

Glacier National Park Native Fish Population and Lake Fisheries Monitoring

Program Report 2016







Prepared by:

Christopher C. Downs, Jonathan L. McCubbins
National Park Service, West Glacier, Montana
May 2018



Suggested citation:

Downs, C.C., and J. L. McCubbins. 2018. Glacier National Park Native Fish Population and Lake Fisheries Monitoring 2016. National Park Service, West Glacier, Montana.

Front cover photo caption: Lake fisheries monitoring.

Inside photo captions (top to bottom): Native fish population monitoring in Sherburne Reservoir, snorkel survey in classic west side creek, native fish population monitoring in Slide Lake and native fish population monitoring in Red Eagle Lake.

TABLE OF CONTENTS

Native Fish Population Monitoring

ABSTRACT.....	8
INTRODUCTION.....	9
METHODS.....	13
RESULTS AND DISCUSSION.....	16
LITERATURE CITED.....	26
ACKNOWLEDGEMENTS.....	27

LIST OF TABLES

Table 1.	Native (N) and introduced (I) salmonids in Glacier National Park.....	10
Table 2.	Native (N) and introduced (I) non-salmonids in Glacier National Park.....	11
Table 3.	Location information for native fish population monitoring efforts in 2016.....	15
Table 4.	Size class, species, and count of all fish seen snorkel surveys in Mineral Creek in 2016.....	16
Table 5.	Size class, species, and count for fish observed during snorkel surveys in McDonald Creek in 2013, 2015 and 2016.....	17
Table 6.	UTM's and set parameters of Sherburne Reservoir live trapping and seining. For fyke nets, "Depth" refers to the depth of the trap entrance, for seine depth refers to the maximum depth in the haul.....	18
Table 7.	UTM's and set parameters of Red Egel Lake live trapping and seining. For fyke nets, "Depth" refers to the depth of the trap entrance, for seine depth refers to the maximum depth in the haul.....	21
Table 8.	UTM's and set parameters of Red Egel Lake live trapping and seining. For fyke nets, "Depth" refers to the depth of the trap entrance, for seine depth refers to the maximum depth in the haul.....	23

LIST OF FIGURES

Figure 1.	Major watersheds of Glacier National Park, Montana.....	12
Figure 2.	Stream and lake sampling sites for temperature monitoring, snorkeling, and trapping efforts in Glacier National Park, Montana, 2015. Site numbers from Table 3.....	14
Figure 3.	Locations of fyke net sets (1 and 2) and the seine haul (S) in Swiftcurrent Ridge Lake, July 21-22, 2015.....	18
Figure 4.	Length-frequency histogram for NPK captured in trap nets in Sherburne Reservoir, Glacier National Park, in 2016.....	19
Figure 5.	Locations of fyke net sets (1, 2, 3, 4, 5, 6, 7, 8, 9 and 10) in Red Eagle Lake, August 29-July 2, 2016.....	20
Figure 6.	Length-frequency histogram for WCT and BLT captured in trap nets in Red Eagle Lake, Glacier National Park, in 2016.....	21
Figure 7.	Locations of fyke net sets (1, 2, 3, 4, 5, 6, 7, 8 and 9) in Slide Lake (upper), July 11-July 13, 2016.....	22
Figure 8.	Length-frequency histogram for BLT and YCT captured in trap nets in Slide Lake, Glacier National Park, in 2016.....	23

Lake Fisheries Monitoring

ABSTRACT.....	28
INTRODUCTION.....	29
METHODS.....	30
RESULTS AND DISCUSSION.....	32
ACKNOWLEDGEMENTS.....	39
LITERATURE CITED.....	40

LIST OF TABLES

Table 1.	Gillnet locations and set and retrieval dates for Kintla, Bowman, and McDonald lakes in GNP, 2015.....	31
Table 2.	Catch composition and catch per unit effort for Lower Quartz, Saint Mary and Harrison lakes, GNP, 2016.....	33
Table 3.	Mean length (TL;mm), mean weight (g), Fulton-type condition factor (K), and relative weight (Wr) for species captured in overnight sinking gill net sets conducted during late summer in Glacier National Park, 2016 (BLT = bull trout, BKTxBLT = brook trout/bull trout hybrid, BBT = Burbot, KOK = Kokanee, LSS = largescale sucker, LKT = lake trout, LNS = longnose sucker, LWF = lake whitefish, MWF = mountain whitefish,, WCT = westslope cutthroat trout and WS = white sucker).....	38

LIST OF FIGURES

Figure 1.	Location of Lower Quartz, Harrison and Saint Mary lakes, Glacier National Park.....	30
Figure 2.	Number of bull trout (BLT) and lake trout (LKT) caught historically, in relation to 2016 standardized gill nets in Lower Quartz Lake, GNP.....	34
Figure 3.	Historical catch composition in relation to 2016 standardized gill net sets in Lower Quartz Lake, GNP.....	34
Figure 4.	Historical catch composition in relation to 2016 standardized gill net sets in Saint Mary Lake, GNP.....	35
Figure 5.	Number of bull trout (BLT) and lake trout (LKT) caught historically, in relation to 2016 standardized gill nets in Harrison Lake, GNP.....	36
Figure 6.	Historical catch composition in relation to 2016 standardized gill net sets in Harrison Lake, GNP.....	36

Native Fish Population Monitoring

ABSTRACT

In 2009, Glacier National Park (GNP) began development of a monitoring program for native salmonids inhabiting park streams. The intent of the program is to establish baseline abundance levels in a variety of park waters to serve as useful benchmarks for monitoring changes in populations over time. We continued this work through 2016, sampling in three waterbodies. We conducted snorkel surveys on Mineral and Upper McDonald (Middle Fork Flathead drainage) creeks. Trap netting was conducted in Slide and Red Eagle Lakes and Sherburne Reservoir. We noted presence or absence along with relative abundance of amphibians in our surveys. In general, the largest threat currently facing migratory native fish species on the east side of the park is the unscreened St. Mary River irrigation diversion near Babb, part of the Milk River Irrigation Project. Other threats include non-native species (walleye) found in the St. Mary River downstream of the U.S./Canada border. The most significant threat to native fish on the west side of the park comes from invasive species, such as rainbow, brook, and lake trout. However, management and conservation of native fish in the North and Middle forks of the Flathead River remains complicated due to the presence of migratory and resident populations of native salmonids, and expanding distribution of invasive fish species.

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 approximately 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 perennial stream habitat for aquatic species. A diversity of native and introduced fish species inhabits park waters (Table 1; Table 2).

GNP encompasses the headwaters of three continental scale watersheds (Figure 1). The western portions of the park drain into the Pacific Ocean via the Columbia River, the southeastern portions of the park drain into the Atlantic Ocean via the Mississippi River, while the northeastern portions of the park drain into both the Arctic and the North Atlantic oceans via the Hudson Bay Drainage.

In order to effectively manage fishery resources and understand how landscape level changes impact these resources, data on species abundance and distribution is needed. Limited quantitative, repeatable historic fisheries data exists, and most of it was collected decades ago by Montana Fish, Wildlife, and Parks in the Flathead River drainages of the park (Read et al. 1982, Weaver et al. 1983). There were also a couple of efforts in the late 1960's and 1970's (NPS files, unpublished data) to conduct standardized gill-net surveys in some of the large lowland lakes in the North Fork Flathead Drainage of the park by the USFWS, and these data have served as useful baseline to evaluate fish species composition changes over time (e.g. lake trout versus bull trout). Later work by Mogen and Kaeding (2004) on bull trout populations in the St. Mary drainage represented the start of limited, but more intensive monitoring efforts for bull and westslope cutthroat trout in that drainage.

Establishing baseline data sets will be key to understanding how populations are responding to a changing climate and the associated changes in water temperatures, storm frequency, runoff timing, increase fire frequency, etc. Developing population estimate sections spread across the park should be valuable to monitor changes over time in fish community composition and abundance in response to expanding non-native fish species populations and climate change. This report represents a summary of data collected during 2016 field season.

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

Species	Columbia Drainage	Missouri Drainage	Hudson Bay Drainage
Arctic grayling <i>Thymallus arcticus</i>	--	--	I
Brook trout (ebt) <i>Salvelinus fontinalis</i>	I	I	I
Bull trout (blt) <i>S. confluentus</i>	N	--	N
Kokanee <i>Oncorhynchus nerka</i>	I	--	--
Lake trout <i>S. namaycush</i>	I	I	N
Lake whitefish <i>Coregonus clupeaformis</i>	I	--	N
Mountain whitefish (mwf) <i>Prosopium williamsoni</i>	N	N	N
Pygmy whitefish <i>P. coulteri</i>	N	--	N
Rainbow trout (rbt) <i>O. mykiss</i>	I	I	I
Westslope cutthroat trout (wct) <i>O. clarkii lewisi</i>	N	N	N
Yellowstone cutthroat trout <i>O. c. bouvieri</i>	I	I	I
Fathead minnow <i>Pimephales promelas</i>	--	--	--
Northern pikeminnow <i>Ptychocheilus oregonensis</i>	N	--	--
Peamouth <i>Mylocheilus caurinus</i>	N	--	--
Redside shiner <i>Richardsonius balteatus</i>	N	--	--

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

Species	Columbia Drainage	Missouri Drainage	Hudson Bay Drainage
Longnose sucker (Ins) <i>Catostomus catostomus</i>	N	N	N
Largescale sucker (Iss) <i>C. macrocheilus</i>	N	--	--
White sucker (wsu) <i>C. commersoni</i>	--	N	N
Deepwater sculpin <i>Myoxocephalus thomsoni</i>	--	--	N
Mottled sculpin <i>Cottus bairdi</i>	--	N	N
Slimy sculpin <i>C. cognatus</i>	N	--	--
Shorthead sculpin <i>C. confusus</i>	N	--	--
Spoonhead sculpin <i>C. ricei</i>	--	--	N
Burbot <i>Lota lota</i>	--	--	N
Northern pike <i>Esox Lucius</i>	--	--	N
Trout-perch <i>Percopsis omiscomaycus</i>	--	--	N
Lake Chub <u><i>Couesius plumbeus</i></u>	--	N	N

