Glacier National Park Fisheries Inventory and Monitoring

Annual Report – 2008

Glacier National Park Fisheries Inventory and Monitoring Annual Report – 2008

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Front cover photo captions (clockwise): Independent consulting biologist Craig Stafford and volunteer Elizabeth McGarry pull gill nets from Lake McDonald for mercury sampling (photo by Chris Downs); Akokala Lake in the North Fork Flathead River drainage (photo by Chris Downs); USGS Aquatic Ecologist Clint Muhlfeld counting migratory bull trout redds in Akokala Creek (photo by Chris Downs).

Inside cover photo captions (top and bottom): Adult bull trout from Lake Isabel (photo by Wade Fredenberg, USFWS); cutthroat trout captured in Rose Creek as part of St. Mary River drainage native fish surveys (photo by Jim Mogen, USFWS).

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2008 Mercury sampling in fish from Glacier National Park

ABSTRACT

We sampled four lakes in Glacier National Park to characterize mercury contamination in various fish species. Lake McDonald, Bowman Lake, and Harrison Lake were sampled on the west side of the park, while St. Mary Lake was sampled on the east side of the park. Lake trout, bull trout, and lake whitefish were tested on the west side of the park, while lake trout, bull trout, lake whitefish and burbot were tested on the east side of the park. Within species, lake trout and lake whitefish were similarly contaminated on both sides of the park. Among species, burbot and lake trout were similarly contaminated and lake whitefish generally had lower mercury concentrations than did lake trout, bull trout, or burbot. Within species comparisons revealed that Glacier National Park lake trout were more contaminated than those from Yellowstone Lake, while comparisons with other area lakes (i.e. Flathead, Swan, Waterton) indicated similar levels of contamination for both lake trout and lake whitefish. Fish consumption guidance was developed for visitors to the park who wish to consume fish caught in Glacier National Park.

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INTRODUCTION

Glacier National Park (GNP), located in northwest Montana, represents some of the most pristine and biologically diverse habitat for plants and animals found in the Intermountain West. Sitting at the core of the Crown of the Continent Ecosystem, GNP provides a diversity of stream and lake habitats for aquatic species. GNP covers over 1,000,000 acres, providing high-quality lentic and lotic fish habitat. GNP supports over 700 perennial lakes/ponds, ranging in size from less than an acre, up to Lake McDonald, covering almost 7,000 surface acres. GNP also provides over 2,200 km of high-quality stream habitat for aquatic species. A diversity of native and introduced fish species inhabit park waters (Tables 1 and 2).

Although GNP represents some of the last best wild areas in North America, recent studies have demonstrated that GNP is not immune to the impacts of human development, land use, and ultimately environmental contamination. Recent studies have demonstrated the aerial transport and deposition of metals (e.g. mercury), semi-volatile organic compounds (pesticides and herbicides), industrial compounds (e.g. PCB's), and emerging chemicals (e.g. fire retardant PBDE) into the GNP ecosystem (Watras et al. 1995, Landers et al. 2008).

Aerial deposition of mercury (Hg) to watersheds and subsequent uptake by aquatic biota is of increasing concern. Atmospheric deposition of mercury is the dominant source of labile mercury to most watersheds, particularly those in remote settings such as GNP. About 2/3 of the mercury in the atmosphere globally is from human activities (Mason et al. 1994), and coal burning is the largest source (Nriagu and Pacyna 1988). Regionally, glacial cores from the Wind River Range, Wyoming show that in the 20^{th} century about 70% of the mercury deposited aerially was from human sources (Schuster et al. 2002). Elemental mercury is transformed into the bio-available form (methyl mercury) primarily by sulfate reducing bacteria (Gilmour and Henry 1991). Most methyl mercury is produced in lakes and their watersheds, although some methyl mercury is deposited aerially (Fitzgerald et al. 1991, Watras et al. 1995). Methyl mercury biomagnifies as it moves up the food chain, and top level consumers such as humans and piscivorous wildlife are particularly at risk. Mercury can damage developing nervous systems in humans and other animals if ingested in sufficient amounts, and early life stages are particularly at risk. It is estimated that the developing fetus is 5-10 times more sensitive to methyl mercury than adults (Clarkson 1990). An estimated eight percent of women of childbearing age have mercury levels deemed unsafe for childbearing by the EPA **(**Schober et al. 2003**).** The primary exposure pathway for humans and wildlife to methyl mercury is through consumption of contaminated fish.

Recently, mercury testing of fish tissue from lake trout *Salvelinus namaycush* and lake whitefish *Coregonus clupeaformis* from Upper Two-Medicine Lake in GNP (T. Selch, Montana Fish, Wildlife, and Parks (MFWP), personal communication) and from the Waterton Lakes in Waterton Lakes National Park in Canada was completed (Brinkmann 2007). The testing demonstrated elevated levels of mercury in the tissue samples, resulting in fish consumption advisories for these waters and species.

The purpose of the study was to provide information on the levels of mercury in fish tissue in selected waters of Glacier National Park (GNP). This information will be used primarily to evaluate risks to human health from consuming contaminated fish, but also to gain insight into the potential impacts of mercury on GNP wildlife resources.

Table 1. Native (N) and introduced (I) salmonids in Glacier National Park.

Species	Columbia Drainage	Missouri Drainage	Hudson Bay Drainage
Arctic grayling *Thymallus arcticus*	--	--	I
Brook trout *Salvelinus fontinalis*	I	I	I
Bull trout (BLT) *S. confluentus*	N	--	N
Kokanee (KOK) *Oncorhynchus nerka*	I	--	I
Lake trout (LKT) *S. namaycush*	I	--	N
Lake whitefish (LWF) *Coregonus clupeaformis*	I	--	N
Mountain whitefish (MWF) *Prosopium williamsoni*	N	N	N
Pygmy whitefish *P. coulteri*	N	--	N
Rainbow trout *O. mykiss*	I	I	I
Westslope cutthroat trout *O. clarkii lewisi*	N	N	N
Yellowstone cutthroat trout *O. c. bouvieri*	I	I	I

METHODS

We primarily utilized gill netting (but also some angling) to collect fish for tissue sampling from Bowman, McDonald, Harrison, and St. Mary lakes (Figure 1). Sampling took place between August 19 and September 4, 2008. Gill netting involved deploying 150’ monofilament gill nets consisting of three 50’ panels of graduated mesh (2.5”, 3”, and 3.5” stretch) at each sample site. We generally set our nets deep to target lake trout and reduce by-catch, but did vary the set depths from 17’ to 230’ depending on the bathymetry of the lake. We set up to four nets per night. Nets were typically set in the late afternoon or early evening, and retrieved in the early morning hours. Nets generally were deployed with the smallest mesh nearest to shore. In addition to gill nets, a few lake trout were also collected using vertical jigging techniques on Harrison and Bowman lakes. We desired to sample between 10 and 15 individual fish per target species (lake trout and lake whitefish), but budget constraints ultimately dictated sample analysis allocation.

Nets generally were retrieved in the morning, labeled, and taken to shore to be cleared of fish. Fish were identified to species, weighed (g) and measured (total length (TL); mm). A long piece of skinless dorsal muscle tissue was removed for mercury analysis. Muscle tissue was removed with a stainless steel fillet knife on a polyethylene cutting board. During fish processing all materials in contact with the muscle tissue were rinsed in acid (vinegar) then repeatedly rinsed in lake water. Processed samples were placed into a re-sealable plastic bag and the excess air was purged to reduce desiccation. Samples were frozen in the field using dry ice and then stored frozen until mercury analysis.

Samples were analyzed for total mercury at the University of Montana Environmental Biogeochemistry Laboratory. Sample preparation, homogenization and digestion were performed according to USEPA Method 1631 (Total mercury in tissue, sludge, sediment and soil by acid digestion and BrCl Oxidation). A slice of tissue was removed from the center of each sample and homogenized by finely chopping with stainless steel tools on an acid washed plastic cutting board. Subsamples of 1 to 1.5 g were digested using hot re-fluxing HNO3/H2SO4 followed by BrCl oxidation. Following digestion, samples were diluted to 50 mL before analysis. Mercury analysis was conducted according to USEPA Method 1631E (Cold Vapor Atomic Fluorescence Spectrometry, CVAFS, with double gold trap preconcentration). Quality assurance procedures included blanks, standard reference materials (DORM-3 dogfish muscle reference material 0.382±0.060 mg/kg), mercury spikes, and duplicate digestions, and duplicate runs of the same digest. Selected samples were re-tested using a Milestone Inc. model DMA-80 Direct Mercury Analyzer for verification. The USEPA recently listed this technique as Method 7473. All mercury results are expressed on a wet weight basis. Evaporable content was determined for 26 muscle tissue sub-samples by drying to a constant weight at 65C in a drying oven. These data were used to assess if samples dried during storage (which would inflate mercury values when expressed on a wet weight basis).

Table 2. Native (N) and introduced (I) non-salmonids in Glacier National Park.

