BULL TROUT (*Salvelinus confluentus*)
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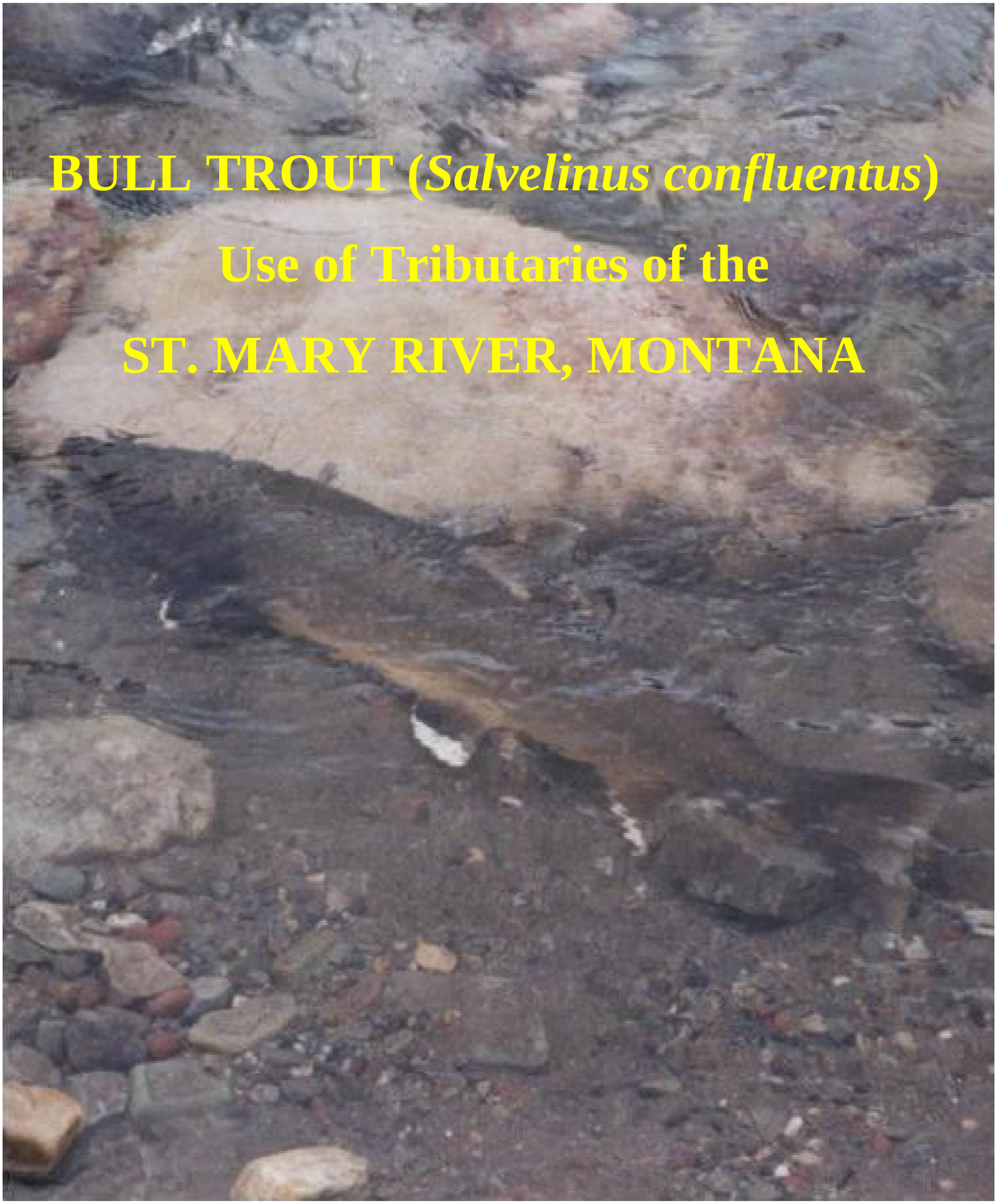
ST. MARY RIVER, MONTANA



U.S. Fish and Wildlife Service
Bozeman, Montana

May 2004

BULL TROUT (*Salvelinus confluentus*)
Use of Tributaries of the
ST. MARY RIVER, MONTANA

A Report

Based on Field Investigations Conducted During 1997-2003

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EXECUTIVE SUMMARY

The bull trout (*Salvelinus confluentus*) inhabits mainly freshwater environments in western North America, primarily west of the Continental Divide. The historic decline of bull trout led to its classification as a "threatened" species, under the U.S. Endangered Species Act, in 1999. As part of that designation, bull trout were said to collectively exist as five "distinct population segments," only one of which occurred east of the Continental Divide, in the St. Mary River and Belly River drainages in Montana and Alberta. The study described here, conducted between 1997 and 2003, determined key characteristics of bull trout populations in St. Mary River tributaries in Montana, including locations of spawning areas, sizes of spawning stocks, and the extent that bull trout move among tributaries; identified factors that may unduly limit the populations; and recommended management actions to eliminate or ameliorate the effects of those factors.

Electrofishing showed bull trout were widely distributed and often abundant in St. Mary River tributaries. Moreover, the species remained in all of the waters that it historically inhabited in the drainage in Montana. The occurrence of age-0 bull trout indicated recent spawning and reproduction in each creek in which the species was found, except lower Otatso and Divide creeks, and annual reproduction was indicated by multiple age-classes of young fish. In contrast, the occurrence of redds revealed bull trout spawning areas in only two creeks, Boulder and Kennedy. Bull trout caught from St. Mary River tributaries had growth rates similar to those of bull trout elsewhere, including marked growth of age-4 fish that probably resulted from their ontogenetic transition to a largely piscivorous diet. Capture of post-spawning bull trout in traps operated at the mouths of four creeks suggested most migratory fish had spawned by late September. Scarcity of age-4 bull trout in trap samples suggested most migratory, age-4 fish were immature and that migratory bull trout in the St. Mary River drainage reached first maturity mainly as age-5 fish, when most were $\geq$ 300 TL. Population estimates suggested that spawning stocks of migratory bull trout were significantly larger than indicated by the annual catches of those fish in traps alone. The annual catch of adult bull trout in a trap was not an index of spawning stock size. Recaptures of tagged fish revealed bull trout movements among most creeks, as well as movements both upstream and downstream over the St. Mary Diversion dam and downstream over the rockslide that forms the Slide Lakes. Although both migratory and non-migratory bull trout remained in the St. Mary River drainage, migratory fish were most obvious because they were caught in traps or moved between creeks. Resident bull trout probably also occurred in several creeks but, in most instances, it was not possible to definitively identifying those fish.

Results of our study and concurrent investigations supported some previous U.S. Fish and Wildlife Service conclusions that bull trout in the St. Mary River drainage are negatively affected by operation of water-storage and delivery systems that are part of the Milk River Irrigation Project. A concurrent study, described in a separate report, showed that bull trout are entrained in the St. Mary Canal and thereby lost from the reproducing population. In addition, our results from radio telemetry, which will be described in a subsequent report, suggested the acute reductions in discharge from Sherburne Dam in the fall produced low-flow

conditions downstream in Swiftcurrent Creek that led to the death of bull trout. On the other hand, results from the present study showed movements of bull trout past the St. Mary Diversion dam, which had previously been thought to be a major barrier to such movements. Timing of those movements is not precisely known but probably occurred when the dam was open, usually between October and April. Brook trout constituted a small portion of the fish communities in St. Mary River tributaries. We found no evidence that brook trout had displaced or were displacing bull trout or that hybridization with brook trout was an emerging threat to the bull trout genome.

Recommended actions that would benefit bull trout in the St. Mary River drainage include: (1) facilitation of year-round movement of adult bull trout over the St. Mary Diversion dam; (2) release of water from Sherburne Dam to provide adequate winter habitat for bull trout downstream in Swiftcurrent Creek; (3) prevention of bull trout entrainment in the St. Mary Canal; and (4) assessment and remediation, if necessary, of the effects of water diversion into the St. Mary Canal (i.e. the removal of water from the drainage) on bull trout habitat in the St. Mary River downstream from the diversion.

INTRODUCTION

The bull trout (*Salvelinus confluentus*) is a char (i.e. Genus *Salvelinus*) that inhabits mainly freshwater environments in western North America. Bull trout historic range (Cavender 1978, Haas and McPhail 1991, Nelson and Paetz 1992) extends from northern areas of California and Nevada to upstream regions of the Yukon River in Alaska and the Yukon, and encompasses Puget Sound and major coastal river systems in Washington, British Columbia, and southeast Alaska. Inland, bull trout inhabit rivers and lakes of the Columbia River basin, including headwater areas in Idaho, Montana, and British Columbia, as well as the Klamath River basin in Oregon. Bull trout also occur east of the Continental Divide, in the upper MacKenzie River basin (Arctic drainage) in the Northwest Territories, British Columbia, and Alberta, the upper Peace, Athabasca, North Saskatchewan, and South Saskatchewan River basins (Hudson Bay drainage) in Alberta, and the upper South Saskatchewan River basin in Montana. Bull trout apparently colonized the waters east of the Continental Divide from refugia in the MacKenzie and Columbia River basins and elsewhere, soon after the Pleistocene glaciation (~12,000 years ago; Haas and McPhail 2001).

Bull trout usually mature when 5 to 7 years old and spawn entirely in coldwater streams, primarily small (second- to fourth-order) tributaries, between late summer and late fall (Fraley and Shepard 1989; for reviews, see Goetz 1989, Rieman and McIntyre 1993). Like most inland salmonids, bull trout have been broadly categorized into two life-history forms on the basis of their migratory behaviors (Rieman and McIntyre 1993, McCart 1997, Northcote 1997). Non-migratory bull trout move little and spend their lives entirely within their natal stream, whereas migratory fish spawn in small streams but their resultant young eventually move downstream to either rivers or lakes, where the fish mature. After spawning, migratory adult bull trout return to the rivers or lakes. Although bull trout have been collected from estuaries and sometimes moved between coastal rivers (Cavender 1978, Haas and McPhail 1991), anadromy – characterized in part by residence of the fish in the sea for a substantial period (McDowall 1987) – has not been conclusively shown for the species.

Both non-migratory and migratory bull trout may occur in a single drainage (Fitch 1997, Jakober et al. 1998) and it is unknown whether those life-history forms represent heritable (i.e. genetically based) traits, conditional behaviors whose individual expressions are dependent upon the variety of accessible aquatic habitats (i.e. phenotypic plasticity), or a combination of those factors (Rieman and McIntyre 1993, McCart 1997, Nelson et al. 2002; see also Northcote 1992, Jonsson and Jonsson 1993). Within the non-migratory form, McCart (1997) distinguished the "resident" type from the "isolated" type, which occurs upstream from a natural or man-made physical barrier (e.g., waterfall or dam) that prevents the return of fish that move downstream. The resident type is not confined by such barriers.

Like the young of other salmonids, young bull trout in both streams and lakes are opportunistic feeders that mainly eat macro-invertebrate organisms. Adult bull trout, however, feed predominantly on other fishes (Boag 1987, Fraley and Shepard 1989, Donald and Alger 1993). Because lakes and large rivers are often more biologically productive than headwater streams, migratory bull trout usually attain larger size and, accordingly, exhibit more frequent piscivory than resident bull trout (Fraley and Shepard 1989, Donald and Alger 1993).

Today, bull trout have been extirpated from areas near the southern limit of their historic range in California and all but one river system in Nevada, and have declined in many other areas in the contiguous United States (*Office of the U.S. Federal Register* [i.e. *Federal Register*] 64: 58910 [1 November 1999]). That decline is broadly attributed to adverse, human-caused modifications of the aquatic environment, including population fragmentation resulting from blockage of migration routes by dams and other barriers; hybridization or competition with introduced, nonnative brook trout (*S. fontinalis*), lake trout (*S. namaycush*), and brown trout (*Salmo trutta*); and excessive harvest by anglers. The bull trout decline led the U.S. Fish and Wildlife Service (Service) to formally classify (i.e. "list") the species as "threatened" throughout its historic range in the contiguous United States, under the U.S. Endangered Species Act, in 1999 (*Federal Register* 64: 58910).

In reaching its decision to list bull trout, the Service concluded that the species now occurs as five "distinct population segments" (DPSs) in the contiguous United States (*Federal Register* 64: 58910). Only one of those DPSs lies east of the Continental Divide, in the St. Mary River and Belly River drainages of the upper South Saskatchewan River basin in Montana and Alberta. The Service also concluded that the St. Mary River-Belly River DPS consisted of four bull trout subpopulations, each of which inhabited a separate geographic region. Subpopulation designation was based on the assumption that bull trout were reproductively isolated among subpopulations. Furthermore, a subpopulation was considered at risk of extirpation from natural events if it was: (1) unlikely to be reestablished by fish from another subpopulation; (2) limited to using a single spawning area; (3) characterized by low numbers of fish or spawning adults; or (4) primarily consisted of fish of a single life-history form. The Service also acknowledged, however, that historic information on bull trout in the St. Mary River-Belly River DPS was largely anecdotal and definitive, contemporary information was meager.

Objectives of the study described here were to: (1) determine key characteristics of bull trout populations in St. Mary River tributaries in Montana, including locations of spawning areas, sizes of spawning stocks, and the extent that bull trout move among tributaries; (2) identify factors that may unduly limit the populations; and (3) recommend management actions to eliminate or ameliorate the effects of those factors. Those objectives were closely tied to the previously described factors that were thought to make a bull trout subpopulation at risk of extirpation from natural events (*Federal Register* 64: 58910). Also as part of the present study, the status of westslope cutthroat trout (*Oncorhynchus clarki lewisi*) in the drainage was determined. That subspecies declined appreciably across its natural range during the twentieth century (Behnke 1992). The small part of the Belly River drainage that lies in the United States is entirely within Glacier National Park and was not investigated as part of this study.

The present report provides a comprehensive description of the results of investigations, except for our radiotelemetry study, performed on the major tributaries of the St. Mary River in Montana between 1997 and 2003. Radiotelemetry results will appear in a subsequent report. The present report is intended to be a foundational document that provides, among other things, key background information on the study area and methods. As such, our subsequent reports will not include similarly detailed descriptions of those aspects of our ongoing investigations but will instead refer the reader to the present document.

