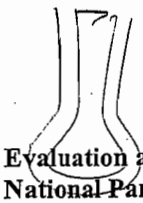

Evaluation and action plan for protection of 15 threatened adfluvial populations of bull trout in Glacier National Park, Montana

Annual Report of Research

November 2004

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November 17, 2004

Introduction

Nonnative lake trout (*Salvelinus namaycush*) are invading and rapidly compromising native fish species assemblages in large glaciated lakes of the upper Columbia River Basin. Recent research (Fredenberg 2002) has identified dramatic recent declines of bull trout (*S. confluentus*) over the last 25 years in the four largest lakes on the west side of Glacier National Park (Lake McDonald, Kintla Lake, Bowman Lake, and Logging Lake). These declines are associated with corresponding increases in numbers of invasive lake trout, which have colonized these waters from downstream sources in the Flathead River drainage. Over the past four years the invasion of Harrison and Lower Quartz lakes by lake trout has been verified. Best available science indicates that conversion of these unique native bull trout ecosystems to lake trout-dominated systems is a common result once lake trout invade and become established (Donald and Alger 1993; Fredenberg 2002). Extirpation of bull trout from at least some of these lakes is likely to occur in the foreseeable future.

Quartz Lake, Upper Kintla Lake, and Trout Lake in Glacier National Park (along with Big Salmon Lake in the adjacent Bob Marshall Wilderness) are the four largest lakes remaining in the entire Columbia River basin that contain native bull trout populations uncompromised by the presence of nonnative fish species. Protection of these waters is a US Fish and Wildlife Service recovery priority and an issue of importance on a regional and national scale. Glacier National Park stands out within the range of bull trout as an area where population ecology of adfluvial populations of the species is poorly understood. This area has great potential for maintaining source populations important to the Columbia River Basin. It is critical that we understand the population ecology of bull trout and potential threats of invasion by lake trout in these areas if we want to develop a functional action plan and effective recovery effort.

This study is occurring in the watersheds associated with 15 lakes in the Flathead River Basin on the west side of Glacier National Park in northwest Montana (Figure 1). Sampling methods include, but are not limited to, electrofishing, habitat survey, gill netting, angling surveys, and redd counts. The methods used will provide data on the population ecology (e.g., recruitment, growth, mortality) of bull trout in the selected waters. These data will provide information that will be used to develop an action plan for the ongoing protection, management, and recovery of bull trout resources in these 15 lakes in Glacier National Park. Implementation of the action plan will be accomplished through partnerships created through the Bull Trout Recovery Plan and National Park

Conservation Association (NPCA) initiative in association with the National Parks Service fisheries program. This document presents project activities and preliminary results associated with the period of April 2004 through September 2004, as well as outlines future activities.

Project activities

Lake Sampling

Fish assemblages in five lakes on the west side of Glacier National Park were sampled during the months of June 2004 through September 2004. The lakes sampled were Arrow Lake (June 24-29), Akokala Lake (July 9-13), Cerulean Lake (July 26-30), Lincoln Lake (August 5-10), and Lake Isabel (September 1-8) including an unnamed lake directly upstream of Lake Isabel. Fish within these lakes were sampled by gill netting, angling, and electrofishing; electrofishing surveys were also conducted in the primary inlet and outlet of these lakes.

Sinking, experimental gill nets were generally set within 1 h of sunset and removed the next day within 1 h of sunrise (i.e., nets were set to collect fish overnight) with the exception of four nets used in the morning crepuscular period (approximately 3 h) in Arrow Lake and one net used during the late afternoon in Cerulean Lake. All fish sampled with gill nets were identified to species and measured for length (mm) and mass (g). Catch Per Unit Effort (CPUE) was calculated separately for each lake, fish species, and individual gill net as the number of fish sampled per hour. Mean CPUE for each lake and species was calculated from CPUE values from individual gill nets.

A small portion (approximately 25 mm^2) of the anal fin was removed from all bull trout and a sub-sample of westslope cutthroat trout (*Oncorhynchus clarki lewisi*). Anal fin tissue was stored in 95% ethanol and was archived for future genetic examinations of these species. A soft-tissue biopsy needle was used to remove a portion of white muscle from a sub-sample of all fish species present (except sculpin, *Cottus* spp.). Muscle samples were immediately frozen with and stored in liquid nitrogen. Muscle samples may be used to compare stable isotope ratios among fish species to examine trophic relationships within and among lakes sampled. Scales were removed from all bull trout and a sub-sample of cutthroat trout, and attempts will be made to determine fish age from annular growth patterns of scales. After sampling, fish were released back into the lake. In the event that individual bull trout or cutthroat trout perished as a result of sampling, otoliths were removed for age determination.

Angling surveys were used to supplement the number of individuals sampled. Sections of the lake

shoreline were sampled for all species present using a backpack electrofishing unit. Individuals sampled by angling and electrofishing were processed in a manner similar to those sampled by gill nets with the exception that individuals sampled by electrofishing were often too small to remove tissue samples.

Maximum depth, temperature, dissolved oxygen, conductivity, and salinity were measured at each lake. The maximum depth measurement for Lake Isabel was determined from National Park Service log-book entries (C. Spencer and K. Methuen, Upper Park Creek Cabin Log) as time constraints precluded personal observations. Nitrate (mg/L), phosphate (mg/L), and phosphorous (mg/L) were measured once at each lake, except Arrow Lake.

Stream sampling

Primary inlet and outlet streams for each lake, within close proximity to the lake (e.g., < 100 m from the lake), were sampled using a backpack electrofishing unit. Sampling consisted of a single pass through a stream section approximately 100 m in length and all fish sampled were identified to species and measured for length (mm) and mass (g). Fish were returned to streams following sampling. Within each stream section transects were spaced at 10-m intervals along the thalweg. Physical habitat was quantified at these transects with the variables wetted width (m), maximum depth (m), average depth (m), substrate type, and gradient (Bain 1999a; Peterson et al. 2002).