Species	Columbia Drainage	Missouri Drainage	Hudson Bay Drainage
Fathead minnow *Pimephales promelas*	--	--	--
Northern pikeminnow *Ptychocheilus oregonensis*	N	--	--
Peamouth *Mylocheilus caurinus*	N	--	--
Redside shiner *Richardsonius balteatus*	N	--	--
Longnose sucker (LNSU) *Catostomus catostomus*	N	N	N
Largescale sucker *C. macrocheilus*	N	--	--
White sucker (WSU) *C. commersoni*	--	--	N
Deepwater sculpin *Myoxocephalus thomsoni*	--	--	N
Mottled sculpin *Cottus bairdi*	--	N	N
Slimy sculpin *C. cognatus*	N	--	--
Shorthead sculpin *C. confusus*	N	--	--
Spoonhead sculpin *C. ricei*	--	--	N
Burbot (BUR) *Lota lota*	--	--	N
Northern pike *Esox lucius*	--	--	N
Trout-perch *Percopsis omiscomaycus*	--	--	N

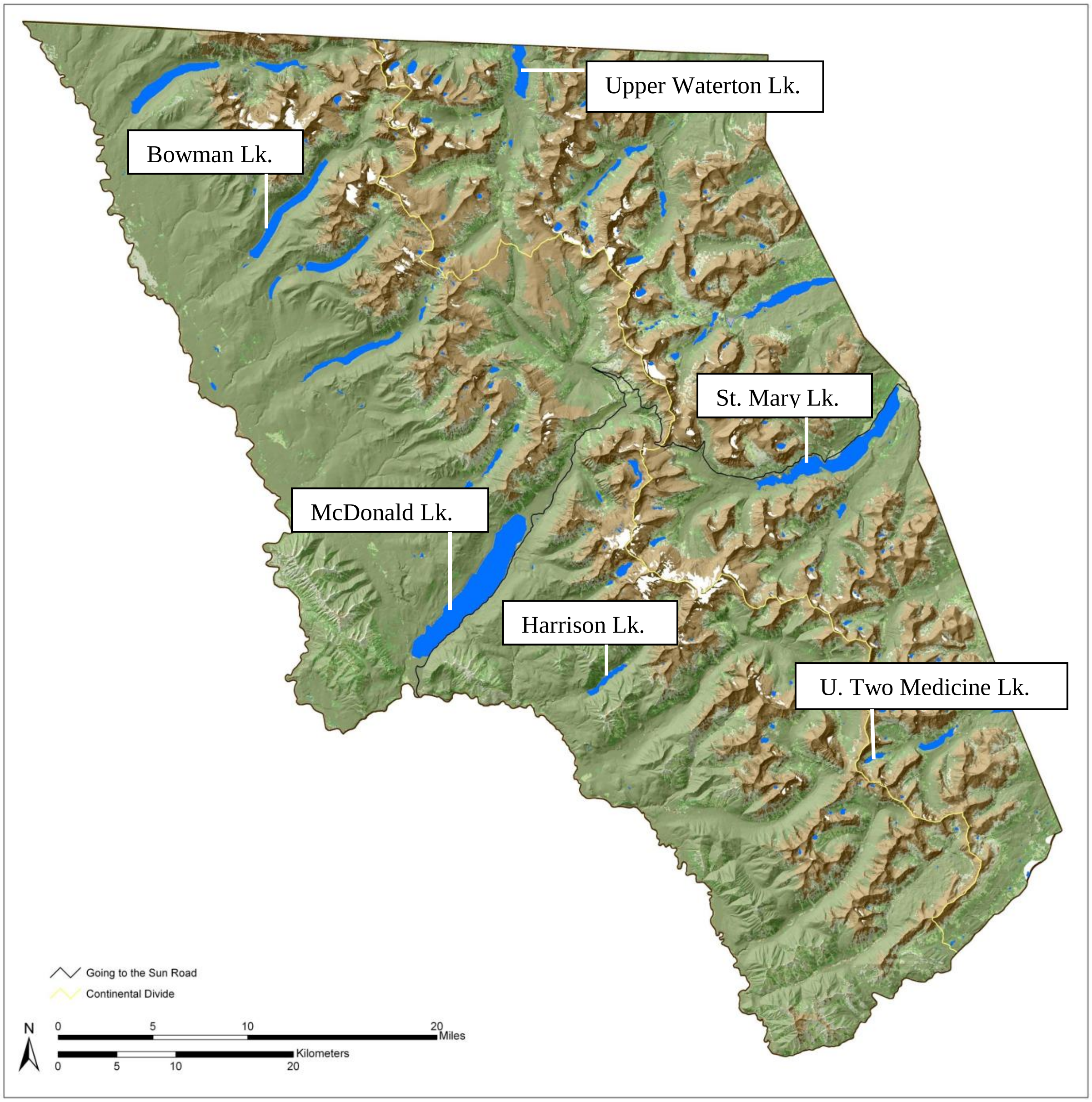

Figure 1. Glacier National Park waters recently sampled for fish tissue concentrations of mercury. Upper Waterton Lake was sampled in the Alberta, Canada portion of the lake (Brinkman 2007). Upper Waterton and Upper Two Medicine lakes were sampled by other investigators prior to initiation of this project.

Tissue samples were also collected and archived for genetic analysis from burbot *Lota lota* and lake trout, as well as any incidentally captured bull trout *S. confluentus* and westslope cutthroat trout *Oncorhynchus clarkii lewisi*. Photographs of lake trout were taken for future morphometric analyses.

We estimated catch-per-unit-effort (CPUE) as the number of fish captured per net-night of sampling, and also as the number of fish captured per hour in over-night net sets. Some net sets were conducted during the day in an effort to reduce by-catch mortality of non-target fish species (i.e. bull and westslope cutthroat trout). These sets were not included in the CPUE estimates, as catch rates are likely to be different for day versus night sets. We calculated average length and weight for each species to facilitate comparisons of size structure between populations, and also provide information useful in comparing changes in all of the population and sampling metrics through time. It should be noted that not all captured fish were used for mercury analysis, so these averages do not reflect the average size of fish analyzed for mercury. We estimated relative weight (*Wr*) (Anderson and Neuman 1996) for selected fish species to evaluate growth conditions across the sampled waters. We used standard weight equations for lake trout (Picolo et al. 1993), burbot (Fisher et al. 1996), and lake whitefish (Rennie and Verdon 2008) to estimate *Wr* for each water.

RESULTS AND DISCUSSION

We collected fish tissue samples for mercury analysis from three waters west of the Continental Divide and one water east of the Continental Divide (Figure 1). The number of net sets required to capture approximately 10-15 lake trout and/or lake whitefish varied by water (Table 3). Bowman Lake had the highest CPUE for lake trout, and St. Mary Lake had the lowest. CPUE was similar for lake whitefish captured in McDonald and St. Mary lakes. We only captured native fish in St. Mary Lake. In contrast, we captured primarily non-native fish in all the lakes on the west side of GNP. The highest species richness was observed in St. Mary and McDonald lakes (Figures 2 and 3). However, much of the species richness observed in the St. Mary Lake catch may be attributable to sampling shallower habitats than were sampled in other waters.

Table 3. Gill netting catch-per-unit-effort (CPUE) for species captured in overnight gill net sets in four Glacier National Park lakes during late summer, 2008.

Water (total number of overnight net sets)	Species	Number captured	CPUE (fish/net night)	CPUE (fish/hour for overnight sets)
Bowman Lk. (4)	Lake trout	16	4.00	0.26
McDonald Lk. (5)	Bull trout	5	1.00	0.08
	Kokanee	1	0.20	0.02
	Lake trout	12	2.40	0.20
	Lake whitefish	33	6.60	0.56
	Longnose sucker	2	0.40	0.03
Harrison Lk. (1)	Lake trout	3	3.00	0.22
St. Mary Lk. (7)	Bull trout	1	0.14	<0.01
	Burbot	26	3.71	0.23
	Lake trout	14	2.00	0.12
	Lake whitefish	38	5.43	0.33
	Longnose sucker	36	5.14	0.32
	Mountain whitefish	3	0.43	0.03
	White sucker	1	0.14	<0.01

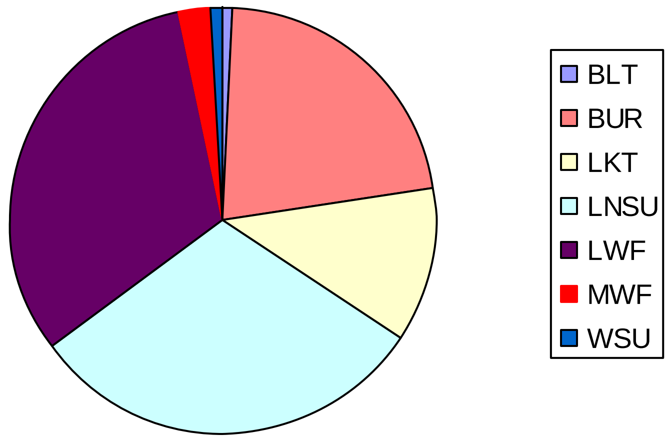

Figure 2. Percent species composition for fish species captured using gill nets in St. Mary Lake, Glacier National Park, during late summer, 2008.

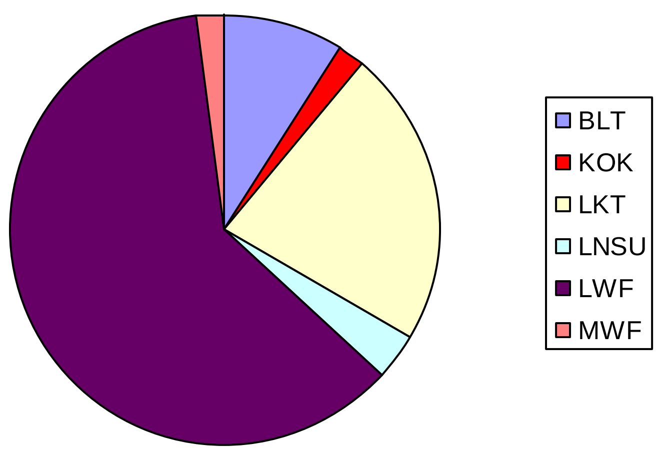

Figure 3. Percent species composition for fish species captured using gill nets in McDonald Lake, Glacier National Park, during late summer, 2008.

Average length of lake trout was greatest in Harrison Lake and lowest in Bowman Lake (Table 4). Of note however is that Bowman Lake had both the highest gill net catch rate and the smallest average size. Fish condition, although low for all lakes, was lowest in Bowman Lake as well (Table 5).

This may be indicative of a lake trout population that has reached a density in Bowman Lake that is sufficiently high to begin impacting their own growth and condition.

Table 4. Mean length and mean weight for species captured in day and over-night gill net sets conducted during late summer in Glacier National Park, 2008.

