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Large-Scale, Seasonal Movements of Radiotagged, Adult Bull Trout in the St. Mary River Drainage, Montana and Alberta

Abstract

Radio telemetry was used to determine the large-scale, seasonal movements and wintering areas of adult bull trout (*Salvelinus confluentus*) in the St. Mary River drainage, Montana and Alberta, between 1998 and 2003. The fish ($n = 42$; total length, 434–763 mm) had been radiotagged in their spawning creeks (river tributaries) during August–October. Data from automated, stationary radio receivers operated adjacent to the river showed the post-spawning and subsequent pre-spawning movements of tagged bull trout occurred during October–November and May–July, respectively. Searches conducted from the ground and aircraft during winter (December–April) found tagged fish ($n = 22$) distributed in the St. Mary River between the mouth of Lee Creek (Alberta) and Lower St. Mary Lake (Montana), and in the tributaries ($n = 15$ fish). Maximum stream distance between contact locations for individual fish (median, 25.5 km; range, 1–83 km) was not associated with fish length or weight when tagged. Some bull trout passed the St. Mary River diversion dam, although passage timing was not precisely determined and may have occurred when the dam was open. Nevertheless, upstream passage of some bull trout appeared to be impeded by the dam during pre-spawning movements, when the dam was closed for the irrigation season.

Introduction

The bull trout (*Salvelinus confluentus*) is primarily a freshwater fish whose natural range extends from northern areas of California and Nevada to upstream regions of the Yukon River basin in Alaska and the Yukon, encompassing Puget Sound and most major coastal river systems in Washington, British Columbia, and southeast Alaska (Cavender 1978; Haas and McPhail 1991; Nelson and Paetz 1992). 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 South Saskatchewan River basin in Montana.

Highly piscivorous as adults, bull trout usually mature when 5–7 years old and spawn entirely in coldwater streams, primarily second- to fourth-order tributaries (Fraley and Shepard 1989; Mogen and Kaeding 2005; 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 movements (e.g., McCart 1997). Non-migratory bull trout spend their lives entirely within their natal stream, whereas migratory fish spawn in small streams but their young eventually move downstream to either rivers or lakes, where the fish mature. Bull trout may travel more than 250 km to reach spawning areas (e.g., Fraley and Shepard 1989). After spawning, migratory adult bull trout return to the rivers or lakes.

The bull trout was classified as a "threatened" species throughout the contiguous United States, under the U.S. Endangered Species Act, in 1999 (USFWS 1999). Although they are not similarly classified under the Canadian Species at Risk Act, bull trout are considered a "Group 1—Highest Priority Candidate" species by Canada's Committee on the Status of Endangered Wildlife. Central to the classification in the United States was the belief that many migratory bull trout had been lost due to the construction of dams or other barriers to fish movement. Information on "threatened" bull trout east of the Continental Divide was especially meager, however. On the basis of interviews of elderly Alberta anglers and a review of agency reports, Fitch (1997) concluded that migratory bull trout no longer occurred in the St. Mary River (South Saskatchewan River basin) in Alberta but the species persisted in the river's tributaries in Alberta and Montana. However, Mogen and Kaeding (2005) subsequently caught post-spawning, ostensibly migratory bull trout in

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traps operated near the mouths of the tributaries in Montana. Objectives of our present study, conducted between 1998 and 2003, were to determine (1) the timing of the pre- and post-spawning movements of migratory, adult bull trout in the St. Mary River; (2) the wintering areas of adult bull trout captured in their spawning tributaries of the river in Montana; and (3) the extent to which the St. Mary River diversion dam impeded bull trout movements.

Study Area

The St. Mary River begins at Gunsight Lake in Glacier National Park (GNP) and flows northeast 13 km before entering St. Mary Lake (16 km long; Fig. 1). From the 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 in Alberta.