Redd surveys

Bull trout redd surveys were conducted on Logging Creek (October 5, 2004), Harrison Creek (October 6-7, 2004), Bowman Creek (October 10, 2004), Quartz Creek (October 12-13, 2004), and Rainbow Creek (October 13, 2004). Logging Creek was surveyed from the inlet of Logging Lake upstream to Grace Lake (Figure 2). Harrison Creek was surveyed from the inlet of Harrison Lake upstream to a point where stream gradient rapidly increased (Figure 3). Bowman Creek was surveyed from the inlet of Bowman Lake upstream to a point where the creek went subsurface (Figure 4). Quartz Creek was surveyed from Lower Quartz Lake upstream to Middle Quartz Lake (Figure 5), form Middle Quartz Lake to Quartz Lake (Figure 6), and from Quartz Lake upstream to a point where habitat no longer appeared to be suitable for spawning (Figure 7). Rainbow Creek was surveyed from approximately 0.25 km upstream from its confluence with Quartz Creek to approximately 0.75 km upstream from its confluence with Quartz Creek (Figure 8). Redd surveys where conducted by two (Logging Creek, Harrison Creek, Bowman Creek, lower and middle Quartz Creek) or three (upper Quartz Creek, Rainbow Creek) trained technicians in a downstream to upstream direction. The date, time, water temperature (° C), and starting location (UTM) were

recorded at the beginning of the survey. When redds were encountered, a location was recorded (UTM). The time and location (UTM) were recorded at the end of the survey.

Preliminary results

Lake sampling

The number of individuals sampled and species diversity varied among lakes (Table 1). Species assemblages varied from lakes containing only bull trout and westslope cutthroat trout (e.g., Arrow Lake and Lake Isabel) to lakes containing bull trout, westslope cutthroat trout, mountain whitefish (*Prosopium williamsoni*), sculpin (*Cottus* spp.), longnose sucker (*Catostomus catostomus*), and brook trout (*S. fontinalis*) (e.g., Lincoln Lake). Small samples of unknown salmonids were observed (Table 1), all of which were age-0 individuals and were likely brook trout and mountain whitefish. These individuals were preserved and will be identified in the laboratory.

The total number of gill nets set per lake varied as did the duration of set times and the total number of bull trout sampled using gill nets (Table 2). The number of gill nets set was limited by the number of bull trout that perished as a result of sampling activities (Federal Fish and Wildlife Permit # TE070140-1). Mean CPUE varied among species and lakes (Figure 9). Gill nets were generally effective at sampling all species present in a Lake; however, sculpins were never observed in gill nets. Westslope cutthroat trout were not effectively sampled using gill nets at Cerulean Lake although they were sampled during angling surveys. The bathymetry of Cerulean Lake (e.g., depth and gradient of lake bottom) may have resulted in gill nets being set deeper than at other lakes affecting their ability to sample westslope cutthroat trout. The number of bull trout sampled during angling surveys was 7 at Arrow Lake, 3 at Akokala Lake, 14 at Cerulean Lake, and 0 at Lincoln Lake (although a high amount of angling effort was expended). Angling surveys were not conducted at Lake Isabel due to time constraints; however, 7 bull trout were sampled during angling surveys at the unnamed lake directly upstream of Lake Isabel. Shoreline electrofishing resulted in the sampling of 18 bull trout from 279 m of shoreline at Arrow Lake, 2 bull trout from 400 m of shoreline at Akokala Lake, 0 bull trout from 400 m of shoreline at Lincoln Lake, and 9 bull trout from approximately 200 m of shoreline at Lake Isabel. Electrofishing surveys were not conducted at Cerulean Lake due to logistic constraints.

A summary of anal fin samples for potential genetic analysis, muscle samples for stable isotope analysis, and scale samples collected during gill net surveys, angling surveys, and shoreline electrofishing surveys is

presented in Table 3. In addition, seven fin clips were collected from bull trout sampled at the unnamed lake directly upstream of Lake Isabel. The size distributions of all species sampled during gill net surveys, angling surveys, and shoreline electrofishing surveys are presented with length-frequency histograms (Figures 10-14). The length-frequency histogram for longnose suckers sampled at Lincoln Lake was produced from a sub-sample (100 individuals) of the total number of longnose suckers sampled (188 individuals).

Nitrate, phosphate, and phosphorous were virtually undetectable in all lakes sampled, and lakes could be categorized as "undisturbed in a forested basin" (< 0.1 mg/L nitrate; < 0.05 mg/L phosphorous; Bain 1999b). Salinity was consistent among lakes (0.0 ppt) and dissolved oxygen levels were adequate for fish in all lakes (> 5.0 mg/L; Bain 1999b). Temperature and conductivity varied among lakes and sample depths, but remained low (Table 4). Maximum depth was 16.8 m at Arrow Lake, 6.9 m at Akokala Lake, 35.9 m at Cerulean Lake, 22.7 m at Lincoln Lake, and 16.0 m at Lake Isabel.

Stream electrofishing

Electrofishing surveys of lake inlet and outlet streams yielded low numbers of bull trout (Table 5). Stream electrofishing surveys were not conducted at Cerulean Lake (as above) and physical habitat was not measured for the inlet and outlet of Arrow Lake due to extreme flow conditions (for a summary of physical habitat characteristics of stream electrofishing sites see Table 6).

Redd surveys

The distributions of bull trout redds observed are presented in Figure 15. Due to stream channel dynamics, current stream channel location did not always correspond to present map data. Approximate stream lengths of redd survey reaches were determined from map data. However, redd distributions (Figure 15) were determined by euclidian distances between UTM locations for the start of the redd survey reach, the series of redds observed, and the end of the redd survey reach. In the process of conducting redd surveys on Logging Creek, a waterfall was encountered approximately 1.50 km from Logging Lake. The waterfall appears to be a barrier to upstream fish movement due to its size, location, and structure. Three redds were observed in Logging Creek between Logging Lake and the barrier, and no redds were observed from the barrier upstream to Grace Lake (Figure 2; Figure 15a). Water temperature of Logging Creek at the beginning of the survey was 8° C and it took 2 h 9 min to survey the reach. Harrison Creek was surveyed over the course of two days. Approximately 2.00 km of stream, from the inlet