Water	Species	Number captured	Mean length (TL;mm) (95% CI)	Length range	Mean weight (g) (95% CI)
Bowman Lk.	Lake trout	20	470.3 (57.9)	347-743	922.8 (384.9)
McDonald Lk.	Bull trout	5	489.4 (71.8)	431-564	1045.2 (451.4)
	Kokanee	1	410	N/A	700 (N/A)
	Lake trout	12	486.8 (67.2)	327-729	969.1 (456.4)
	Lake whitefish	33	470.6 (9.9)	428-535	918.3 (56.3)
	Longnose sucker	2	287.0 (N/A)	174-400	673.0 (N/A)
Harrison Lk.	Lake trout	13	617.6 (37.6)	494-743	1868.1 (350.5)
St. Mary Lk.	Bull trout	1	608 (N/A)	N/A	2140 (N/A)
	Burbot	26	506.6 (41.3)	368-890	844.6 (288.5)
	Lake trout	14	512.7 (55.4)	363-735	1114.5 (475.3)
	Lake whitefish	38	421.3 (8.5)	394-524	615.2 (51.4)
	Longnose sucker	36	287.3 (13.1)	231-394	301.5 (49.8)
	Mountain whitefish	3	397.3 (12.5)	394-524	615.2 (51.4)
	White sucker	1	266 (N/A)	(N/A)	232 (N/A)

Table 5. Fish condition expressed as relative weight (*Wr*) for selected species and waters in Glacier National Park sampled with gill nets during late summer, 2008.

Water	Species	Sample size	Mean *Wr* (95% CI)
Bowman Lk.	Lake trout	20	74.8 (4.0)
McDonald Lk.	Lake trout	12	75.7 (6.0)
	Lake whitefish	33	83.1 (2.8)
Harrison Lk.	Lake trout	13	76.2 (2.0)
St. Mary Lk.	Burbot	26	79.5 (3.1)
	Lake trout	14	74.8 (4.1)
	Lake whitefish	38	78.4 (1.7)

Based on *Wr*, all species evaluated appeared to have less than optimal body condition (Table 5). Lake trout from Bowman Lake had the lowest average fish condition, while lake whitefish from McDonald Lake had the highest. Overall, lake trout condition was similar across all sampled waters, suggesting less than optimal feeding and/or temperature conditions may exist. A *Wr* of 100 represents the 75^{th} percentile of average weight for a given length across a large number of populations for a particular species. In concept, a *Wr* of 100 is generally representative of good physiological and feeding conditions, and has been shown to be positively correlated with fat content in fish (Anderson and Neuman 1996, Renne and Verdon 2008) and prey availability (Renne and Verdon 2008). Ellis et al. (1992) evaluated trophic status for a number of GNP lakes, including McDonald and St. Mary lakes and concluded all of the waters they sampled were either oligotrophic or ultra-oligotrophic. It would not be unexpected to find lower fish condition in such unproductive waters. This conclusion is supported by the findings of Stafford et al. (2002) who found lake trout from Lake McDonald grew considerably slower than those from the more productive waters of Flathead Lake.

Mercury concentration in fish tissue varied by species and sampled water (Tables 6 through 9). All sampled waters contained fish with detectable mercury levels. In general, top level predators such as lake trout and burbot had the highest concentrations of mercury in both absolute and size normalized comparisons. In Lake McDonald, lake trout had the highest mercury concentrations, whitefish had the lowest, with bull trout intermediate between the two (Figure 4). Size (total length; TL) normalized mercury values were compared for lake trout among the three west side lakes, and no significant differences were observed. Based on this observation, the west side lake trout data were pooled, revealing a significant positive relationship between mercury and TL ($Hg = 0.000764*TL - 0.098$; $R^2 = 0.51$; $p < 0.001$, Figure 5). In Lake McDonald a weak correlation was identified for lake whitefish mercury concentration and fish length ($R^2 = 0.38$), but the relationship was not statistically significant ($p = 0.06$). A significant relationship may exist, but small sample size (n = 10) and a narrow range of sampled fish lengths may have obscured this relationship.

Quality assurance results generally supported the veracity of the mercury analysis. However, some of the small lake trout from Bowman Lake appeared to have unrealistically low mercury values. These fish were re-analyzed on the DMA analyzer and in fact were found to be biased low. At this point the samples had exceeded their holding time and perhaps had been desiccated through repeated freeze/thaw and freezer burn. The different analyzer and/or perhaps the desiccation may have contributed to the slightly higher readings on the DMA. To address these differences, we adjusted the mercury values from the DMA analysis using samples run on both analyzers from lakes other than Bowman ($CVFAS = 0.85*DMA - 0.01$, $r^2 = 0.96$, $p < 0.001$, n = 22) to create the DMA adjusted value (Table 6). For the largest Bowman Lake fish, the raw CVFAS mercury values were used and appear to be reasonable. This data was pooled with the DMA adjusted data to create the final Bowman Lake data set for use (Table 6). The Bowman Lake data are in good agreement with the mercury versus fish size relationships from the other two west side lakes, but nevertheless should be considered provisional.

The evaporable component (mostly water) was typical for well preserved fish muscle tissue. Twenty six muscle sub-samples were dried, and the evaporable component averaged 79.6% (range = 73.3-85.1%). These data indicate that desiccation during collection and storage was not an issue.

Fish length was not significantly correlated with fish tissue mercury concentration for either lake trout or lake whitefish in St. Mary Lake (Figure 6). Average mercury concentrations for smaller lake trout from St. Mary Lake were higher than similar size fish in McDonald Lake, while larger fish from St. Mary Lake had lower average mercury levels than similar sized fish from Lake McDonald. Lake trout less than 500 mm had higher average mercury concentrations than lake trout greater than 500 mm from St. Mary Lake. This is an unusual pattern as mercury concentrations are generally expected to increase with fish size. The St. Mary Lake trout samples were re-run on the DMA analyzer, and the mercury concentration-size relationship remained similar. Several sampling issues may be responsible for the lack of a typical mercury versus fish size relationship in the St. Mary lake trout and lake whitefish. In the lake whitefish sample it is suspected that the small sample size (n = 10) and limited size variation (397-459 mm TL, excluding a single 524 mm fish) contributed to the lack of relationship. In the lake trout, the modest sample size (n = 14) and limited size variation (TL range 363-735mm) also may have limited our ability to detect trends. This is the most likely explanation for this observation for both species in St. Mary Lake, particularly when we place these data points within larger sample sizes collected from other waters (Figures 7 and 8). However, another possible explanation is a confounding of capture depth and fish size. In Flathead Lake it has been shown that individual lake trout have long-term depth preferences, and that fish living in deeper water have higher mercury levels (Stafford et al. 2004). Three of the four smallest St. Mary lake trout were captured at the deepest depths for this lake. Interestingly, these three deep caught small fish had relatively high mercury levels while the one small fish caught in the shallower water of these four had lower mercury levels. A pattern of increasing contamination with depth may also be present in the Lake McDonald fish. The deepest caught McDonald Lake fish (54 m, over twice as deep as the next deepest fish from McDonald Lake) had a very high mercury concentration for its size (548 mm TL; Figure 4) compared to the other McDonald Lake lake trout. Native lake trout populations sometimes develop different morphotypes typically associated with depth and/or diet differences (Moore and Bronte 2001, Blackie et al. 2003). If multiple populations of lake trout are present in St. Mary Lake, differences in their physiology (particularly growth rate), habitat use (i.e. depth), and diet could lead to mercury differences between groups that could obscure the mercury versus size relationship.

Table 6. Mercury concentrations in lake trout tissue from Bowman Lake, Glacier National Park.

Species (Sample number)	Fish length (TL;mm)	DMA raw mercury concentration (mg/kg)	DMA adjusted mercury concentration (mg/kg)	CVAAFS raw mercury concentration (mg/kg)	Mercury data for use (mg/kg)
Lake trout (BLKT 2)	743	.421	0.350		0.350
Lake trout (BLKT 4)	390	.155	0.126		0.126
Lake trout (BLKT 9)	373	.267	0.220		0.220
Lake trout (BLKT 16)	460	.195	0.159		0.159
Lake trout (BLKT 17)	453	.253	0.209		0.209
Lake trout (BLKT 19)	483	.349	0.290		0.290
Lake trout (BLKT 23)	646	.679	0.569		0.569
Lake trout (BLKT 1)	676			0.443	0.443
Lake trout (BLKT 3)	800			0.410	0.410
Lake trout (BLKT 20)	668			0.374	0.374

Table 7. Mercury concentrations in lake trout tissue from Harrison Lake, Glacier National Park.

Species (Sample number)	Fish Length (TL;mm)	Mercury concentration (mg/kg)
Lake trout (H LKT 1)	494	0.277
Lake trout (H LKT 2)	557	0.290
Lake trout (H LKT 3)	651	0.425
Lake trout (H LKT 4)	594	0.354
Lake trout (H LKT 5)	601	0.454
Lake trout (H LKT 6)	599	0.461
Lake trout (H LKT 7)	624	0.237
Lake trout (H LKT 8)	603	0.443
Lake trout (H LKT 9)	615	0.342
Lake trout (H LKT 10)	635	0.437
Lake trout (H LKT 11)	708	0.498
Lake trout (H LKT 12)	605	0.338
Lake trout (H LKT 13)	743	0.313
Lake trout (H LKT 14)	836	0.532
Lake trout (H LKT 15)	648	0.481

Table 8. Mercury concentrations in fish tissue from McDonald Lake, Glacier National Park.