Each major tributary of the St. Mary River examined during the present study begins at high elevation (> 1800 m) in GNP, flows mainly through coniferous forest, and supports spawning by bull trout (Mogen and Kaeding 2005). Boulder Creek (a third-order stream; Fig. 1) originates

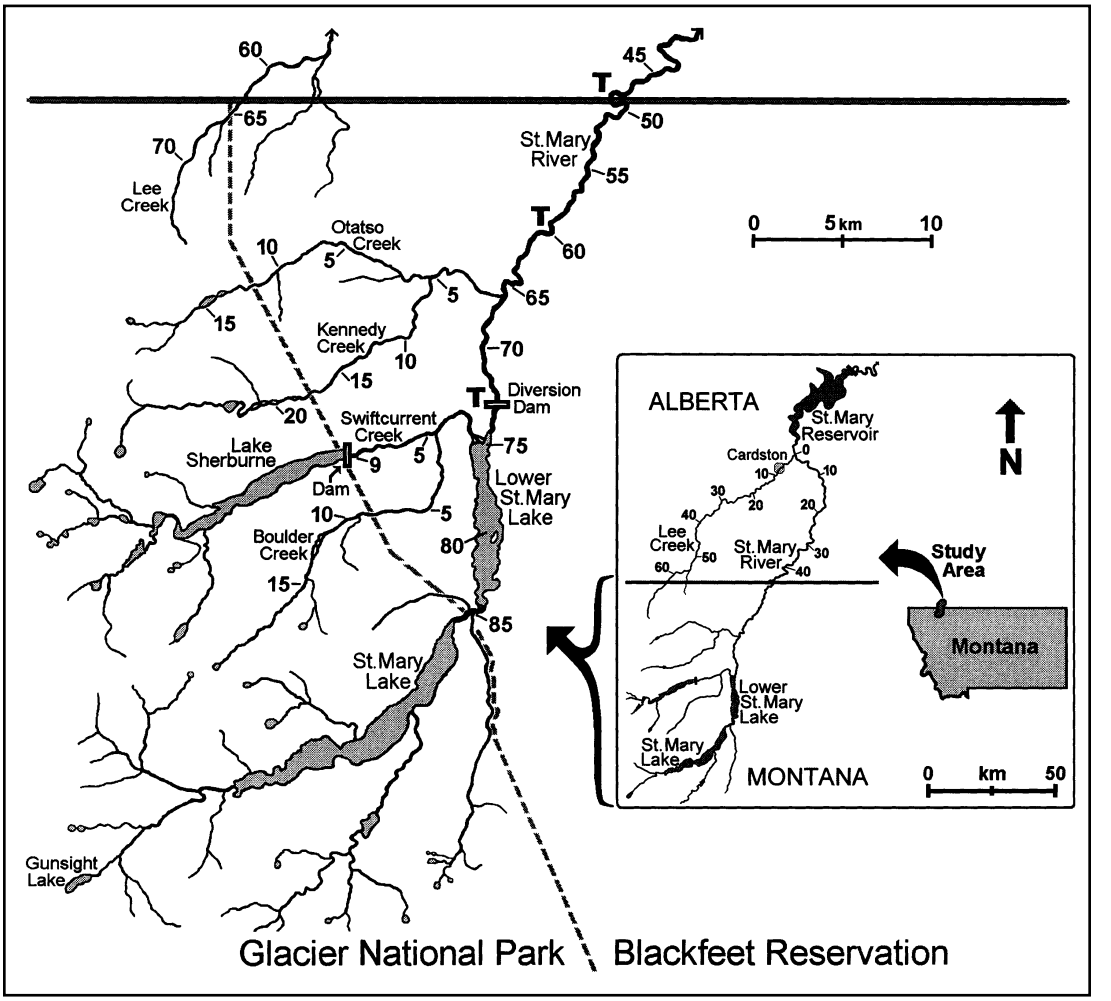

Figure 1. Study area and its relevant locations, St. Mary River drainage, Montana and Alberta. River distances (km) upstream from the confluence of the St. Mary River and Lee Creek, as well as from mouths of the major tributaries, are indicated. Locations of the 3 automated, stationary radio receivers are indicated by **T**.

from snowmelt and flows northeast 23 km before entering Swiftcurrent Creek, 4 km above Lower St. Mary Lake. 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. Otatso Creek (third order) begins at Otatso Lake and flows east 21 km before entering Kennedy Creek, 5 km above the St. Mary River. Lee Creek (third order) originates as snowmelt and flows north 13 km before crossing the international border. From the border the creek meanders 64 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. Discharges of each of these creeks rarely exceed 0.5 m^3/s during the seasonal low-flow period (i.e., late summer through winter).