STUDY AREA

Aquatic Habitats

The St. Mary River begins at Gunsight Lake, in Glacier National Park, and flows northeast 13 km before entering St. Mary Lake, just after the river had passed over a 10-m-high fall (Figure 1). After leaving that 16-km-long lake, the river flows northeast 2 km before entering Lower St. Mary Lake (9 km long), on the Blackfeet Reservation. From that lake, the river meanders northerly 25 km to the international border, then continues north through mainly shrub-grassland habitat ~55 km to St. Mary Reservoir, a large (storage capacity, ~395 M m^3), man-made impoundment whose 62-m-high dam was closed in 1951.

Each major tributary of the St. Mary River or its intervening lakes begins at high elevation (> 1,800 m) in the park, flows mainly through coniferous forest, and has one or more natural, year-round or seasonal barriers to fish movement somewhere along its length (Figure 1). Rose Creek, a second-order stream, begins at Otokomi Lake and flows southeast 8 km to the north shore of St. Mary Lake. A 2-m-high, concrete dam (formerly used to impound water for a nearby campground) 1 km upstream from the creek's mouth blocks the upstream movement of fish.

Red Eagle Creek (third order) originates from glacier melt near the Continental Divide and flows northeast 16 km, over a series of falls, to Red Eagle Lake. From the lake, the creek continues northeast 8 km to the south shore of St. Mary Lake.

Wild Creek (second order) begins as snowmelt and flows east 7 km, cascading over boulders and abundant woody debris before entering the river between the St. Mary lakes. A complex of debris jams, small falls, and cascades 3 km upstream from the St. Mary River may block the upstream movement of fish.

Divide Creek (second order) originates from a cluster of small alpine lakes and flows northeast 16 km before entering the river between the St. Mary lakes. The creek contains abundant woody debris and substrates dominated by cobble and boulders. About 11 km upstream from its mouth, Divide Creek becomes entirely subsurface in a reach 0.2 to 0.5 km long, depending on flow volume, as it passes through gravel-cobble alluvium during the seasonal low-flow (i.e. non-runoff) period. Downstream from that location, the creek emerges as groundwater upwellings along a 1.5-km reach. The lowermost 2 km of the Divide Creek channel is routinely altered by management authorities who seek to protect adjacent, developed facilities from potential seasonal flooding.

Swiftcurrent Creek (fourth order) originates from a complex of creeks and small lakes near the Continental Divide and flows east 30 km before entering Lower St. Mary Lake near its outlet. In 1919, Swiftcurrent Creek was impounded by closure of a 33-m-high dam, 10 km upstream from the creek's mouth, thereby forming Lake Sherburne (Figure 1). That 10-km-long reservoir has a storage capacity of ~84 M m^3. Present-day

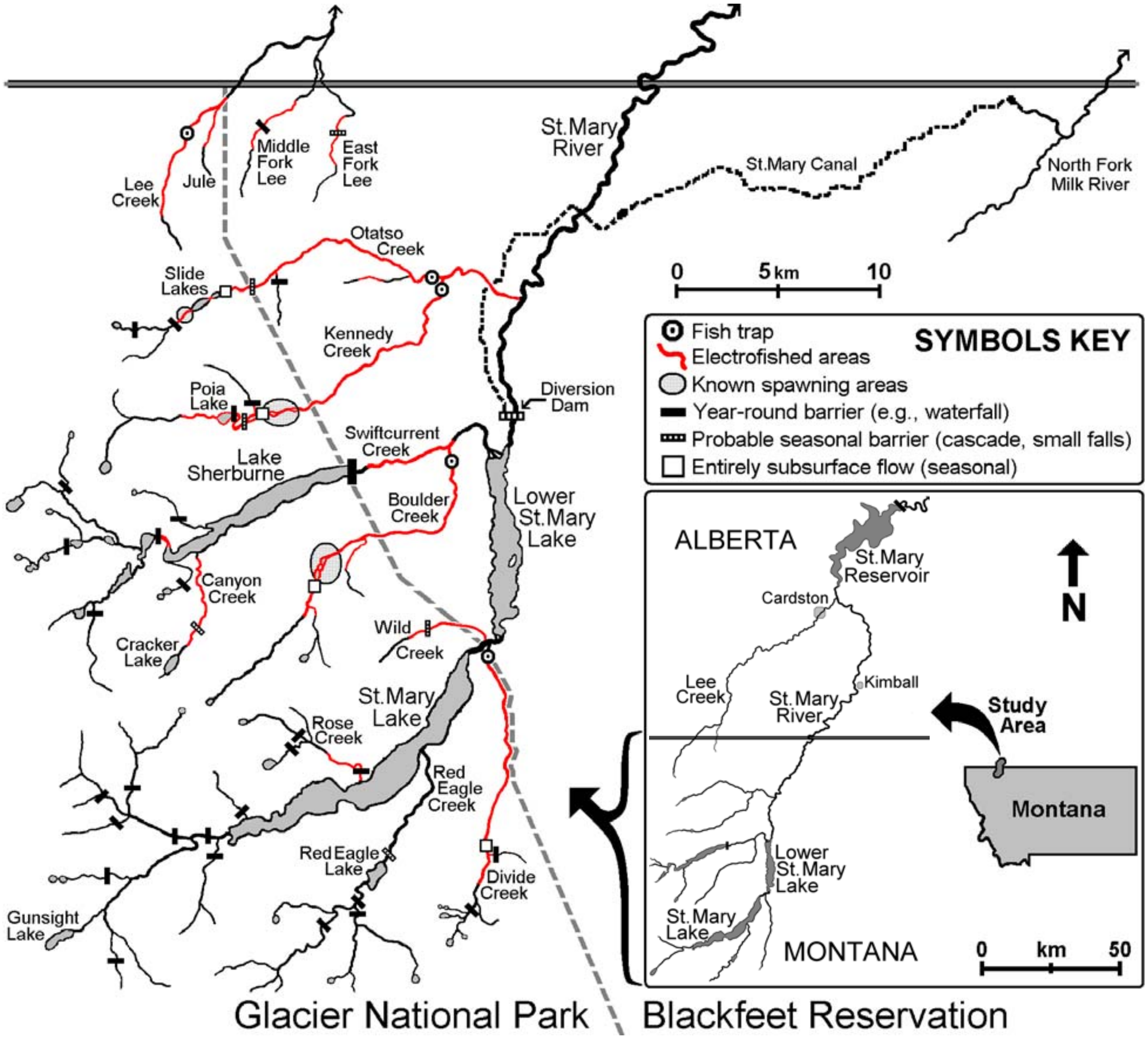

Figure 1. Study area, St. Mary River drainage, Montana and Alberta.

operations often result in reservoir levels that range between full and entirely drained (leaving two small, relic lakes) within a single year. About 0.2 km upstream from Lake Sherburne, a 30-m-high series of falls is a year-round barrier to fish movement.

Canyon Creek (second order) begins near Cracker Lake and flows north 7 km before entering upper Lake Sherburne. About 4 km upstream from its mouth, Canyon Creek flows over a 2-m-high fall, which may, at least seasonally, prohibit fish movement.

Boulder Creek (third order) originates from snowmelt and flows northeast 23 km before entering Swiftcurrent Creek, 4 km above Lower St. Mary Lake. About 13.5 km upstream from its mouth, Boulder Creek becomes entirely subsurface in a reach 0.5 to 1.5 km long, depending on flow volume, as it passes through gravel-cobble alluvium during the non-runoff period. The creek then emerges as groundwater upwellings and flows through a 3-km, low-gradient reach characterized by a braided channel and abundant damming by beaver (*Castor canadensis*). Because Boulder Creek periodically has substantial runoff flows and accompanying bedload movement, much of the channel in the creek's lower reach is wide and braided and has substrates consisting mainly of boulders and large rubble.

Kennedy Creek (third order) begins at Kennedy Lake and flows northeast 31 km before entering the St. Mary River, 9 km downstream from Lower St. Mary Lake. The creek passes over a 10-m-high fall at the outlet of Poia Lake, 22 km upstream from its mouth. Immediately downstream from the fall, Kennedy Creek enters a high-gradient, boulder-strewn canyon. At the lower end of the canyon, 1 km below the fall, the valley widens, the creek's gradient declines, and flows become entirely subsurface for 0.5 to 1.1 km during the non-runoff period. Kennedy Creek then emerges as groundwater upwellings and flows through a 2-km, low-gradient reach characterized by a braided channel and abundant beaver activity.

Otatso Creek (third order) begins at Otatso Lake and flows east 21 km before entering Kennedy Creek, 5 km above the St. Mary River. The creek flows over a 50-m-high fall 18 km upstream from its mouth. Two km downstream from the fall, the Slide Lakes are formed by a rockslide that prehistorically swept across Otatso Creek. Creek flows are entirely subsurface while passing through the extant rubble pile (~0.1 km wide) during the non-runoff period. From that location, Otatso Creek flows through a 2-km-long, high-gradient, boulder-strewn canyon, before passing over another fall and cascades (3 m high) 13 km above the creek's mouth. Downstream from that fall, Otatso Creek enters a shale-walled canyon wherein its sediment load increases substantially and most creek gravels and cobbles are entirely embedded.

Lee Creek (second order in the study area) and three of its tributaries, Jule, Middle Fork Lee, and East Fork Lee creeks (first-order streams), comprise the northern part of the St. Mary River drainage in Montana. Lee Creek originates as snowmelt and flows north 13 km before crossing the international border. From there, the creek meanders ~50 km through the mostly shrub-grassland habitat of southern Alberta before entering the St. Mary River near the town of Cardston, upstream from St. Mary Reservoir.

Land-use practices that may impair bull trout habitat are limited in the St. Mary River drainage in Montana. Within Glacier National Park, no extant land-use activities are known to adversely affect bull trout. On the Blackfeet Reservation, land-use practices that may adversely affect bull trout primarily consist of livestock grazing and timber harvest. Although both practices occur in limited areas, timber harvest is extensive in some parts of the Lee Creek drainage.

Additional water-control and delivery structures

Between 1906 and 1924, the U.S. Bureau of Reclamation (Bureau) built several water-control and delivery structures in the St. Mary River drainage, as part of the Milk River Irrigation Project. Along with the dam that created Lake Sherburne, those structures included the 2-m-high, concrete, St. Mary Diversion dam, 1.2 km downstream from Lower St. Mary Lake (Figure 1). Annually between about April and October, that dam deflects water (~18.4 m^3/s [650 ft^3/s]) into the St. Mary Canal, which conveys the water 46 km to the North Fork Milk River, in the Missouri River basin. In addition, the lower reach of Swiftcurrent Creek, which historically flowed into the St. Mary River downstream from Lower St. Mary Lake, was channeled into the lake itself. That allowed water released from Lake Sherburne to be diverted into the St. Mary Canal.

Similar water-control and delivery structures have been built in Alberta. Beginning at Kimball, ~25 km downstream from the international border (Figure 1), a canal historically conveyed St. Mary River water northeast to agricultural lands. Like the St. Mary Canal, the Kimball Canal has no headgate screen or other device to prevent fish entrainment. However, unlike the St. Mary Diversion, the Kimball Diversion is a rock jetty, does not span the entire St. Mary River, and has not been operated in recent years.

Fish Species

The historic distribution of native fishes in the St. Mary River drainage was delimited by the natural, year-round barriers to fish movement. Waters that were upstream from such barriers and historically barren of fish included the entire upper Red Eagle, Swiftcurrent, Kennedy and Otatso Creek watersheds, and the headwaters of the St. Mary River itself (Figure 1).

Among the fishes indigenous to the drainage, bull trout, westslope cutthroat trout, and mountain whitefish (*Prosopium williamsoni*) are believed to have occurred in all of the streams and lakes to which they had access, including the Slide Lakes, while lake trout inhabited only St. Mary and Lower St. Mary lakes (Brown 1971). Nowhere else in the contiguous United States are bull trout naturally sympatric with lake trout (Donald and Alger 1993). Also indigenous to the drainage are northern pike (*Esox lucius*), burbot (*Lota lota*), and perhaps lake whitefish (*Coregonus clupeaformis*), all of which inhabit the St. Mary lakes, and white sucker (*Catostomus commersoni*), longnose sucker (*Catostomus catostomus*), mountain sucker (*Catostomus platyrhynchus*), lake chub (*Couesius plumbeus*), trout-perch (*Percopsis omiscomaycus*), longnose dace (*Rhinichthys cataractae*), pearl dace (*Margariscus margarita*), mottled sculpin (*Cottus bairdi*), and spoonhead sculpin (*Cottus ricei*), which inhabit many of the streams and lakes to which the fish had natural access (Brown 1971).

Stocking of nonnative fishes in the St. Mary River drainage began in the 1890s and continued in Glacier National Park until the mid-twentieth century. Such stocking continues today only in some reservation waters, mainly isolated lakes and ponds. Nonnative fishes that have established self-sustaining populations at various locations in the drainage include brook trout, as well as rainbow trout (*O. mykiss*), Yellowstone cutthroat trout (*O. clarki bouvieri*), and especially the genetic intergrades (i.e. "hybrids") among those two fishes and westslope cutthroat trout. Brook trout, rainbow trout, Yellowstone cutthroat trout, and rainbow trout × Yellowstone cutthroat trout intergrades inhabit Gunsight and Red Eagle lakes (Fredenberg 1996, Michels 1996). Yellowstone cutthroat trout occur in Flattop Lake in the Boulder Creek drainage (R. Wagner, Service, pers. comm.), and their intergrades with westslope cutthroat trout occur in the Slide Lakes (Fredenberg 1996, Michels 1996). Rainbow trout, brook trout, and kokanee (*O. nerka*) occur in Lake Sherburne, along with native mountain whitefish, burbot, northern pike, and the three suckers (Wagner and FitzGerald 1995, Fredenberg 1996). Brook trout and rainbow trout have established reproducing populations in the formerly fishless complex of lakes and creeks upstream from the fall just above Lake Sherburne (Figure 1).