Species (Sample number)	Fish Length (TL;mm)	Mercury concentration (mg/kg)
Bull trout (MC BLT 01)	499	0.135
Bull trout (MC BLT 02)	431	0.157
Bull trout (MC BLT 03)	521	0.142
Bull trout (MC BLT 04)	564	0.156
Bull trout (MC BLT 05)	432	0.198
Lake trout (MC LKT 01)	492	0.343
Lake trout (MC LKT 02)	451	0.170
Lake trout (MC LKT 03)	327	0.100
Lake trout (MC LKT 04)	493	0.197
Lake trout (MC LKT 05)	556	0.284
Lake trout (MC LKT 06)	729	0.498
Lake trout (MC LKT 07)	535	0.266
Lake trout (MC LKT 08)	512	0.283
Lake trout (MC LKT 09)	445	0.187
Lake trout (MC LKT 10)	389	0.236
Lake trout (MC LKT 11)	365	0.186
Lake trout (MC LKT 12)	548	0.688
Lake whitefish (MC LWF 01)	432	0.092
Lake whitefish (MC LWF 02)	535	0.202
Lake whitefish (MC LWF 03)	480	0.151
Lake whitefish (MC LWF 04)	468	0.110
Lake whitefish (MC LWF 05)	491	0.189
Lake whitefish (MC LWF 06)	505	0.153
Lake whitefish (MC LWF 07)	467	0.107
Lake whitefish (MC LWF 08)	530	0.091
Lake whitefish (MC LWF 09)	517	0.148
Lake whitefish (MC LWF 10)	428	0.076

In contrast to the lake trout and lake whitefish, mercury increased clearly with size in the St. Mary Lake burbot sample (Hg = 0.000659 (total fish length) - 0.0562; $R^2 = 0.76$; $p < 0.01$). The larger size range (405-890 mm TL) presumably helped detect this trend despite the small sample size (n = 6).

To put the current GNP mercury results into context, a comparison of mercury values from other nearby lake trout populations was made. Lake trout collected by the U.S. Environmental Protection Agency (EPA) from Upper Two-Medicine Lake in GNP had moderate levels of mercury in fish tissue (0.136 mg/kg; length range 371-406 mm; mean length 389 mm) (T. Selch, MFWP, personal communication). Mercury levels in Upper Two-Medicine Lake were similar to those for similar sized lake trout from the west side of the Continental Divide in GNP, but considerably lower than similar sized lake trout from St. Mary Lake. We also compared our data to data from Waterton Lakes in Waterton Lakes National Park (Brinkmann 2007), Flathead Lake (Stafford 2004), Yellowstone Lake (Koel et al. 2008), and Swan Lake (L. Rosenthal, MFWP, unpublished data) for lake trout and lake whitefish (Figures 7 and 8). The comparison reveals that the GNP lakes are similarly contaminated as other nearby, less pristine systems (Swan and Flathead), and similar or perhaps slightly less contaminated than Waterton Lakes. One important observation from these pooled data is that above about 800 mm lake trout mercury values increase sharply. In the current project the largest fish was 836 mm, undoubtedly larger lake trout exist in GNP and they presumably have very high mercury concentrations.

Table 9. Mercury concentrations in fish tissue from St. Mary Lake, Glacier National Park.

Species (Sample number)	Fish Length (TL;mm)	Mercury concentration (mg/kg)
Bull trout (SM BLT 1)	608	0.458
Burbot (SM BUR 01)	583	0.241
Burbot (SM BUR 02)	405	0.162
Burbot (SM BUR 03)	629	0.374
Burbot (SM BUR 04)	890	0.519
Burbot (SM BUR 05)	596	0.404
Burbot (SM BUR 06)	475	0.320
Lake trout (SM LKT 1)	735	0.326
Lake trout (SM LKT 2)	513	0.170
Lake trout (SM LKT 3)	608	0.355
Lake trout (SM LKT 4)	524	0.449
Lake trout (SM LKT 5)	451	0.208
Lake trout (SM LKT 6)	588	0.132
Lake trout (SM LKT 7)	491	0.417
Lake trout (SM LKT 8)	480	0.321
Lake trout (SM LKT 9)	579	0.201
Lake trout (SM LKT 10)	484	0.423
Lake trout (SM LKT 11)	528	0.353
Lake trout (SM LKT 12)	374	0.323
Lake trout (SM LKT 14)	363	0.325
Lake whitefish (SM LWF 01)	447	0.164
Lake whitefish (SM LWF 02)	420	0.151
Lake whitefish (SM LWF 03)	438	0.171
Lake whitefish (SM LWF 05)	428	0.106
Lake whitefish (SM LWF 06)	397	0.184
Lake whitefish (SM LWF 07)	524	0.106
Lake whitefish (SM LWF 09)	419	0.162
Lake whitefish (SM LWF 10)	459	0.148
Lake whitefish (SM LWF 11)	458	0.169
Lake whitefish (SM LWF 12)	440	0.099

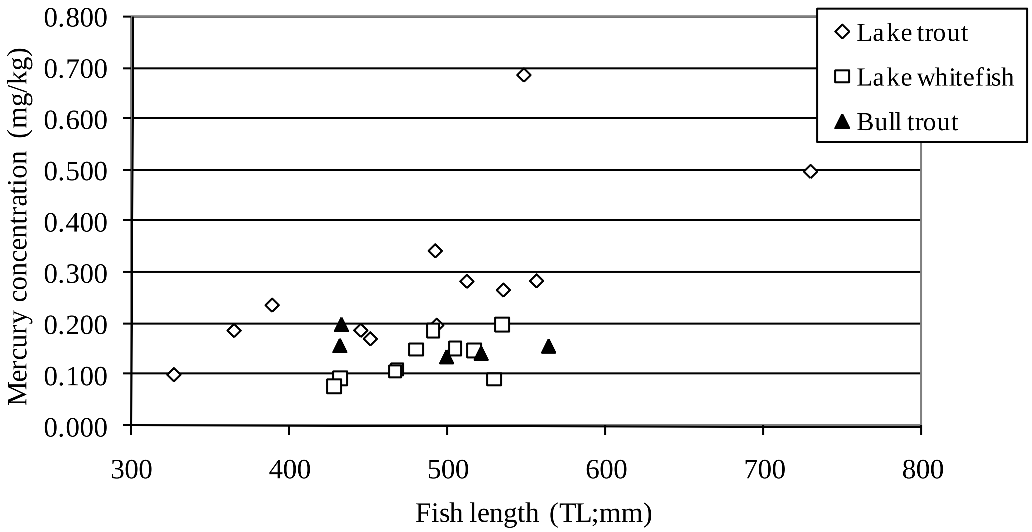

Figure 4. Length-mercury concentration (wet weight) relationship for fish sampled from McDonald Lake, Glacier National Park.

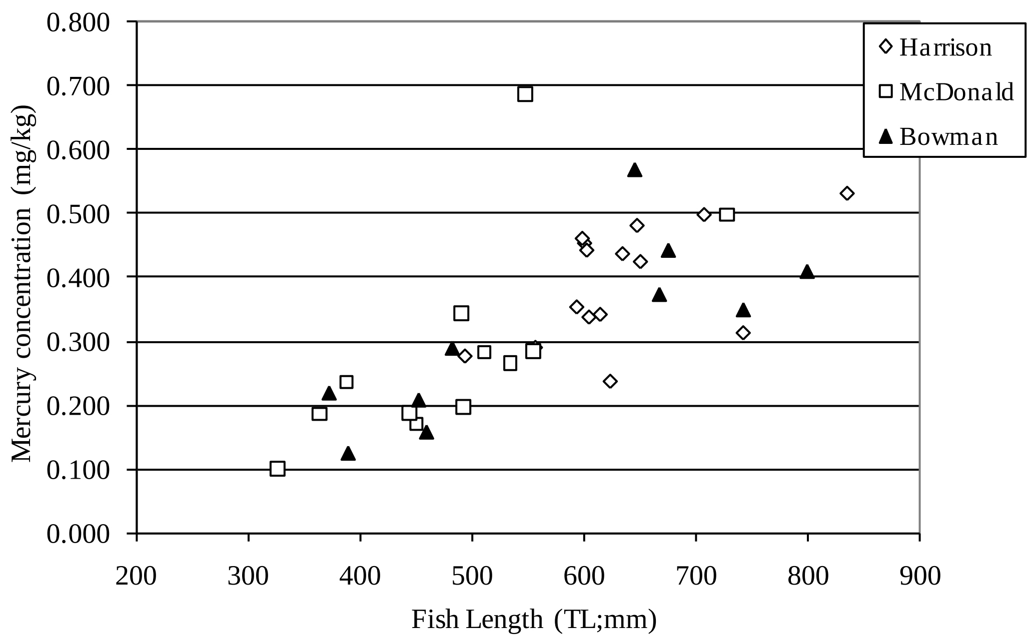

Figure 5. Length-mercury concentration (wet weight) relationship for lake trout sampled from waters located west of the Continental Divide, Glacier National Park.

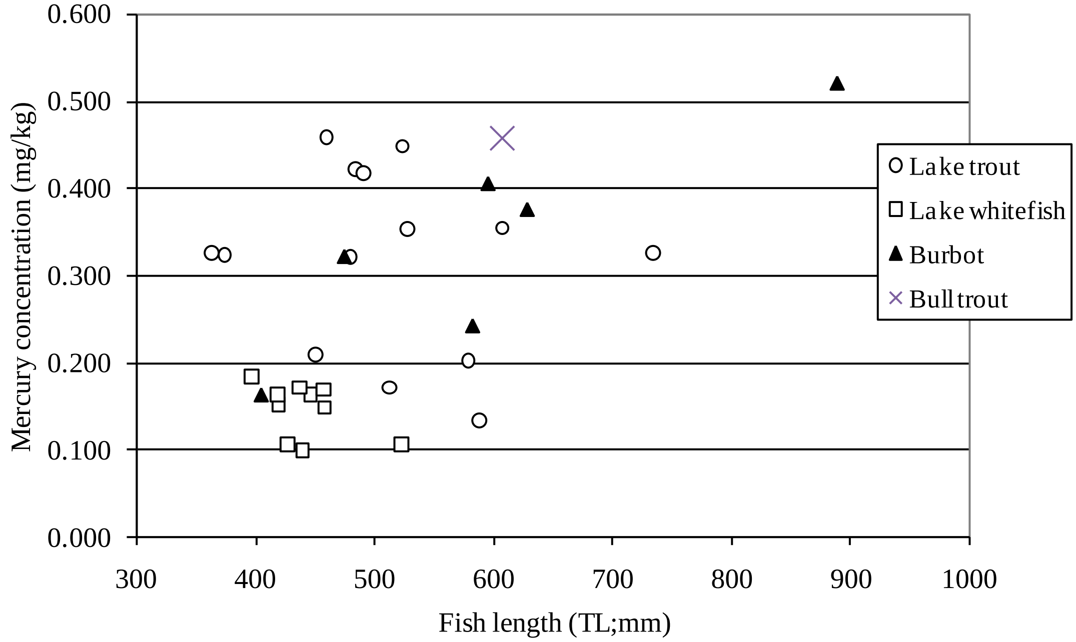

Figure 6. Length-mercury concentration (wet weight) relationship for fish sampled from St. Mary Lake, Glacier National Park.