Between 1906 and 1924, several water-control and delivery structures were built in the St. Mary River drainage in Montana. They included Sherburne Dam on Swiftcurrent Creek, which created Lake Sherburne, as well as a 2-m-high diversion dam 1.2 km downstream from Lower St. Mary Lake on the St. Mary River (Fig. 1). Water is released from Sherburne Dam almost exclusively during the irrigation season (i.e., April–September) and the diversion dam is closed (thereby diverting much of the river into a canal) only during that time. Additional water- or land-use practices that may impair bull trout habitat are limited in the St. Mary River drainage in Montana (Mogen and Kaeding 2005).

Salmonids indigenous to the drainage include bull trout, westslope cutthroat trout (*Oncorhynchus clarki lewisi*), and mountain whitefish (*Prosopium williamsoni*), all of which are believed to have occurred in all of the streams and lakes to which they had access, while lake trout (*S. namaycush*) inhabit the St. Mary and Lower St. Mary lakes (Brown 1971). Nowhere else in the contiguous United States were bull trout naturally sympatric with lake trout (Donald and Alger 1993). Introduced, nonnative salmonids that have established self-sustaining populations at various locations in the drainage include brook trout (*S. fontinalis*) as well as rainbow trout (*O. mykiss*), Yellowstone cutthroat trout (*O. c. bouvieri*), and genetic intergrades (i.e., "hybrids") among the 3 oncorhynchids (Brown 1971; Marnell 1988; Mogen and Kaeding 2005).

Methods

Capture of Bull Trout

Bull trout were caught either by electrofishing in an established sampling reach of each creek during August, or in traps continually operated between late August and mid-October near creek mouths or in Lee Creek near the international border. Traps were primarily intended to capture downstream-moving, post-spawning bull trout. Bull trout were measured to total length (TL, mm) and weighed (g); we did not distinguish between sexes. Passive integrated transponder (PIT) tags, each uniquely coded, were injected into muscle directly below the dorsal fin of each bull trout. Capture methods were extensively described by Mogen and Kaeding (2005).

Radio Transmitters and Their Implantation

Radio telemetry was used to determine the seasonal movements and wintering areas of adult bull trout. Forty-two bull trout (mean TL, 568 mm; range, 434–763 mm) were surgically implanted with radio transmitters: 13 fish in 1998, 7 in 1999, 7 in 2000, and 15 in 2001. On the basis of scale annuli, length-frequency distributions, and the recapture and repeated ageing of tagged fish over several years, Mogen and Kaeding (2005) concluded that bull trout of this size were adults and at least 6 years old. Fifteen radiotagged bull trout had been caught by electrofishing and 27 in traps. Seventeen radiotagged bull trout had been caught from Boulder Creek, 15 from Kennedy, 8 from Otatso, and 2 from Lee Creek.

Transmitters (Advanced Telemetry Systems [ATS], Isanti, MN) had external antennas, were powered by batteries that had estimated minimum lives of either 287 d or 475 d, weighed ~ 18 g or ~ 24 g in air, and emitted unique signals in the 30 MHz range (each transmitter separated by at least 10 kHz). Small transmitters were implanted in 8 small bull trout (mean weight, 958 g), whereas large transmitters were implanted in large bull trout (mean weight, 1628 g). Transmitter weight exceeded 2.0% of recipient fish weight in air (cf. Winter 1996) for 8 fish but did not exceed 2.5%.