of Harrison Lake upstream, was sampled on October 6, 2004. It took 1 h 25 min to survey this section, the water temperature was 8° C, and four redds were encountered (Figure 3; Figure 15b). An additional 1.00 km of Harrison Creek was surveyed on October 7, 2004. This section was surveyed in 55 min, the water temperature was 7° C, and no redds were encountered. Heavy rain the morning of October 7, 2004 resulted in high flows and turbid water in Harrison Creek, reducing our ability to detect redds. No redds were encountered in Bowman Creek from the inlet of Bowman Lake upstream to where the stream went subsurface. This reach was approximately 3.00 km long, took 3 h 49 min to survey, and water temperature was 6° C (Figure 4). One redd was encountered on Quartz Creek between Lower Quartz Lake and Middle Quartz Lake. This redd was approximately 0.01 km upstream from the inlet of Lower Quartz Lake (Figure 5; Figure 15c). Water temperature in this reach was 11° C and it took 2 h 24 min to survey. Water temperature between Middle Quartz Lake and Quartz Lake was 12° C and no redds were observed (Figure 6). Quartz Creek was surveyed from the inlet of Quartz Lake approximately 2.00 km upstream (Figure 7). Water temperature in this section was 6° C, it took 2 h 31 min to survey, and 55 redds were observed (Figure 15d). Rainbow Creek was surveyed from approximately 0.25 km upstream from its confluence with Quartz Creek to approximately 0.75 km upstream from its confluence with Quartz Creek (Figure 8). Rainbow Creek was 7° C, it took 42 min to sample this reach, and no redds were observed.

Planned future activities

2005

- Laboratory analysis of scale samples and otolith samples for age determination.
- Data analysis.
- Lake sampling (methods similar to those discussed above) of Upper Kintla Lake, Quartz Lake, Lower Quartz Lake, Logging Lake, and Harrison Lake.
- Stream surveys for waterfalls and other potential migratory barriers within Glacier National Park.
- Redd surveys (methods similar to those discussed above) of Quartz Creek, Logging Creek, and Harrison Creek.
- Preparation of on interim scientific report detailing preliminary findings to be submitted on December 31, 2005 to U.S. Geological Survey.

2006

- Laboratory analysis of scale samples and otolith samples for age determination.
- Data analysis.
- Lake sampling (methods similar to those discussed above) of Upper Kintla Lake, Quartz Lake, Cerulean Lake, Logging Lake, Harrison Lake, and Lake Isabel.
- Redd surveys (methods similar to those discussed above) of Quartz Creek, Logging Creek, and Harrison Creek.
- Preparation of a final scientific report summarizing electrofishing, redd count, habitat, and gill netting surveys and monitoring results to be submitted on December 31, 2006 to U.S. Geological Survey.

2007

- Laboratory analysis of scale samples and otolith samples for age determination.
- Data analysis.
- Preparation an action plan for the long-term monitoring, management, and recovery of bull trout resources in 15 lakes in Glacier national Park to be submitted on June 30, 2007.

References

Bain, M. B. 1999a. Substrate. Pages 95-103 *in* M. B. Bain and N. J. Stevenson, editors. Aquatic habitat assessment: common methods. American Fisheries Society, Bethesda, Maryland.

Bain, M. B. 1999b. Interpreting chemical data. Pages 181-192 *in* M. B. Bain and N. J. Stevenson, editors. Aquatic habitat assessment: common methods. American Fisheries Society, Bethesda, Maryland.

Donald, D. B., and D. J. Alger. 1993. Geographic distribution, species displacement, and niche overlap for lake trout and bull trout in mountain lakes. Canadian Journal of Zoology 71:238-247.

Fredenberg, W. 2002. Further evidence that lake trout displace bull trout in mountain lakes. Intermountain Journal of Sciences 8:143-152.

Peterson, J., J. Dunham, P. Howell, R. Thurow, and S. Bonar. 2002. Protocol for determining bull trout presence. Western Division American Fisheries Society. Available: www.wdafs.org/committees/bull_trout/protocolFinal-2-02.doc. (September 2004).

Table 1. The number of individuals per species sampled at each of the five lakes employing all sampling techniques; gill netting, angling, shoreline electrofishing, and stream electrofishing in five lakes in Glacier National Park from June through September 2004. The number of bull trout sampled at Lake Isabel includes seven individuals sampled during angling surveys from the un-named lake upstream of Lake Isabel.

Species	Arrow Lake	Akokala Lake	Cerulean Lake	Lincoln Lake	Lake Isabel
Bull trout	40	22	20	12	77
Cutthroat trout	101	25	61	41	163
Mountain whitefish	0	86	56	65	0
Sculpin sp.	0	84	0	32	0
Longnose sucker	0	0	0	188	0
Brook trout	0	0	0	29	0
Unknown salmonid	0	4	0	5	0

Table 2. Total number of gill nets set, median duration that gill nets were fishing, and the total number of bull trout sampled using gill nets in five lakes in Glacier National Park from June through September 2004.

Lake	Total number of gill nets set	Median gill net set duration (h)	Total number of bull trout sampled
Arrow Lake	12	9.25	15
Akokala Lake	7	9.33	13
Cerulean Lake	5	8.37	6
Lincoln Lake	12	11.10	9
Lake Isabel	3	17.17	57

Figure 3. The number of fin clips (genetic samples), muscle samples (SIA samples: stable isotope analysis), and scale samples collected for fish species encountered at five lakes in Glacier National Park. The number of samples is the total collected through the combination of gill net surveys, angling surveys, and shoreline electrofishing surveys.