An extant, self-sustaining bull trout population may have resulted from intentional stocking of the fish into a formerly fishless lake in the St. Mary River drainage. Fredenberg (1996) reported that early in the twentieth century bull trout were stocked into Cracker Lake (Figure 1), where they persist today. Why bull trout were stocked instead of brook trout or rainbow trout, both of which were commonly stocked at that time, is unknown. An alternative explanation is also possible. Although the outlet stream of Cracker Lake (i.e. Canyon Creek) presently flows over a 2-m-high fall, the fall may have formerly been lower and may not even now be a barrier to the upstream movement of fish during seasonal runoff. No additional barriers to such movement are apparent in the creek. Thus it seems most probable that bull trout are indigenous to Cracker Lake.

Annual Hydrologic Conditions

Annual hydrologic conditions varied greatly during our study, as indicated by total Swiftcurrent Creek discharge measured between 1 May and 30 August (which encompasses the seasonal runoff period) at a location just upstream from Lake Sherburne (U.S. Geological Survey gage 05014500; Figure 2). Discharge at that location is entirely natural and, we assumed, broadly representative of trends in concurrent, annual discharges of the other study creeks. When our study began, in 1997, total upper Swiftcurrent Creek discharge had been mostly increasing since 1992. In contrast, during our study those discharges mostly declined until 2001, markedly increased in 2002, and declined sharply in 2003.

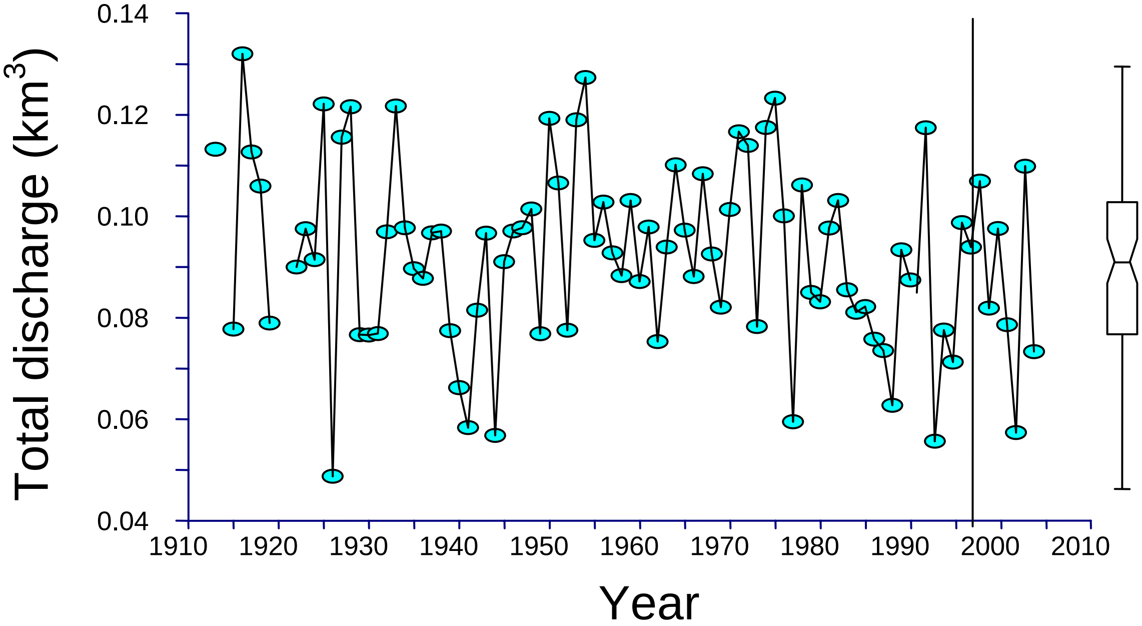

Figure 2. Total annual Swiftcurrent Creek discharge measured upstream from Lake Sherburne between 1 May and 30 August, 1913 to 2003. The connecting line is broken where data are missing. Vertical line indicates the beginning of the present study. Box plot at right indicates the median discharge value at the box notch, interquartile range by the box itself, and the range of values by horizontal lines at the ends of vertical lines.

METHODS

Electrofishing (1998-2003)

Electrofishing was performed between mid-July and late August to broadly characterize the bull trout populations and fish communities in the creeks. Because the creeks were mainly accessible only by foot, it was not possible to annually electrofish entire creeks. We therefore established in each creek an approximate sampling reach that contained a variety of mesohabitats and, where present, bull trout of a broad range of size-classes, as determined by creek-wide, reconnaissance electrofishing conducted during 1998 and 1999.

Electrofishing occurred annually, unless otherwise noted (Table 1), in: (1) a 2-km reach of Divide Creek that extended downstream from the region of entirely subsurface flow; (2) a 4- to 7-km reach of Boulder Creek that extended downstream from the region of entirely subsurface flow; (3) a 6- to 9-km reach of Kennedy Creek that extended downstream from the region of entirely subsurface flow; (4) Otatso Creek's 3 reaches, i.e. (a) lower Otatso, a 1- to 3-km reach that extended downstream from the fall ~13 km upstream from the creek's mouth; (b) middle Otatso, from the fall upstream 1.9 km to the rockslide that forms Slide Lakes; and (c) Slide Lakes, the subsequent 2.5-km reach to the fall above the lakes, except the lakes themselves were not sampled; and (5) a 4-km reach of Lee Creek that extended upstream from Chief Mountain International Highway. In addition, periodic electrofishing occurred in (6) the lowermost 2 km of Rose Creek; (7) a 1-km reach of Wild Creek that extended upstream from the park boundary; (8) a 2- to 3-km reach of Canyon Creek that encompassed the small fall but mainly extended downstream; and (9) Jule, (10) Middle Fork Lee, and (11) East Fork Lee creeks, each within ~0.5 km upstream and downstream from their crossings with the highway. Except for Red Eagle Creek and the few, additional creeks subsequently described in this report, remaining creeks appeared too small or to have gradients too steep to support substantive fish communities and were not electrofished. Red Eagle Creek was not examined because the creek was difficult to access and too large for our electrofishing equipment.

We used a battery-powered, backpack electrofisher (Smith-Root Model 15-B) operated at 500-800 volts, pulsed (25-30 Hz) direct current to capture fish. During electrofishing, a single, upstream-moving pass was made through each reach. Creek flows were seasonally low and clear and we selectively netted bull trout and other char and trout. Although small, age-0 fish were not specifically sought during 1998 and 1999 and often passed through our nets, beginning in 2000 we also caught representative samples of age-0 bull trout.

Captured char and trout were identified to species and counted, whereas the occurrences of mountain whitefish and the sculpins (the two species not distinguished) were only noted. Accordingly, all char and trout caught from a creek (or each Otatso Creek reach) in a single year constituted an electrofishing sample.

Because it was not practical for us to distinguish the hybrids or genetic intergrades of rainbow trout and cutthroat trout from their parent species or subspecies on the basis of external morphological characteristics

Table 1. Dates and locations of fish trapping and electrofishing in the St. Mary River drainage, Montana, 1997-2003.

Creek, activity	1997	1998	1999	2000	2001	2002	2003
Divide							
Trapping	8/26 - 10/8	8/26 – 10/6	---	---	---	---	---
Electrofishing	---	7/8	8/5	---	---	8/22	8/12, 8/16
Boulder							
Trapping	8/26 - 10/8	8/26 - 10/13	8/30 - 10/20	9/2 - 10/21	---	---	---
Electrofishing	---	7/28	8/23	7/17, 8/9, 8/23	8/13-14	8/7, 8/9, 8/15	8/14, 8/17
Kennedy							
Trapping	8/27 - 10/9	8/25 – 10/8	8/31 - 10/19	9/1 - 10/20	---	---	---
Electrofishing	---	7/15, 7/29, 8/12	7/26-27, 8/9, 8/25	7/12, 7/16, 7/26, 7/30, 8/8, 8/13, 8/25	8/7-8	8/11, 820, 8/22	8/18, 8/21
Otatso							
Trapping	8/27 - 10/9	8/25 – 10/8	8/31 - 10/19	9/1 - 10/20	---	---	---
Electrofishing							
Lower Otatso	---	---	8/6	7/28, 8/22	8/9-10	8/13, 8/29	8/19
Middle Otatso	---	7/22-21	8/19-20	7/27, 8/11	---	8/12-13	8/19-20
Slide Lakes	---	7/21	8/19	7/27	---	8/13	8/20
Lee							
Trapping	---	---	8/30 - 10/14	9/2 - 10/18	---	---	---
Electrofishing	---	8/18	7/24, 8/24	7/13, 7/15, 8/10, 8/24	8/11-12	8/8, 8/21	8/13
Jule							
Electrofishing	---	8/11	7/13	---	---	---	---
Middle Fork Lee							
Electrofishing	---	8/11	7/13	---	---	---	---
East Fork Lee							
Electrofishing	---	---	7/12	---	---	9/26	---
Canyon							
Electrofishing	---	---	---	---	---	8/28	8/26
Wild							
Electrofishing	---	7/27	7/23	---	---	7/25	---
Rose							
Electrofishing	---	---	---	7/25	---	8/10	8/15

evident in the field and such interbreeding appeared widespread, all of those fishes were assigned to a single taxon (i.e. cutthroat × rainbow intergrades), except when they plainly appeared to be westslope cutthroat trout. When an apparent westslope cutthroat trout population was found, specimens were collected for subsequent biochemical genetic (allozyme) analysis at the University of Montana's Wild Trout and Salmon Genetics Laboratory.

Bull trout were measured to total length (TL, mm), weighed (g), and (through 2002) scales were taken from an area just posterior to the dorsal fin and above the lateral line of many fish longer than ~75 mm TL. We did not distinguish between sexes. Passive integrated transponder (PIT) tags, each uniquely coded, were injected into skeletal muscle directly below the dorsal fin of bull trout ≥ 200 mm TL. The adipose fin was removed from tagged fish and some fins were kept for subsequent molecular genetic (microsatellite) analysis, also at the University of Montana. All bull trout were examined for previously applied tags. For analyses of data taken from recaptured bull trout, a recapture event consisted of a recapture that occurred at least one field season after the previous capture. Thus multiple recaptures of individual fish within years were collectively treated as a single recapture event.

Trapping (1997-2000)

Annually between about late August and mid-October, fish traps were operated near the mouths of Divide Creek (1997, 1998), Boulder, Kennedy, and Otatso creeks (1997-2000), and on Lee Creek at the highway crossing (1999, 2000) (Figure 1; Table 1). Trapping was primarily intended to catch post-spawning, migratory bull trout as they departed the creeks. Trapping on Lee Creek succeeded that on Divide Creek, where bull trout were found to be scarce.

Traps caught only downstream-moving fishes and consisted of a holding box and attached weirs. Boxes (1.0 m × 1.0 m × 1.0 m) had steel-tubing frames, 1.3-cm-mesh hardware-cloth walls and bottoms, and lockable plywood lids. Weirs consisted of 1.2-m lengths of 1.7-cm-diameter aluminum conduit that were separated by 2.5-cm plastic spacers and tightly strung on 3 parallel cables to form a picket fence. Weirs were attached to the box entrance, angled upstream to opposing creek banks, and supported by steel fence posts driven into the creek bottom. A 20-cm-long, rubber-coated, hardware-cloth funnel extended from the entrance into the box.

Traps were operated continuously and checked daily. Creek flows were usually clear and rarely exceeded 0.5 m^3/s, except frequent rains and winds in 1999 and 2000 sometimes resulted in higher flows and abundant aspen (*Populus tremuloides*) leaves that frequently clogged weirs, which sometimes collapsed. Lesser problems included periodic overcrowding of fish in boxes and predation by mink (*Mustela vison*), which resulted in the known loss of several mountain whitefish and cutthroat × rainbow intergrades, as well as eight bull trout.

Captured fish were processed as previously described, except only char, trout, and mountain whitefish were counted and in 1997 bull trout were tagged with uniquely coded visual implant (VI) tags injected just under the epidermis, immediately posterior to the left eye. All tallied fish caught in a trap during a single year constituted a sample. For some subsequent analyses, we used TL measurements < 300 mm and ≥ 300 mm to classify bull trout as either juveniles or adults. That delineation was supported by additional data, described herein. Traps were removed for the year when few bull trout were being caught and the post-spawning migration appeared to have ended, or when inclement weather precluded further trapping.

Measurement of creek temperatures.−To broadly characterize temperature regimes during the bull trout spawning season, creek temperatures were recorded bi-hourly between late August and late October by an electronic thermometer installed at each trap site, as well as in Swiftcurrent Creek (downstream from Boulder Creek, 1997-1998; just upstream from Boulder Creek, 2001-2003) and the St. Mary River (at the canal overpass, 1999-2003). Mean-daily temperature was calculated as the average of the bi-hourly measurements for that day.

Estimation of Bull Trout Population Size

Tagging and recapture-event data were used to estimate size of the adult bull trout (i.e. ≥ 300 mm TL) population in each creek. Data from electrofishing and trapping were examined independently, thereby permitting population estimation based on each capture method. Accordingly, a bull trout tagged during electrofishing but subsequently caught in the trap, for example, was treated as a separate fish in the data set for each capture method. Population size for bull trout ≥ 200 mm TL in each creek was also estimated on the basis of electrofishing data.

For population estimation, we fitted the POPAN-5 parameterization of the Jolly-Seber open-population model, provided in program MARK (White and Burnham 1999), to the individual encounter histories for tagged bull trout. We considered both constant and time-dependent forms for each of the three relevant parameters estimated by the model (i.e., Phi [apparent survival between years], *p* [probability of detection], and *pent* [probability of entrance into the population]), although we report results only for those models that also provided estimates of population size. The logit function was used to link the linear model specified in the design matrix; however, when the model being fitted had multiple *pent* parameters, the multinomial logit link function was used to constrain the real parameters. Because open-population models require data for at least three years, only trapping data from Boulder, Kennedy, and Otatso creeks and electrofishing data from those creeks (lower and middle Otatso Creek reaches combined) as well as Lee Creek, could be used for population estimation (altogether, 11 data sets).

