FURTHER EVIDENCE THAT LAKE TROUT DISPLACE BULL TROUT IN MOUNTAIN LAKES

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ABSTRACT

I surveyed five large mountain lakes in Glacier National Park, Montana, with gill nets in 2000 to assess the status of bull trout (*Salvelinus confluentus*) populations. I compared results to previous surveys, conducted in 1969 and 1977, at which time numbers of native bull trout were higher than recently established populations of lake trout (*Salvelinus namaycush*). The data indicate a broad decline in bull trout numbers and corresponding increases in lake trout population size in Kintla, Bowman, Logging, and McDonald lakes. In Quartz Lake, where lake trout are not known to occur, bull trout catch was stable across years. These data suggest that lake trout expansion has had a substantial detrimental impact on Glacier National Park bull trout populations especially because variables commonly implicated in bull trout population decline elsewhere across the species' range are not significant factors in Park lakes. I contend that effective recovery actions for adfluvial bull trout populations, in mountain lakes where nonnative lake trout have become established, must be directed at reducing species interaction through directed control actions on lake trout. I suggest that the rate and magnitude of the transition from native bull trout to introduced lake trout may depend on multiple factors, including migration of either species, the extent and quality of bull trout spawning and rearing habitat, and the structure of the lacustrine food chain. Four of the five bull trout populations I studied in Glacier National Park lakes are currently at high risk of extirpation, due primarily to incompatibility with introduced lake trout populations.

Key words: bull trout, introduced, lake trout, mountain lakes, nonnative, population

INTRODUCTION

In 1998 bull trout (*Salvelinus confluentus*) in the Columbia River basin were listed as a threatened species under the U.S. Endangered Species Act (USDI Fish and Wildlife Service 1998). Since that time there has been an increased emphasis on determining their distribution, abundance, and genetic status. Status information is a critical component of the federal bull trout recovery planning process (Lohr et al. 2001).

The Montana Bull Trout Scientific Group (MBTSG) identified evaluation of the status of bull trout in lakes on the west side of Glacier National Park (Park) as a priority research need (MBTSG 1995). This study lies within the Flathead River watershed, part of the headwaters of the Columbia River basin in northwestern Montana (Fig. 1). Bull trout occur in 16 lakes across 10 drainages within the Flathead River watershed in the Park (MBTSG 1995). The Montana Bull Trout Scientific Group (MBTSG 1995) considers these populations to be disjunct, suggesting they are located in headwaters lakes that are reproductively isolated from the downstream population in Flathead Lake.

Lakes in the Flathead River drainage within the Park support a low diversity of native fish species, probably because of incomplete postglacial recolonization from downstream. Flathead Lake, itself the largest natural freshwater lake in the western United States and a source for postglacial dispersal, contained only 10 native fish species (Spencer et al. 1991). A typical native species assemblage in Park lakes west of the Continental Divide consists of bull trout, westslope cutthroat trout (*Oncorhynchus clarki lewisi*), mountain whitefish (*Prosopium williamsoni*), longnose sucker (*Catostomus*