Lake	Species	Genetic samples	SIA samples	Scale samples
Arrow Lake	Bull trout	36	8	17
	Westslope cutthroat trout	24	17	69
Akokala Lake	Bull trout	16	16	16
	Westslope cutthroat trout	14	14	14
	Mountain whitefish	.	25	.
Cerulean Lake	Bull trout	20	20	20
	Westslope cutthroat trout	25	25	61
	Mountain whitefish	.	26	.
Lincoln Lake	Bull trout	9	9	9
	Cutthroat trout	30	14	29
	Mountain whitefish	.	14	.
	Longnose sucker	.	15	.
	Brook trout	12	11	12
Lake Isabel	Bull trout	54	25	44
	Westslope cutthroat trout	25	25	25

Table 4. Mean (± standard deviation) temperature (Temp), dissolved oxygen (DO), conductivity (Cond), and salinity (Sal) measured at 0.0 m (surface), 1.5 m and 3.0 m for five lakes sampled in Glacier National Park from June through September 2004. Parameters were measured three times over the course of 2 d. Measurements were taken at 1 h before sunset on days one and two and at 1 h before sunrise on day two. Parameters were measured only at one time (mid-day) and at the surface for Lake Isabel due to logistic constraints.

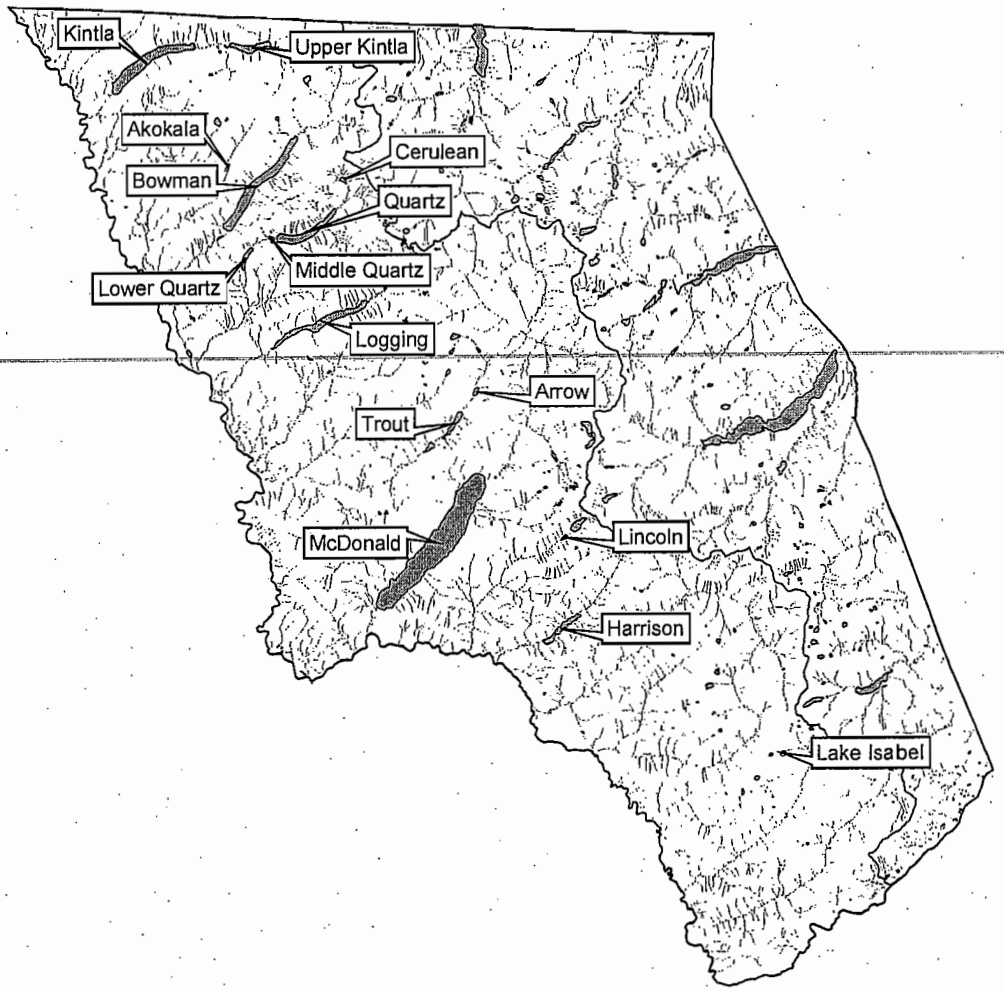
Lake	*N*	Depth (m)	Temp (° C)	DO (mg/L)	Cond (?S/cm)	Sal (ppt)
Arrow Lake	3	0.0	12.9 ± 2.5	9.35 ± 0.21	17.8 ± 16.7	0.0 ± 0.0
	3	1.5	10.9 ± 0.6	9.72 ± 0.63	39.2 ± 0.5	0.0 ± 0.0
	3	3.0	9.8 ± 0.1	9.77 ± 0.66	38.4 ± 0.4	0.0 ± 0.0
Akokala Lake	3	0.0	9.5 ± 2.3	9.76 ± 0.22	25.8 ± 23.3	0.0 ± 0.0
	3	1.5	8.6 ± 0.7	9.91 ± 0.06	31.1 ± 26.3	0.0 ± 0.0
	3	3.0	8.2 ± 0.2	9.78 ± 0.13	30.6 ± 26.1	0.0 ± 0.0
Cerulean Lake	3	0.0	12.8 ± 1.6	8.89 ± 0.44	36.5 ± 18.0	0.0 ± 0.0
	3	1.5	12.0 ± 0.5	9.14 ± 0.07	50.8 ± 0.2	0.0 ± 0.0
	3	3.0	11.6 ± 0.2	9.11 ± 0.13	50.4 ± 0.8	0.0 ± 0.0
Lincoln Lake	3	0.0	13.6 ± 0.2	10.73 ± 2.09	20.4 ± 0.1	0.0 ± 0.0
	3	1.5	13.6 ± 0.2	10.61 ± 2.05	20.4 ± 0.1	0.0 ± 0.0
	3	3.0	13.5 ± 0.2	10.71 ± 2.01	20.4 ± 0.1	0.0 ± 0.0
Lake Isabel	1	0.0	10.2	10.85	23.3	0.0

Table 5. Number of bull trout sampled during electrofishing surveys in inlet and outlet streams in five lakes in Glacier National Park from June through September 2004. Asterisk indicates estimated sample site length.