Bull Trout Age Estimation

Scales taken from bull trout were impressed on cellulose-acetate cards. Magnified impressions were examined by a single analyst (JTM), who counted the apparent annuli (i.e. zones of closely spaced circuli) used to estimate age. Impressions for 891 (90%) of 989 bull trout sampled for scales were useful for such counts. As one means of checking our ageing technique, we compared mean total lengths at capture for the scale-based age-classes of bull trout to representative length-frequency distributions for bull trout caught by electrofishing. As a second check, we compared the increase in scale-based age (yr) for each recaptured bull trout to the fish's known increase in age (i.e. the year of recapture minus the year of initial capture).

Redd Surveys (1997-2003)

During October and November 1997, a single visual reconnaissance was conducted along the entire length of Divide, Boulder, Kennedy, and lower Otatso creeks, to identify bull trout spawning areas on the basis of the occurrence of redds. To monitor trends in annual bull trout spawning effort, those spawning areas alone were surveyed for redds in subsequent years, mainly during mid-October. When searching for redds, crew members wore polarizing sunglasses, walked creek banks, and proceeded upstream until an obvious barrier to the upstream movement of fish was encountered. Validity of potential redds was decided on the basis of their visual characteristics and consensus among crew members. Locations of redds and general characteristics of spawning areas were recorded.

Statistical Analyses

Statistical analyses, apart from those provided in program MARK (White and Burnham 1999), were performed using the Number Cruncher Statistical System (Hintze 2001), after tests had been conducted to assure that the routine assumptions of normality and equal variance in the error term had been met. When necessary, transformations of appropriate variables were performed to meet those assumptions (Neter et al. 1996). Bonferroni's All-Pairwise, Multiple-Comparison Test was used to reveal which treatment-population means differed statistically.

RESULTS

Distribution of Bull Trout and other Fishes

Bull trout were found in each of the creeks, except East Fork Lee, Wild, and Rose creeks. They constituted more than half of the fish in each electrofishing sample from Boulder, Lee, and Canyon creeks and the Middle Otatso and Slide Lakes reaches, as well as many of the samples from Kennedy and Lower Otatso creeks (Figure 3). Average size of the 51 electrofishing samples was 91 fish (range, 2 to 434 fish); samples did not exceed 48 fish for first-order creeks. Collectively, 88% of the other fishes in samples were cutthroat × rainbow intergrades (including a few westslope cutthroat trout, described in a subsequent section of this report). Brook trout were found only in Divide, Boulder, Kennedy and Rose creeks, where they averaged 8% (range, 0% to 21%) of samples. Sculpins were found in Divide, Boulder, Kennedy and lower Otatso creeks, as were mountain whitefish, which were also found in Rose Creek.

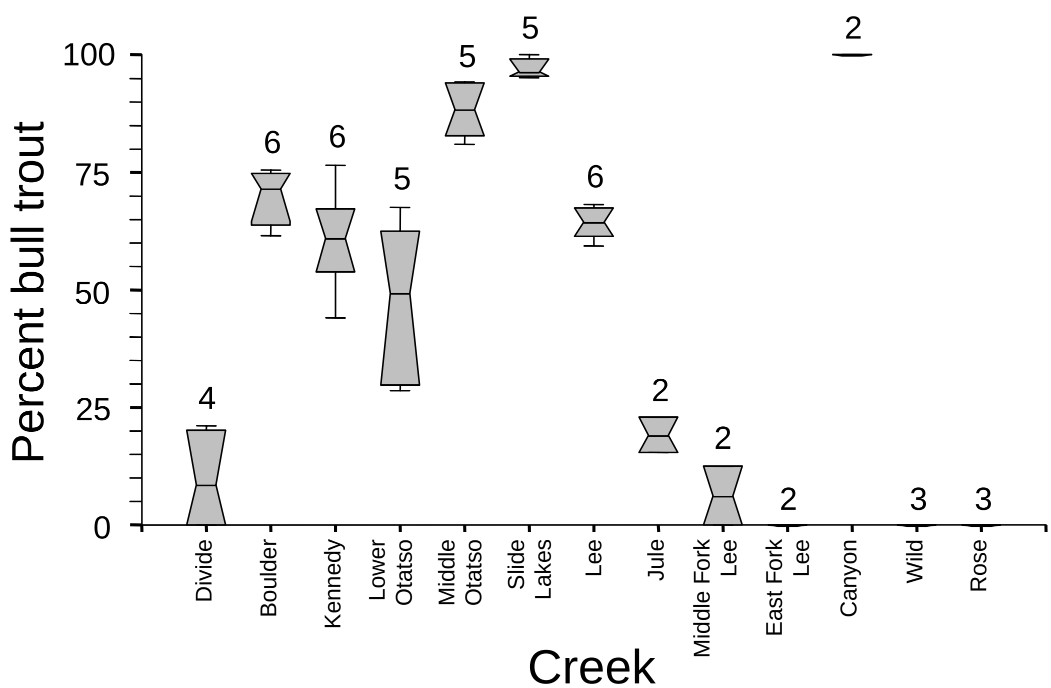

Figure 3. Box plots of percent bull trout in samples caught by electrofishing in creeks, 1998-2003. Box plots indicate the median value at the box notch, interquartile range by the box itself, and the range of values by horizontal lines at the end of vertical lines. Numbers indicate number of samples (years).

Detailed summaries for individual creeks

Electrofishing in Boulder Creek revealed bull trout (43-763 mm TL; Figure 4), cutthroat × rainbow intergrades (85-482 mm TL), brook trout (87-238 mm TL), and mountain whitefish. Many large (> 400 mm TL) bull trout were caught just downstream from the reach of entirely subsurface flow. One of 12 (8%) adult bull trout caught in 1998, 8 of 10 (80%) adult bull trout caught in 1999, 12 of 23 (52%) adult bull trout caught in 2000, 11 of 17 (65%) adult bull trout caught in 2001, 12 of 27 (44%) adult bull trout caught in 2002, and 15 of 26 (58%) adult bull trout caught in 2003 were recaptured fish. The region of subsurface flow is apparently only a seasonal barrier to fish movement because each species of fish found downstream in Boulder Creek was also caught above that region. Two first-order tributaries that enter upper Boulder Creek from the south were sampled in 2000; bull trout (< 200 mm TL) and westslope cutthroat trout (≥ 95% genetic purity) were found in lower reaches of both creeks. Remaining tributaries appeared too small or too high-gradient to support fish, and were not sampled.

In Kennedy Creek, no fish were found upstream from the waterfall at the outlet of Poia Lake, but bull trout (range, 44-725 mm TL; Figure 4), cutthroat × rainbow trout intergrades (33-450 mm TL), brook trout (92-284 mm TL), and mountain whitefish were caught downstream. Many bull trout > 400 mm TL were caught from the 5-km reach of Kennedy Creek near the park boundary. Seven of 22 (32%) adult bull trout caught in 1998, 9 of 22 (41%) adult bull trout caught in 1999, 19 of 39 (49%) adult bull trout caught in 2000, 6 of 18 (33%) adult bull trout caught in 2001, 7 of 34 (21%) adult bull trout caught in 2002, and 11 of 47 (23%) adult bull trout caught in 2003 were recaptured fish. About 3.5 km upstream from the park boundary, a second-order tributary that enters Kennedy Creek from the north appeared large enough to support fish but a large waterfall (20 m high) near the tributary's mouth prohibits fish passage upstream. Remaining Kennedy Creek tributaries appeared too small or too high-gradient to support fish, and were not sampled.

In Lower Otatso Creek, bull trout (109-662 mm TL; Figure 5), cutthroat × rainbow intergrades (76-357 mm TL), and mountain whitefish were caught. None of 3 adult bull trout caught in 1999, none of 10 adult bull trout caught in 2000, 10 of 18 (56%) caught in 2001, 8 of 17 (47%) adult bull trout caught in 2002, and 11 of 30 (37%) adult bull trout caught in 2003 were recaptured fish. Most adults caught in this reach were just downstream (< 100 m) from the fall near the park boundary. In middle Otatso, many bull trout (53-493 mm TL; Figure 5) were found, along with a few cutthroat × rainbow intergrades (65-382 mm TL); none of 10 adult bull trout caught in 1998, 2 of 38 (5%) caught in 1999, 3 of 11 (27%) caught in 2000, none of 9 adult bull trout caught in 2002, and 2 of 55 (4%) caught in 2003 were recaptured fish. The Slide Lakes reach supports populations of bull trout and cutthroat × rainbow intergrades. Otatso Creek is fishless above the large fall, 1 km upstream from the lakes. Bull trout (61-572 mm TL; Figure 5) and cutthroat × rainbow intergrades (105-341 mm TL) were caught from the Slide Lakes reach. In this reach, none of 5 adult bull trout caught in 1998, none of 6 caught in 1999, neither of the 2 caught in 2000, none of the 13 adult bull trout caught in 2002, and none of the 90 adult bull trout caught in 2003 was a recaptured fish.

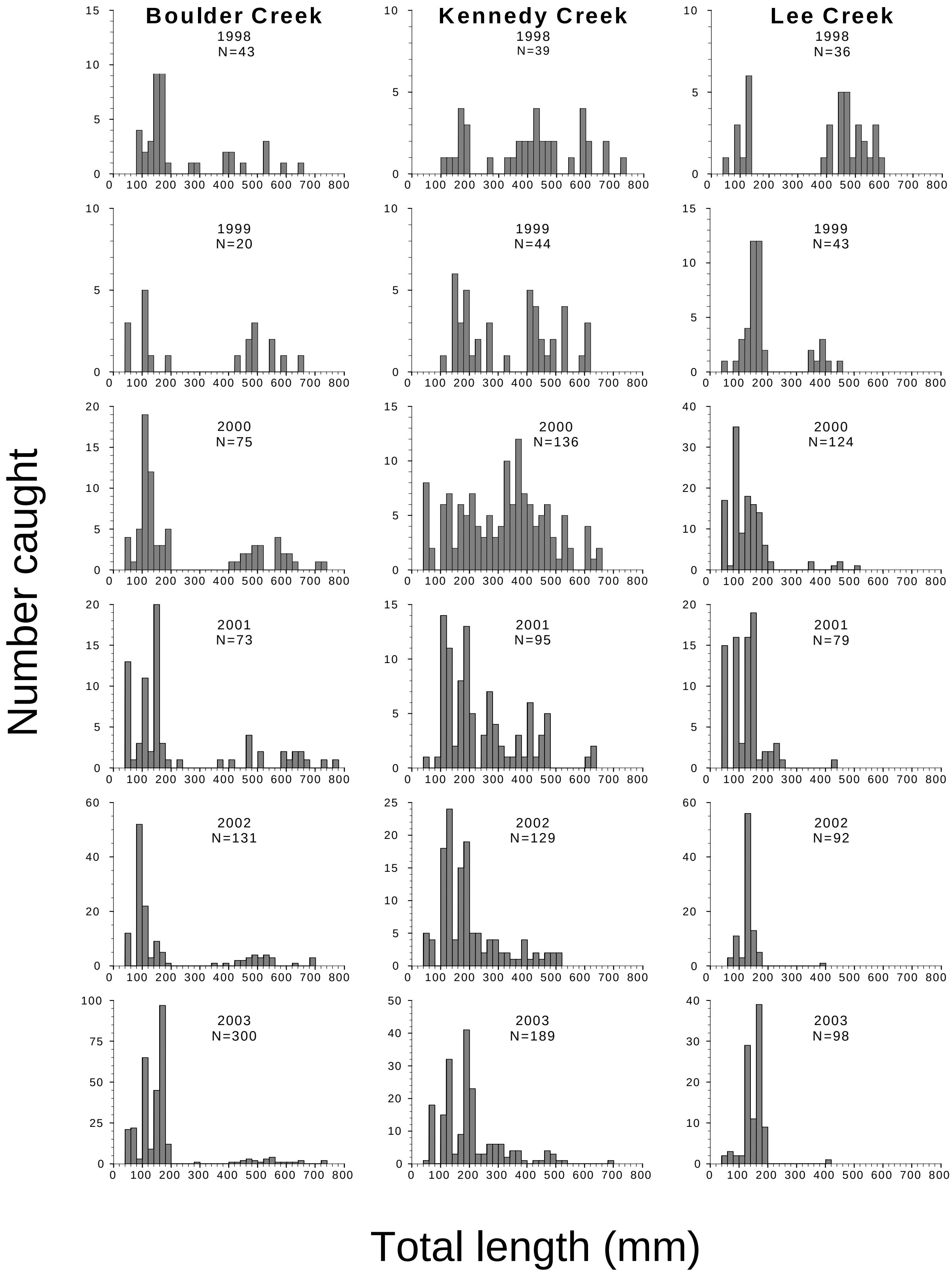

Figure 4. Length-frequency distributions for bull trout caught by electrofishing in Boulder, Kennedy, and Lee creeks, St. Mary River drainage, Montana, 1998-2003.

In Lee Creek, bull trout (46-592 mm TL; Figure 4), cutthroat × rainbow intergrades (70-382 mm TL), and mountain whitefish were caught. None of 25 adult bull trout caught in 1998, none of 8 caught in 1999, and 1 of 6 (17%) adult bull trout caught in 2000 was a recaptured fish. The single adult bull trout caught in 2001, 2002, and 2003 were not recaptured fish.

The lower 4 km of Jule Creek, entirely within the park, provides summer habitat for juvenile bull trout (89-148 mm TL) and cutthroat × rainbow intergrades (63-195 mm TL). Streamside livestock grazing and extensive logging in the Middle Fork Lee Creek drainage result in large silt loads and substantial creek turbidity. No fish were caught from a 200-m reach upstream from an elevated highway culvert that is a barrier (2-m fall) to the upstream movement of fish, whereas two bull trout (175-235 mm TL) and several cutthroat × rainbow intergrades (115-234 mm TL) were caught from a 500-m reach downstream from the culvert. Although also affected by grazing and logging, East Fork Lee Creek supports a population of small westslope cutthroat trout (96-217 mm TL). A sample (N = 25) of these fish collected in 2002 was subsequently determined to genetically consist of 97.7% westslope cutthroat trout (2.3% rainbow trout genes).