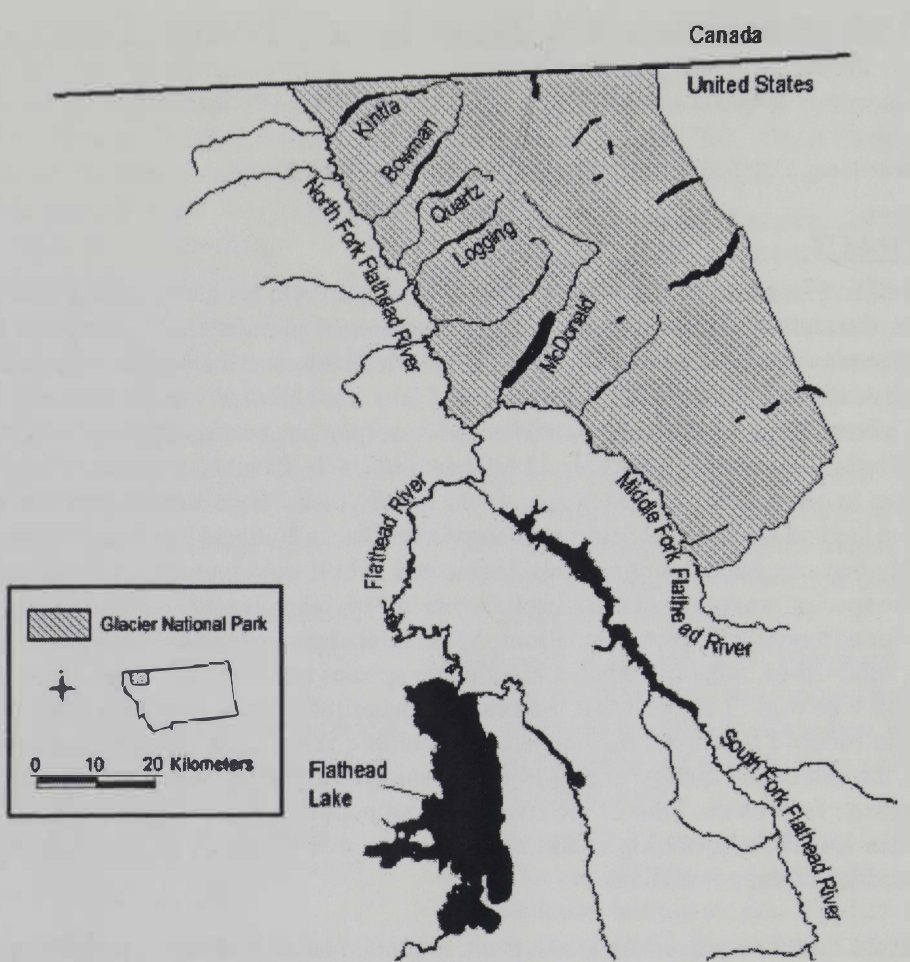

Figure 1. Map of study area, showing lakes in Glacier National Park which were surveyed in 2000.

catostomus), largescale sucker (*Catostomus macrocheilus*), and slimy sculpin (*Cottus cognatus*). Native cyprinid species including northern pikeminnow (*Ptychocheilus oregonensis*), peamouth (*Mylocheilus caurinus*), and redside shiner (*Richardsonius balteatus*) as well as pygmy whitefish (*Prosopium coulteri*) exhibit spotty distribution in these large glaciated lakes. In several of the lakes nonnative kokanee (*Oncorhynchus nerka*), brook trout (*Salvelinus fontinalis*), or rainbow trout (*Oncorhynchus mykiss*) occur, though none of these are abundant. In this ecosystem bull trout is the only native fish species that is highly piscivorous.

Lake trout are native only to the Saint Mary River drainage on the east side of the Park in the headwaters to the Hudson Bay drainage. There is no historical documentation of the intentional introduction of lake trout into any Park lakes in the Flathead River drainage (Morton 1968a, 1968b). The initial introduction of lake trout outside the Park in the Flathead drainage is believed to have been carried out by the U.S. Fish Commission in 1905 (Spencer et al. 1991), leading to establishment of this species in Flathead Lake.

Telemetry studies have illustrated the mobility of lake trout, e.g., fish tagged in the Flathead River system ranged through most accessible waters, including possible movement upstream into Lake McDonald in the Park (Muhlfeld et al. 2000). The authors surmised that lake trout movements could be related to water temperature, stream flow, and food availability. Seasonally cold water temperatures, e.g. in early summer, in streams emanating from headwater lakes may provide attractive thermal refuge for migrating lake trout in the Flathead River, offering one possible explanation for lake trout invasion of Park lakes.

Unrecorded stocking or illegal transplants cannot be ruled out as original sources of lake trout that colonized Park waters, but there is no anecdotal or documented verification of either case. Obtaining and transporting small lake trout for live transplant, particularly several decades ago, would have been exceedingly difficult. Natural migration of fish from Flathead Lake is a more likely source of these populations.

Regardless of the mechanism of introduction, over the past 50 years lake trout have become established in most of the larger Park lakes in the North Fork Flathead and Middle Fork Flathead River drainages. With their naturalization has come potential impacts to native species. Donald and Alger (1993) studied the interaction between lake trout and bull trout in mountain lakes of the Rocky Mountain region of southern Alberta and British Columbia into northwest Montana. They documented substantial niche overlap in which lake trout dominate. They concluded that lacustrine populations of bull trout usually cannot be maintained if lake trout are introduced. Donald and Stelfox (1997) recommended that stocking of other *Salvelinus* species not occur in waters where the objective was to maintain adfluvial populations of bull trout.