Lake	Stream	Length of sample site (m)	Bull trout sampled
Arrow Lake	Inlet	200*	0
	Outlet	100*	0
Akokala Lake	Inlet	156	3
	Outlet	111	1
Cerulean Lake	Inlet	.	.
	Outlet	.	.
Lincoln Lake	Inlet	100	3
	Outlet	100	0
Lake Isabel	Inlet	87	4
	Outlet	111	0

Table 6. Mean wetted width, mean depth, maximum depth, dominant substrate, and mean channel gradient for stream electrofishing sites in lake inlets and outlets in Glacier National Park from June through September 2004. Dominant substrate class follows definitions in Bain (1999a) where pebble = 16-63 mm, cobble = 64-256 mm, and boulder = >256 mm.

Lake	Stream	Mean wetted width (m)	Mean depth (m)	Maximum depth (m)	Dominant substrate	Mean channel gradient (%)
Arrow Lake	Inlet	.	.	.	.	.
	Outlet	.	.	.	.	.
Akokala Lake	Inlet	9.37	0.27	0.91	Pebble	0.45
	Outlet	12.86	0.24	0.79	Cobble	3.76
Cerulean Lake	Inlet	.	.	.	.	.
	Outlet	.	.	.	.	.
Lincoln Lake	Inlet	3.58	0.11	0.48	Cobble	6.68
	Outlet	7.03	0.19	0.58	Boulder	3.57
Lake Isabel	Inlet	3.68	0.11	0.41	Cobble	6.12
	Outlet	6.50	0.17	0.77	Pebble	3.37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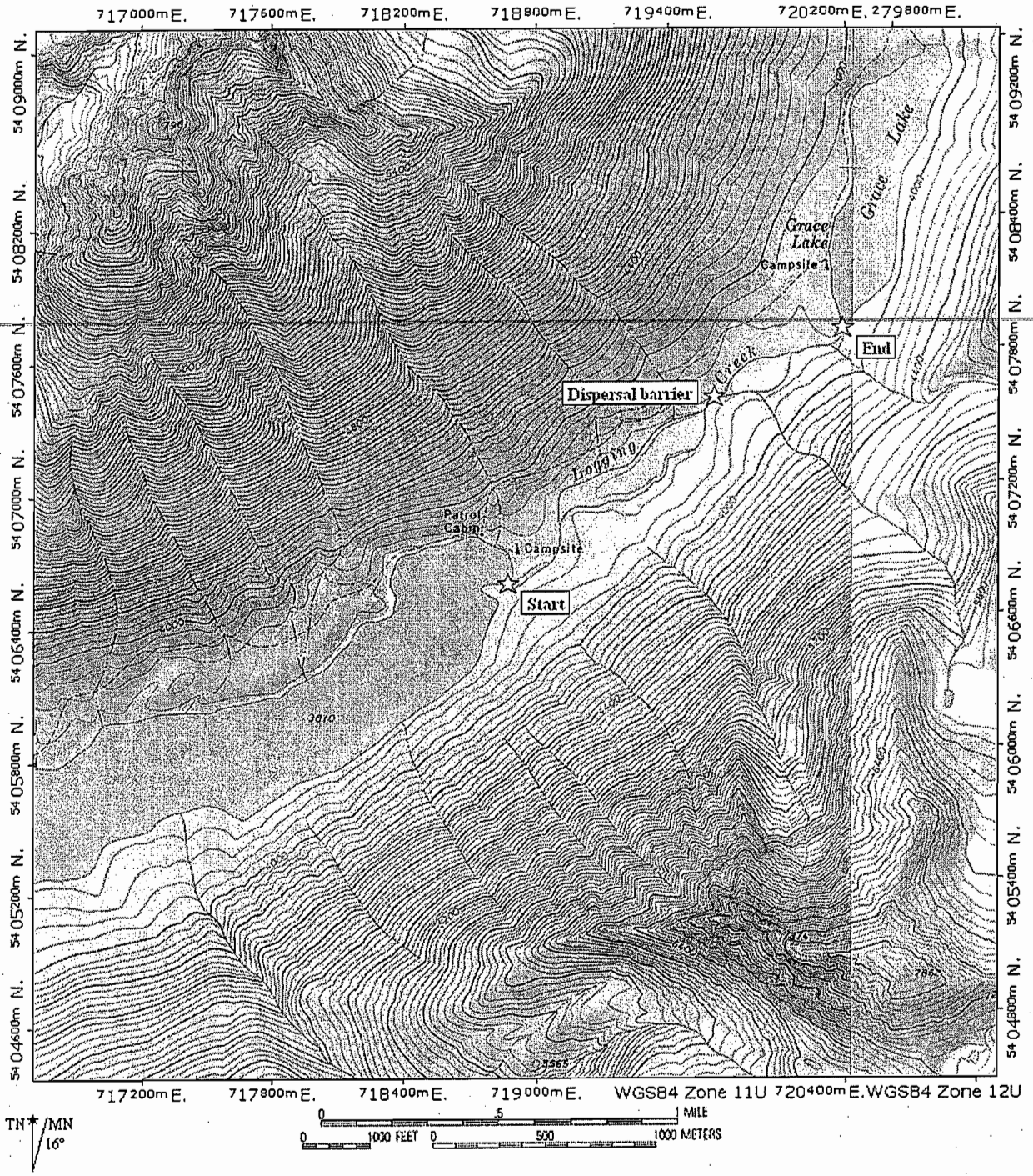
Upper Kintla
Akokala
Cerulean
Bowman
Quartz
Middle Quartz
Lower Quartz
Logging
Arrow
Trout
McDonald
Lincoln
Harrison
Lake Isabel