The upper Divide Creek drainage was surveyed at several locations in the park, from its head to the park boundary, in 1998 (Table 1). No bull trout and only two cutthroat trout (80 and 220 mm TL) were caught, just inside the park. Lower Divide Creek was surveyed at several locations along the reach from its mouth to the park boundary in 1999 (Table 1). The few fish encountered were cutthroat × rainbow intergrades (69-186 mm TL) and mountain whitefish. Upper Divide Creek was resurveyed in August 2002 and 2003 (Table 1). In a 1.6- km reach beginning at the park boundary, 32 juvenile bull trout (156-190 mm TL; Figure 6), 120 cutthroat × rainbow intergrades (54-270 mm TL), and one mountain whitefish were captured in 2002 and 28 juvenile bull trout (199-245 mm TL; Figure 6), one adult bull trout (547 mm TL: Figure 6) and 138 cutthroat × rainbow intergrades (61-494 mm TL) were captured in 2003. Although no obvious barrier to the upstream movement of fish was encountered in Divide Creek, high-gradient cascades probably prohibit fish movement into the creek's few small tributaries.

Canyon Creek was surveyed in 2002 along the entire reach from near its mouth to the small fall 4.0 km upstream, and in 2003 along the entire reach beginning 2 km below the fall and ending 2 km above the fall (Table 1). Although few fish were found in the lower 2 km of Canyon Creek, the creek supports a population of small bull trout (50-321 mm TL; Figure 6) in its middle and upper reaches (i.e. both below and above the fall).

Wild Creek was surveyed at several locations along a 2-km reach near the park boundary (Table 1). The creek appeared to be barren of fish upstream from the complex of small logjams, falls, and cascades 3 km upstream from its mouth. The middle reach of Wild Creek, immediately downstream from the apparent barrier complex, supports a population of small (55-197 mm TL) cutthroat trout. A sample (N = 13) of cutthroat trout collected

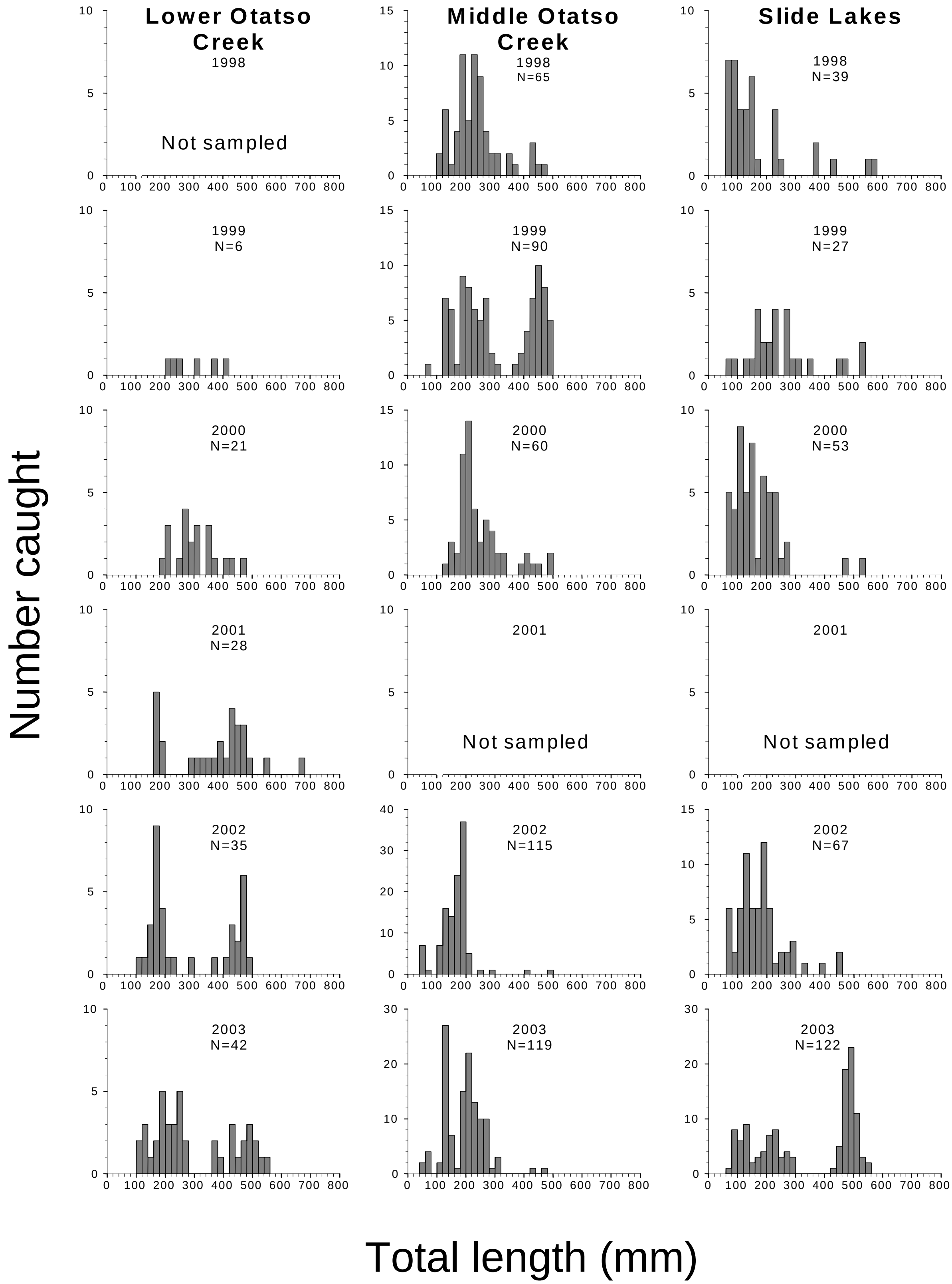

Figure 5. Length-frequency distributions for bull trout caught by electrofishing in the three reaches of Otatso Creek, St. Mary River drainage, Montana, 1998-2003.

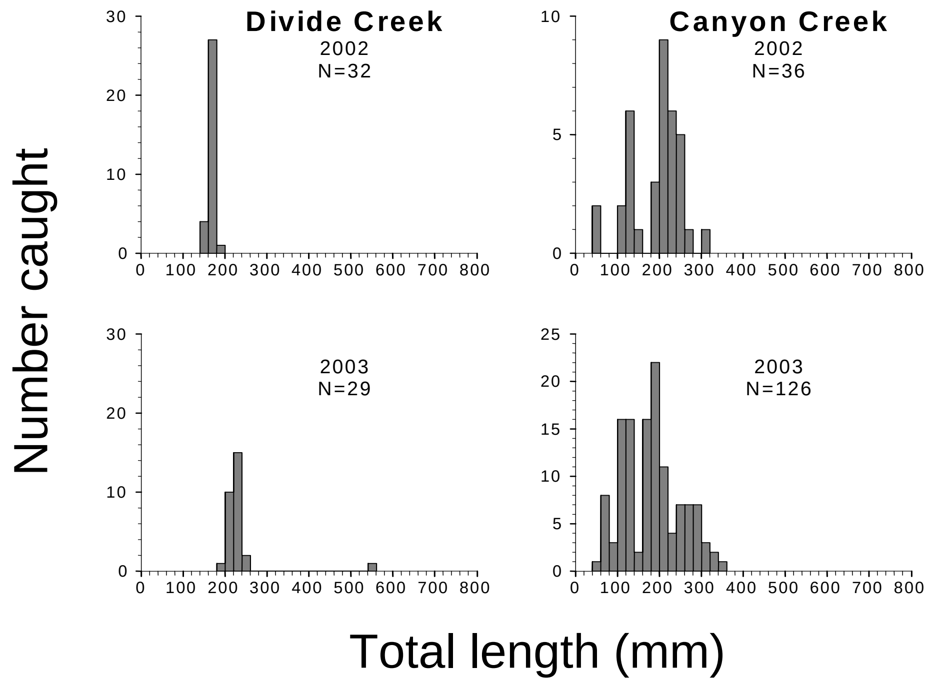

Figure 6. Length-frequency distributions for bull trout caught by electrofishing in Divide and Canyon creeks, St. Mary River drainage, Montana, 2002-03.

from that reach in 1998 was subsequently determined to consist of genetically pure westslope cutthroat trout. Farther downstream, near the creek's confluence with the St. Mary River, small cutthroat × rainbow intergrades and brook trout were found.

Rose Creek was surveyed at several locations between its mouth and 2 km upstream (Table 1). The creek appeared barren of fish in its upper reaches, upstream from the abandoned, 2-m-high dam 1 km upstream from its mouth. Although no fish were found above the dam, cutthroat × rainbow intergrades (32-263 mm TL), brook trout (128-230 mm TL), and mountain whitefish were found downstream.

Length Frequency of Electrofished Bull Trout

Length-frequency distributions for bull trout caught by electrofishing revealed multiple size-classes and suggested recent reproduction in each creek, except Divide and lower Otatso, as evidenced by fish < 100 mm TL (Figures 4-6). Many distributions for bull trout in Boulder and Kennedy creeks (Figure 4) showed modal size-classes centered around fish ~50 mm TL, ~100 mm TL, and ~180 mm TL that may have been age-0, age-1, and age-2 fish. However, similar size-classes were not readily apparent in the other creeks, except Canyon (Figure 6). The single bull trout size-class in Divide Creek was ~180 mm TL in 2002 and ~220 mm TL in 2003, when one 547 mm TL bull trout was also caught (Figure 6). The largest bull trout caught, from Boulder Creek, was 763 mm TL.

Bull Trout Age and Growth

The first scale annulus was formed during the second year of life, as evidenced by its occurrence near the margin on scales taken from nearly all bull trout considered age 1 on the basis of length frequency. The relation between bull trout TL and scale-based age at capture indicated growth at all ages, particularly as age-4 fish (Figure 7). Among study years, we found no consistent within-age differences in mean TL of bull trout, either among creeks or reaches or between collective samples of bull trout caught by electrofishing or in traps in each creek where those methods were concurrently employed. Mean total lengths at capture for age-1, age-2, and age-3 bull trout were 103.2 $\pm$ 5.2 mm (95% confidence interval), 155.4 $\pm$ 3.8 mm, and 191.5 $\pm$ 3.9 mm. Thus the length-frequency distributions (Figures 4-6) revealed age-1 (and age-0) bull trout, but age-2 and age-3 fish apparently formed a single size-class. The single size-class of bull trout in Divide Creek in 2002 (Figure 6) consisted entirely of age-2 fish (scales were not collected in 2003).

For the 83 recaptured bull trout that had useful scales, known increase in age equaled the age increase determined from scales for 60 (72%) fish and was one yr greater for 15 (18%) fish (Figure 8). Seventy-eight (94%) of the recaptured fish were $\geq$ age 5 when initially caught (overall mean, age 6.5); known increase in age exceeded the increase in scale-based age only for bull that were $\geq$ age 5 when initially caught (Figure 9).

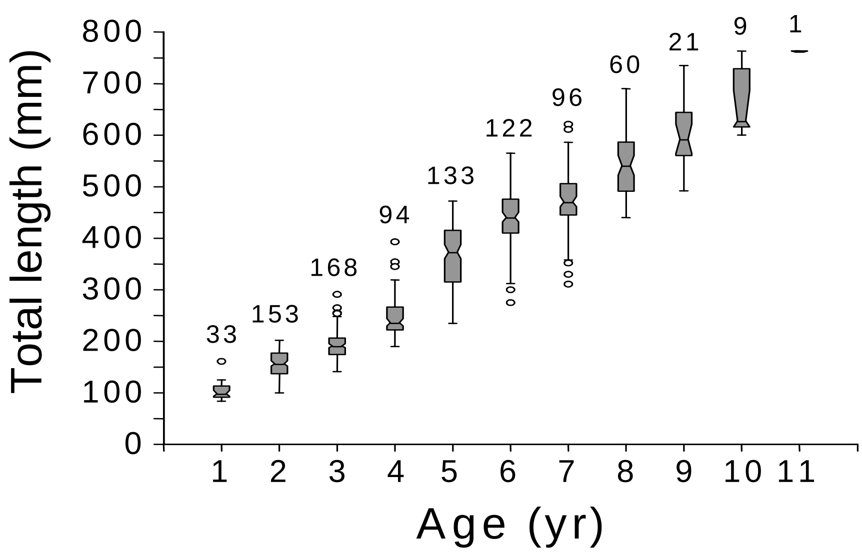

Figure 7. Box plots of total length at capture by scale-based age for 890 bull trout (the single age-0 fish is not shown) caught by electrofishing and in traps. Box plots indicate the median value at the box notch, the interquartile range (IQR) by the box itself, and the range of values by horizontal lines at the end of the vertical lines; outliers (i.e. data values > 1.5 IQR from the box) are indicated by circles. Numbers indicate number of fish.

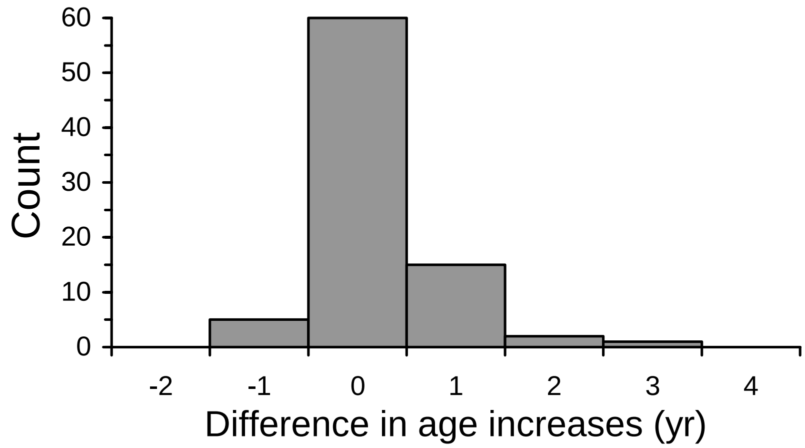

Figure 8. Histogram of known increase in age (yr) minus estimated increase in scale-based age for 83 recaptured bull trout, St. Mary River drainage, 1997-2002.