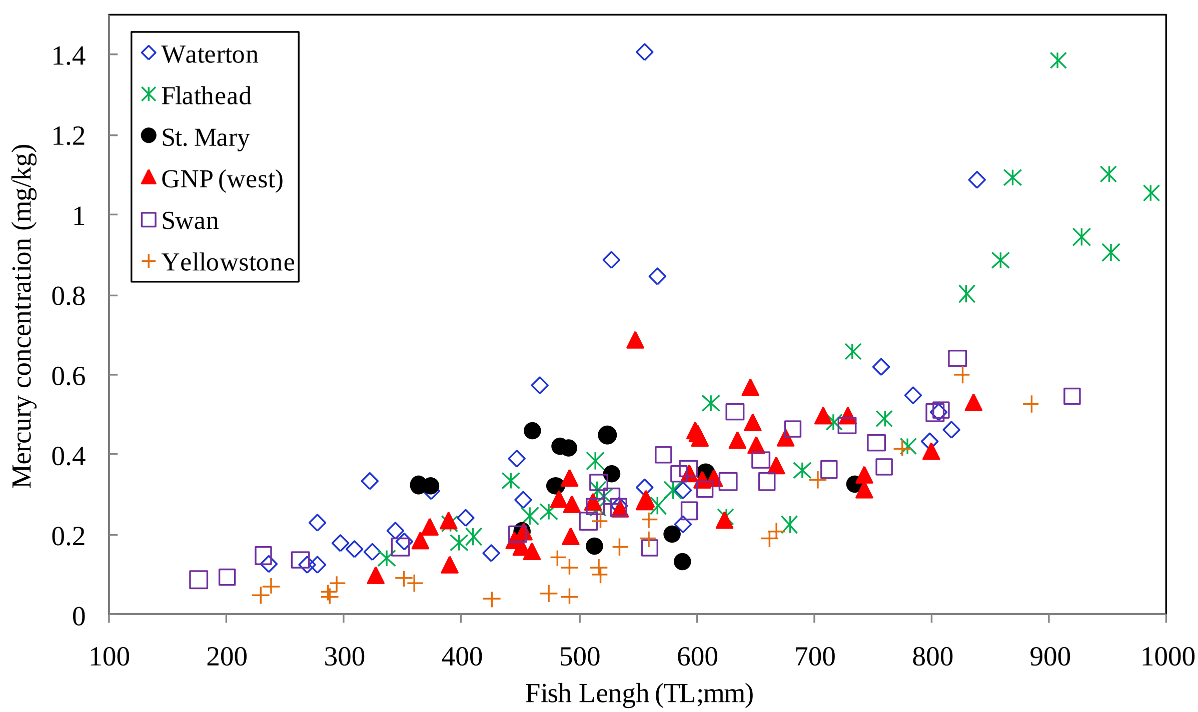

Figure 7. Comparison of lake trout mercury concentration versus fish total length (TL;mm) for the current project (GNP west side lakes and St Mary) and other regional lakes (Stafford et al. 2004; Brinkmann 2007; L. Rosenthal, MFWP, personal communication; Koel et al. 2008).

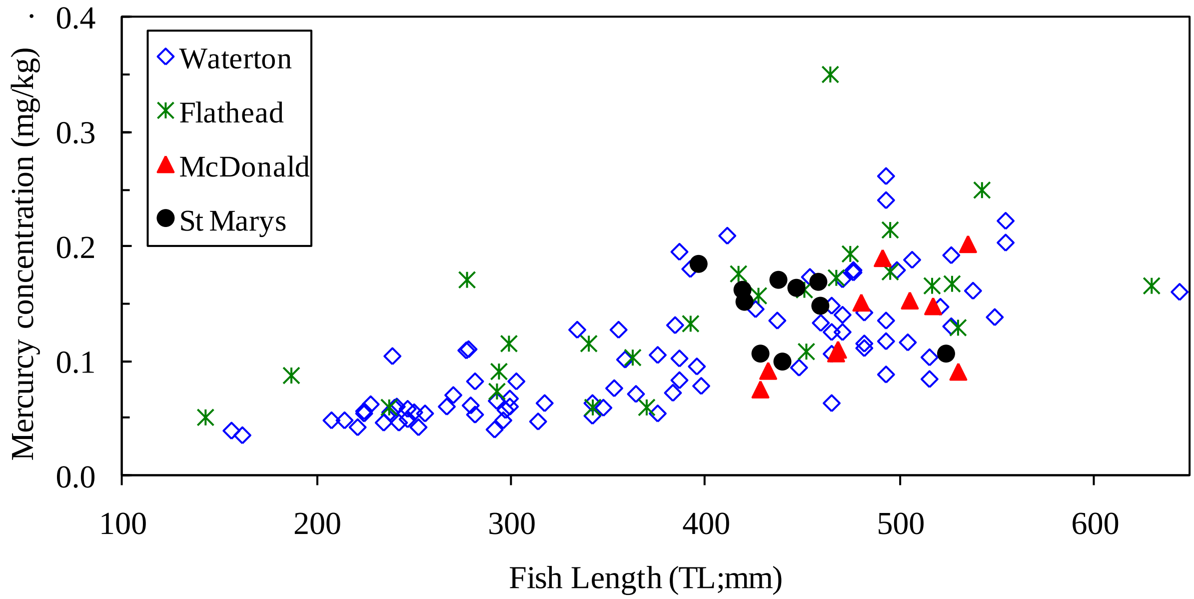

Figure 8. Comparison of lake whitefish mercury concentration versus fish total length (TL;mm) for the current project (McDonald and St Mary lakes) and other nearby lakes (Stafford et al. 2004, Brinkmann 2007).

EPA provides reference dose data for fish consumption by humans based on fish tissue mercury concentrations. Montana Fish, Wildlife, and Parks has taken these data and developed fish consumption guidelines based on fish tissue mercury concentrations (T. Selch, MFWP, personal communication). When we apply the MFWP consumption guidance criteria to our samples, we can offer some general guidance to anglers who wish to consume fish caught in GNP waters, but also want to minimize their intake of mercury. Scatter plots of the data for lake trout collected from the three west side GNP waters suggested the relationship between fish length and mercury concentration was fairly consistent across these waters (Figure 4). Therefore, we combined the samples across these west-side waters into one single data set and developed guidance based on the combined data (Table 10). In general, smaller lake trout contained less mercury than larger ones. Due to the weak statistical relationship between fish length and mercury concentration for lake whitefish from McDonald Lake, we used the average mercury concentration measured (0.132 mg/kg) in our sample of lake whitefish to provide consumption guidance (Table 10).

Our data also provide information useful for providing fish consumption guidance on St. Mary Lake for three species of fish. Burbot was the only species to show a significant positive relationship between fish length and mercury concentration in St. Mary Lake. Although sample size is small (n=6), we used the average mercury concentration measured in smaller and larger burbot to provide guidance for two size groups (Table 10). Consistent with the data from the west side of GNP, lake whitefish were the least contaminated species evaluated. The average mercury concentration in lake whitefish was 0.146 mg/kg. We used the average mercury concentration across the size range of sampled fish to develop consumption guidance for St. Mary Lake lake whitefish (Table 10). Lake trout had similar mercury burdens as did burbot in St. Mary Lake. Due to the lack of an obvious fish length versus mercury concentration relationship, we used the average mercury concentration in lake trout to arrive at consumption guidelines for lake trout from St. Mary Lake (Table 10).

Table 10. Fish consumption guidance for Glacier National Park waters based on Montana Fish, Wildlife and Parks mercury consumption guidelines (T. Selch, MFWP, personal communication).

Water	Species	Sample length range (TL;mm) (sample size) (inch length interval)	Mean mercury concentration (mg/kg)	Consumption guidance (M)[a]	Consumption guidance (WC)[b]
Lakes west of the Continental Divide	Lake trout	327 (1) (10”-14”)	0.100	U[c]	11
		365-453 (7) (14”-18”)	0.191	U	6
		460-557 (10) (18”-22”)	0.308	9	3
		594-651 (11) (22”-26”)	0.413	6	2
		668-743 (6) (26”-30”)	0.413	6	2
		800-836 (2) (30”-33”)	0.471	5	2
McDonald Lk.	Lake whitefish	428-535 (10) (16”-22”)	0.132	U	8
St. Mary Lk.	Burbot	405-583 (3) (15”-23”)	0.241	11	4
		596-890 (3) (23”-36”)	0.433	6	2
	Lake trout	363-735 (14) (14”-29”)	0.319	9	3
	Lake whitefish	397-524 (10) (15”-21”)	0.146	U	8

[a] Maximum number of meals per month recommended for men and women not of reproductive age. Based on a single 8-ounce fillet and a 150 lb. person.
[b] Maximum number of meals per month recommended for women of child-bearing age and children under 6. Based on a single 6-ounce fillet.
[c] Unlimited.