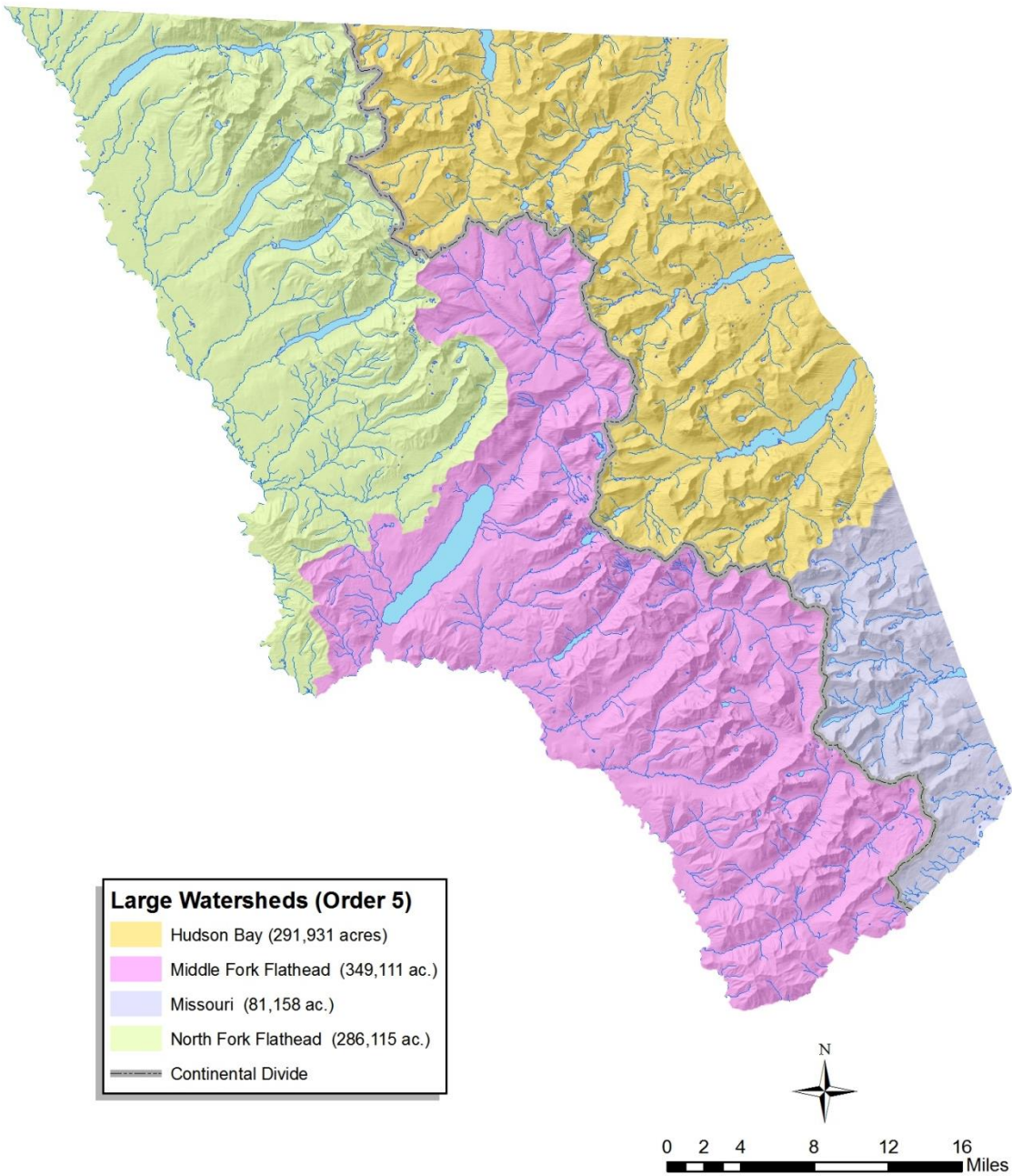


Figure 1. Major watersheds of Glacier National Park, Montana.

METHODS

Netting

We used custom-made miniature fyke nets to sample Slide and Red Eagle lakes and Sherburne Reservoir, located in the Saint Mary drainage (Figure 2). Fyke nets were constructed of 12mm (bar measure) brown nylon mesh. Each net measured 3 m in length and had leads 7 m long X 0.66 m tall, with a leadcore and polyfoam line used to hold the lead upright, while maintaining contact with the lake bottom. Their rectangular opening at the mouth of the fyke net measured 66 cm tall by 1 m wide. The remainder of the trap consisted of a single throat (approximately 15 cm opening at the small end) and four hoops. Fyke nets were not baited.

Fyke nets were set by staff wading into the deepest water they could without overtopping their chest waders and dropping the cod end of the trap to the bottom anchored by a weight. The lead end was then pulled to shore to set the trap. The shallow end of the lead was set where it would obstruct the entire depth of the water column (about 0.66 m), which was typically within 1-2 m of shore. Fyke nets were set angled along the shoreline such that the entrance to the trap was generally set in <1-m deep water. These shallow sets were used because test netting failed to catch any fish in deeper water. Overnight sets were used and nets were typically set in late afternoon and retrieved early the following morning.

Snorkeling

In addition to trapping, we also used snorkeling to assess species composition and size structure in Mineral and Upper McDonald Creeks (Figure 2, Table 3). Surveying for fish using standardized snorkeling techniques has long been understood to be a valid method to survey abundance, species composition, size structure, and habitat use (Thurrow 1994). We defined three size classes of fish; Class I: <49mm TL, Class II: 46-149mm TL, Class III: >150mm. Surveyors snorkeled in an upstream direction. At least one observer walked alongside the snorkeler measuring stream width, recording time snorkeler was surveying, species found, and to watch for safety hazards. When creek size allowed, two snorkelers moved upstream side by side. Fish were not counted in the survey until the snorkeler had moved past them in order to avoid duplicate counting of fish. Snorkel estimates involved identifying a representative reach of stream approximately 100-200 m long. We used a high-gradient riffle break or other natural drop in the stream channel as section starting and ending points. When possible, snorkel surveys were performed within previously sampled electrofishing or historical (e.g. Read et al. 1982) snorkeling sections.

Due to the cold water temperatures generally found in the park, the timing of our sampling, and previous length-frequency data, we assumed bull trout (blt) ≥ 60 mm and westslope cutthroat trout (wct) ≥ 45 mm were age-1 and older for estimation of abundance and catch-per-unit effort (CPUE). This was confirmed by examining the length-at-capture data from our 2009 field sampling. These assumptions are further supported by other studies. In some cold systems similar to GNP, wct fry may not even emerge from the gravel until mid-August (Scarnecchia and Bergersen 1986, Downs 1995). Scarnecchia and Bergersen (1986) indicated few cutthroat trout from headwater systems in Colorado exceeded lengths of 30-35 mm before they entered their first winter. Therefore using a lower limit (i.e. 45 mm) as a cutoff for inclusion in estimates of age-1 and older wct is more appropriate for most park waters containing rearing wct. Fishes of these sizes (blt ≥ 60 mm and wct ≥ 45 mm) can be efficiently

sampled with electrofishing gear and thereby provide for estimation of abundance and catch per unit effort (CPUE). Water temperatures were continuously recorded over the course of the summer using temperature loggers in Starvation, Ole, and Lee creeks.

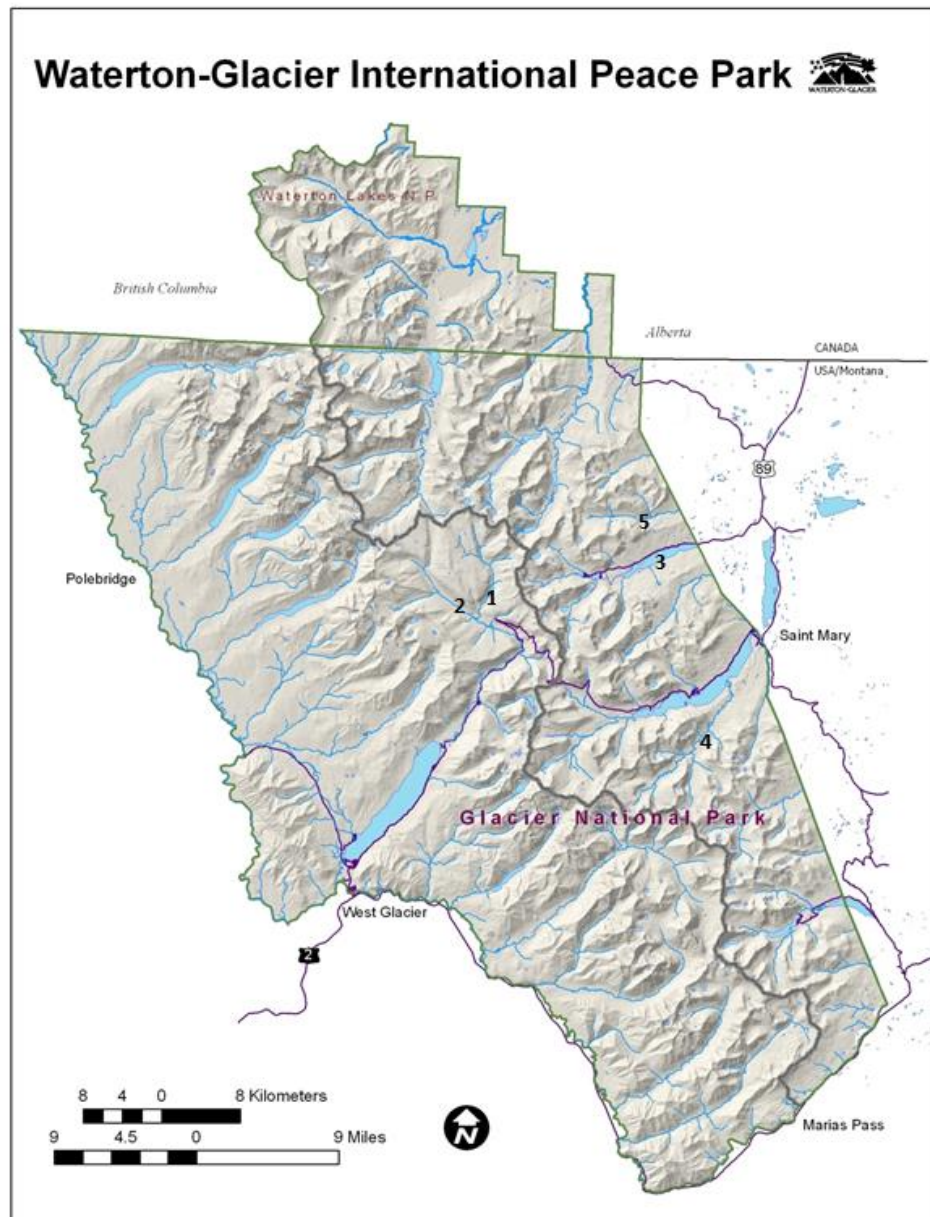


Figure 2. Stream and lake sampling sites for snorkeling, and trapping efforts in GNP, Montana 2016. Site numbers from Table 3.