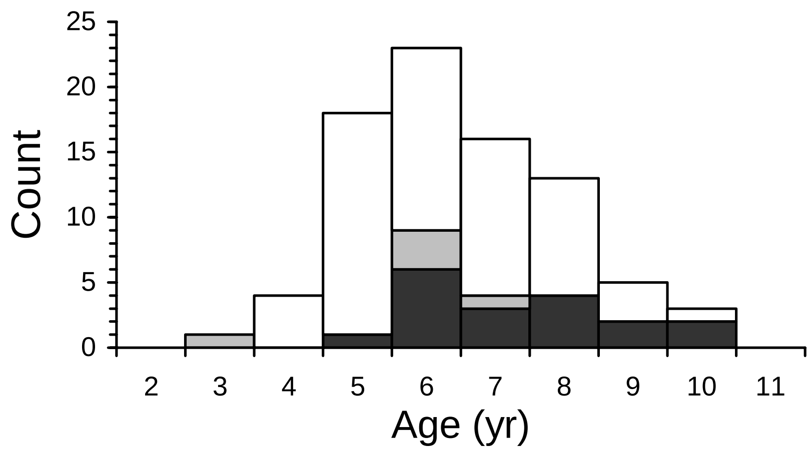

Figure 9. Age frequency of 83 recaptured bull trout for which increases in known age and scale-based age were compared. Horizontal axis is scale-based age at time of initial capture. Fish are separated into three groups: those for which the increases in ages were equal (open bars); known increase was more than scale-based increase (black bars); and known increase was less than scale-based increase (shaded bars).

Trapped Bull Trout

Creek temperatures

Seasonal trends in mean-daily creek temperatures were similar among trap locations and the other measurement sites within years (Figure 10). Among years and creeks, Kennedy Creek often exhibited the warmest temperatures, followed by Otatso, Boulder, Divide, and Lee creeks, respectively. However, each of those creeks was almost always cooler than Swiftcurrent Creek and the St. Mary River.

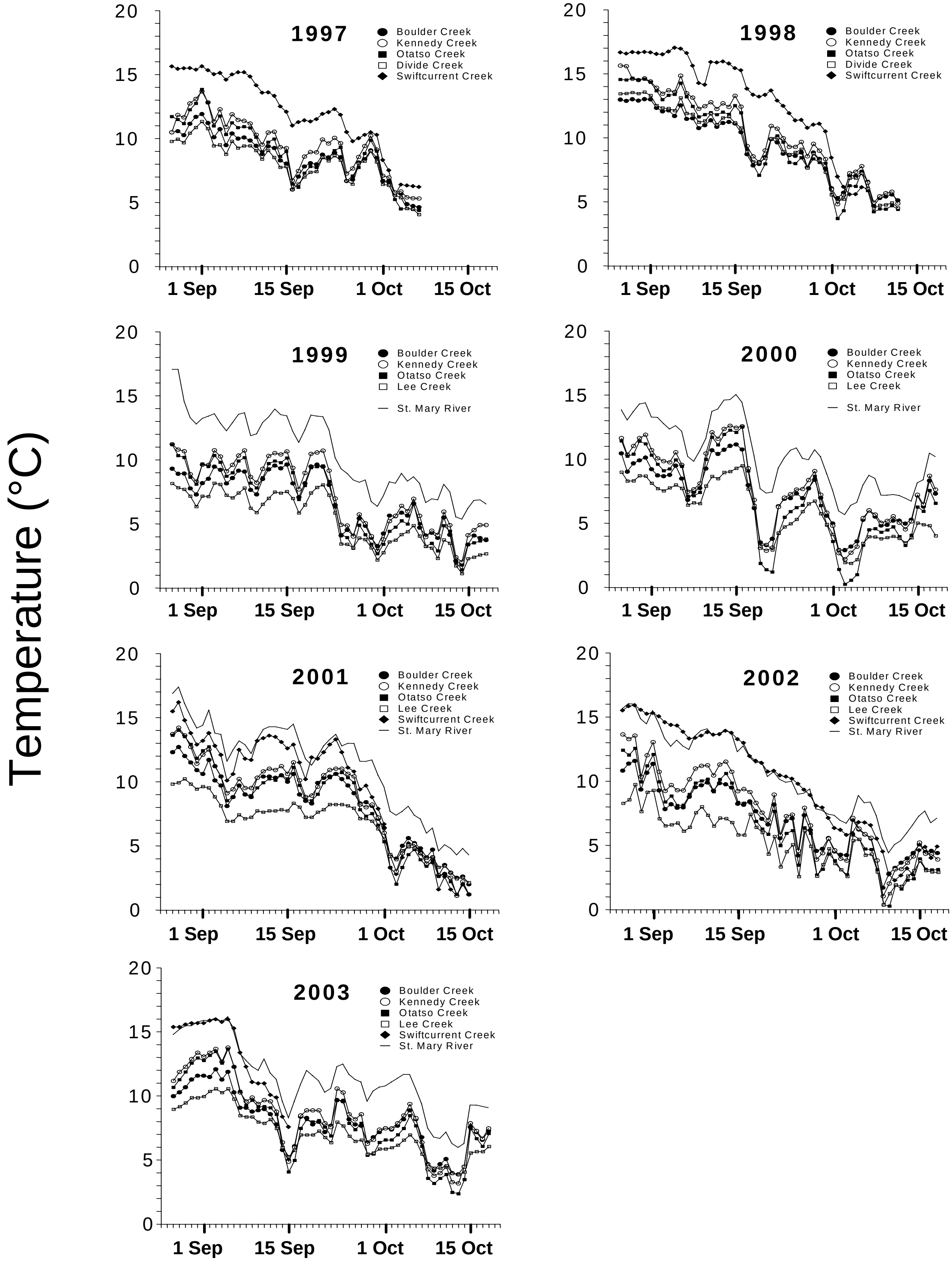

Figure 10. Mean-daily temperatures (°C) of the creeks and the St. Mary River, late August-late October, 1997-2003, St. Mary drainage, Montana.

Trapped fish

Average size of the 16 trap samples was 155 fish (range, 21 to 333 fish). Bull trout were annually caught in each trap (Tables 2 and 3), except in Divide Creek in 1998, and there was little variation in their percent occurrence among samples within individual creeks (Figure 11). Average number of bull trout in samples was 39 (range, 0 to 88 fish). Among the 626 bull trout caught, 317 (51%) were considered juveniles (i.e. < 300 mm TL) and 309 (49%) adults ($\geq$ 300 mm TL). Average number of adults in samples was 19 (range, 0 to 64 fish); only 2 bull trout (both adults) were caught in the Divide Creek trap, in 1997. When Divide Creek was excluded, mean number of adult bull trout per sample did not differ among creeks (ANOVA of ln number of adults, $F_{3,10} = 1.95$, $P = 0.19$; overall mean, 22 $\pm$ 8 adults per sample). Collectively, 85% of the other fishes in samples were mountain whitefish and 15% were cutthroat × rainbow intergrades. Four brook trout were caught − three in Boulder Creek and one in Divide Creek.

Although adult bull trout were often caught soon after traps were installed each year, capture of half of the eventual total annual catch of those fish in a trap was usually not attained until after mid-September (Figure 12). In most instances, annual trapping ended after no adult bull trout had been caught for several days. Length-frequency distributions for bull trout caught in traps are presented in Figure 13.

Table 2. Total numbers of char, trout, and mountain whitefish caught in traps, St. Mary River drainage, Montana, 1997-2000.

	Juvenile Bull Trout (< 300 mm TL)				Adult Bull Trout ($\geq$ 300 mm TL)				Totals			
Creek	**1997**	**1998**	**1999**	**2000**	**1997**	**1998**	**1999**	**2000**	**1997**	**1998**	**1999**	**2000**
Boulder	30	23	36	31	17	64	23	23	47	87	59	54
Kennedy	1	6	10	2	32	38	20	9	33	44	30	11
Otatso	1	17	6	1	16	19	11	12	17	36	17	13
Lee	--	--	69	84	--	--	19	4	--	--	88	88
Divide	0	0	--	--	2	0	--	--	2	0	--	--
Totals	32	46	121	118	67	121	73	48	99	167	194	166

	Cutthroat × Rainbow intergrades				Brook Trout				Mountain Whitefish			
Creek	**1997**	**1998**	**1999**	**2000**	**1997**	**1998**	**1999**	**2000**	**1997**	**1998**	**1999**	**2000**
Boulder	27	15	26	12	0	2	1	0	63	132	49	43
Kennedy	13	6	7	5	0	0	0	0	181	147	82	36
Otatso	16	19	15	9	0	0	0	0	220	278	152	120
Lee	--	--	19	56	--	--	0	0	--	--	3	3
Divide	27	3	--	--	1	0	--	--	44	18	--	--
Totals	83	43	67	82	1	2	1	0	508	575	286	202

Table 3. Total numbers and means and ranges in total lengths (TL) and weights for bull trout caught in the Boulder, Kennedy, Otatso, and Lee Creek traps, St. Mary River drainage, Montana, 1997-2000.

Creek, Variable	Juvenile Bull Trout (< 300 mm)				Adult Bull Trout (≥ 300 mm)			
	1997	1998	1999	2000	1997	1998	1999	2000
Boulder								
N	30	23	36	31	17	64	23	23
Mean TL (mm)	211	183	180	186	494	493	538	500
Range	178-255	163-235	158-216	162-222	416-586	311-690	389-695	346-763
Mean Weight (g)	81	47	47	53	1048	1121	1532	1255
Range	44-144	24-104	32-86	36-88	654-1650	306-2678	582-3220	310-3754
Kennedy								
N	1	6	10	2	32	38	20	9
Mean TL (mm)	156	230	189	249	513	442	478	485
Range	---	190-279	145-213	222-275	356-720	316-650	361-603	340-633
Mean Weight (g)	26	107	59	158	1172	808	968	1187
Range	---	52-200	26-86	116-200	406-2504	256-2236	430-1700	306-2230
Otatso								
N	1	17	6	1	16	19	11	12
Mean TL (mm)	196	203	207	217	463	448	441	417
Range	---	166-291	185-246	---	304-617	307-615	321-531	335-660
Mean Weight (g)	58	75	72	94	840	829	779	726
Range	---	34-246	46-120	---	234-1720	298-2108	288-1272	314-2312
Lee								
N			69	84			19	4
Mean TL (mm)			184	193			432	427
Range			137-289	130-272			358-580	335-606
Mean Weight (g)			53	64			720	636
Range			20-190	20-196			358-1710	276-1418

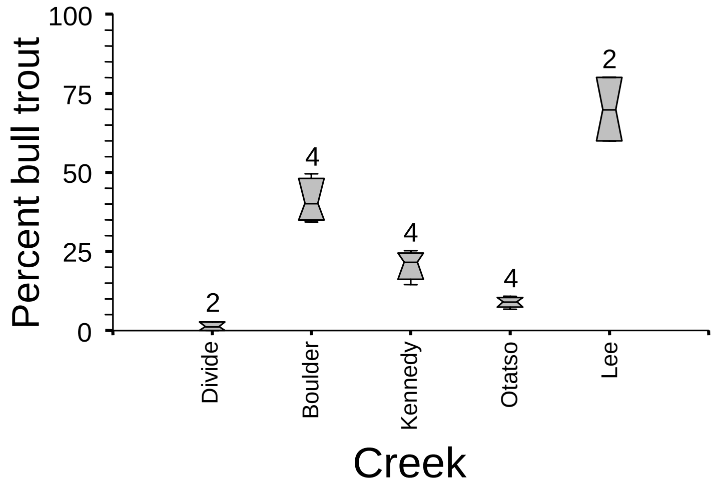

Figure 11. Box plots of percent bull trout in samples caught in traps in five creeks, 1997-2000. Box plots indicate the median value at the box notch, interquartile range by the box itself, and the range of values by horizontal lines at the end of vertical lines. Numbers indicate number of samples (years).

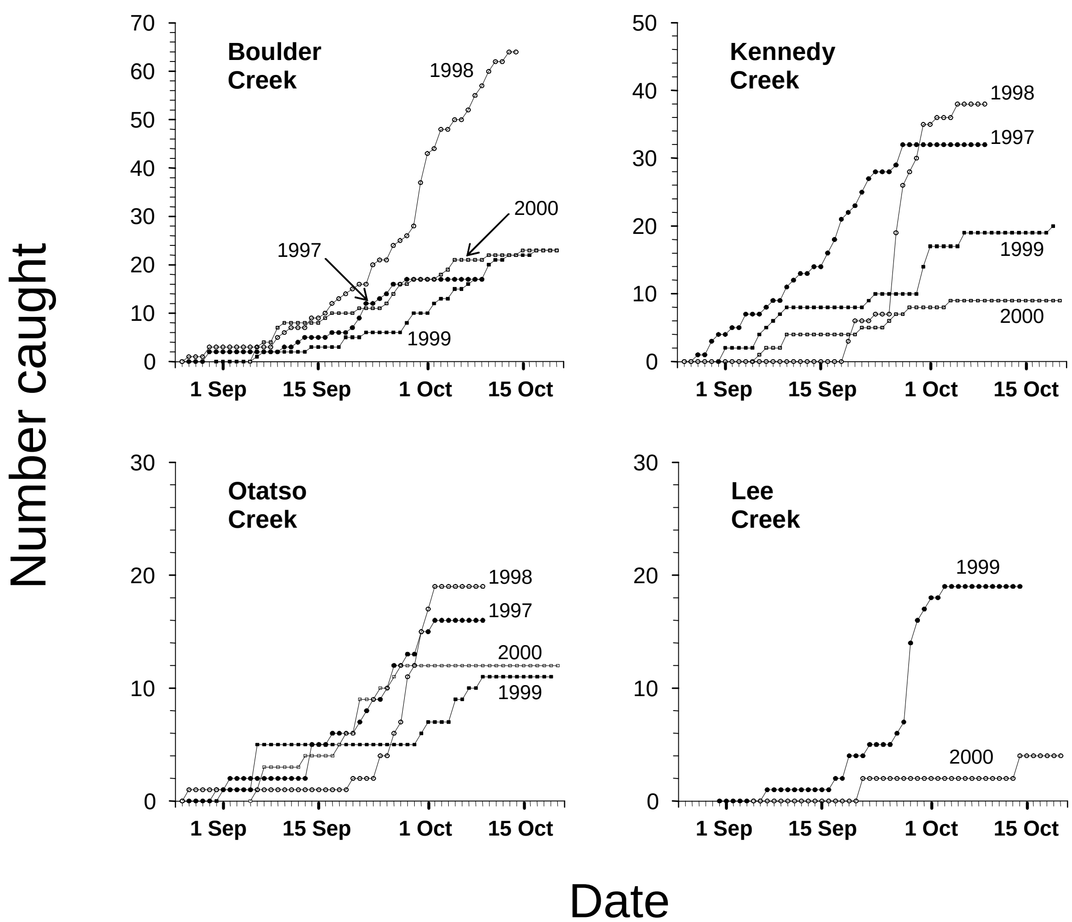

Figure 12. Cumulative catches of adult bull trout (≥ 300 mm TL) in the Boulder, Kennedy, Otatso, and Lee Creek traps, St. Mary River drainage, Montana, August-October, 1997-2000.