These results demonstrate that aerial deposition of biomagnified contaminants is of concern in GNP. In general, unproductive water bodies such as those in GNP are at greater risk for biomagnified contaminants because the slow growth rates of fish reduce biodilution of persistent contaminants (Thomann 1989, Stafford and Haines 2001; Stafford et al. 2004), and because there is less organic matter in these systems to dilute the contaminants (Pickhardt et al. 2002) and facilitate their burial in the sediments. Given these results for mercury, mercury testing in additional burbot and pike (another high mercury risk species) should be future priorities. Additional sampling of lake trout and lake whitefish from St. Mary Lake would also be of value in understanding any fish size related patterns in mercury concentration. Other studies have suggested that reservoir environments may have elevated mercury levels compared to natural lakes (Jackson 1991), making Sherburne Reservoir a high priority water body for future mercury testing. Organic biomagnified contaminants should also be considered for testing especially given the moderately high levels of DDE, chlordane’s, and dieldrin found recently in GNP cutthroat trout (Landers et al. 2008). These results are particularly concerning as cutthroat presumably have a very low propensity to biomagnify organic contaminants due to their small size, low fat content, and invertebrate feeding pattern. It is possible that elevated levels of biomagnified organic contaminants may also exist in large lake trout given their piscivorous feeding behavior and high fat content, and future testing should be a priority.

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2008 Glacier National Park bull trout redd counts

ABSTRACT

We conducted bull trout *Salvelinus confluentus* redd counts in 12 streams/stream reach's in Glacier National Park in 2008. Eleven streams/stream reach's were surveyed in the N. Fk. Flathead River drainage, and one was surveyed in the M. Fk. Flathead River drainage. In addition, two other streams were surveyed in the St. Mary River drainage by the US Fish and Wildlife Service, while three other bull trout streams in the M. Fk. Flathead River drainage were surveyed by Montana Fish, Wildlife, and Parks, bringing the total stream reaches monitored in Glacier National Park to 17 in 2008. The total number of bull trout redds counted in these areas in 2008 was 193. The Quartz/Cerulean lakes complex remains the strongest monitored bull trout population residing wholly within the park, with a total of 82 redds counted. 2008 redd counts for bull trout populations spawning in the Middle Fork Flathead River tributaries were average to above average based on a redd count data set extending from 1980 through 2008. Redd counts for bull trout populations spawning in the St. Mary drainage were above average based on a redd count data set extending from 1997 through 2008. Monitored bull trout populations in other park waters continue to show low escapement and reflect the adverse impacts non-native lake trout are having in park waters.

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INTRODUCTION

Bull trout *Salvelinus confluentus* are one of only four native salmonids present in Glacier National Park (GNP) waters located west of the Continental Divide. They are one of six native salmonids present in GNP waters located east of the Continental Divide. GNP and the Blackfeet Nation have the unique distinction of supporting the only bull trout populations located east of the Continental Divide in the U.S. portion of their range. In addition, GNP supports both native (Hudson Bay drainage) and introduced (Columbia River drainage) populations of lake trout found occupying lake habitats along with bull trout, creating unique management challenges.

Bull trout exhibit three distinct general life-history forms – resident, fluvial, and adfluvial. Resident bull trout spend their entire lives in small tributaries, whereas fluvial and adfluvial forms hatch in small tributary streams then migrate into larger rivers (fluvial) or lakes (adfluvial). In the lakes of GNP, bull trout exhibit adfluvial and lacustrine-adfluvial life history strategies. These bull trout grow to maturity in the lakes, and then spawn in tributaries (adfluvial) or lake outlets (lacustrine-adfluvial). Migratory adult bull trout generally move upstream to spawning or staging areas from May through July, although some fish wait until the peak spawning time of September and October before entering spawning streams (Fraley and Shepard 1989; Schill et al. 1994; Downs and Jakubowski 2006). Spawning typically occurs in tributary streams between late August and early November (USFWS 1998), but more commonly in September and October in the Flathead Lake system (Block 1953; Fraley and Shepard 1989; Meeuwig 2008). Eggs over-winter in spawning streams until the following spring, when newly hatched fry emerge from the gravel. Age-0 bull trout can often be found in side-channels and along channel margins following emergence (Fraley and Shepard 1989). Migratory juvenile bull trout have been documented emigrating from natal streams in two pulses, with one pulse occurring in the spring with high water and the other in the fall associated with declining water temperatures and fall precipitation events (Downs et al. 2006). Juveniles may rear from one to five years in natal streams, with most emigrating at age-2 and age-3 (Downs et al. 2006). Age-0 outmigrants have been reported in some adfluvial populations, but these outmigrants did not appear to survive well to adulthood where studied (e.g. Downs et al. 2006). Resident and migratory forms may be found together, and either form can produce resident or migratory offspring.

Bull trout egg incubation success has been inversely correlated to increasing levels of fine sediment (<6.35 mm diameter) in spawning nests (redds) (Montana Bull Trout Scientific Group 1998). Spawning site selection has been related to areas of strong intragravel flow exchange (both upwelling and downwelling) (Baxter and Hauer 2000). Juvenile bull trout abundance has been positively correlated with low summer maximum water temperatures (below 14^0C) and with the number of pocket pools in stream reaches (Saffel and Scarnecchia 1995). Unembedded cobble substrate is an important overwinter habitat type for juvenile bull trout (Thurow 1997; Bonneau and Scarnecchia 1998). Excess fine sediment holds the potential not only to reduce egg and embryo survival, but might also limit juvenile bull trout abundance in streams by reducing the amount of interstitial spaces available for overwinter habitat. Channel stability, habitat complexity, and connectivity are all important components in bull trout population persistence (Rieman and McIntyre 1993).

Bull trout are part of a historic fishery that is a fundamental to the biodiversity of GNP, and represent the evolutionary legacy of a top-level aquatic predator in GNP. Protecting native fish resources is a high priority for the park's conservation and management programs (NPS 2006). Ongoing research, monitoring, and management efforts conducted by GNP and its partners remain critical in understanding bull trout population dynamics in the park, and in establishing management programs to benefit native fish.

Redd counts, or spawning nest counts, are used across the range of bull trout to monitor population trends. They are typically used as an index of abundance to gauge the relative strength of adult escapement from year to year. They can also be used to estimate actual adult escapement by expanding the redd counts to fish numbers using various spawner to redd ratios. Redd counts require far less effort to conduct than other traditional monitoring methods such as trapping, and yet provide valuable information on bull trout at the watershed and/or population scale. However, redd counts are not without their limitations, as the technique has been shown to be prone to observer variability and error (Dunham et al. 2001, Muhlfeld et al. 2006), yet they continue to remain an important monitoring tool for bull trout populations.

Redd counts are conducted in Glacier National Park (GNP) annually by the National Park Service (NPS), the U.S. Fish and Wildlife Service (USFWS), the Montana Fish, Wildlife, and Parks (MFWP), and the U.S. Geological Survey (USGS). The longest redd count dataset on bull trout spawning activity in GNP is from three tributaries (Ole, Park, and Nyack creeks) to the Middle Fork Flathead River, associated with monitoring bull trout populations from Flathead Lake. MFWP biologists have been counting bull trout redds annually in Ole Creek and approximately every five years in Nyack and Park creeks, in GNP since 1980. The USFWS has been conducting bull trout redd counts in the St. Mary drainage on the east side of the park since 1997.

GNP is unique as it and the adjacent Blackfeet Indian Reservation are the only place where bull trout occur east of the Continental Divide in the U.S. portion of their range. GNP supports a diversity of life-history strategies for bull trout, including both resident and migratory forms. Resident bull trout have been documented in the St. Mary River drainage (Mogen and Kaeding 2004), while migratory fish from Flathead Lake use tributaries to the Middle and North forks of the Flathead River for spawning and rearing (Weaver et al. 2006). Other populations on the west side of GNP use the lake systems within the park for subadult rearing and adult residence, while spawning and rearing in upstream reaches of their inflow tributaries (e.g. Quartz Lake) (Meeuwig 2008). Less commonly, other west side populations (e.g. Upper Kintla Lake) appear to use the lake environment for subadult rearing and adult residence, while spawning occurs in the outlet stream.

Bull trout spawning surveys were initiated by USFWS staff between 2002 and 2004 for a number of these "disjunct" west side bull trout populations (Meeuwig et al. 2007). A number of other bull trout populations on the west side of the park have not been monitored beyond recent single year electrofishing and gill net surveys (Meeuwig et al. 2007), and we simply do not know where they spawn or long-term population trends (e.g. Lincoln, Trout, Arrow, Isabel, Upper Isabel lakes). It will be critical to establish index redd count monitoring in these populations on some frequency, as they represent the majority of "secure" populations of bull trout on the west side of GNP (Fredenberg et al. 2007).

METHODS

Experienced fisheries staff from GNP, USGS, MFWP, USFWS, and Montana State University (MSU) identified and enumerated bull trout redds in 2008. Redd surveys generally occurred between October 1 and October 24. Early to mid-October is the preferred time for counting bull trout redds as most bull trout spawning has already occurred (peak spawning occurs in September), most redds are still clearly visible, and it is consistent with the timing of earlier counts.

Redds were located visually by walking along annual monitoring sections within each tributary. Redds were defined as areas of clean or "bright" gravels at least 0.3 x 0.6 m in size with gravels of at least 76.2 mm in diameter having been moved by the fish (where other fall spawning species may be present such as brook trout), and with a mound of loose gravel downstream from a depression (Pratt 1984). In areas of superimposition, each distinct depression was counted as one redd. Only disturbed areas of the streambed that observers felt were likely made by fish were classified as bull trout redds and were included in the counts (as opposed to those disturbed areas of the streambed that may have been caused by stream hydraulics). Individual redd locations were located using GPS technology where the spatial distribution of spawning activity was of particular interest.

The draft U.S. Fish and Wildlife Service Bull Trout Recovery Plan (USFWS 2002) suggests using at least 10 years of redd count data for trend analysis. Both Kennedy and Boulder creeks on the east side of the park, and Ole and Nyack creeks on the west side of the park meet this criteria. We used a nonparametric rank-correlation procedure, Kendall's tau (Daniel 1990), to test for trends in "count year" versus "redd count" in the long-term redd count data set (Rieman and Myers 1997). We used tau-b to compensate for any bias caused by ties in the data, and noted statistical significance at the $\alpha = 0.05$ level (Rieman and Myers 1997).