Where established lake trout populations exist in Park waters west of the divide, an abundance of anecdotal evidence (Glacier National Park, West Glacier, unpublished data and file reports) suggests that the number of bull trout present has declined over the past 25 years. Because of recent concern for bull trout, the primary objective of my study was to document temporal changes in bull trout abundance in Park lakes west of the divide. A second objective was to examine whether bull trout abundance was correlated with lake trout abundance. Empirical evidence was used to test the hypothesis of Donald and Alger (1993) that lake trout, when introduced in waters with native bull trout, soon become the prevailing species.

Study Area

The five lakes surveyed in this study (Kintla, Bowman, Quartz, Logging, and McDonald) are located on the west side of the Park, in the North Fork Flathead and Middle Fork Flathead river drainages (Fig. 1). These are the largest (360-2763 ha) and deepest (60-142 m maximum depth) lakes on the west side of the Park (Table 1). They are classified as oligotrophic mountain lakes, occupying narrow glaciated mountain valleys at 961-1396 m elevation. Each lake is approximately 6-15 km long and 1- 3 km wide. Headwaters originate in snow fields of the Livingston Range at elevations extending to approximately 3000 m. The shoreline and substrate of all five lakes consists primarily of glacial rubble, dominated by cobble and large boulders, with an abundance of large woody debris along the shoreline. Each of the lakes has an alluvial fan at the upstream end where the primary inlet stream enters the lake. The littoral zone is generally steep with deltas formed where tributaries enter or landslides contact the lake.

Inlet streams to each lake are sufficiently large to provide potential spawning and rearing habitat for bull trout, though natural barriers block portions of each watershed. Morton (1968a) summarized the findings of a number of earlier investigators and noted that Park lakes provided differing potential for spawning and recruitment of bull trout and westslope cutthroat trout. Although not well documented, the highest quality spawning and rearing habitat for bull trout is believed to occur in Bowman, Quartz and Logging creeks, with more limited potential in McDonald and Kintla creeks. Due to the steep and glaciated valleys there are very few permanent lateral tributaries to the lakes and they seldom provide substantial spawning or rearing habitat for bull trout.

Lake trout were first verified in Lake

Table 1. Surface area, elevation, maximum depth, and known nonnative salmonid species composition of lakes surveyed in Glacier National Park, 2000.

Lake Name	Surface Area (ha)	Elevation (m)	Maximum Depth (m)	Nonnative Salmonids Present	Year Lake Trout Verified as Present
Kintla	688	1222	119	Lake Trout Kokanee	1962
Bowman	691	1229	77	Lake Trout Kokanee	1962
Quartz	360	1346	83	None	Not Present
Logging	444	1162	60	Lake Trout Kokanee	1984
McDonald	2763	961	142	Lake Trout Brook Trout Rainbow Trout Kokanee Lake Whitefish	1959

McDonald (1959), followed by Bowman and Kintla lakes (1962), and Logging Lake (1984) (Glacier National Park, unpublished data). Lake trout have not been found in Quartz Lake.

Recent and historical fish distribution data indicates that the outlet streams of large lakes in the Flathead drainage are seldom occupied by juvenile or adult bull trout (MBTSG 1995). Because these lakes are large and deep and they stratify, lake surface temperature greatly influences water temperatures in their outlet streams. While the streams are cold in spring and early summer, they are relatively warm later in the summer and fall with daily maxima often exceeding 15 °C. At that time, temperatures are warmer than the range preferred by bull trout for spawning and rearing (USDI Fish and Wildlife Service 1998) and bull trout spawning and rearing has not been reported in lower Kintla, Bowman, Logging, Quartz, or McDonald creeks below the lakes.

Methods

In June and July 1969, Park staff conducted a systematic gill net survey in the five study lakes to assess the survival of stocked hatchery cutthroat trout. A total of 53 nets were set overnight in the five lakes (6-15/lake). I was unable to determine depth and location of net sets or other individual net catch information since the original data sheets could not be located. A summary report described the aggregate catch of fish by species and weight in each lake (Glacier National Park, unpublished data). Specific net design was not detailed in the summary report, but the wide distribution of species and size ranges of fish captured indicate that panels of variable mesh sizes, i.e., experimental, were used.