Transmitters were implanted in anesthetized (tricaine methanesulfonate) bull trout via a 3-cm-long, longitudinal incision made just anterior to the left pelvic fin base, ~ 2 cm from the mid-ventral

line. We used an angiocath (12 gauge) in a modified shielded-needle technique similar to that of Ross and Kleiner (1982) to make an outlet for the external antennae ~ 2 cm posterior to the left pelvic fin base. Incisions were closed with 4–5 non-absorbable nylon, monofilament sutures. Each surgery lasted 4–7 min, during which the fish's gills were continuously irrigated with water and dilute anesthetic. Beginning ~ 1 min before surgery completion, fresh water alone was used to hasten recovery from the anesthetic. Radiotagged bull trout were released at their site of electrofishing capture or just downstream from the capture trap as soon as they had recovered.

Tracking Radiotagged Bull Trout

Active searches for radiotagged bull trout were conducted from the ground and aircraft, and passive searches were conducted by automated, stationary receivers. An ATS Model 2100 receiver, equipped with a directional loop antenna, was used to track fish. Only about half of the St. Mary River in Montana was accessible using trucks or all-terrain vehicles and the creeks in Montana and the entire St. Mary River in Alberta were inaccessible. Boat-based tracking was even more constrained because of small creek size and limited access. Consequently, beginning in 2000, tracking from a fixed-wing aircraft became the principal method for active searches.

The airplane had loop antennae attached to struts on both wings and flew 90–120 km/h, ~ 150 m above the water during searches. Although high winds and low clouds frequently precluded aerial searches, particularly near the mountains (i.e., especially affecting searches of creeks), when flights were possible the entire river between St. Mary Lake and St. Mary Reservoir was usually flown in both downstream and upstream directions. Altogether, 15 searches of the entire river were conducted between 2000 and 2003, most (11) in 2002 and 2003. Among the 15 searches, 9 (60%) were conducted between January and May and 5 (33%) during September or October. Locations of tagged fish were recorded on topographic maps and by the global-positioning system in the aircraft. Accuracy of those locations was within ~ 0.2 km, based on our ability to locate 2 transmitters periodically placed at fixed locations in the river during aerial searches. Although the creeks were searched less frequently than the river from the air, we periodically searched for radiotagged bull trout while walking to and from electrofishing areas. Locations along the St. Mary River were demarcated as river distances (km) upstream from the confluence of the river with Lee Creek; locations along creeks were similarly demarcated from each creek's mouth (Fig. 1).

If a radiotagged bull trout did not move after repeated contacts and its location was readily accessible, the fish was closely approached and either observed or displaced to assure that the transmitter remained in a living fish. When a transmitter remained stationary at an inaccessible location, we considered only the first contact in the series at that location to be with a living fish. For bull trout that ostensibly died (or expelled their transmitter), location data collected subsequent to the last contact when the fish was considered alive were excluded from further analyses. Radiotagged bull trout were sometimes recaptured during electrofishing or trapping (Mogen and Kaeding 2005). However, because the field crew did not routinely have a radio receiver and was therefore unable to determine whether the transmitter was functional, those recaptures were treated as radio contacts only when they were followed by a radio contact with the fish.

For passive searches, ATS Model DCC II data loggers, operated in concert with receivers and antennae of the aforementioned types, were established as automated, stationary receiving stations at 3 river locations where electric power was available and the equipment could be secured (Fig. 1). Data recorded by the stations revealed the passage of bull trout, particularly the periods of pre- and post-spawning movement. Station 1 (located 11 km upstream from the international border) was installed in January 1999, Station 2 (at the border) in January 2000, and Station 3 (at the diversion dam) in June 2000; the stations were continuously operated through 2002. When possible, the single loop antenna (positioned 5–10 m above the water) for each station was directed at a nearby river pool (20–80 m away) that may have provided resting habitat for adult bull trout. Stationary receivers scanned sequentially (5 s per frequency per cycle) for each deployed transmitter, as well as for "dummy transmitter" frequencies that we established between several of the most widely separated, successive transmitters.