For snorkeling surveys, GPS coordinates of the upstream and downstream end of the sections were recorded in UTM using the WGS 84 datum. Digital photographs were taken of the upstream and downstream ends of each section, and wetted widths were measured at approximately 20m intervals to calculate the wetted stream area sampled. Channel gradient was estimated in percent with a clinometer by taking multiple measurements (four or more) of slope in each study reach and averaging them. Stream temperature was recorded at the time of sampling in Celsius with a handheld thermometer. Dominant and sub-dominant substrate sizes for the entire reach were estimated visually, using six general size classes of bed material: bedrock, boulder, cobble, gravel, sand, and silt. The presence and relative abundance of amphibians was noted as present-common or present-rare.

Table 3. Location information for native fish population monitoring efforts in 2016.

Major Drainage	Water name (Site No.)	Method	Location of downstream end of reach (WGS 84, UTM)	Dates sampled	Sample Reach Length (m)
Middle Fork Flathead	Mineral Cr (3)	Snorkel	12U 0303790N292587, 5360495W5404462W	8/21/2013; 8/13/14; 8/11/15; 8/3/2016	377
	Upper McDonald Creek (4)	Snorkel	12U 292335N, 5403907W	8/20/13; 8/12/15; 8/4/2016	329
Saint Mary (Hudson Bay)	Sherburne Reservoir (6)	Mini fyke nets	Multiple sites	8/11-8/13/16	
	Red Eagle Lake (7)	Mini fyke nets	Multiple sites	6/29-7/2/2016	
	Upper Slide Lake (8)	Mini fyke nets	Multiple sites		

RESULTS AND DISCUSSION

Middle Fork Flathead River Drainage

Mineral Creek

Mineral Creek is a second order tributary to McDonald Creek in the McDonald Lake drainage (Figure 2). The downstream end of the sampling site is located at the trail crossing for stock which is located ~300 m upstream of the confluence of Mineral Creek and upper McDonald Creek.

Based on the size structure of the population and the location of the sampling site in the drainage, it is likely this population is resident. Mineral Creek contains genetically pure wct based on samples collected from Mineral Creek in 2008.

In 2016 wct were the only species of fish observed in this reach of Mineral Creek. Fish in all size groups were observed (Table 4). One hundred and ninety five wct were observed by snorkelers on 8/3/2016, resulting in a density estimate of 3.1 wct/100 m². This section was difficult to snorkel due to shallow water and a lack of pools. We will revisit the location of this sampling site in 2017.

Large cobble was estimated to be the dominant substrate type followed by gravel in the reach. Average wetted-width measured 11.3 m in 2016. Water temperature was measured at 19.5 °C at the time of sampling in 2015. No amphibians were observed in Mineral Creek in 2016.

Table 4. Size class, species, and count for fish observed during snorkel surveys in Mineral Creek in 2016.

Species	Lengths	2016
WCT	<45 mm	94
	46-149 mm	90
	≥150 mm	11
	Age 1+ /100m ²	2.7
MWF	<49 mm	0
	50-149 mm	0
	≥150 mm	0
	Age 1+ /100m ²	0

Upper McDonald Creek

Upper McDonald Creek above the confluence with Mineral Creek is a third order tributary to the M. Fk. Flathead River (Figure 2). It flows primarily southeast, until it joins Mineral Creek at which time it flows southwest to Lake McDonald. Upper McDonald Creek drains approximately 28,700 ha. In 2013, 2015 and 2016 we snorkeled from the confluence with Mineral Creek upstream for 329m, the elevation

at the sampling site was approximately 1,147m. Sections below Lake McDonald have been surveyed previously by Weaver et al (1983), however, we do not believe that others have snorkeled above the Mineral Creek confluence. McDonald Creek upstream of McDonald Falls is known to contain genetically pure wct (NPS, unpublished data).

In both 2013, 2015 and 2016 wct were the only species of fish observed in this reach of McDonald Creek. Fish in all size groups were observed (Table 5). Sixty five wct were observed by snorkelers in 2013 (8/20/2013) resulting in a density estimate of 1.4 wct/100 m². We repeated the snorkeling effort in 2015 (8/12/2015) and 2016 (8/4/2016) and observed a total of forty wct in 2015 and twenty three wct in 2016 which resulted in a density estimate of 0.62 wct/100 m² and 0.48 wct/100 m² respectively. Observed cutthroat trout density was higher in 2013 than in 2015 and 2016 (Table 5). Although the 2013 estimate was higher, the 2013, 2015 and 2016 wct density estimates suggest upper McDonald Creek contains a relatively low density of cutthroat trout. This reach has very little woody debris, reasonable stream gradient, and desirable pool/run ratio. However, further exploration in 2016 around this reach found that large beaver dams exist in a small braid that leaves McDonald Creek upstream of the current sampling reach. Since the entire wetted width is not being sampled, the future reach to be snorkeled in upper McDonald Creek will most likely be moved to a more ideal reach upstream of the current reach. These low densities of wct within upper McDonald Creek are expected due to the low productivity and nutrient-poor nature of the system.

Cobble was estimated to be the dominant substrate type followed by gravel in the reach. Average wetted-width measured 11.43 m in 2013, 10.78 m in 2015, and 11.8 m in 2016. Water temperature was measured at 13 °C in 2013, 12°C in 2015 and 13 °C at the time of sampling in 2016. No amphibians were observed in McDonald Creek in 2013, 2015 or 2016.

Table 5. Size class, species, and count for fish observed during snorkel surveys in McDonald Creek in 2013, 2015 and 2016.

Species	Lengths	2013	2015	2016
WCT	<45 mm	11	18	6
	46-149 mm	31	19	16
	≥150 mm	23	3	1
	Age 1+ /100m ²	1.44	0.62	0.48

St. Mary River Drainage

Sherburne Reservoir *Fyke Trap Netting* Between 1906 and 1924, the U.S. Bureau of Reclamation built several water-control and delivery structures in the St. Mary River drainage, as part of the Milk River Irrigation Project. One of the structures built during that time was Sherburne Dam, which impounds Swiftcurrent Creek and was constructed between 1914 and 1921. This dam is a 33 meter high compacted earth dam and created what is now known as Sherburne reservoir. Sherburne reservoir is located in the Many Glacier valley in Glacier National Park. It has a surface elevation of approximately (due to variable pool elevation) 1,490 meters, a maximum length of 9.7 kilometers and a maximum width of 1.3 kilometers. The reservoir is the principal water storage component of the U.S. Bureau of Reclamation's Milk River Project, which provides irrigation water to north central Montana farms. Bull trout, mountain whitefish, lake whitefish, northern pike and long nose suckers are native to the system

and were trapped above the dam after its construction. Sampling efforts in 2010 showed that these species still exist in the reservoir. Records document the planting and introduction of arctic grayling in the reservoir in 1934 but that population is not presumed to exist today. We set two trap nets per night for two nights in Sherburne Reservoir. The reservoir has shallow littoral zones so it was relatively difficult to find good set locations for the fyke nets to fish effectively. All four net set locations were toward the West end of the lake (Figure 3). During these fyke net sampling efforts, we captured a total of 6 northern pike and one lake whitefish. This resulted in a CPUE of 3 northern pike/net night and 0.5 lake whitefish/net night. Mean length for northern pike captured via netting was 729 mm. Length at capture ranged from 156 to 1098 mm (Figure 4).

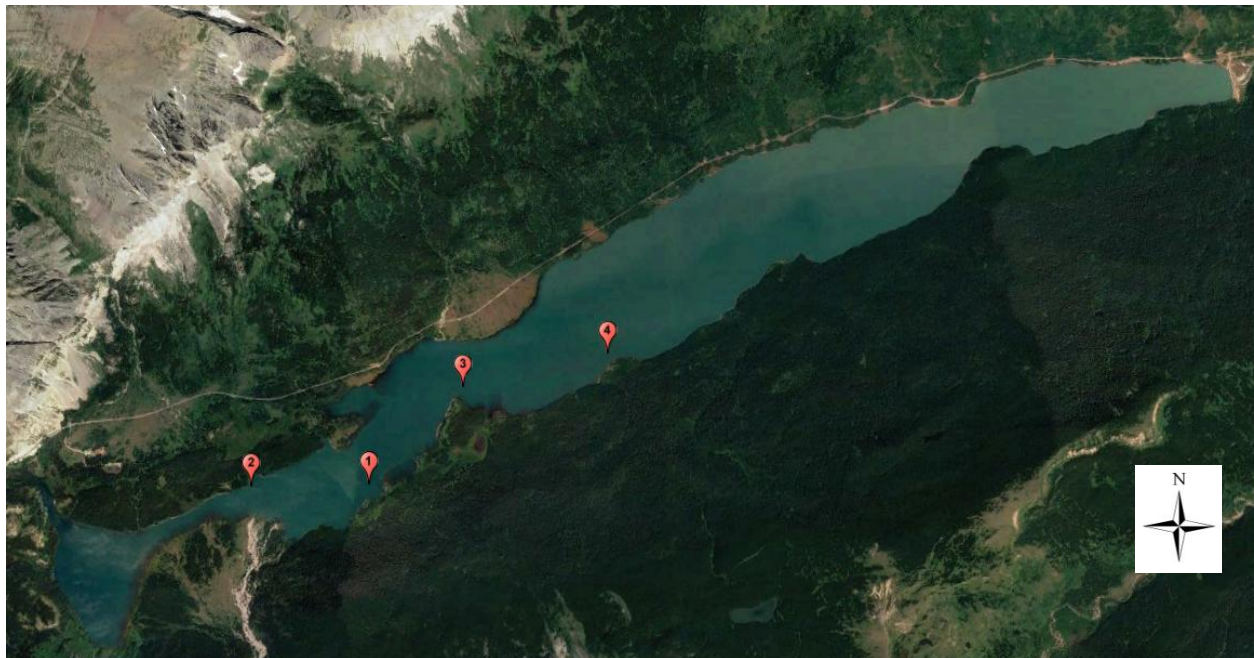


Figure 3. Locations of fyke net sets (1, 2, 3 and 4) in Sherburne Reservoir, August 11-13, 2016.