Figure 1. Fifteen lakes in the Flathead River Basin on the west side of Glacier National Park, Montana.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54 07600m N.
54 07000m N.
54 06400m N.
54 05800m N.
54 05200m N.
54 04600m N.
54 09200m N.
54 08400m N.
54 07800m N.
54 07200m N.
54 06600m N.
54 06000m N.
54 05400m N.
54 04800m N.
Grace Lake
Grace Lake Campsite 1
End
Dispersal barrier
Creek
Loggy Mtn
Patrol Cabin
Campsite
Start
717200m E.
717800m E.
718400m E.
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WGS84 Zone 11U
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TN
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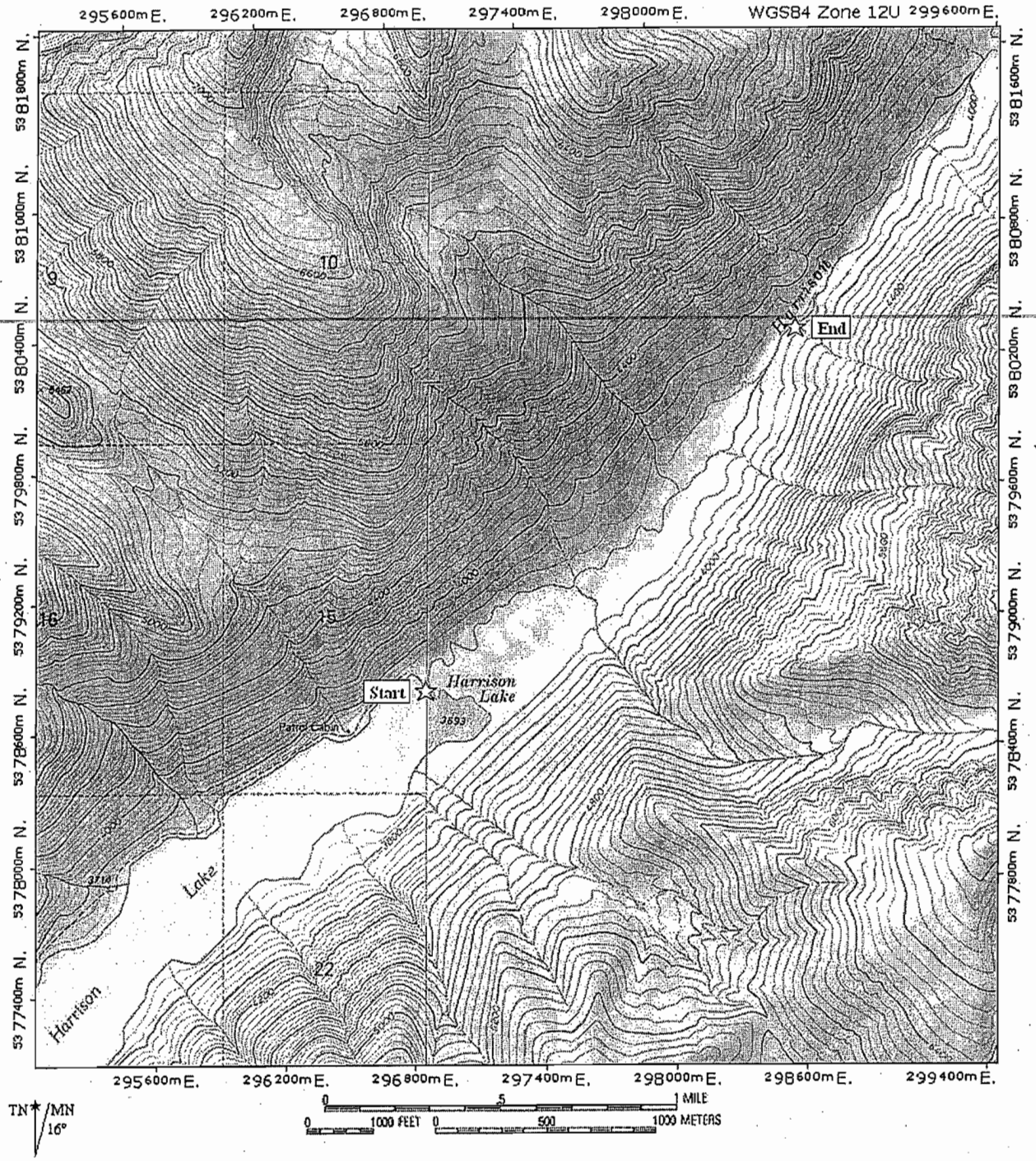
Figure 2. Location of redd survey reach on Logging Creek between Logging Lake and Grace Lake. A potential barrier to upstream fish dispersal (waterfall) was encountered on Logging Creek and its location is marked.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5379000m N.
5378600m N.
5378400m N.
5378000m N.
5377800m N.
5377400m N.
Start
End
Harrison Lake
Patrol Cabin
Harrison Lake
Highway 1
9
10
15
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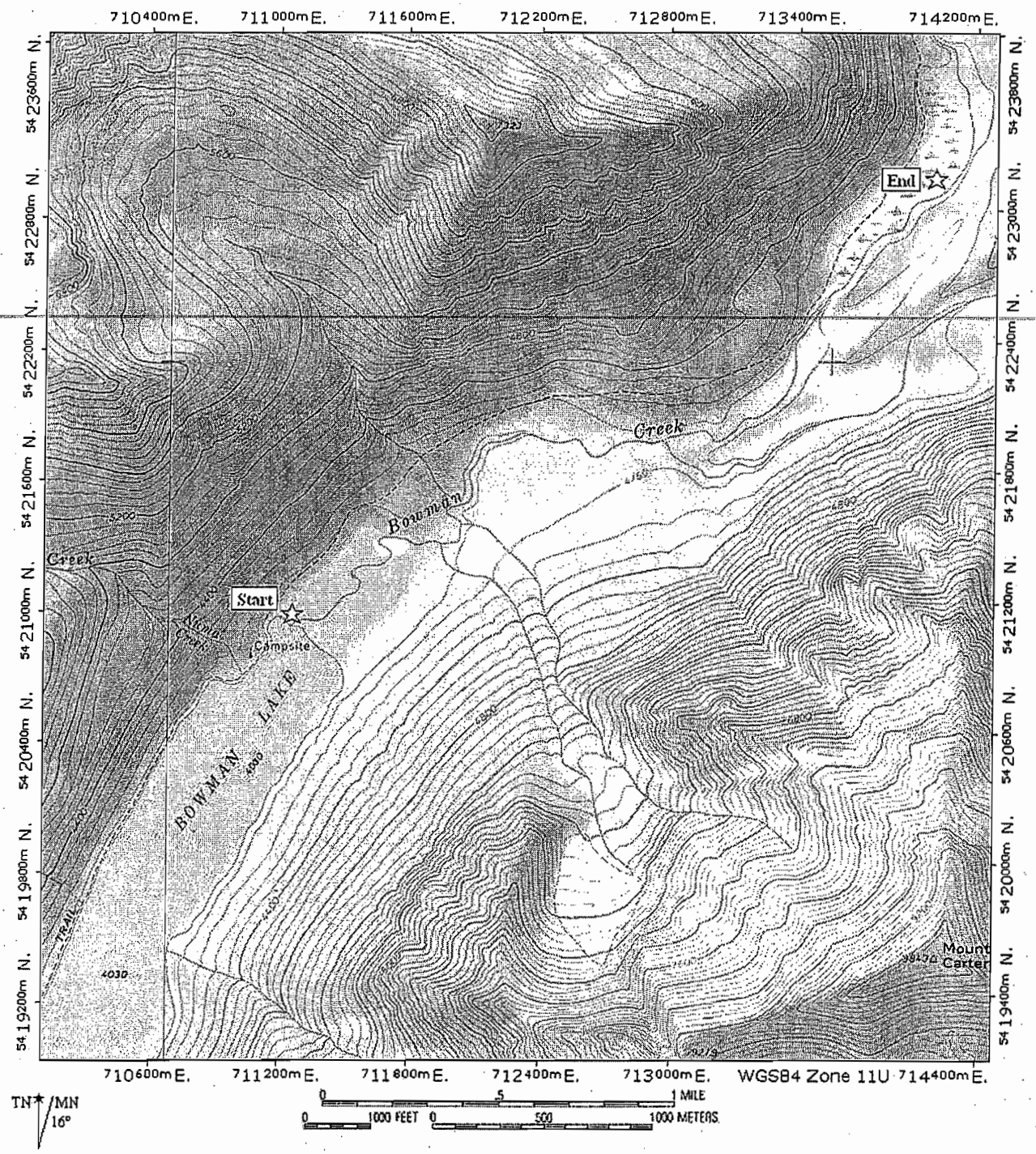
MN
16°
0 5 1 MILE
0 1000 FEET 0 500 1000 METERS