In 1977 the U.S. Fish and Wildlife Service conducted a series of baseline limnological and fishery surveys in Park waters. Four of the five study lakes, with the exception of Quartz Lake, were surveyed. Between 8 and 18 overnight sets of 76-m (250-foot) or 91-m (300-foot) sinking gill nets were made in each lake (62 nets total), between mid-August and mid-September. Standard 76-m nets constructed with five experimental mesh sizes (19, 25, 32, 38, and 51 mm; or 3/4 to 2 inch bar measure) were used. Each mesh panel was

15 m (50 feet) long and 2 m (6 feet) deep with the panel of smallest mesh on one end, progressing to the panel of largest mesh on the opposite end of the net.

Twenty-four of 62 total net sets made in 1977 used 91-m nets that included an extra 15-m panel of 102-mm (4-inch) bar mesh. Comments in the summary report did not indicate any variation in catch efficiency in nets with the extra panel of large mesh. The author's past experience in gill netting Flathead Lake and other waters with a similar mixed species assemblage indicated that large (102-mm) mesh is usually inefficient in capturing all but the largest fish. Catch/net in the 91-m nets (~16 fish/net) was actually lower than in the standard 76-m nets (~23 fish/net), and no adjustment was made in the data to reflect the variation in net length.

In 1977 nets in each lake were set perpendicular to shore at representative sites in the upper, midsection, and lower end of each lake to incorporate a diversity of depth and habitat types. Net set duration was similar for all sets, and summaries of catch information were reported (USDI Fish and Wildlife Service 1978). Individual net catches and depths of sets were not reported, and original data sheets could not be located. Baseline surveys using the protocol developed in 1977 were not repeated in subsequent years, until 2000.

In 2000 I made an effort to duplicate the basic procedures of the 1977 survey, using sinking gill nets set overnight in the same general areas of each lake at the same time of year (14 Aug-19 Sep). The nets used were constructed of multifilament nylon and were 38 m long by 2 m deep with five panels of 19-, 25-, 32-, 38-, and 51-mm bar mesh. This has become the standard net used for bull trout surveys in other waters of the Flathead River basin (Deleray et al. 1999).

To mimic the 1977 protocol of 76-m nets, the 38-m nets deployed in 2000 in Kintla, Bowman and McDonald lakes were set in pairs, tied end to end, with the small mesh nearest shore. Total surface area of each mesh size in a pair of 38-m nets is identical to a single 76-m net, but the panels are half as long. For comparison purposes, catch in paired 38-m nets was treated as if they were from a single 76-m net. In 2000 I also surveyed Quartz Lake, which was previously surveyed in 1969 but not in 1977. I set nets in Quartz and Logging lakes singly rather than in pairs to reduce the possibility of having them snag on the abundant downed logs where they would be difficult to retrieve from a canoe.

Intensity of net sampling in 2000 was approximately half of 1977 levels (one night set at each site instead of two) to minimize mortality of bull trout. I estimated depths of each set by measuring the vertical length of line attached to floats on either end. The shallow end (small mesh size) was typically set at 3-9 m and the deep end at 9-30 m, depending on basin morphology at each site. All nets were set overnight (average 16.5 hours). Set time increased in more remote lakes due to logistic concerns, and later in the fall as day length decreased. I did not standardize net catch by hours set since that information was not available in 1969 and 1977. Set time was not considered to be an important factor since species composition and not catch per unit effort was the primary variable I evaluated.

Because the raw data for individual net catches from 1969 and 1977 were not available, only the total or average net catch for each year could be used as count data. Upon examination of preliminary results, I concluded that the number of samples (average counts) were too low to conduct meaningful statistical tests.

I identified and measured all captured fish for total length (nearest mm). I standardized 2000 net surveys to catch/76-m equivalents in order to compare with 1969 and 1977 efforts.

Results

I captured 1437 fish in the five study lakes during 2000 (Table 2) with the dominant species being mountain whitefish, longnose suckers, and lake trout. Lake trout were captured in four of the five waters surveyed, absent only in Quartz Lake. Bull

Table 2. Number of each species captured in gill nets set in Glacier National Park lakes, 2000. Number of nets has been standardized to 76-m equivalents.