Table 6. UTM's and set parameters of Sherburne Reservoir live trapping . "Depth" refers to the depth of the trap entrance.

Net	UTM X	UTM Y	Date Set	Time Set	Date Pulled	Time Pulled	Depth (feet)
Fyke Net 1	12U 0308005	5408482	8/11/16	18:33	8/12/16	8:13	6.5
Fyke Net 2	12U 0307096	5408499	8/11/16	19:05	8/12/16	8:35	6.5
Fyke Net 3	12U 0308741	5409206	8/12/16	18:56	8/13/16	8:42	6.5
Fyke Net 4	12U 0309875	5409429	8/12/16	19:17	8/13/16	8:58	5.5

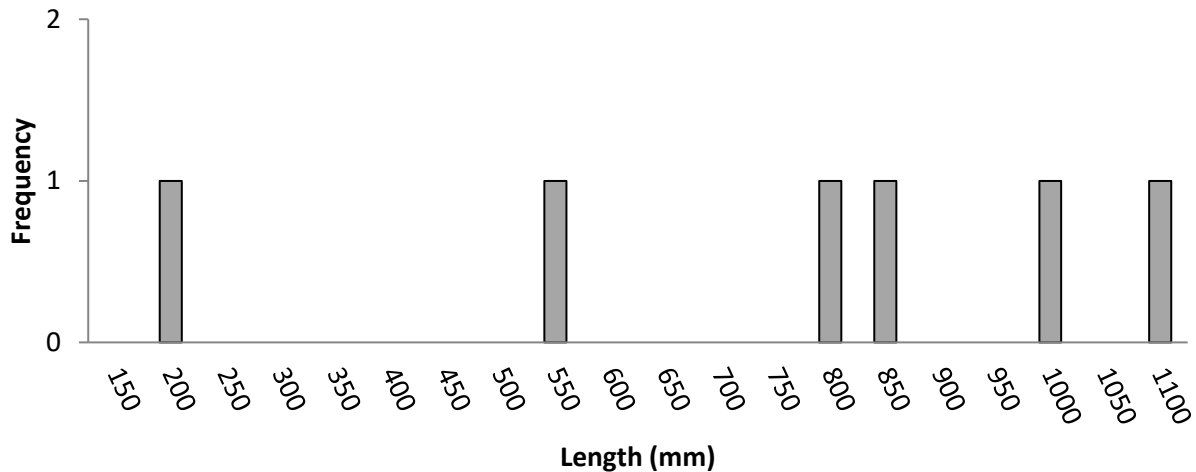


Figure 4. Length-frequency histogram for NPK captured in trap nets in Sherburne Reservoir, Glacier National Park, in 2016.

Red Eagle Lake Fyke Trap Netting

Red Eagle Lake is 1.21 kilometers long and 0.48 kilometers wide, the deepest determined depth is 14.94 meters and the lake has a surface elevation of 1,439 meters. Westslope cutthroat trout, mountain whitefish and bull trout are native to the lake. Records from the 1930's show the stocking of "cutthroat" trout but do not designate whether those fish were Yellowstone cutthroat trout or westslope cutthroat trout. Rainbow trout have been introduced to the system and a recent study shows the hybridized rainbow/cutthroat trout population to genetically be 80.1% rainbow trout, 19.4% westslope cutthroat trout and 0.4% Yellowstone cutthroat trout (Muhlfeld et. al 2017). Creel surveys from the 1960's show that brook trout were caught in Red Eagle Lake by hook and line during that time. There is no record of brook trout being captured in the lake in recent years so it is unknown if a remnant of the lakes previous brook trout population persists today.

We set ten nets in Red Eagle Lake, five nets on the first night and five nets on the second night. Nets were set in suitable locations around the circumference of the lake (Figure 5). In these ten nets, we captured six presumed hybrid cutthroat trout (due to displayed physical characteristics) and one bull trout. This resulted in a CPUE of 0.1 bull trout/net night and 0.6 hybrid cutthroat trout/net night. The single bull trout captured measured 595 mm and the mean length for hybrid cutthroat trout captured was 150 mm. Hybrid cutthroat trout length at captured ranged from 118 mm to 186 mm (Figure 6).



Figure 5. Locations of fyke net sets (1, 2, 3, 4, 5, 6, 7, 8, 9 and 10) in Red Eagle Lake, August 29-July 2, 2016.

Table 7. UTM's and set parameters of Red Eagle Lake live trapping . Depth refers to the depth of the trap entrance.

Net	UTM X	UTM Y	Date Set	Time Set	Date Pulled	Time Pulled	Depth (feet)
Fyke Net 1	12U 0315352	5391309	7/5/2016	15:38	7/6/2016	9:05	3.5
Fyke Net 2	12U 0315407	5391428	7/5/2016	9:16	7/6/2016	9:16	3.5
Fyke Net 3	12U 0315481	5391595	7/5/2016	16:17	7/6/2016	9:29	3.5
Fyke Net 4	12U 0315652	5391847	7/5/2016	16:44	7/6/2016	9:41	3.5
Fyke Net 5	12U 0315764	5392015	7/5/2016	17:00	7/6/2016	9:57	3.5
Fyke Net 6	12U 0315712	5392257	7/6/2016	10:26	7/7/2016	8:52	3.5
Fyke Net 7	12U 0315391	5392399	7/6/2016	10:58	7/7/2016	9:25	3.5
Fyke Net 8	12U 0315142	5391869	7/6/2016	11:36	7/7/2016	9:36	3.5
Fyke Net 9	12U 0315248	5392177	7/6/2016	11:57	7/7/2016	10:02	3.5
Fyke Net 10	12U 0314877	5391807	7/6/2016	12:30	7/7/2016	10:12	3.5

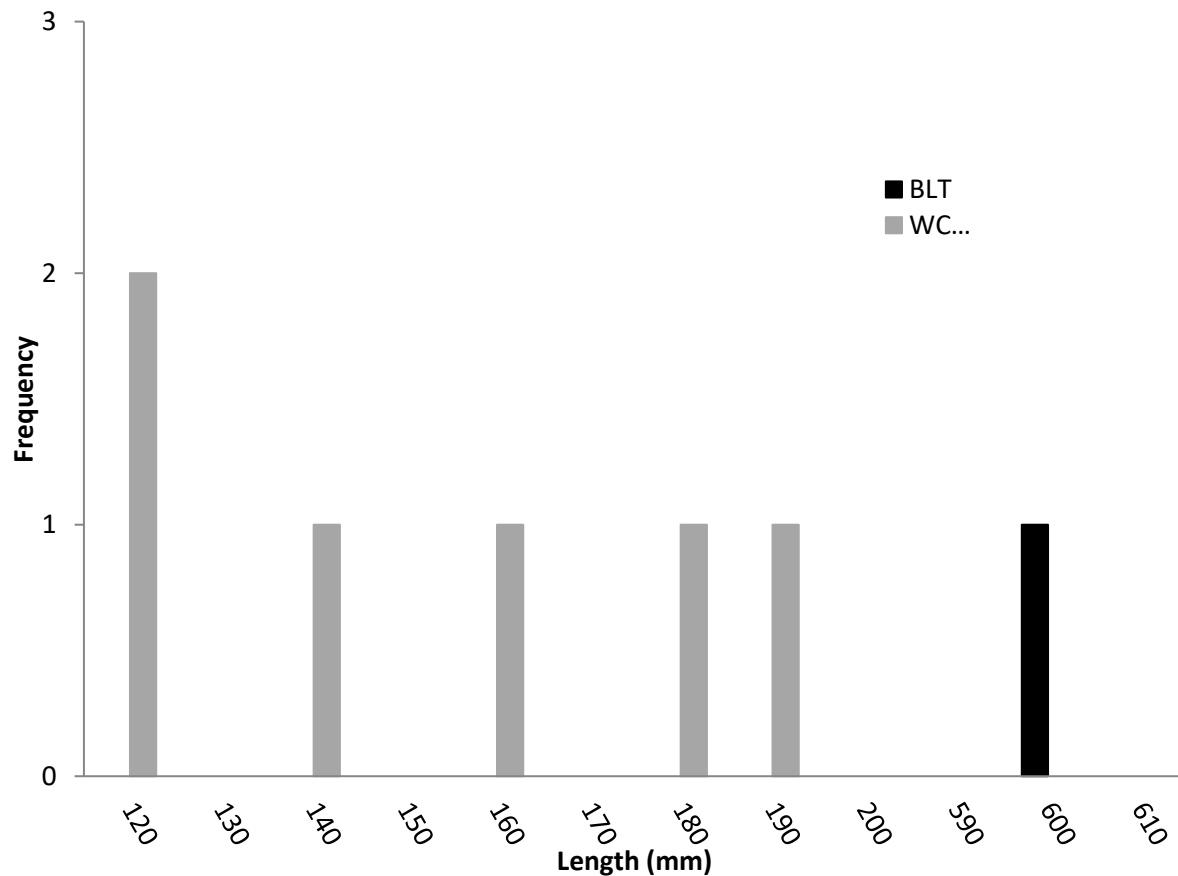


Figure 6. Length-frequency histogram for Hybrid cutthroat and BLT captured in trap nets in Red Eagle Lake, Glacier National Park, in 2016.