Electronic interference often occurred during normal work-day hours and probably resulted

mainly from operation of extraneous motorized or electronic equipment. Because such interference could not be completely tuned out and sometimes resulted in the recording of erroneous contacts by stationary receivers, only records that consisted of at least 5 consecutive contacts outside the daily period of interference were tentatively considered reliable. Records that met that criterion were compared to records for neighboring actual or dummy transmitter frequencies at that location to assure that those records did not show a similar pattern of contacts, which would otherwise indicate common interference. If common interference was evident, the tentative transmitter record was considered unreliable and excluded from further analyses. For data recorded by each stationary receiver, only the initial contact among what may have been numerous contacts with a fish during a period of several days was used in subsequent analyses.

Statistical Analyses

One-way analysis of variance (ANOVA; Hintze 2001) was used to compare mean number and duration of radio contacts between fish that died during the study and fish that lived through the study period; mean duration of radio contact with fish that lived through the study and carried transmitters with either 287-d or 475-d batteries; and mean size when tagged of fish subsequently located during winter in creeks or the St. Mary River or Lower St. Mary Lake. Simple linear regression (Hintze 2001) was used to determine whether significant associations occurred between maximum stream distance between contact locations for individual bull trout and the fish's TL or weight when tagged. ANOVAs and regression analyses were preceded by routine tests to assure that the assumptions of normality and equal variances in the error term were met. When necessary, transformations of appropriate variables were performed to meet those assumptions (Neter et al. 1996). Significance level was set at $P < 0.05$ for all tests.

Results

Three radiotagged bull trout (1 from each of Boulder, Otatso, and Lee creeks) were not contacted after their release. Among the remaining 39 fish, 9 (23%) died some time after release and 30 (77%) were considered alive when last contacted. Altogether, 209 post-release contacts were made with radiotagged bull trout: 91 (43.5%) from the airplane, 62 (29.6%) by the stationary receivers, 38 (18.2%) during ground-based searches, and 18 (8.6%) during electrofishing or trapping. Mean duration of radio contact with bull trout that died (334 $\pm$ 161 d [95% confidence interval]) was significantly less than for fish that lived (731 $\pm$ 88 d). Mean number of contacts with bull trout that died (1.4 $\pm$ 0.7) was significantly less than for fish that lived (5.6 $\pm$ 1.5). Among the bull trout that lived, mean duration of radio contact was significantly less for fish given transmitters with 287-d batteries (401 $\pm$ 183 d) than for fish with 475-d batteries (797 $\pm$ 82 d). For the 30 bull trout that lived, maximum stream distance between contact locations for individual fish averaged 35.6 km (median, 25.5 km; range, 1–83 km). There was no significant association between the maximum distance and either the TL (range, 434–763 mm; mean, 568 mm) or weight (range, 760–3,754 g; mean, 1,624 g) of bull trout when tagged. Among the 9 bull trout that died, 5 died in the St. Mary River, 2 in Kennedy Creek, and 2 in Swiftcurrent Creek between the dam and Boulder Creek. The 2 bull trout died in Swiftcurrent Creek while stranded in shallow (< 1 m), ice-covered pools that remained after Sherburne Dam had been closed for the year.

Identification of Movement Periods

Stationary receivers recorded the presence of 20 different bull trout. Distribution of the 62 radio contacts with those fish, by month, was bimodal. Most contacts occurred in June–July and October but there were also many contacts in May, September, and November (Fig. 2). On the basis of these data (and those reported by

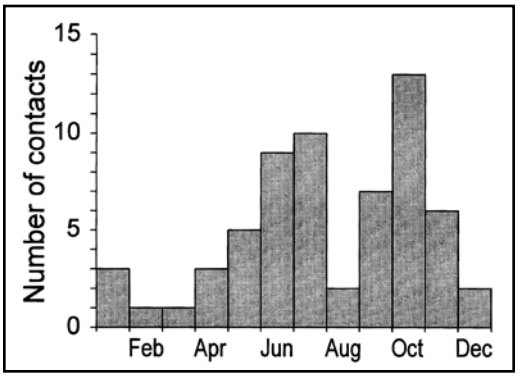

Figure 2. Distribution of 62 contacts with 20 radiotagged bull trout recorded by stationary receivers, by month, St. Mary River, 1999–2002.