Lake (No. Nets)	Bull Trout	Lake Trout	Cutthroat Trout	Mountain White-fish	Pygmy White-fish	Lake White-fish	Long-nose Sucker	Large-scale Sucker	Pea-mouth	Northern Pike-	Redside Shiner minnow
Kintla (10)	2	45	2	187			79	25	66		
Bowman (10)	10	57		320			51	4			
Quartz (3)	20		6	85			32	2			
Logging (4)	7	12	13	112			21	2		37	1
McDonald (10)	7	24		37	4	48	25	4	26	60	4

trout were captured in all five lakes, making up 0.5-3.4 percent of the catch in the four lakes where lake trout were present, but 13.8 percent of the catch in Quartz Lake. In each of the four lakes with both bull trout and lake trout present, lake trout catch exceeded that of bull trout. Lake trout comprised 5.9-12.9 percent of the total fish catch in those four lakes.

Mountain whitefish were the most ubiquitous of all species captured in 2000. They were found in all lakes and numerically dominated the catch in most waters (Table 2). Lake whitefish (*Coregonus clupeaformis*), an introduced species, were captured only in Lake McDonald. Lake whitefish were reportedly established in Lake McDonald prior to 1941 (Morton 1968b).

The 1969 survey of Kintla Lake captured 54 bull trout, comprising 94% of the balance between the two *Salvelinus* species, and 3 lake trout (6%) in 9 nets (Fig. 2). In 1977 total catch was 12 bull trout (40%) and 18 lake trout (60%) in 18 nets. In 2000 I caught 45 lake trout (96%) and only 2 bull trout (4%) in 10 net sets.

Lake trout were first reported in the voluntary creel survey from Bowman Lake in 1962 and then were documented annually in low numbers in the angler catch for several more years in the 1960s (Morton 1968a). There were no lake trout captured in either the 1969 or 1977 net surveys (Fig. 2), apparently because numbers were below detectable levels. In 1969 a total of 97 bull trout were captured in 11 nets, and in 1977 a total of 41 bull trout were captured in 18 nets in Bowman Lake. However, by 2000 lake trout had become the dominant char species in Bowman Lake. In 2000 I caught 57 lake trout (85%) and 10 bull trout (15%) in 10 sets.

In Logging Lake bull trout were captured in net surveys in 1969 (61 in 12 nets) and 1977 (6 in 10 nets), but lake trout were not detected (Fig. 2). National Park Service staff first verified the presence of lake trout in Logging Lake in 1984. My 2000 survey indicated that lake trout are now the dominant char species in this lake. I captured 12 lake trout (63%) and 7 bull trout (37%) in 4 nets.

Lake McDonald was the first lake in the Park where nonnative lake trout were verified (1959) and lake trout were frequently noted in the angler catch in the 1960s (Glacier National Park, unpublished data). Lake McDonald is geographically the closest lake to Flathead Lake within the Park (Fig. 1) and is about 100 km upstream from Flathead lake. A Park file memo, dated 1964 (Glacier National Park, unpublished), noted unusual catches of three to sixteen pound lake trout in the lower end and outlet of Lake McDonald during the last 10 days