RESULTS AND DISCUSSION

Eleven stream reaches were surveyed by GNP, USGS, and MSU staff in the N. Fk. Flathead River drainage and one was surveyed in the M. Fk. Flathead River drainage. In addition, two other streams were surveyed in the St. Mary River drainage by the USFWS, while three other bull trout streams in the M. Fk. Flathead River drainage were surveyed by MFWP, bringing the total monitored to 17 streams/stream reaches in 10 watersheds in 2008 (Figure 1).

East of the Continental Divide, bull trout redd counts continue to remain relatively strong, although few populations are monitored (Figure 2; Appendix A). Redd counts were above average for Boulder Creek, and close to average for Kennedy Creek. Correlations in "count year" versus "redd count" failed to identify any statistically significant trends ($P > 0.05$), however for Boulder Creek, the correlation was relatively strong and bordering on statistical significance (tau-b = 0.41, $p = 0.08$). If strong redd counts continue, it may be possible to detect a significant positive trend in Boulder Creek in the near future. The correlation between "count year" and "redd count" for Kennedy Creek was weakly negative, and not statistically significant (tau-b = -0.15, $p = 0.53$).

In order to meet bull trout recovery objectives in the St. Mary River drainage established by the USFWS (USFWS 2002), expanded monitoring of bull trout population abundance and trends is needed in GNP. Recovery criteria focus on quantitative measures of adult bull trout abundance and population trends. Recovery Criteria 1 (there are four criteria in total) calls for the presence of nine stable local bull trout populations in the St. Mary-Belly River Recovery Unit, well distributed across the landscape. Recovery Criteria 2 calls for documentation of at least one population in each of the six Core Areas supporting at least 100 adults annually. Recovery Criteria 3 calls for documenting a stable or increasing population of bull trout in the Recovery Unit over time, using at least 10 years of trend data. Recovery Criteria 4 addresses the need for resolution to operational issues associated with Sherburne Dam and the St. Mary Irrigation Canal operated by the Bureau of Reclamation (BOR). The most cost-effective way to evaluate progress against the first three criteria may be through bull trout redd counts, but existing efforts focusing on monitoring only 2 of the 6 core area populations may fall short in their ability to allow us to adequately evaluate local populations against established recovery criteria.

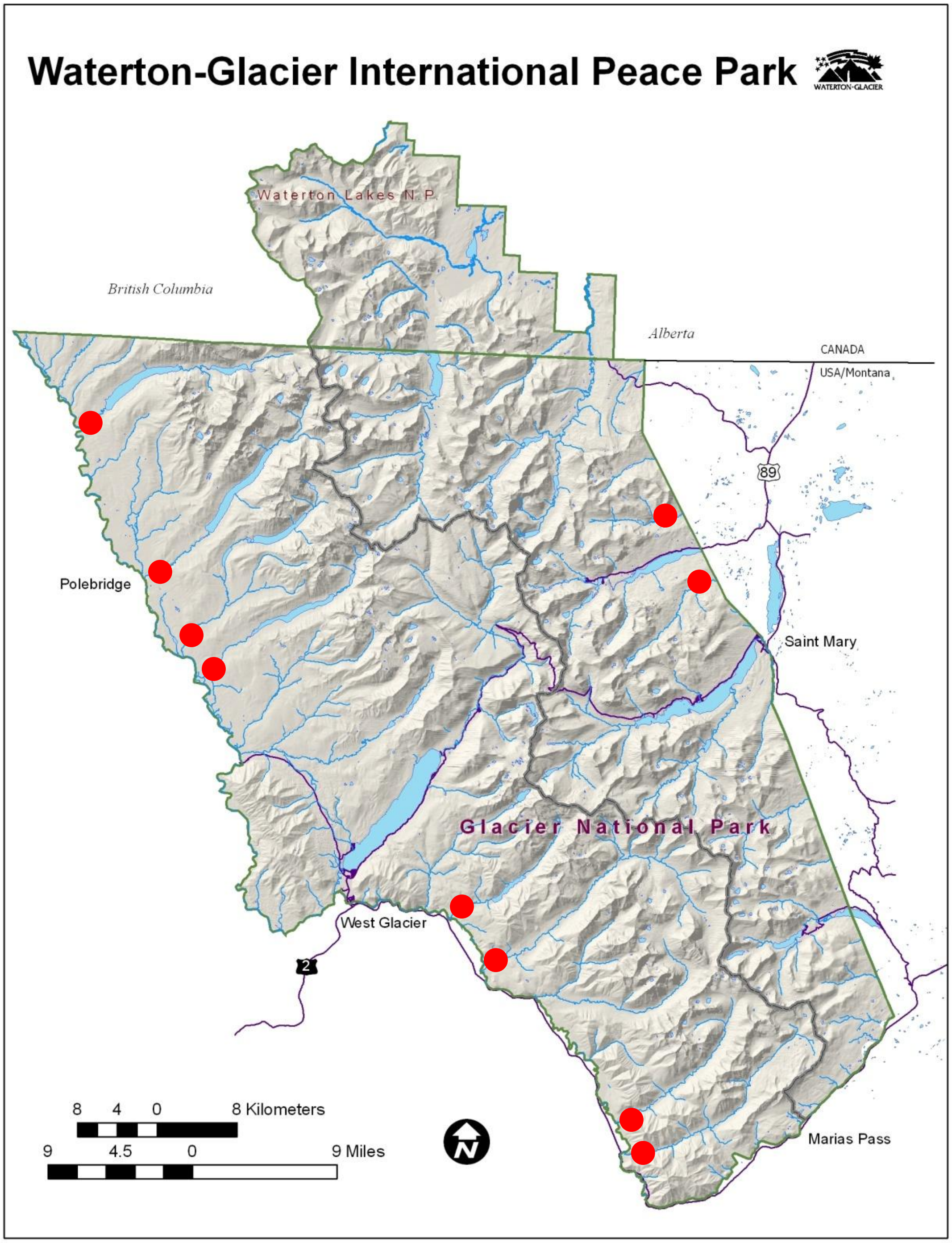

Figure 1. Drainages monitored for bull trout spawning activity (red circles) in Glacier National Park, Montana in 2008.

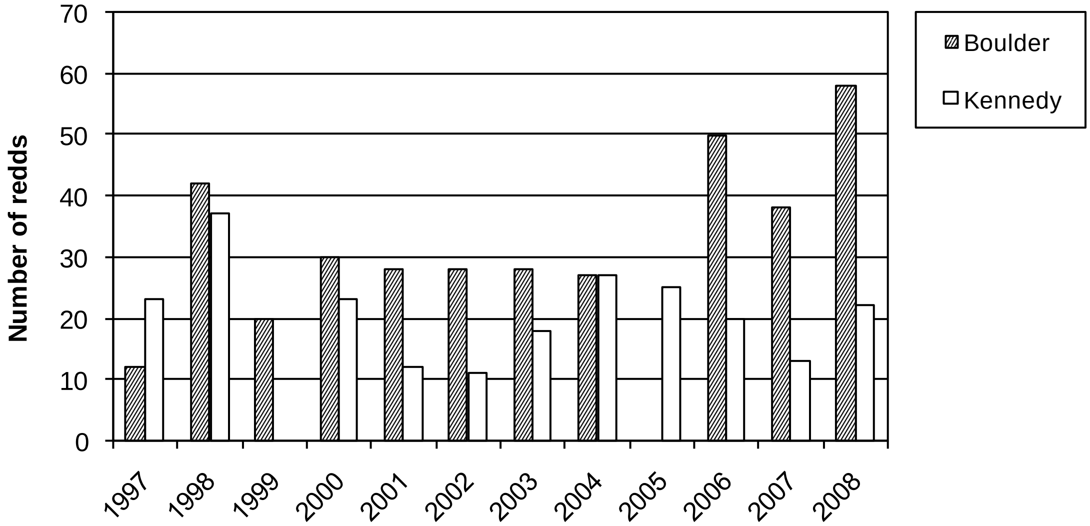

Figure 2. Bull trout redd counts for Boulder and Kennedy creeks, Hudson Bay Drainage, Glacier National Park.

Because the identified spawning habitat for these populations occurs within GNP, it is largely unaffected by threats typically associated with bull trout spawning habitat in other areas of their range (i.e. road building, residential development, timber harvest). Some traditional threats do exist however, largely in the form of trespass cattle grazing in the GNP portion of the Kennedy Creek drainage and the construction and operation of Sherburne Dam and the Milk River Irrigation Project (USFWS 2002). Due to a lack of fencing, trespassing cattle have been observed wading in Kennedy Creek in GNP in the primary bull trout spawning area during and after bull trout spawning (J. Mogen, USFWS, personal communication), potentially impacting bull trout incubation and emergence success in the area. Recent studies (Gregory and Gamett 2009) have identified the potential for significant damage to bull trout spawning nests as a result of cattle trampling.

Sherburne Dam and the St. Mary Irrigation Canal impact GNP native fish populations and represent the single largest “connectivity” issue bull trout populations face in the U.S. portion of the Hudson Bay drainage (USFWS 2002). Construction of Sherburne Dam, located just outside of the GNP boundary, created Sherburne Reservoir which flooded over 8 km of shallow lake and stream habitat in the park within the Swiftcurrent Creek drainage, downstream of Swiftcurrent Falls. Annual operation of the dam dewaters Sherburne Creek downstream of the dam in some months, resulting in the loss of native fish including bull trout (Mogen and Kaeding 2001). The associated St. Mary Irrigation Canal, used to deliver irrigation water to the Milk River, remains unscreened and results in the loss of bull trout and other native fish from the system (Mogen and Kaeding 2001). The St. Mary Diversion Dam, used to provide water into the irrigation canal, creates an approximately 6’ high impediment to upstream migration of bull trout during the migration season (Mogen and Kaeding 2005). Funding has been requested by the BOR to modify the diversion system to alleviate some of the adverse impacts to bull trout, and when implemented, the modifications will directly benefit GNP native fish populations.