Mogen and Kaeding [2005] for spawning time), we considered May–July and October–November as the periods of pre- and post-spawning movement of bull trout in the St. Mary River, respectively; August–September as the period of pre-spawn staging and spawning; and December–April as the winter period. Those periods were used as temporal constraints in analyses of radiotelemetry data obtained from active searches.

Winter Locations of Bull Trout

Active searches during the winter period resulted in 34 radio contacts with 22 different bull trout in the St. Mary River or Lower St. Mary Lake. Contact locations were distributed between the mouth of Lee Creek and the upstream end of the lake (Fig. 3). Bull trout that had been tagged in Kennedy or Otatso Creek were found farthest downstream, whereas the most upstream contact locations, in Lower St. Mary Lake, were with 3 fish that had been tagged in Boulder Creek. In addition, 1 Lee Creek fish (not in Fig. 3) was found near the confluence of Lee Creek and the St. Mary River.

Fifteen radiotagged bull trout were found in creeks during winter. Among those bull trout, 10 had been tagged in Boulder Creek, 3 in Kennedy Creek, and 2 in Otatso Creek. Among the 20 contacts with Boulder Creek fish, 15 were in Swiftcurrent Creek between the dam and Boulder Creek, 1 was in Swiftcurrent Creek downstream from Boulder Creek, and 4 were in Boulder Creek. Four bull trout tagged in Boulder Creek were found in a deep (~ 2 m) pool immediately downstream from the Sherburne Dam outlet, or in deep water that remained in the concrete outlet structure itself after the dam had been closed for the year. The 5 bull trout tagged in Kennedy or Otatso Creek were located in Kennedy Creek, either upstream or downstream from Otatso Creek.

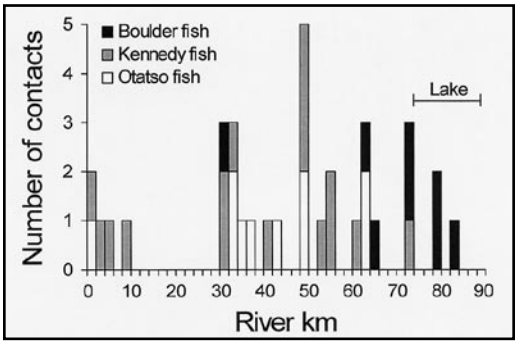

Figure 3. Locations (river km) of 34 contacts with 22 radiotagged bull trout in the St. Mary River and Lower St. Mary Lake during the winter period. See Figure 1 for key to river km. The creek from which the bull trout was originally captured (i.e., Boulder, Kennedy, or Otatso) is indicated.

Only 2 bull trout, both tagged in Boulder Creek, were found in creeks as well as the St. Mary River or Lower St. Mary Lake during winter. The 13 bull trout that were located exclusively in creeks during winter did not significantly differ from the 20 fish found only in the river or lake in either their mean TL or mean weight when tagged.

Among the 35 bull trout contacted during winter, 25 were contacted during only 1 winter, 7 during 2 winters, and 3 during 3 winters. For bull trout contacted during multiple winters, the maximum stream distance between winter contact locations for each fish averaged 6.6 km (median, 2 km; range, 0–20 km). Among the 35 bull trout contacted during winter, 17 (49%) were in the St. Mary River downstream from the diversion dam (7 in Montana; 10 in Alberta).

Passage of the Diversion Dam

Active searches revealed that 6 bull trout, all tagged in Boulder Creek, passed the St. Mary River diversion dam: 3 fish were only known to have moved downstream past the dam, 1 both downstream and upstream, 1 twice downstream and once upstream, and 1 twice in both directions. The precise timing of those movements could not be determined because long periods often occurred between consecutive contacts. In addition, the stationary receiver recorded the presence below the dam of 7 bull trout (3 Boulder, 2 Kennedy, and 2 Otatso Creek fish) that were not, when subsequently contacted during active searches, located upstream from the dam. Among the 15 contacts with those fish recorded by the stationary receiver, 12 (80%) occurred between April and September.