Figure 3. Location of redd survey reach on Harrison Creek upstream of Harrison Lake.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54 21200m N.
54 20400m N.
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54 19800m N.
54 20000m N.
54 19200m N.
54 19400m N.
End
Start
Creek
Bowman
Creek
Atomic
Creek
Campsite
LAKE
BOWMAN
TRAIL
4030
Mount
Carter
710600m E.
711200m E.
711800m E.
712400m E.
713000m E.
WGS84 Zone 11U
714400m E.
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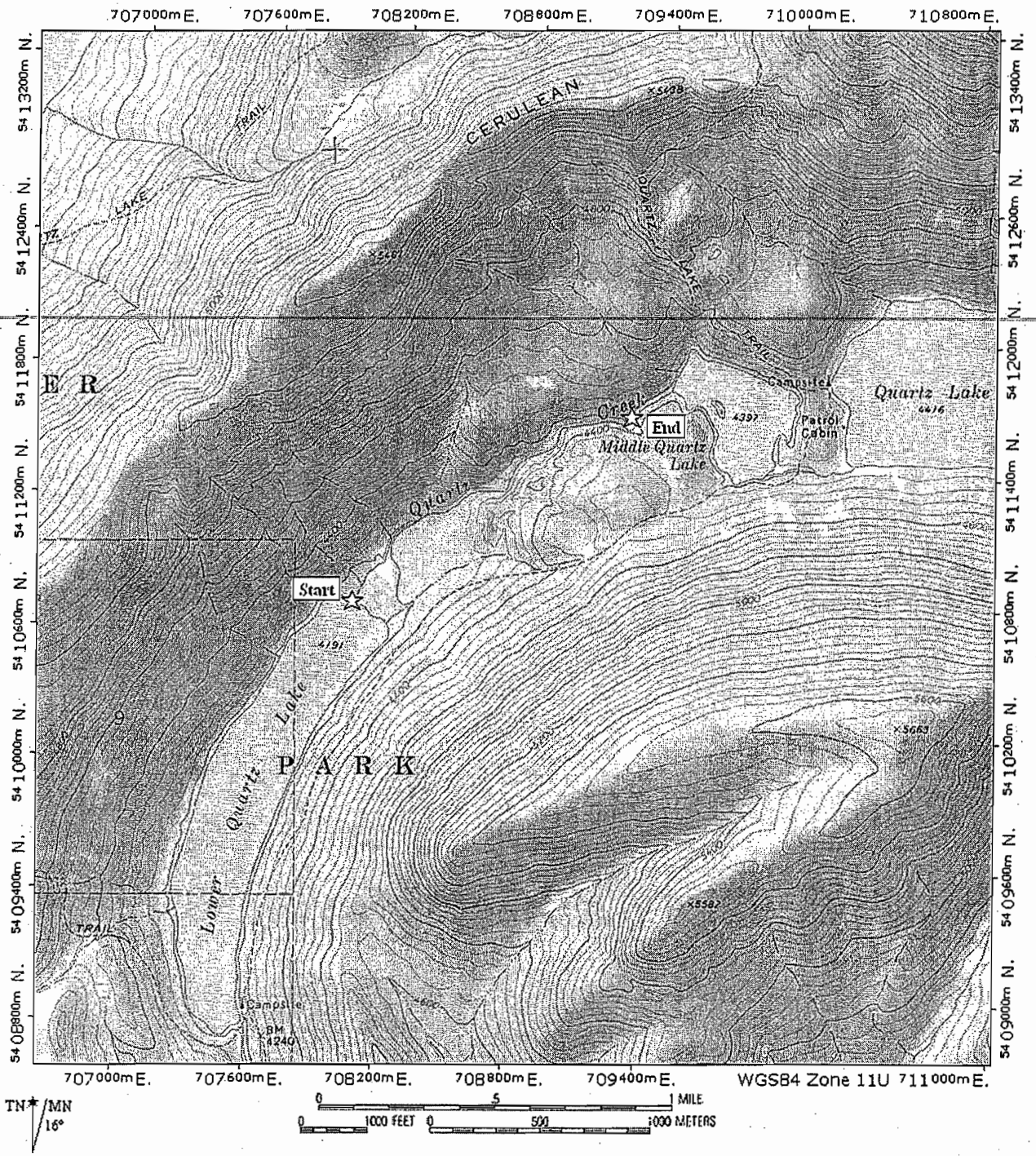
Figure 4. Location of redd survey reach on Bowman Creek upstream of Bowman Lake. The ending of the redd survey reach for Bowman Creek corresponds to where the creek went subsurface.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54 12400m N.
54 12600m N.
54 11800m N.
54 12000m N.
54 11200m N.
54 11400m N.
54 10600m N.
54 10800m N.
54 10000m N.
54 10200m N.
54 09400m N.
54 09600m N.
54 08800m N.
54 09000m N.
CERULEAN
TRAIL
LAKE
QUARTZ
Quartz Lake
Campsite
Creek
End
Middle Quartz Lake
Patrol Cabin
Start
Quartz
Lower Quartz Lake
PARK
TRAIL
Campsite
BM 4240
WGS84 Zone 11U
TN
MN
16°
MILE
1000 FEET
500
1000 METERS