On the west side of GNP, both migratory stocks of bull trout from Flathead Lake as well as populations that reside entirely within the park (known locally as "disjunct" migratory populations) are monitored (Appendix A). Flathead Lake migratory bull trout stocks underwent dramatic declines starting in about 1990, and declines are believed to have been the result of the introduction of mysis shrimp *Mysis relicta* into the system and resulting major alterations in trophic dynamics (i.e. rapidly expanding lake trout population) in the lake, as well as drought conditions (Weaver et al. 2006). As the spawning and stream rearing habitats for the Flathead Lake populations that use GNP are largely located within the park, the traditional land-use threats to habitat quality (i.e. road building, timber harvest, residential development) are not the primary issue of concern for these individual populations. One of the most significant contemporary threats to these populations is predation with and competition by non-native fish species in both the migratory habitats between spawning and rearing areas in GNP and Flathead Lake (i.e. mainstem Flathead River) (Muhlfeld et al. 2008), as well as Flathead Lake itself (Deleray et al. 1999).

The only populations that have been monitored for more than 10 years with redd counts on the west side of GNP are Ole and Nyack creeks. Bull trout redd counts in Ole Creek have been monitored annually by MFWP since 1980 (Weaver et al. 2006). The 2008 redd count for Ole Creek of 42 was higher than the long-term average of 26 redds. No statistically significant trends are evident in the long (full data set; tau-b = -0.09, $p = 0.50$) or short-term (most recent 10 years; tau-b = 0.07, $p = 0.79$) data sets for Ole Creek (Figure 3, Appendix A). Nyack Creek has been monitored periodically by MFWP and is generally counted approximately every five years as part of a basin-wide bull trout redd count effort (Weaver et al. 2006). The 2008 redd count on Nyack Creek was 16, which is equivalent to the long-term average redd count for this stream (Figure 3, Appendix A). No statistically significant trends were detected in the long-term redd count data set for Nyack Creek (tau-b = -0.14, $p = 0.56$). Sufficient data does not exist to analyze short-term (10 year) trends on Nyack Creek due to the intermittency of the counts. High annual variability in counts can make detecting trends difficult and require long data sets. Previous authors using similar data sets predicted it may take over 100 years of continuous redd count data collection before a statistically significant trend can be detected in some systems (Rieman and Myers 1997). However, evaluation of observer error in bull trout redd counts (Dunham et al. 2001, Muhlfeld et al. 2006), as well as documented relationships between redd counts and actual adult spawning escapement (Bonar et al. 1997, Dunham et al. 2001, Downs and Jakubowski 2006) support their continued use a key monitoring tool for bull trout populations in GNP.

Similarly, expanding populations of lake trout from Flathead Lake have colonized almost all of the accessible lake habitats on the west side of GNP, and now threaten the persistence of the majority of the "disjunct" migratory bull trout populations remaining on the west side of GNP. Ten of seventeen lake-dwelling populations of bull trout located on the west side of GNP have been compromised by lake trout (Fredenberg et al. 2007), and lake trout have been documented replacing bull trout as the dominant predator in these waters, where long-term data on fish populations exists (Fredenberg 2002).

Successful conservation of native fish species in GNP will ultimately require aggressive actions, including development of a multi-year fisheries management plan for GNP to guide conservation and management of native fish. Such a plan would likely include a strategy of non-native fish removal in some waters, protecting existing natural native fish populations from colonization by non-native fish, as well as potentially establishing new populations of native fish in areas of the park secure from invasion by non-native species. The recently developed Action Plan to Conserve Bull Trout in Glacier National Park (Fredenberg et al. 2007) will serve as a key reference in developing conservation strategies in the future.

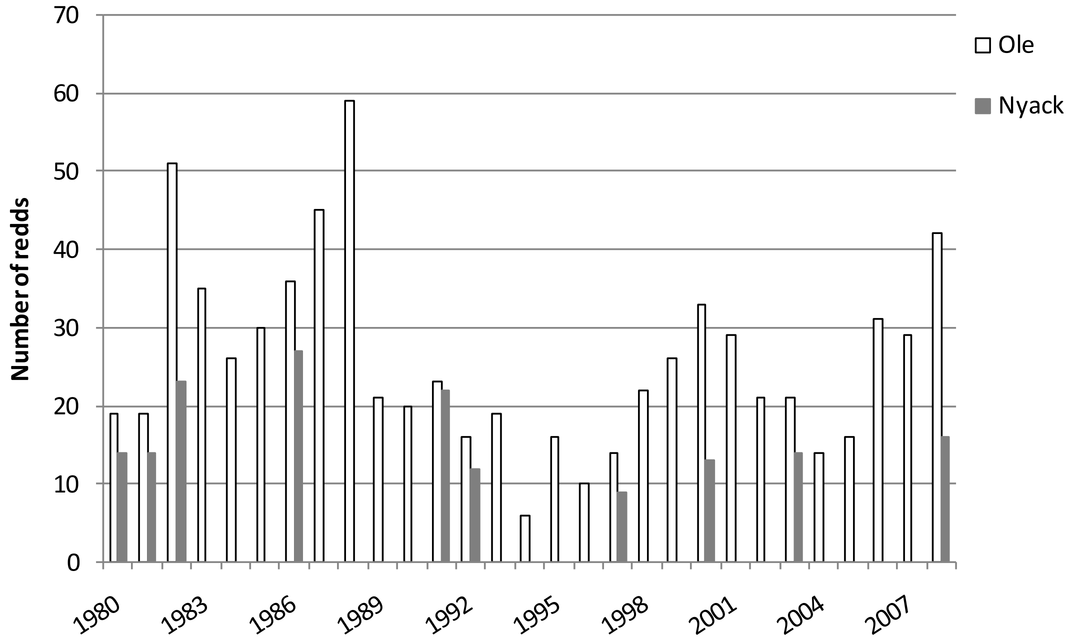

Figure 3. Bull trout redd counts conducted in Ole and Nyack creeks, Middle Fork Flathead River Drainage, Glacier National Park.

In the interim, additional population monitoring and evaluation is appropriate. Several bull trout waters are surveyed on a 5-year netting interval. The next scheduled netting survey of bull trout waters is scheduled for 2010. The survey should be expanded to include more waters that will provide a broader index of bull trout and native fish community health. In addition, monitoring sections for juvenile native fish abundance (i.e. bull and westslope cutthroat trout) should be established using electrofishing and snorkeling techniques. Finally, redd count index streams/sections should be established for additional bull trout populations to provide a frame of reference to gauge any future changes in population status.

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Appendix A. Bull trout redd counts conducted in Glacier National Park, Montana, 1980 to present.

Table A.1. Bull trout redd counts conducted in Glacier National Park, Montana, 1980 to present.

Stream	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Hudson Bay Drainage																
Boulder Cr.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Kennedy Cr.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
N. Fk. Flathead Drainage																
Akokala Cr.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Agassi Cr.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bowman Cr.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Harrison Cr.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Jefferson Cr.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Logging Cr.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Quartz Cr. (lower)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Quartz Cr. (middle)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Quartz Cr. (upper)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Rainbow Cr.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Upper Kintla outlet	--	--	--	--	--	--	--	--	--	--	--	--	--	--	52	--
Upper Kintla inlet	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
M. Fk. Flathead Drainage																
Ole Cr.	19	19	51	35	26	30	36	45	59	21	20	23	16	19	6	16
Nyack Cr.	14	14	23	--	--	--	27	--	--	--	--	22	12	--	--	--
Park Cr.	--	13	0	--	--	--	87	--	--	--	--	19	1	--	--	--
Starvation Cr.	1	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table A.1. Continued.

Stream	1996	1997	1998	1999	2000	2001	2002	2003	2004f	2005b,f	2006	2007a,c	2008c,d,e
Hudson Bay Drainage													
Boulder Cr.	--	12	42	20	30	28	28	28	27	--	50	38	58
Kennedy Cr.	--	23	37	--	23	12	11	18	27	25	20	13	22
N. Fk. Flathead Drainage													
Akokala Cr.	--	--	--	--	--	--	--	--	--	--	--	--	11
Agassi Cr.	--	--	--	--	--	--	--	--	--	--	--	--	0
Bowman Cr.	--	--	--	--	--	--	0	0	0	0	2	1	0
Harrison Cr.	--	--	--	--	--	--	--	--	4	0	8	15	14
Jefferson Cr.	--	--	--	--	--	--	--	--	--	--	--	--	0
Logging Cr.	--	--	--	--	--	--	--	--	3	20	0	--	5
Quartz Cr. (lower)	--	--	--	--	--	--	--	--	1	3	2	2	3
Quartz Cr. (middle)	--	--	--	--	--	--	--	0	0	0	0	0	0
Quartz Cr. (upper)	--	--	--	--	--	--	--	31	46	4	36	14	51
Rainbow Cr.	--	--	--	--	--	--	--	--	--	--	--	--	28
Upper Kintla outlet	--	--	--	--	--	--	--	--	--	--	--	--	0
Upper Kintla inlet	--	--	--	--	--	--	--	--	--	--	--	--	0
M. Fk. Flathead Drainage													
Ole Cr.	10	14	22	26	33	29	21	21	14	16	31	29	42
Nyack Cr.	--	9	--	--	13	--	--	14	--	--	--	--	16
Park Cr.	--	2	--	--	10	--	--	0	--	--	--	--	23
Starvation Cr.	--	0	--	--	0	--	--	--	--	--	--	--	--

a = spawning activity on Upper Quartz likely inhibited by weir at mouth.
b = minimum count due to high flows in Upper Quartz.
c = count accuracy may have been compromised to due to kokanee spawning activity in Harrison.
d = cumulative count based on multiple survey events in Upper Quartz.
e = count conducted by helicopter on Park.
f = minimum count on Ole as high flows may have obliterated some redds.