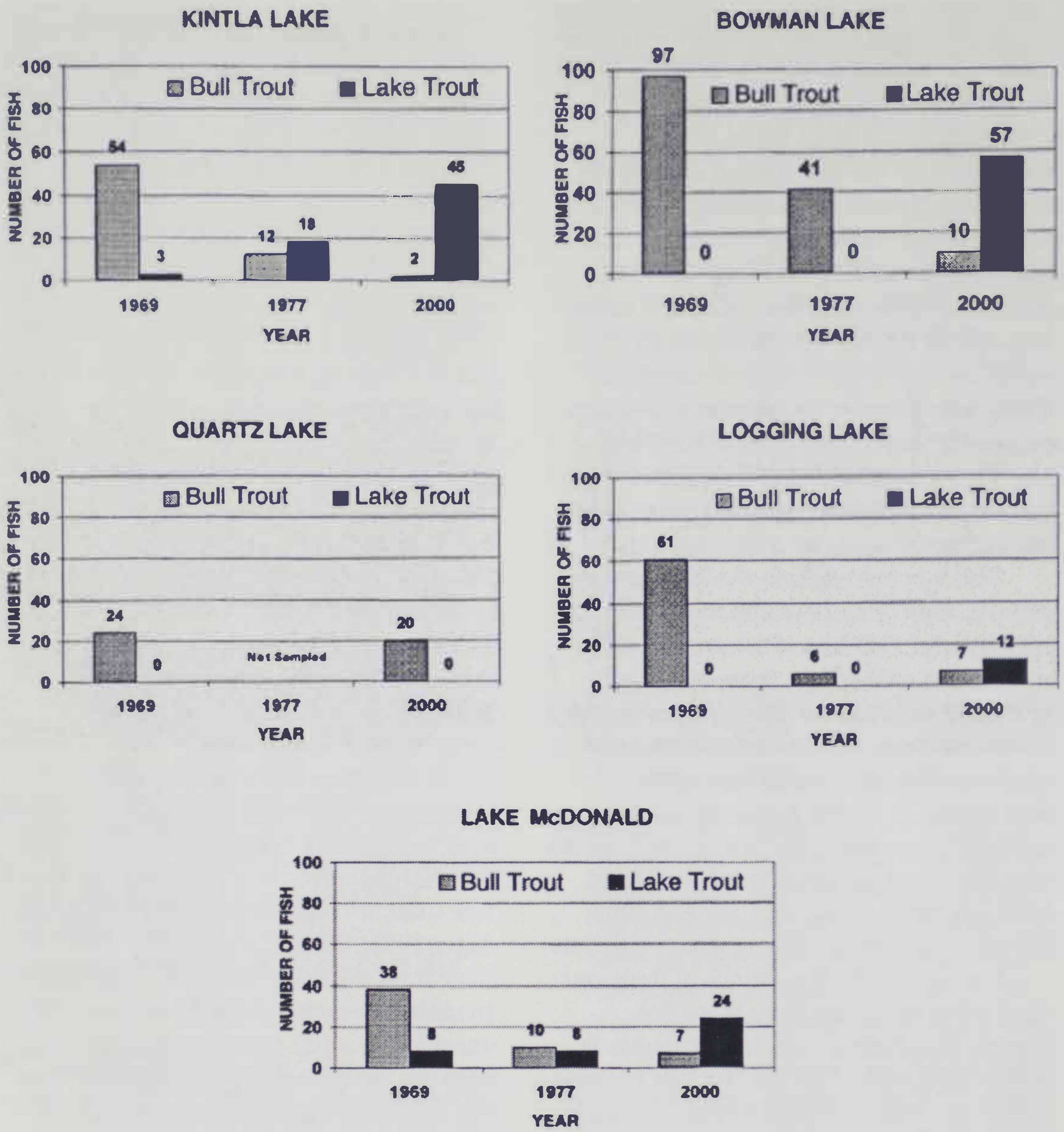

Figure 2. Comparative catch of bull trout and lake trout from gill net surveys conducted in five Glacier National Park lakes in 1969, 1977, and 2000.

of June, 1964, following a 100-year flood. The 1969 gill net survey captured 38 bull trout (83%) and 8 lake trout (17%) in 15 nets (Fig. 2). In 1977 net surveys captured 10 bull trout (56%) and 8 lake trout (44%) in 19 nets. In 2000 surveys I captured 7 bull trout (23%) and 24 lake trout (77%) in 10 nets.

In 1969, six gill net sets captured 24 bull trout in Quartz Lake. Quartz Lake was not surveyed in 1977. In the 2000 survey, I captured 20 bull trout in only three sets.

Dicussion

Bull trout populations have declined in many lakes throughout the upper Columbia River basin (USDI Fish and Wildlife Service 1998). Habitat and water quality degradation and fragmentation, past fisheries management practices and overfishing, and competition from introduced nonnative fish species are listed as three primary causes of widespread bull trout population declines (MBTSG 1995, Donald and Stelfox 1997, USDI Fish and Wildlife Service 1998).

