and/or growth of bull trout in the lake. More restrictive limits (shorter season,

partial closure) on bull trout in the river system during the spawning migration would increase escapement to tributaries. Also, additional tributaries used by spawning bull trout in the Middle Fork drainage could be closed to angling for bull trout.

A bull trout stocking program is a promising management option for enhancing the recreational fishery in Flathead Lake. Bull trout use a variety of lake and river habitats, and they are opportunistic feeders (they eat whitefish, perch and Mysis). Bull trout could be cultured in hatcheries and released into Flathead Lake to increase bull trout populations in the Flathead system. Hatchery fish could compensate for part of the loss of bull trout spawning and rearing areas caused by the construction of Hungry Horse and Bigfork dams. Two major methods are available to culture bull trout: taking eggs from wild fish and incubating the eggs in a hatchery, or developing a captive brood stock of mature fish that would remain in the hatchery.

A large hatchery program for bull trout would require careful planning and evaluation of culture methods. Several years would be required to determine the feasibility of raising young fish to two or three years of age for release into tributaries or Flathead Lake to simulate the natural life cycle. Managers have had limited success in increasing populations of bull trout by stocking hatchery juveniles in the Arrow Lakes system (Peter Brown, British Columbia Ministry of the Environment, pers. comm.). Five years would be required to develop and determine the feasibility of captive brood stock. A large bull trout stocking program could alter the genetics and size of wild bull trout in Flathead Lake.

These and other fisheries management options are now being considered in a five-year plan for fisheries co-management for the Flathead system being developed by the Confederated Salish and Kootenai Tribes and Montana Department of Fish, Wildlife and Parks (1988).

CONCLUSIONS

Virtually all human activities in the upper Flathead watershed have affected (or could affect) bull trout or their habitat negatively (Table 1). Many of these activities (timber harvest, road building, residential development, hydropower operation, poaching) to some degree continue to affect the bull trout population and habitat. Hydropower construction blocked nearly half of the original upstream range and all of the downstream range of adult bull trout in Flathead Lake. This major restriction of habitat availability and diversity reduced the population in the lake and probably resulted in increased sensitivity of the population to further environmental disturbance. Cumulative effects can be more than simply additive; loss of habitat in one tributary could reduce the overall spawning stock, making other stocks more vulnerable to overharvest.

The bull trout population has been relatively stable since monitoring began in 1979 (Fraley and Shepard, 1989). However, we have no index of the historical population level. The present population could be near a threshold where continued cumulative negative effects on habitat or adults could lead to a steep decline. A major information need for better management is an analysis of limiting factors for each bull trout life stage.

Table 1. Cumulative effects of human activities on bull trout in the upper Flathead watershed.

Activity	Potential Effects	Life Stage Affected	Direction[1/] of Effect	Mitigation/Management Options
Mining	increased sediment, groundwater contamination channel changes	embryo, juvenile	--	restrict mining activities in critical drainages
Timber harvest road building	increased sediment, channel changes	embryo, juvenile	--	restrict activities in sediment delivery areas, follow BMP and riparian guidelines, enforce streambed protection laws
Residential and agricultural	lower water quality and harm physical habitat	embryo, juvenile, adult	--	strictly enforce water quality and streambed protection laws
Hydropower development and operation	block spawning migrations, change rearing habitat below dams	adult, juvenile	--	improve fish passage, plant hatchery fish for compensation, maintain minimum flows
Sport fishing/ poaching	remove maturing fish from the population	adult	--	reduce catch limits or seasons, close tributaries to angling, increase enforcement
Introduction of non-native fish and invertebrates	genetic hybridization, competition, change in food supply in Flathead Lake	juvenile, adult	-- or +	impose liberal catch limits on non-natives, poisoning of tributary fish populations, restrict new species introductions

1/ -- Negative effect on growth and/or abundance
\+ Positive effective on growth and/or abuncance

The most likely opportunities for increasing the populations are: (1) a successful hatchery program to supply young fish for recruitment into Flathead Lake, and (2) opening blocked areas to increase rearing habitat. Management efforts, such as habitat protection and improvement and regulations probably will not increase the population significantly, but will preserve quality rearing and spawning habitat. The population should be closely monitored through redd counts and estimates of juvenile abundance to detect any signs of decline of spawning or rearing fish in important tributaries. Also, managers should continue to monitor the quality of spawning and rearing habitat by measuring substrate composition and substrate score.

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