Slide Lake (upper) Fyke Trap Netting

Slide Lake is located in the Otatso Creek drainage and is actually made up of an upper and lower lake that were divided by a large rock slide off of yellow mountain in 1914 immediately to the south of the lake. However, sampling in 2016 only consisted of setting fyke nets in the upper lake. The lake is 0.64 km long and 0.8 km wide and has a surface elevation of 1,840 m.

Bull trout and westslope cutthroat trout are native to the lake. Stocking records indicate that “cutthroat trout” were stocked in the lake in the 1930’s. A recent study shows the genetic admixture of cutthroat in Upper Slide Lake to be 87.5% yellowstone cutthroat trout and 12.5% westslope cutthroat trout (Muhlfeld et. al 2017).

We deployed nine fyke nets in total, five were deployed the first night and four the second night. During our sampling efforts, we captured thirty five bull trout and two hybrid yellowstone/westslope cutthroat trout (Figure 8). This resulted in a CPUE of 3.8 bull trout/net night and 0.2 hybrid westslope/yellowstone cutthroat trout/net night. The mean length of bull trout captured was 357 mm and the length of the two hybrid westslope/yellowstone cutthroat trout was 446 mm and 500 mm (Figure 8).



Figure 7. Locations of fyke net sets (1, 2, 3, 4, 5, 6, 7, 8 and 9) in Slide Lake (upper), July 11-July 13, 2016.

Table 8. UTM's and set parameters of Slide Lake live trapping . Depth refers to the depth of the trap entrance.

Net	UTM X	UTM Y	Date Set	Time Set	Date Pulled	Time Pulled	Depth (feet)
Fyke Net 1	12U 0307869	5420077	7/11/2016	15:26	7/12/2016	8:45	3.5
Fyke Net 2	12U 0307780	5420072	7/11/2016	15:56	7/12/2016	9:10	3
Fyke Net 3	12U 0307644	5419986	7/11/2016	16:17	7/12/2016	9:28	3
Fyke Net 4	12U 0307495	5419856	7/11/2016	16:27	7/12/2016	9:42	4.3
Fyke Net 5	12U 0307335	5419748	7/11/2016	16:48	7/12/2016	9:56	3.5
Fyke Net 6	12U 0307338	5419747	7/12/2016	12:51	7/13/2016	10:30	3.5
Fyke Net 7	12U 0307680	5419751	7/12/2016	13:09	7/13/2016	10:17	3.5
Fyke Net 8	12U 0307824	5419802	7/12/2016	13:39	7/13/2016	10:00	3
Fyke Net 9	12U 0307877	5419839	7/12/2016	13:55	7/13/2016	9:45	3

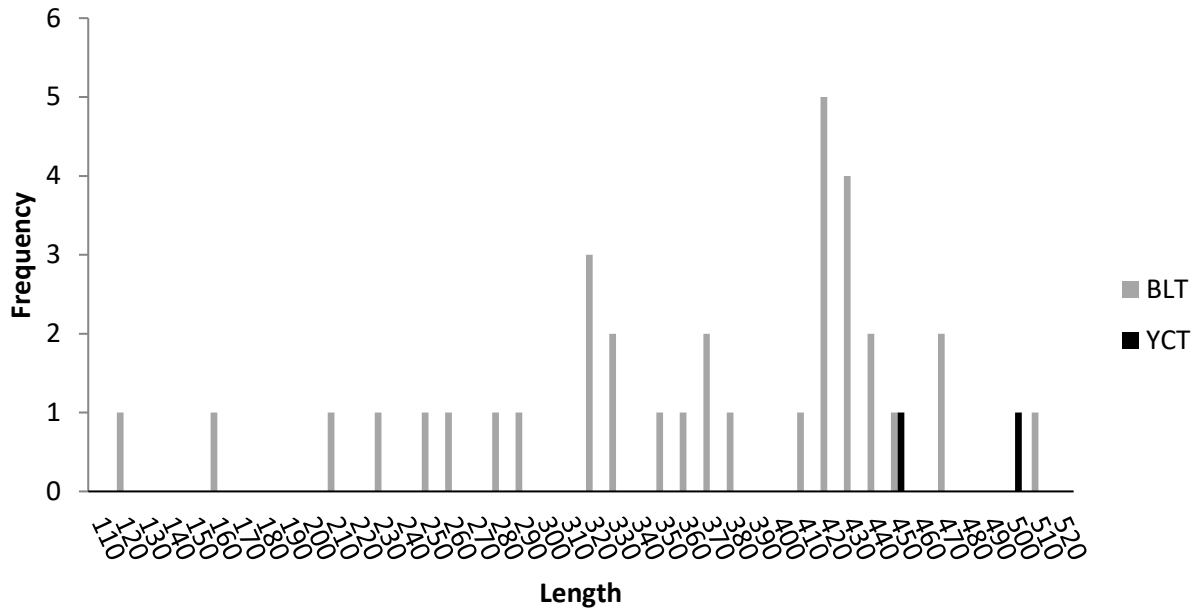


Figure 8. Length-frequency histogram for BLT and YCT captured in trap nets in Slide Lake, Glacier National Park, in 2016.

LITERATURE CITED

- Downs, C.C. 1995. Age determination, growth, fecundity, sexual maturity, and longevity for isolated, headwater populations of westslope cutthroat trout. MS Thesis. Montana State University, Bozeman.
- Downs, C.C., C. Stafford, H. Langner, and C.C. Muhlfeld. 2011. Glacier National Park Fisheries Inventory and Monitoring Bi-Annual Report, 2009-2010. National Park Service, Glacier National Park, West Glacier, Montana.
- Fredenberg, W., M. Meeuwig, and C. Guy. 2007. Action plan to conserve bull trout in Glacier National Park. U.S. Fish and Wildlife Service, Creston, Montana.
- Meeuwig, M., C. Guy, W.A. Fredenberg. 2007. Research Summary for Action Plan to Conserve Bull Trout in Glacier National Park, Montana. Montana State University, Bozeman.
- Meeuwig, M.H. 2008. Ecology of lacustrine-adfluvial bull trout populations in an inter-connected system of natural lakes. Ph.D. Dissertation. Montana State University, Bozeman.
- Muhlfeld, C.C., T.E. McMahon, M.C. Boyer, and R.E. Gresswell. 2009. Local habitat, watershed, and biotic factors influencing the spread of hybridization between native westslope cutthroat trout and introduced rainbow trout. *Transactions of the American Fisheries Society* 138: 1036-1051.
- Muhlfeld, C.C., T.E. McMahon, D. Belcer, and J.L. Kershner. 2009b. Spatial and temporal spawning dynamics of native westslope cutthroat trout *Oncorhynchus clarkii lewisi*, introduced rainbow trout *O. mykiss*, and their hybrids. *Canadian Journal of Fisheries and Aquatic Sciences* 66:1153-1168.
- Muhlfeld, C.C., V. S. D'Angelo, C. Downs, J. Powell, S. Amish, G. Luikart, R. Kovach, M. Boyer, and S. Kalinowski 2016. Genetic Status and Conservation of Westslope Cutthroat Trout in Glacier National Park, *Transactions of the American Fisheries Society*, 145:5, 1093-1109
- Read, D., B.B. Shepard, and P.J. Graham. 1982. Fish and habitat inventory of streams in the North Fork Drainage of the Flathead River. Montana Department of Fish, Wildlife and Parks, Helena.
- Scarnecchia, D.L. and E.P. Bergersen. 1986. Production and habitat of threatened and endangered greenback cutthroat and Colorado River cutthroat trout in Rocky Mountain headwater streams. *Transactions of the American Fisheries Society* 115:382-391.
- Thurow, R.F. 1994. Underwater Methods for Study of Salmonids in the Intermountain West. US Department of Agriculture. Forest Service, Intermountain Research Station. General Technical Report INT-GTR-307.
- Weaver, T.M., J.J. Fraley, and P. Graham. 1983. Fish and habitat inventory of streams in the Middle Fork Drainage of the Flathead River. Montana Department of Fish, Wildlife, and Parks, Helena.

ACKNOWLEDGEMENTS

We thank Carter Fredenberg and Kevin Perkins of the GNP fisheries crew for their dedication and hard work.

Lake Fisheries Monitoring

ABSTRACT

We sampled Lower Quartz, Harrison and Saint Mary lakes in GNP in 2016 to characterize and assess fish communities and trends occurring within the fish communities over time. We used sinking multi-filament experimental mesh gill nets, set overnight, to sample all lakes from late July through late August, when the lakes were thermally stratified. Relative abundance of most species have remained stable when compared to historical sampling. Decline in bull trout relative abundance has been occurring since introduced lake trout migrated from downstream areas into each of these three lakes. Following the dramatic decline in bull trout abundance throughout the 1970's and 1980's, bull trout have remained at extremely low numbers when compared to historic abundance estimates. Although vastly reduced in numbers, bull trout persist within all three of the lakes sampled in 2016.