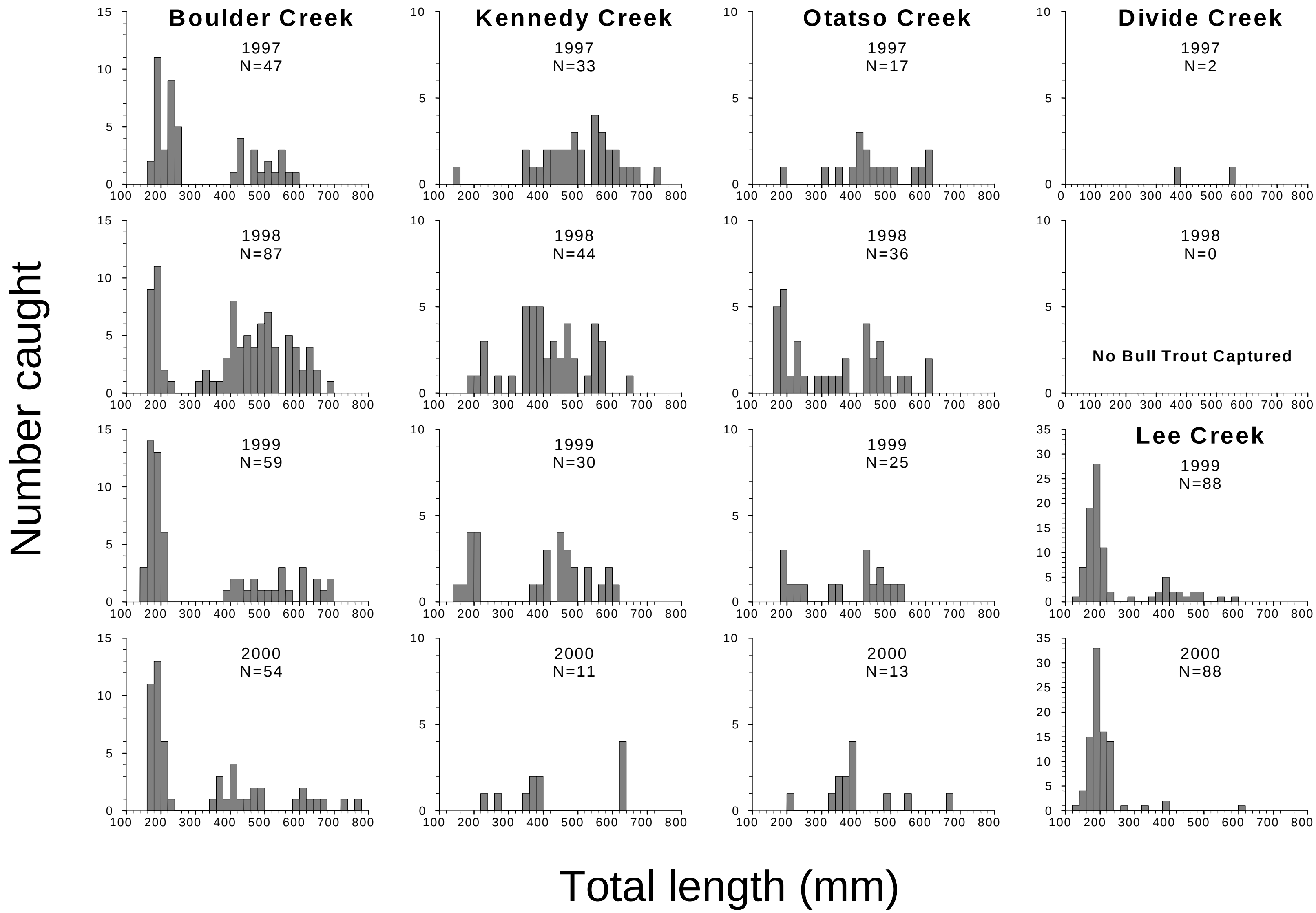

Figure 13. Length-frequency distributions for bull trout caught in Boulder, Kennedy, Otatso, Divide and Lee Creek traps, St. Mary River drainage, Montana, 1997-2000.

Bull Trout Population Size

When the POPAN-5 model was fitted to each of the 11 data sets, 7 sets afforded estimates of bull trout population size. Convergence to a population estimate was not achieved for the remaining data sets. Only models with constant Phi, *p*, and *pent* parameters afforded population estimates, each of which (Table 4) represents (Williams et al. 2002) the estimated total number of bull trout of the specified size-class available for capture at any time during the study.

Bull trout ≥ 200 mm TL were more abundant in Kennedy Creek than in Boulder Creek and fish of that size-class were more abundant than adult bull trout (i.e. ≥ 300 mm TL) in both Kennedy and Otatso creeks (Table 4). In both Kennedy and Otatso creeks, the populations of adult bull trout estimated on the basis of electrofishing data were more than twice as large as populations caught in the trap. Populations of adult bull trout caught in the Kennedy and Otatso Creek traps were two or more times larger than the mean number (22 ± 8) of adults in each trap sample, although the Otatso Creek population was smaller than that of Kennedy Creek.

Table 4. Bull trout population estimates and their measures of precision, based on fits of the Phi(.), *p*(.), *pent*(.), N formulation of the POPAN-5 model.

Creek	Capture method	Bull trout size-class	Estimated population size	Asymmetric confidence interval (95%)
Boulder	Electrofishing	≥ 200 mm TL	134	113-171
Kennedy	Electrofishing	≥ 200 mm TL	453	353-630
Kennedy	Electrofishing	≥ 300 mm TL	279	220-412
Kennedy	Trapping	≥ 300 mm TL	105	88-168
Otatso (Middle and Lower combined)	Electrofishing	≥ 200 mm TL	326	271-445
Otatso (Middle and Lower combined)	Electrofishing	≥ 300 mm TL	126	112-163
Otatso	Trapping	≥ 300 mm TL	49	43-84

Age Frequencies of Electrofished and Trapped Bull Trout

Scale-based age frequencies of bull trout caught by electrofishing or in traps differed consistently in the third-order creeks (i.e. Boulder, Kennedy, and Otatso) during years when both capture methods were employed (Figure 14). Although ranges in ages were similar between methods within all creeks, compared to adjacent age-classes age-4 bull trout were conspicuously scarce in trap samples, except in Lee Creek, the only second-order stream. Scarcity of age-4 fish in trap samples resulted in two modal groups that consisted mainly of ages 2-3 and ages 5-6. No age-4 or age-5 bull trout occurred in electrofishing samples from Lee Creek. In contrast, age-4 bull trout represented the most common age-class in electrofishing samples from Otatso Creek.

Movements of Tagged Bull Trout

Either VI (N = 84) or PIT (N = 770) tags were placed in 854 bull trout (Table 5), 628 (74%) of which had been caught by electrofishing and 226 (26%) in traps. On the basis of captured fish that already had excised adipose fins, 147 (23%) of the tagged bull trout were recaptured in subsequent years (Tables 6) and tags were retained in 139 (95%) of those fish. Most (84%) recapture events occurred in the creek where the fish had been tagged, although there were 35 instances of bull trout movements between creeks (Table 7). Such movements occurred among all creeks, except Divide, Lee, and Canyon. None of the few bull trout tagged in Divide (2 fish) or Canyon (22 fish) creeks was recaptured. An adult bull trout tagged in Kennedy Creek was recaptured in a net deployed on the headgate of the St. Mary Canal, as part of a study to estimate the extent of fish entrainment in the canal (Table 7; Mogen and Kaeding, 2002).

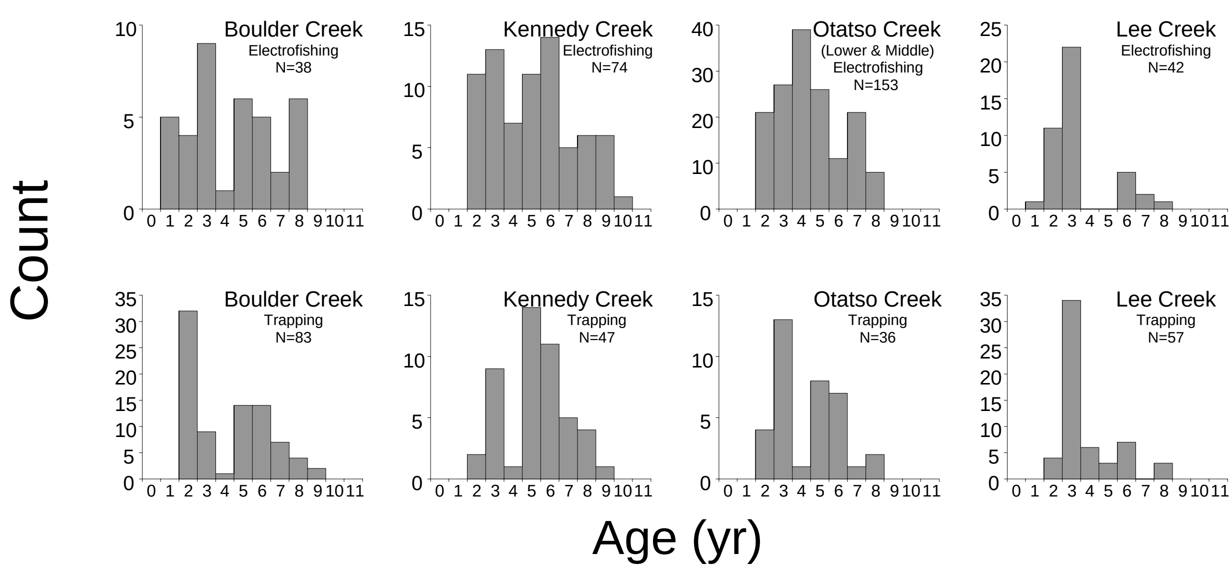

Figure 14. Age-frequency distributions for bull trout caught by electrofishing or in traps in Boulder, Kennedy, Otatso (1998 and 1999 combined) and Lee (1999) creeks.

Table 5. Total numbers of bull trout tagged in the St. Mary drainage, Montana, 1997-2003.

Year, Method of Capture	**Divide Creek**	**Boulder Creek**	**Kennedy Creek**	**Lower Otatso**	**Middle Otatso**	**Slide Lakes**	**Lee Creek**	**Canyon Creek**	**Combined Totals**
1997 (VI Tags)									
Trapping	2	34	32	16	---	---	---	---	84
1998 (PIT Tags)									
Electrofishing	---	11	22	---	39	0	25	---	97
Trapping	0	53	28	17	---	---	---	---	98
Combined	0	64	50	17	39	0	25	---	195
1999 (PIT Tags)									
Electrofishing	---	2	17	5	41	0	8	---	73
Trapping	---	6	4	4	---	---	10	---	24
Combined	---	8	21	9	41	0	18	---	97
2000 (PIT Tags)									
Electrofishing	---	10	61	13	17	3	5	---	109
Trapping	---	11	3	4	---	---	2	---	20
Combined	---	21	64	17	17	3	7	---	129
2001 (PIT Tags)									
Electrofishing	---	7	36	11	---	---	7	---	61
2002 (PIT Tags)									
Electrofishing	0	14	27	9	4	13	1	22	90
2003 (PIT Tags)									
Electrofishing	29	11	36	21	53	47	1	0	198
Grand Total	31	159	266	100	154	63	59	22	854

Table 6. Summary of annual bull trout tagging and recapture events, St. Mary River drainage, Montana, 1997-2003. Numbers in parentheses are percent maximum possible value, based on the number of tags at large, for that category.

Year	Number of fish tagged that year	Maximum tags at large at end of field season	Number of recapture events for fish tagged 1-5 years earlier					
			1 year	2 years	3 years	4 years	5 years	Combined
1997	84	84	---	---	---	---	---	---
1998	195	279	24 (29)	---	---	---	---	24 (28.6)
1999	97	376	41 (21)	7 (8)	---	---	---	48 (17.2)
2000	129	505	9 (9.0)	34 (17)	5 (6)	---	---	48 (12.8)
2001	61	566	13 (10)	1(1)	12 (6)	1 (1)	---	27 (5.3)
2002	90	656	9 (15)	14 (11)	1 (1)	4 (2)	---	28 (4.9)
2003	198	854	15 (17)	7 (11)	9 (7)	2 (2)	4 (2)	37 (5.6)

Table 7. Summary of bull trout tagging and recapture events, 1997-2003 combined, by location of initial capture, St. Mary River drainage, Montana. Numbers in parentheses is percent for that tagging location, or of the total numbers of either fish tagged or recapture events.