As evidence of the effects of nonnative species, Donald and Alger (1993) evaluated the relative status of bull trout and lake trout populations in 34 lakes, where distribution of the two species overlaps in the Rocky Mountains, including portions of northwest Montana. They concluded that lake trout are usually dominant over bull trout when both species are present (either naturally or by introduction) in lakes at an elevation <1500 m. In circumstances in which lake trout are introduced into waters containing native bull trout, Donald and Alger (1993) reported that lacustrine populations of bull trout usually cannot be maintained.

Data I collected from the 2000 survey of Park lakes (Fig. 2) corroborates Donald and Alger's (1993) conclusions. Overall, comparison of the three data sets (1969, 1977, and 2000) in the five lakes indicated a broad decline in bull trout numbers and a corresponding increase in lake trout populations in Kintla, Bowman, Logging, and McDonald lakes. In Quartz Lake, where lake trout have not been found, bull trout catch appeared similar in 1969 and 2000, inferring relative stability in this population.

I recognize the limitations of drawing steadfast conclusions from these few discrete sampling points. Interpretation is further complicated by the fact that I was unable to locate raw data for the 1969 and 1977 samples, and thus could not perform statistical analysis. There also are some acknowledged inconsistencies in timing and sampling methodology. However, magnitude and direction of these changes is compelling. It strongly infers that nearly complete shifts in *Salvelinus* species composition have taken place. Furthermore, these changes have occurred independently in four separate lakes where water and habitat quality are generally not impaired and overfishing is not an issue. I conclude that bull trout abundance in four of the five Park lakes I studied has declined, probably due to interaction with nonnative lake trout, and a corresponding increase in lake trout has occurred.

Another intensively-studied bull trout population is located downstream from the Park, in Flathead Lake (Fraley and Shepard 1989). Donald and Alger (1993) noted that Flathead Lake was one of only two exceptions to their general hypothesis that lacustrine bull trout populations usually decline or are extirpated if lake trout are introduced. More recent data (MBTSG 1995, Deleray et al. 1999) indicate that, in fact, the balance of species in Flathead Lake has shifted dramatically over the past two decades. In 1981 and 1983, spring gill net series in Flathead Lake, using standard sinking nets, as in this study, caught 1.6-2.6 bull trout and 0.0-0.1 lake trout/net. During 1992-1998 annual spring gill net monitoring series captured 0.0-0.5 bull trout and 1.2-3.1 lake trout/net (Deleray et al. 1999), indicating that lake trout now heavily dominate the sympatric char species complex in Flathead Lake.

In mountain lakes of the Rocky Mountains conversion of unique native bull trout ecosystems to lake trout-dominated systems appears to be a common result once lake trout are established (see Donald and Alger 1993, Donald and Stelfox 1997). It is clear from my study that even when habitat conditions remain relatively unaltered the transition to a fish community where lake trout are the dominant piscivore may take place rapidly (Fig. 2). On an ecological scale, 20 or 30 years is a very rapid transition, given that the native fish complexes presumably have been intact for thousands of years.

Whether the introduction of lake trout will ultimately result in the complete extirpation of bull trout from the lakes I studied remains unclear. This will likely depend on several factors. Primary modifiers in the rate and extent of replacement of bull trout by lake trout will likely include migration potential of both species, extent and quality of the upstream (and in some cases downstream) spawning and rearing habitat, and structure and complexity of the food web. Ultimately, the risk of complete extirpation of bull trout may vary from system to system.

Precautions should be taken to prevent further invasions or introductions of lake trout into bull trout waters. I contend that effective recovery actions for adfluvial bull trout populations in mountain lakes, where nonnative lake trout have become established, must be directed at reducing species interaction through targeted control actions on lake trout. In former bull trout strongholds, where lake trout have become well-established, research that explores potential methods of controlling or eliminating lake trout should be a high priority. I conclude that four of the five populations of bull trout in Glacier National Park lakes that I studied are currently at high risk of extirpation, primarily due to invasion and establishment of lake trout.

ACKNOWLEDGEMENTS

Creston Fish and Wildlife Center and Glacier National Park staff were instrumental in the completion of this study. The author wishes to also extend appreciation to David Donald, Chip Corsi, Bruce Rieman, Jim Fredericks, Paul Wilson, and three anonymous reviewers who provided insightful discussion and thoughtful comment on the drafts of this paper.

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Received 15 September 2001
Accepted 1 October 2002