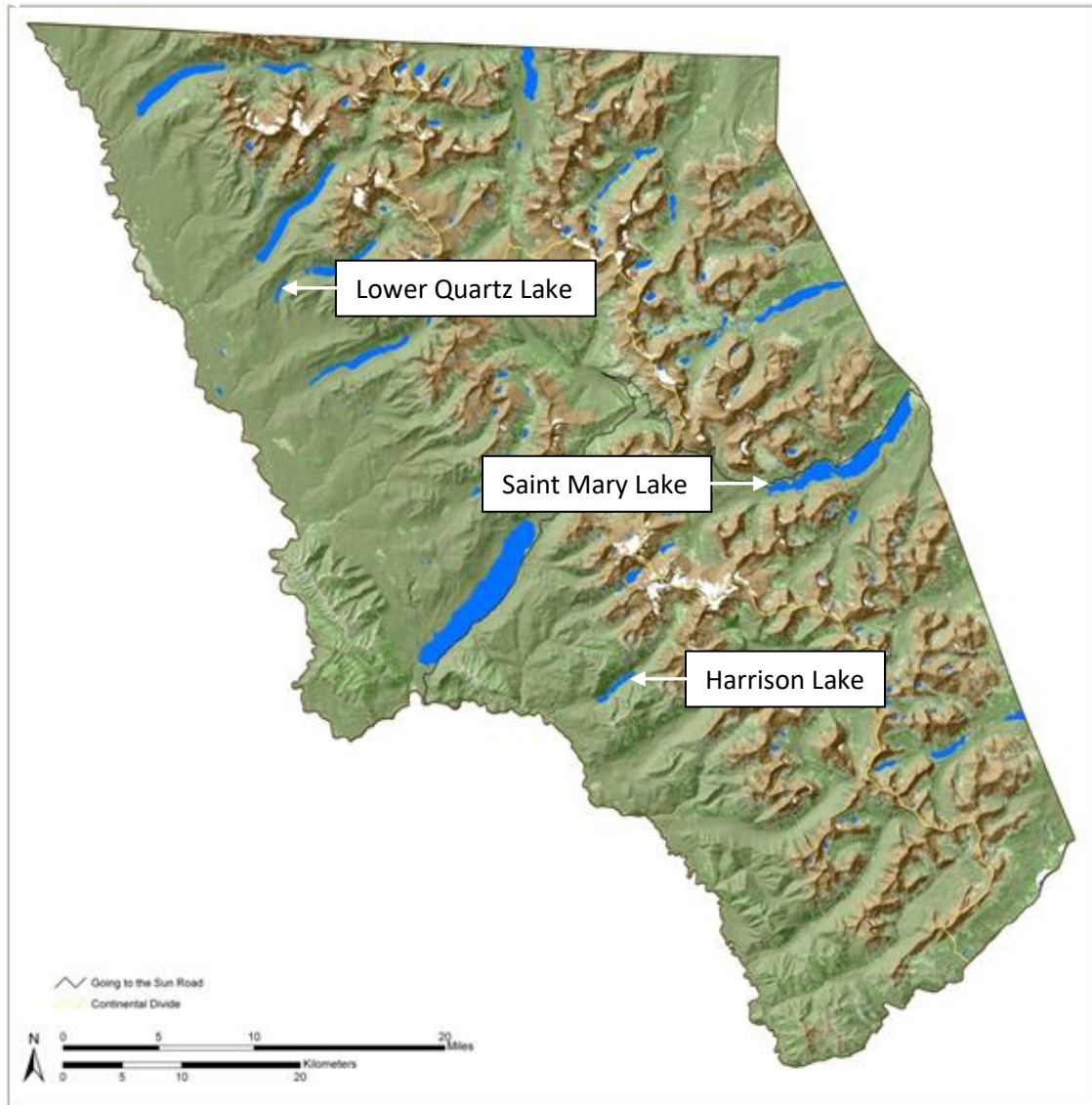
INTRODUCTION

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 approximately 1,000,000 acres, providing high-quality lentic and lotic fish habitat. Glacier National Park supports over 700 perennial lakes/ponds, ranging in size from less than an acre, up to Lake McDonald, covering almost 7,000 surface acres. Glacier National Park also provides over 2,200 km of high-quality perennial stream habitat for aquatic species. A diversity of native and introduced fish species inhabit park waters.

Although GNP represents some of the last best wild areas in North America, recent studies have demonstrated that GNP is not immune to anthropogenic impacts such as exotic species and airborne contaminants. Recent fisheries studies (Marnell et al. 1987, Fredenberg 2002, Hitt et al. 2003, Muhlfeld et al. 2009) have demonstrated the ecological damage and genetic consequences associated with non-native fish species in park waters. For example, Fredenberg (2002) documented the replacement of bull trout as the top predator by non-native lake trout in sympatric lakes on the west side of the park during the last several decades, and lake trout are continuing to expand their numbers and range on the west side of the park (Downs et al. 2015). In response to the lake trout threat the park has recently initiated collaborative efforts to secure remaining at-risk bull trout populations. Monitoring data from park lakes will be key in evaluating any future shifts in fish community structure that may result from additional impacts of non-native species, climate change, or other habitat perturbations.

The purpose of the study was to repeat long-term gill net trend monitoring in Lower Quartz, Harrison and Saint Mary lakes of GNP (Figure 1). This information will be used to assess the status of native fish populations in park lakes over time and to aid managers in preserving the native species existing within the pristine waters of GNP.

Figure 1. Location of Lower Quartz, Harrison and Saint Mary lakes, Glacier National Park.



METHODS

We used sinking multi-filament experimental mesh gill nets to sample the lakes. Nets were 38.1 m (125') X 1.83 m (6') experimental multifilament nylon with five 7.62 m (25') panels consisting of 19 mm (3/4"), 25 mm (1"), 32 mm (1-1/4"), 38 mm (1-1/2") , 51 mm (2") bar measured mesh. Thirty pound leadcore and polyfoam line was used to hold the net upright, while maintaining contact with the lake bottom. Sometimes two nets were ganged together to form a single 250' net by joining the large and small ends of each net. Lower Quartz Lake was sampled 25-27 July 2016, while Saint Mary and Harrison lakes were netted 8-10 August 2016 and 23-25 August 2016 respectively. We attempted to repeat set locations and depths used historically to monitor the lake fish communities (Fredenberg et al. 07 ;Table 1). Nets were set with the smallest mesh towards shore.

Table 1. Gillnet locations and set and retrieval dates for Lower Quartz Lake, Saint Mary Lake, and Harrison lakes in GNP, 2016.

	Net	UTM Zone	UTM Easting	UTM Northing	Set Date	Retrieve Date
Lower Quartz Lake	1	11	0707913	541022	7/26/16	7/27/16
	2	11	0707915	5410350	7/26/16	7/27/16
	3	11	0707686	5410350	7/26/16	7/27/16
	4	11	0707722	5410440	7/26/16	7/27/16
	5	11	707788	5410000	7/25/16	7/26/16
	6	11	0707469	5409990	7/25/16	7/26/16
	7	11	0707681	5409730	7/25/16	7/26/16
	8	11	0707321	5409590	7/25/16	7/26/16
Saint Mary Lake	1	12	0318301	5399385	8/8/16	8/9/16
	2	12	03155856	5397124	8/8/16	8/9/16
	3	12	0314118	5395986	8/8/16	8/9/16
	4	12	0311707	5395694	8/8/16	8/9/16
	5	12	0310358	5394507	8/8/16	8/9/16
	6	12	0309775	5394149	8/9/16	8/10/16
	7	12	0311833	5394831	8/9/16	8/10/16
	8	12	0313982	5395362	8/9/16	8/10/16
	9	12	0315608	5395256	8/9/16	8/10/16
Harrison Lake	1	12	0293812	5376455	8/24/16	8/25/16
	2	12	0294010	5376520	8/24/16	8/25/16
	3	12	0294719	5377019	8/24/16	8/25/16
	4	12	0294907	5377206	8/24/16	8/25/16
	5	12	0295579	5378014	8/24/16	8/25/16
	6	12	0295828	5378098	8/23/16	8/24/16
	7	12	0296557	5378537	8/23/16	8/24/16
	8	12	0296878	5378735	8/23/16	8/24/16
	9	12	0296053	5377901	8/23/16	8/24/16
	10	12	0296010	5377847	8/23/16	8/24/16

* Denotes netting locations that differed from historical gillnetting locations.

Gillnets were set in late afternoon/early evening and allowed to soak overnight. They were retrieved at sunrise the following day. Nets were set with the smallest mesh towards shore. Net locations were replicates of those described by Meeuwig et al. (2007) to allow for historical comparisons. All fish captured alive were removed from the net, counted in the net catch total, and were released. All other fish were measured (TL; mm) and weighed (g). Bull trout were sexed, maturity status was determined, genetic samples were collected and otoliths were removed and collected if fish had expired prior to net removal.

Catch-per-unit effort (CPUE), defined as the number of fish captured per net-night, was used as the primary measure of catch rate over time. In addition, as our comparison across years involves identical numbers of nets set each year, we compared the total number of fish captured for each species as a reflection of relative abundance. We calculated average length and weight for each species to facilitate comparisons of size structure between populations as well as over time within waterbodies. We estimated relative weight (Wr) (Anderson and Neuman 1996) for all sampled fish species to evaluate growth conditions across the sampled waters. We used standard weight equations for lake trout (Picolo et al. 1993), and lake whitefish (Rennie and Verdon 2008) to estimate Wr for each water. Fulton-type (K) condition factors were used for other species (Anderson and Neuman 1996).

RESULTS AND DISCUSSION

Eight to ten nets (four or five per evening) were set in each of the three lakes between 07/25 and 8/25 2016. Species diversity was highest in Saint Mary Lake (Table 2). Catch-per-unit-effort varied by species in each lake, with mountain whitefish being the most abundant in Lower Quartz and Harrison lakes and white suckers being the most abundant in Saint Mary Lake (Table 2). Both Lake trout and bull trout trends in abundance appear to be increasing in Lower Quartz Lake. Lake trout and bull trout are native to Saint Mary Lake. Lake trout in Saint Mary Lake appear to be decreasing since 2008 and bull trout have not been caught in sampling efforts in Saint Mary Lake since 2008 but are thought to exist at a low abundance. Harrison Lake sampling indicates an increasing relative abundance of lake trout and a decreasing relative abundance of bull trout when compared to historical sampling data (Figure 5).

Lower Quartz Lake

Lower Quartz Lake was netted from 25-27 July, 2016. Four nets were set each night resulting in eight net sets. One hundred and seven fish were captured, consisting of six different species. Mountain whitefish were the predominant catch ($N = 74$), followed by long nose sucker ($N = 10$). Catch results from 2016 were similar to years 2000-2016 as most species appear to be fluctuating around a potential carrying capacity (Figure 3). It is important to note that catch per-unit effort of bull trout was higher (1.1 fish/net night) than lake trout catch per-unit effort (0.4 fish/net night) in Lower Quartz Lake in 2016 (Table 2). Trend data from Lower Quartz Lake indicate increasing lake trout numbers even though species composition and catch numbers were lower in 2016 than in 2011 (Figure 2, Figure 3). Lower Quartz Lake bull trout trends in abundance also appear to be increasing since 2000.