Tagging location	Number of fish tagged 1997-2002	Number of fish recaptured 1998-2003	Number of recapture events 1998-2003	Location of recapture events								
				Divide	Boulder	Kennedy	Lower Otatso	Middle Otatso	Slide Lakes	Lee	Canyon	St.Mary Canal
Divide Creek	2	0	0	0	0	0	0	0	0	0	0	0
Boulder Creek	148	51 (35)	82	0	78 (96)	2 (2)	2 (2)	0	0	0	0	0
Kennedy Creek	230	58 (25)	81	0	8 (10)	63 (78)	9 (11)	0	0	0	0	1 (1)
Lower Otatso	79	27 (34)	37	0	1 (3)	10 (27)	25 (67)	1 (3)	0	0	0	0
Middle Otatso	101	4 (4)	5	0	0	0	0	5 (100)	0	0	0	0
Slide Lakes	16	1 (6)	1	0	0	0	0	1 (100)	0	0	0	0
Lee Creek	58	6 (10)	7	0	0	0	0	0	0	7 (100)	0	0
Canyon Creek	22	0	0	0	0	0	0	0	0	0	0	0
Total	656	147 (23)	213	0	87 (41)	75 (35)	36 (17)	7 (3)	0	7 (3)	0	1 (1)

Redd Surveys

Bull trout spawning areas were found only in Boulder and Kennedy creeks. In addition, during electrofishing in 2003 we observed several bull trout spawning in the Slides Lakes reach, just upstream from the lakes (Figure 1). In Boulder and Kennedy creeks, spawning areas were 3 km and 2 km long and occurred in areas of probable groundwater upwelling, just downstream from the regions of entirely subsurface flow. Redds were often associated with nearby undercut banks, root wads, debris jams, or beaver dams and were constructed in substrates that appeared to range from fine gravel (~10-mm diameter) to small cobble (< 150-mm diameter). Although seemingly comparable substrates occurred downstream from both Boulder and Kennedy Creek spawning areas, as well as at various locations in Divide Creek, no redds were found in those areas. Mean numbers of redds counted annually did not differ between the two creeks (ANOVA, $F_{1,11} = 1.41$, $P = 0.26$; overall mean, 24 $\pm$ 5.2 redds), nor were they correlated between creeks ($P = 0.39$).

Bull Trout Genetic Analyses

Spruell and Neraas (2003) used eight microsatellite loci to describe the genetic population structure of bull trout in Glacier National Park, including the St. Mary River drainage. Allele frequencies of bull trout in samples that we collected east of the Continental Divide differed significantly from those for bull trout west of the divide. In addition, genetic differences in bull trout were evident among some creeks in the St. Mary River drainage, particularly Otatso, Canyon, and Lee creeks. Analyses also suggested more interbreeding of bull trout among sampling locations in the St. Mary River drainage than in areas west of the divide, where the sampled bull trout had been caught from lakes in different drainages.

Genetic analyses provided no evidence of hybridization between bull trout and brook trout in the St. Mary River drainage (Paul Spruell, personal communication). However, while electrofishing Boulder Creek in 2002, we caught a 467 mm TL bull trout that appeared to be a hybrid on the basis of external morphological characteristics, namely, vermiculations on the dorsal surface and black spots on the dorsal fin. That fish, which was not sampled for subsequent genetic analyses, was the only apparent bull trout × brook trout hybrid that we captured.

DISCUSSION

Bull trout were widely distributed and often locally abundant in the tributaries of the St. Mary River. Although we did not examine Red Eagle and Swiftcurrent creeks, nor the St. Mary lakes, Lake Sherburne, Cracker Lake, or the St. Mary River itself as part of the study described here, bull trout are known to also occur in those waters (Fredenberg 1996, Michels 1996, Mogen and Kaeding 2003). Thus bull trout presently occur in all of the creeks and lakes that they historically inhabited in the St. Mary River drainage in Montana.

Bull trout in Boulder and Kennedy creeks spawned in areas of probable groundwater upwelling, as has been reported for this species elsewhere (e.g., Fraley and Shepard 1989, Boag and Hvenegaard 1997). However, those Boulder and Kennedy Creek locations were not the only areas where bull trout spawned. The occurrence of age-0 bull trout indicated recent spawning and reproduction in each creek in which bull trout were found, except Divide and lower Otatso. Furthermore, annual reproduction was indicated by the occurrence of multiple age-classes of young bull trout. In contrast, the single year-class of young bull trout in Divide Creek suggested only periodic reproduction there. Divide Creek's bull trout spawning stock was especially small, as indicated by the capture of only two adult fish in the trap and a single adult by electrofishing. Although we have no explanation for the scarcity of that spawning stock, small stock size, coupled with widely varying reproductive success among years, probably account for the single year-class of young bull trout that we found in the creek. In lower Otatso Creek, the mostly embedded gravels and cobbles (and associated absence of groundwater upwellings) may not be conducive to bull trout spawning. Instead, bull trout probably spawn in middle Otatso, where the large rubble and turbulent flows may make their redds difficult to observe. Bull trout also spawned in the Slide Lakes reach, but those spawners probably reside in the Slide Lakes themselves.

Although our estimates of bull trout age could not be validated using known-age fish (cf. Beamish and McFarlane 1983), our analyses suggested scale annuli were broadly representative of age of bull trout in the St. Mary River drainage. When errors in age estimates occurred, they probably resulted most often in underestimates of actual age for bull trout $\geq$ age 5, i.e. mature fish. Bull trout in St. Mary River tributaries had growth rates similar to those of bull trout in Montana's Flathead River drainage (Fraley and Shepard 1989), Idaho's Priest lakes (Bjornn 1961), and elsewhere (Goetz 1989). The marked growth of age-4 bull trout probably resulted from their ontogenetic transition to a largely piscivorous diet, as has been reported for other populations of the species (Rieman and McIntyre 1993).

Cumulative catches of ostensibly post-spawning bull trout in traps suggested most migratory fish had spawned by late September, although those fish continued to be caught in early October in most years. Fraley and Shepard (1989) concluded that post-spawning bull trout generally departed tributaries soon after spawning in the Flathead River drainage. Bull trout spawning has been reported to occur when seasonal creek temperatures decline to between 9°C and 5°C (McPhail and Murray 1979, Fraley and Shepard 1989, Clayton 1998) in the fall, temperatures similar to those of the St. Mary River tributaries in September.

Scarcity of age-4 bull trout in trap samples from Boulder, Kennedy, and Otatso creeks suggested most migratory, age-4 bull trout were immature. Those age-4 fish must have inhabited either the St. Mary lakes or St. Mary River, which are probably more-productive habitats than the tributaries. The marked growth of age-4 bull trout revealed by our analyses supported that age-based pattern of habitat use. Trap samples also indicated that migratory bull trout in the St. Mary River drainage reached first maturity mainly as age-5 fish, at which our scale analyses indicated most bull trout were ≥ 300 TL. Unlike in Boulder, Kennedy, and Otatso creeks, the trap in Lee Creek was far upstream from the St. Mary River. Consequently, bull trout caught in the Lee Creek trap may have consisted primarily of resident and few migratory fish. This may explain why the age structure for bull trout caught in the Lee Creek trap differed from those for bull trout caught in traps in the other creeks. Most spawning by bull trout in Lee Creek may occur downstream from our trap, particularly in low-water years.

Trap samples indicated juvenile migratory bull trout departed creeks as age-2 or age-3 fish. Studies of other bull trout populations indicated most juveniles of migratory stocks remained in natal creeks 1 to 3 years before moving downstream to lakes or large rivers (Bjornn 1961, McPhail and Murray 1979, Oliver 1979, Fraley and Shepard 1989). Because our traps were operated between late August and mid-October, the entire annual period of juvenile bull trout movement from tributaries could not be determined. Juveniles moved downstream between June and August in the Flathead River drainage (Fraley and Shepard 1989) and throughout the summer and fall in the Wigwam River drainage, British Columbia (Oliver 1979).

Population estimates suggested that spawning stocks of migratory bull trout are much larger than indicated by the annual catches of those fish in traps alone. Moreover, when populations could be estimated based on data from both capture methods, size of the adult population based on electrofishing was larger than that caught in the trap. That observation suggested either (1) the spawning period for some migratory fish extended into late October, after traps had been removed; (2) many post-spawning, migratory bull trout lingered in creeks before moving downstream, after the traps had been removed; (3) many migratory bull trout did not spawn annually; (4) bull trout ≥ 300 mm TL in our electrofishing samples included resident fish; or (5) a combination of these factors. In any case, our data indicated that the annual catch of adult bull trout in a trap alone was not an index of spawning stock size.

Our tag-recapture data revealed bull trout movements among all creeks, except Divide, Canyon, and Lee. Each of those three creeks is characterized by small size of its bull trout population or distinct isolation from the other study creeks, either of which may explain our inability to detect between-creek movements of bull trout tagged in those creeks. Movements of bull trout were both upstream and downstream over the St. Mary Diversion dam, as well as downstream over the rockslide that formed the Slide Lakes. None of those movements had been anticipated prior to our study. Although the effects of those movements on the bull trout genomes of each creek are unknown, the movements suggest that the spawning stocks of those creeks are not entirely reproductively isolated.

Both migratory and non-migratory bull trout remain in the St. Mary River drainage. Migratory fish constitute the most obvious form because they were caught in traps or were recaptured in creeks other than those in which they had been tagged. In contrast, although resident bull trout probably also occur in several of the creeks, it was not possible to precisely identify those fish. Studies have shown that growth rates of resident salmonids may not differ from those of migratory fish (McCart 1997) and we found no consistent within-age differences in mean TL of bull trout caught by electrofishing or in traps in creeks where those methods were concurrently employed. However, the abundance of age-4 bull trout in electrofishing samples from Kennedy Creek and lower and middle Otatso Creek, which contrasted with Boulder Creek, may have indicated the presence of numerous resident fish. That speculation is based on the observation that age-4 bull trout were conspicuously scarce in trap samples, which we assumed consisted entirely of migratory fish. One of our tagged bull trout moved downstream from Slide Lakes into the middle Otatso reach, but we saw no reciprocal movements. Nevertheless, it is unclear whether bull trout in the Slide Lakes reach should be considered a resident or isolated population (sensu McCart 1997) because the rockslide that forms the lakes is probably only a seasonal barrier to the upstream movement of fish.

Westslope cutthroat trout were found in three creeks in the St. Mary River drainage, and one of those populations (Wild Creek) apparently consisted of genetically pure fish. Westslope cutthroat trout may have never been widespread or abundant in the St. Mary River drainage (Marnell 1988). Their populations that became established in the Glacier National Park part of the drainage may have occurred only in creeks where they were secure from the highly predacious, native lake trout that subsequently and naturally colonized the St. Mary lakes.

Factors That May Limit Bull Trout

Milk River Project effects on bull trout

In reaching its decision to list the bull trout as a threatened species, the Service concluded (*Federal Register* 64: 58910), among other things, that bull trout in the St. Mary River drainage are negatively affected by operation of water-storage and delivery systems that are part of the Milk River Irrigation Project. Results of our study and concurrent investigations support several Service conclusions important to reaching that decision, including that bull trout are entrained in the St. Mary Canal (Mogen and Kaeding 2002). Because the canal headgates are barriers to the upstream movement of fish, bull trout entrained in the canal are unlikely to return to the river and therefore are lost from the reproducing population. In addition, our results from radio telemetry, which will be described in a subsequent report, suggested the acute reductions in discharge from Sherburne Dam in the fall produced low-flow conditions downstream in Swiftcurrent Creek that led to the deaths of two bull trout.

Although the Service also concluded (*Federal Register* 64: 58910) that the St. Mary Diversion is a substantial barrier to the movement of bull trout in the river, results of the present study showed upstream and downstream movements of bull trout past the dam. Timing of those movements is not precisely known but may have been when the dam was open, usually between October and April. Our radiotelemetry work (Mogen and Kaeding 2003), however, indicated the dam is at least a seasonal barrier to the movement of bull trout in the river. Nevertheless, the present study revealed more extensive movements of bull trout among St. Mary River tributaries than had earlier been suspected (*Federal Register* 64: 58910).

Effects of nonnative fishes on bull trout

Brook trout constituted a small portion of the fish communities in St. Mary River tributaries. Although other studies have reported that bull trout rarely coexist with brook trout (e.g., Watson and Hillman 1997, Paul and Post 2001, Rich et al. 2003), we found no evidence that brook trout, which have persisted in the drainage for many decades, had displaced or were displacing bull trout in tributaries. Similarly, although hybridization has been considered a common problem where bull trout are sympatric with brook trout (Cavender 1978, Leary et al. 1993, Kanda 2002) and the Service concluded (*Federal Register* 64: 58910) that such hybridization was a threat to bull trout in the St. Mary River drainage, we found only one probable brook trout × bull trout hybrid. Furthermore, laboratory analyses of tissues taken from bull trout revealed no evidence of hybridization with brook trout. Thus hybridization with brook trout does not appear to be an emerging threat to the bull trout genome. Finally, the Service also concluded that brown trout posed a threat to bull trout in the drainage, but we found no brown trout in the St. Mary River tributaries.

Management Recommendations

On the basis of information described in the present report and in preceding reports that described our radiotelemetry and canal work (Mogen and Kaeding 2003), we offer several recommendations for actions that would benefit bull trout in the St. Mary River drainage. (1) Year-round movement of adult bull trout over the St. Mary Diversion dam should be facilitated. This would probably require installation of a fish-passage structure (i.e. "ladder"), perhaps on either a modified or completely reconstructed dam. (2) Water should be released from Sherburne Dam to provide adequate winter habitat for bull trout downstream in Swiftcurrent Creek. Among other things, this would apparently require modification of the Sherburne Dam outlet works. (3) Entrainment of bull trout in the St. Mary Canal should be prevented. This may require installation of a fish screen or other barrier, perhaps as part of a modified or completely reconstructed dam. The Bureau, in cooperation with our office, is presently investigating the effectiveness of an electric fish barrier installed on the St. Mary Canal headgate in early 2003. (4) An assessment of the effects of water diversion into the St. Mary Canal (i.e. removal of water from the drainage) on bull trout habitat in the St. Mary River downstream from the diversion should be performed. Our radiotelemetry study showed that many adult bull trout inhibit the St. Mary River downstream from the diversion, in both Montana and Alberta, during the non-spawning season (Mogen and Kaeding 2003). It is important that that feeding and wintering habitat for bull trout be maintained and that adverse effects to that habitat that result from reductions in stream flow be identified and remediated, if possible.

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