Discussion

Our ability to track radiotagged bull trout throughout the St. Mary River drainage was constrained by limited stream access and weather conditions that often precluded aircraft operations. Consequently, our active searches were best characterized as opportunistic and geographically restricted, rather than systematic and comprehensive across

the entire study area. Nevertheless, our results provided important insights into the large-scale, seasonal movements of adult bull trout in the St. Mary River drainage. Collectively, those movements encompassed the river from the mouth of Lee Creek upstream to Lower St. Mary Lake, most of Lee Creek, and the lower reaches of Boulder, Swiftcurrent, Kennedy, and Otatso creeks. Although none of the tagged fish was located there, bull trout are also known to occur in the drainage upstream from Lower St. Mary Lake (Mogen and Kaeding 2005). Thus, bull trout use the entire, accessible regions of the St. Mary River and Lee Creek upstream from St. Mary Reservoir (cf. Fitch 1997; USFWS 1999).

Nine (23%) of the radiotagged bull trout contacted after their release ostensibly died during our study. Although 2 bull trout died under the ice after being stranded in Swiftcurrent Creek, perhaps due to mammalian predators (e.g., Jakober et al. 1998) or the loss of habitable water, we have no explanations for the deaths of the remaining 7 fish. However, because each of the bull trout was at least 6 years old when tagged and few bull trout in the drainage may live more than 10 years (Mogen and Kaeding 2005), death of 23% of the fish during our study may reflect the natural mortality rate. Three (21%) of 14 radiotagged, adult bull trout died during a study in the Blackfoot River drainage in Montana (Schmetterling 2003), as did 23 (33%) of 70 adult bull trout radiotagged in the Morice River watershed in British Columbia (Bahr and Shrimpton 2004).

The pre-spawning movement of tagged bull trout in the St. Mary River began in May, as seasonal runoff was increasing to its annual peak. The post-spawning movement from creeks toward wintering areas occurred in October–November. In the Blackfoot River, Montana, the bull trout spawning migration began on the descending limb of the annual hydrograph in June, and the fish entered spawning creeks between late June and early July (Swanberg 1997). In the Athabasca River in Alberta, radiotagged bull trout arrived at spawning areas between late July and late August, and departed the areas in late August and September (McLeod and Clayton 1977). In the Morice River watershed, British Columbia, mean-daily movement rates of radiotagged bull trout were largest between June and September, the period of migration into spawning tributaries (Bahr and Shrimpton 2004).

We found no significant difference in fish size when tagged between bull trout subsequently located in creeks or the St. Mary River or Lower St. Mary Lake in winter. All of the bull trout that we studied were much larger than 300 mm TL, the approximate maximum size commonly reported for non-migratory (i.e., "resident") bull trout (e.g., Rieman and McIntyre 1993; Nelson et al. 2002). Nevertheless, many of the tagged fish had winter locations only in creeks, as would otherwise be characteristic of the non-migratory life-history form. That observation suggests that conventional criteria for distinguishing between migratory and non-migratory bull trout on the basis of fish size are not always appropriate (see also Mogen and Kaeding 2005). Bahr and Shrimpton (2004) concluded that the disparate movement patterns evident among adult bull trout in the Morice River watershed resulted from habitat availability rather than differences in life history.

In reaching its decision to list the bull trout in the St. Mary River drainage as a threatened species, the USFWS (1999) stated that the St. Mary River diversion dam is a substantial barrier to the movement of fish. However, our results from both radio telemetry and conventional tag-recapture techniques (Mogen and Kaeding 2005) showed upstream and downstream movements of bull trout past the dam. Although timing of those movements is not precisely known, many movements probably occurred when the dam was open between October and March. Nevertheless, our data also suggested that the upstream movements of some bull trout were impeded by the dam, particularly during pre-spawning movements when the dam was closed for the irrigation season.

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