Table 2. Catch composition and catch per unit effort for Lower Quartz, Saint Mary and Harrison lakes, GNP, 2016.

Water	Species	Number Captured	CPUE (fish/net night)
Lower Quartz Lake	Bull trout (BLT)	9	1.1
	Lake trout (LKT)	3	0.4
	Longnose sucker (LNS)	10	1.3
	Largescale sucker (LSS)	2	0.3
	Mountain Whitefish (MWF)	74	9.3
	Westslope cutthroat trout (WCT)	9	1.1
Saint Mary Lake	Bull trout	0	0.0
	Burbot	27	3.0
	Lake trout	17	1.9
	Longnose sucker	29	3.2
	Lake whitefish	52	5.8
	Mountain whitefish	72	8.0
	Northern pike	2	0.2
	Lake chub	6	0.7
	White sucker	146	16.2
Harrison Lake	Bull trout	3	0.3
	Eastern brook trout (EBT)	4	0.4
	Eastern brook trout/bull trout hybrid (EBT/BLT)	4	0.4
	Kokanee	2	0.2
	Lake trout	10	1.0
	Longnose sucker	92	9.2
	Largescale sucker	15	1.5
	Mountain whitefish	335	33.5
	Westslope cutthroat trout	20	2.0

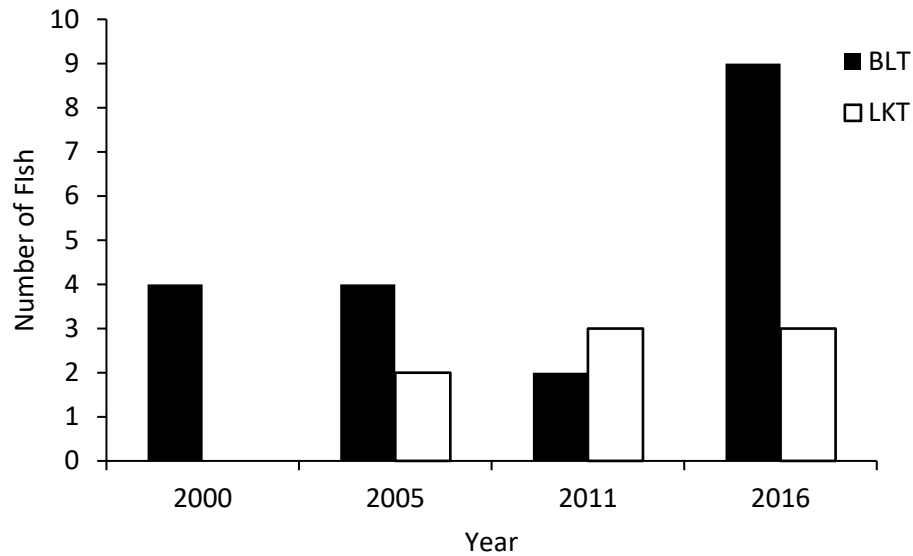


Figure 2. Number of bull trout (BLT) and lake trout (LKT) caught historically, in relation to 2016 standardized gill nets in Lower Quartz Lake, GNP.

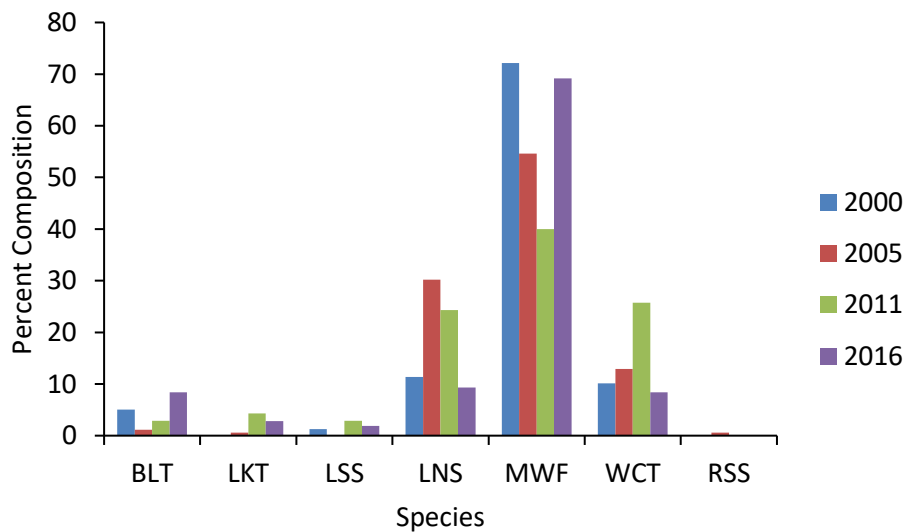


Figure 3. Historical catch composition in relation to 2016 standardized gill net sets in Lower Quartz Lake, GNP.

Saint Mary Lake

Saint Mary Lake was netted from 8 August-10 August, 2016. Five nets were set the first night and four nets were set the second night, one of those nets was tied together to make a single 250 foot long net. This resulted in a total of nine net sets. We captured 351 fish comprising eight species during

gill-netting efforts (Table 2). Bull trout numbers appear to remain low and burbot and lake trout species composition trends appear to decrease from 2008 to 2016. Lake whitefish species composition trends remained similar to 2010 but decreased since 2008 whereas mountain whitefish trends appear to be steadily increasing since 2008 (Figure 5). There is high variability in longnose sucker and white sucker trends. This is possibly due to misidentification between the two species as only one white sucker was identified in 2008, none in 2010 and 146 (41.6% of the species composition) were identified in 2016. Longnose sucker composition trends appear to conversely mirror those of white sucker composition trends (Figure 5). The largest proportion of the catch came from the white suckers ($N = 146$) followed by mountain whitefish ($N=72$) and lake whitefish ($N = 52$) (Figure 4).

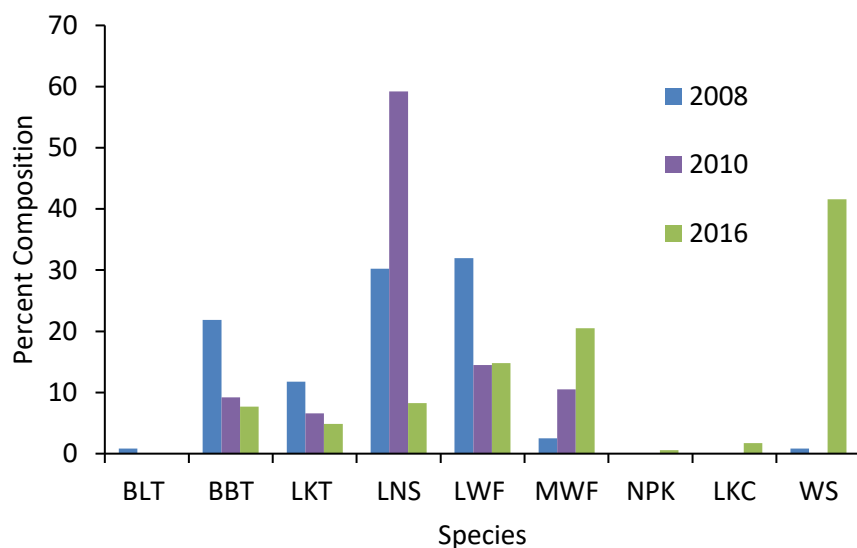


Figure 4. Historical catch composition in relation to 2016 standardized gill net sets in Saint Mary Lake, GNP.

Harrison Lake

Harrison Lake was netted 23 August- 25 August, 2016. We captured 485 fish comprising nine different species during gill-netting efforts in Harrison Lake in 2016. Mountain whitefish were the predominant catch in Harrison Lake ($N = 335$), followed by longnose suckers ($N = 92$) (Figure 7). Bull trout abundance reflected by number of fish captured has greatly decreased since the establishment of lake trout within Harrison Lake (Figure 6). Catch per-unit effort for both lake trout (1.0 fish/net night) and bull trout (0.3 fish/net night) declined since Harrison Lake was last sampled in 2011 (Table 2). However, Catch-per-unit-effort of net sets over time (USFWS, Meeuwig 2008) and species composition trends and number of fish caught from 2000 to 2016 suggest that lake trout are increasing in abundance fairly rapidly in Harrison Lake while bull trout abundances are in decline.

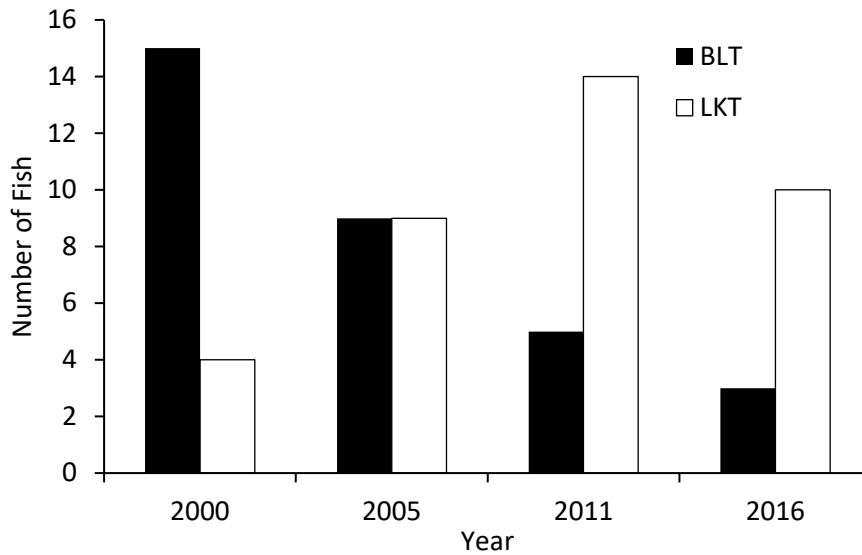


Figure 5. Number of bull trout (BLT) and lake trout (LKT) caught historically, in relation to 2016 standardized gill nets in Harrison Lake, GNP.

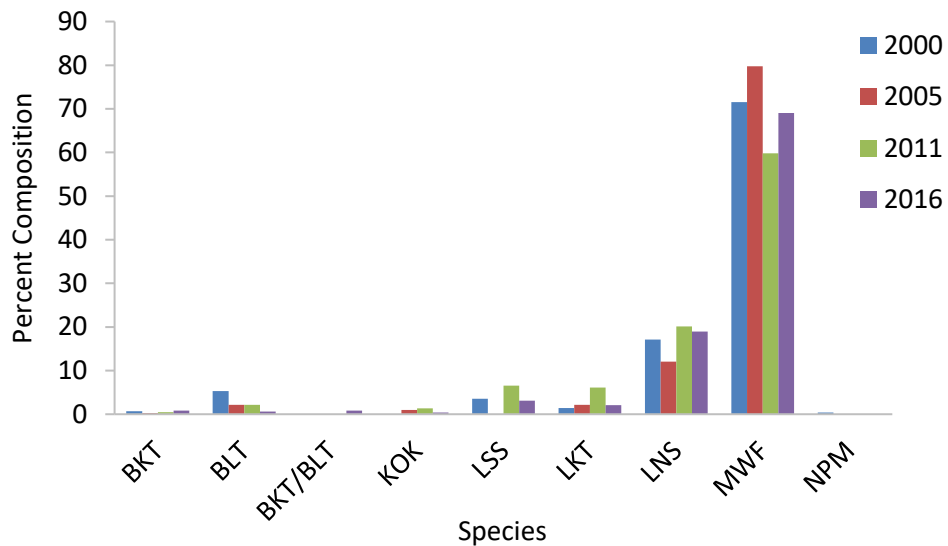


Figure 6. Historical catch composition in relation to 2016 standardized gill net sets in Harrison Lake, GNP.

Both catch rate and total catch of fish varied by water (Table 2). The nine bull trout captured in Lower Quartz lake was the highest number of bull trout captured since trend sampling began in 2000. If this is any indication of the trend in abundance of bull trout in Lower Quartz lake, it could mean good things for the species within this lake and would be the opposite of what is expect by looking at other nearby populations. However, to confirm this we would need more years of data to truly suggest this is actually occurring because between 2000 and 2011, the bull trout trend in abundance appeared to be declining. Lake trout numbers also appear to be increasing in Lower Quartz Lake and since these two

species compete strongly with each other for forage and habitat, we did not anticipate this result in 2016. It is possible that Lower Quartz Lake lacks lake trout spawning habitat sufficient to support a robust population of the species. However, as stated above, we will need more years of data to decipher what the trend in abundance truly is for these two species. Since trend analysis sampling began in Harrison Lake in 2000, bull trout catch numbers have decrease consistently for each sampling year. Contrastly, catch numbers for lake trout has an increasing trend since 2000 when trend sampling began in Harrison Lake (Figure 5). This is troubling, as Harrison Lake once supported a strong bull trout population and this assessment of standardized gill net catch data documents yet another lake in the large-interconnected system of lakes on the west side of the park where the replacement of bull trout by lake trout as the dominant aquatic predator is taking place (Fredenberg 2002). In addition, brook trout in Harrison Lake are known to hybridize with bull trout, which further decreases abundance of the native species. Although we captured westslope cutthroat trout in gill net sets, sinking nets don't effectively sample the upper 6'-10' of the water column where westslope cutthroat trout are most active. A floating gill net series would be a better choice for sampling westslope cutthroat and would most likely display a more accurate representation of the species within Harrison Lake.

Based on W_r and K , most species evaluated appeared to have less than optimal body condition (Table 3). Overall, lake trout condition was poor across all sampled waters, suggesting less than optimal feeding and/or temperature conditions may exist. Bull trout condition was close to optimal condition in Lower Quartz Lake suggesting that lake trout presence may not be affecting the bull trout population in that lake. This too may suggest that suitable lake trout habitat is limited in Lower Quartz Lake and their presence may not be as detrimental to the cohabitating local bull trout population. However, bull trout condition appeared to be lower than optimal in both Harrison and Saint Mary Lakes. A W_r of 100 represents the 75th percentile of average weight for a given length across a large number of populations for a particular species. In concept, a W_r 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.

Table 3. Mean length (TL;mm), mean weight (g), Fulton-type condition factor (K), and relative weight (Wr) for species captured in overnight sinking gill net sets conducted during late summer in Glacier National Park, 2016 (BLT = bull trout, BKTxBLT = brook trout/bull trout hybrid, BBT = Burbot, KOK = Kokanee, LSS = largescale sucker, LKT = lake trout, LNS = longnose sucker, LWF = lake whitefish, MWF = mountain whitefish,, WCT = westslope cutthroat trout and WS = white sucker).

Water Body	Species	Mean Length (SE) (N)	Mean Weight (SE) (N)	Fulton Condition (K)	Relative Weight (Wr)
Lower Quartz Lake	BLT	419.7 (65.3) (9)	1136.6 (395) (7)	0.92 (0.03)	NA
	LKT	510 (159.5) (3)	300.7 (151.4)	0.53 (0.26)	52.1 (25.6)
	LNS	275.8 (31.9) (10)	267.2 (75.9)	0.93 (0.02)	NA
	MWF	205.7 (3.5) (74)	97.8 (9.9)	1.12 (0.14)	113.2 (0.14)
	WCT	222.1 (19.9) (9)	156.2 (46.1)	1.25 (0.29)	125.0 (28.2)
Saint Mary Lake	BBT	434.8 (34.9) (27)	736.1 (165.9)	0.63 (0.02)	NA
	LKT	498.6(123.73) (17)	1085.3 (123.7) (17)	0.75 (0.02)	72.7 (1.73)
	LNS	252.9 (12.02) (29)	229.6 (36.98)	1.15 (0.02)	NA
	LWF	406.8 (5.79) (52)	655.08 (28.56)	0.94 (0.01)	92.51 (0.79)
	MWF	268.36 (10.04) (72)	192.31 (15.31)	0.93 (0.10)	93.15 (10.04)
	WS	233.46 (5.32) (146)	189.92 (17.01) (143)	1.16 (0.02)	NA
Harrison Lake	BLT	335.33 (77.85) (3)	396.67 (257.67)	0.8 (0.02)	NA
	BKT	335 (30.94) (4)	141 (30.94)	1.04 (30.94)	NA
	BKTxBLT	438 (22.05) (4)	660 (118.4)	0.76 (0.03)	NA
	KOK	343.5 (90.5) (2)	439 (273)	0.95 (0.08)	NA
	LKT	483.3 (35.19) (10)	787.4 (173.54)	0.67 (0.07)	65.48 (7.16)
	LNS	276.66 (7.28) (95)	265.05 (21.37) (91)	1.08 (0.04)	NA
	LSS	278.8 (32.19) (15)	212 (53.15) (14)	0.97 (0.02)	NA
	MWF	222.34 (2.03) (336)	134.07 (13.17) (335)	1.11 (0.11)	110.97 (11.05)
	WCT	325.2 (10.73) (20)	357.07 (8.05) (15)	0.95 (0.04)	94.34 (3.61)

ACKNOWLEDGEMENTS

The authors wish to thank GNP employees Carter Fredenberg and Kevin Perkins for their dedication and hard work to collect the field samples.

LITERATURE CITED

- Anderson, R.O. and R.M. Neumann. 1996. Length, weight, and associated structural indices. Pages 447-482 in B.R. Murphy and D.W. Willis, editors. Fisheries Techniques, second edition. American Fisheries Society, Bethesda, Maryland.
- Ellis, B.K., J.A. Stanford, J.A. Craft, D.W. Chess, G.R. Gregory, and L.F. Marnell. 1992. Monitoring of water quality of selected lakes in Glacier National Park, Montana: Analysis of data collected, 1984-1990. Open File Report 129-92 in conformance with Cooperative Agreement CA 1268-0-9001, Work Order 6, National Park Service, Glacier National Park, West Glacier, Montana. Flathead Lake Biological Station, The University of Montana, Polson.
- Fredenberg, W. 2002. Further evidence that lake trout displace bull trout in mountain lakes. Intermountain Journal of Sciences 8:143-151.
- Hitt, N.P., C.A. Frissell, C.C. Muhlfeld, and F.W. Allendorf. 2003. Spread of hybridization between native westslope cutthroat trout, *Oncorhynchus clarkii lewisi*, and nonnative rainbow trout, *Oncorhynchus mykiss*. Canadian Journal of Fisheries and Aquatic Sciences 60:1440-1451.
- Marnell, L.F., R.J. Behnke, and F.W. Allendorf. 1987. Genetic identification of cutthroat trout, *Salmo clarki*, in Glacier National Park, Montana. Canadian Journal of Fisheries and Aquatic Sciences 44:1830-1839.
- Meeuwig, M., C. Guy, W.A. Fredenberg. 2007. Research Summary for Action Plan to Conserve Bull Trout in Glacier National Park, Montana. Montana State University, Bozeman.
- Meeuwig, M.H. 2008. Ecology of lacustrine-adfluvial bull trout populations in an inter-connected system of natural lakes. Ph.D. Dissertation. Montana State University, Bozeman.
- Muhlfeld, C.C., T.E. McMahon, D. Belcer, and J.L. Kershner. 2009. Spatial and temporal spawning dynamics of native westslope cutthroat trout *Oncorhynchus clarkii lewisi*, introduced rainbow trout *O. mykiss*, and their hybrids. Canadian Journal of Fisheries and Aquatic Sciences 66:1153-1168.
- Piccolo, J.J., W.A. Hubert, and R.A. Whaley. 1993. Standard weight equation for lake trout. North American Journal of Fishery Management 13:401-404.
- Rennie, M.D. and R. Verdon. 2008. Development and evaluation of condition indices for lake whitefish. North American Journal of Fishery Management 28: 1270-1293.
- Stafford, C.P., J.A. Stanford, F.R. Hauer, and E.B. Brothers. 2002. Changes in lake trout growth associated with *Mysis relicta* establishment: a retrospective analysis using otoliths. Transactions of the American Fisheries Society 131:994-1003.