Figure 5. Location of redd survey reach on Quartz Creek between Lower Quartz Lake and Middle Quartz Lake.

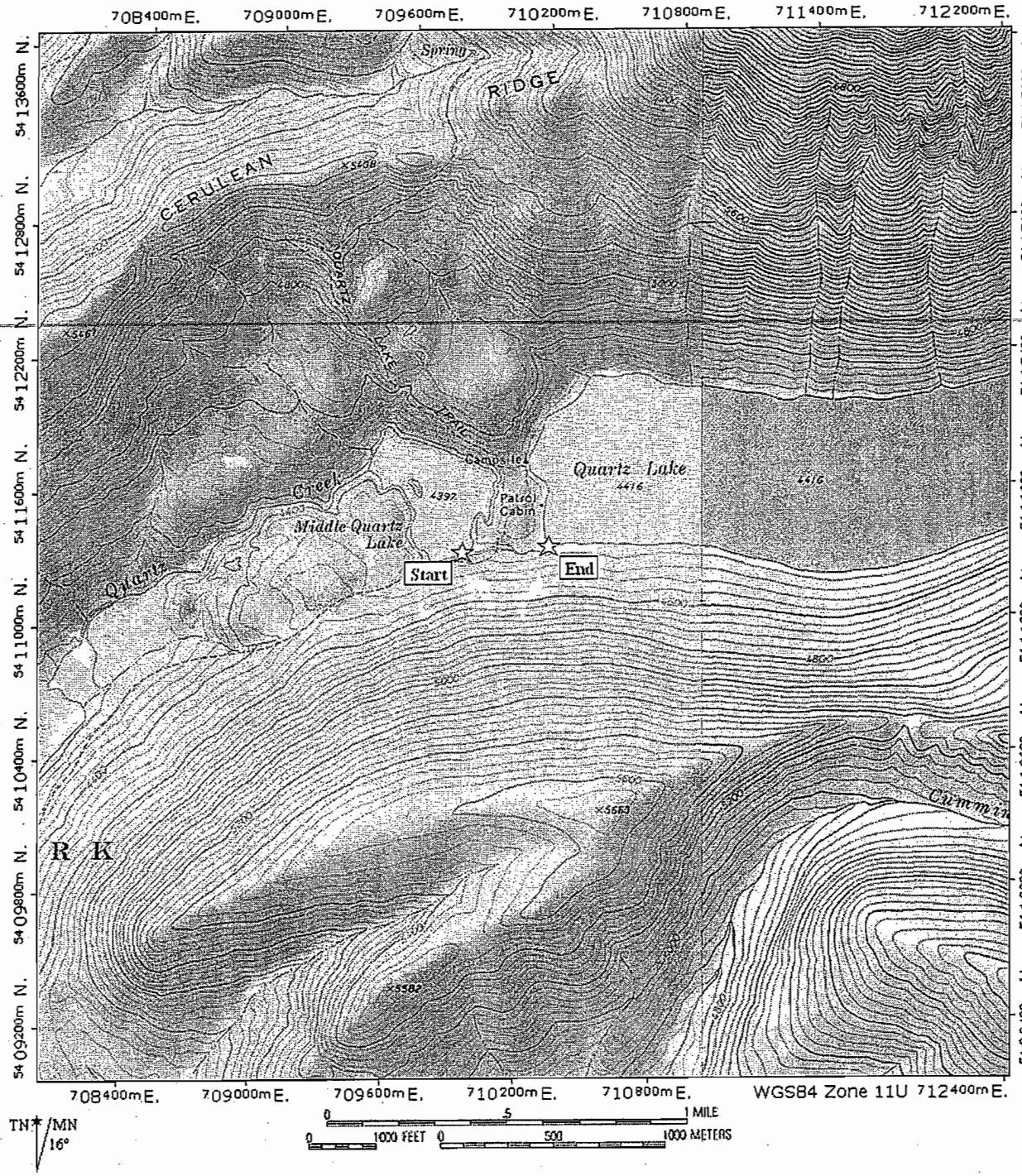

708400mE.
709000mE.
709600mE.
710200mE.
710800mE.
711400mE.
712200mE.
54 13600m N.
54 12800m N.
54 12200m N.
54 11600m N.
54 11000m N.
54 10400m N.
54 09800m N.
54 09200m N.
54 13800m N.
54 13000m N.
54 12400m N.
54 11800m N.
54 11200m N.
54 10600m N.
54 10000m N.
54 09400m N.
Spring
RIDGE
CERULEAN
Quartz
LAKE
TRAIL
Campsite
Quartz Lake
4416
Creek
4392
Patrol Cabin
Middle Quartz Lake
Start
End
Quartz
Cummings
R K
WGS84 Zone 11U
TN
MN
16°
0 .5 1 MILE
0 1000 FEET 0 500 1000 METERS

Figure 6. Location of redd survey reach on Quartz Creek between Middle Quartz Lake and Quartz Lake.

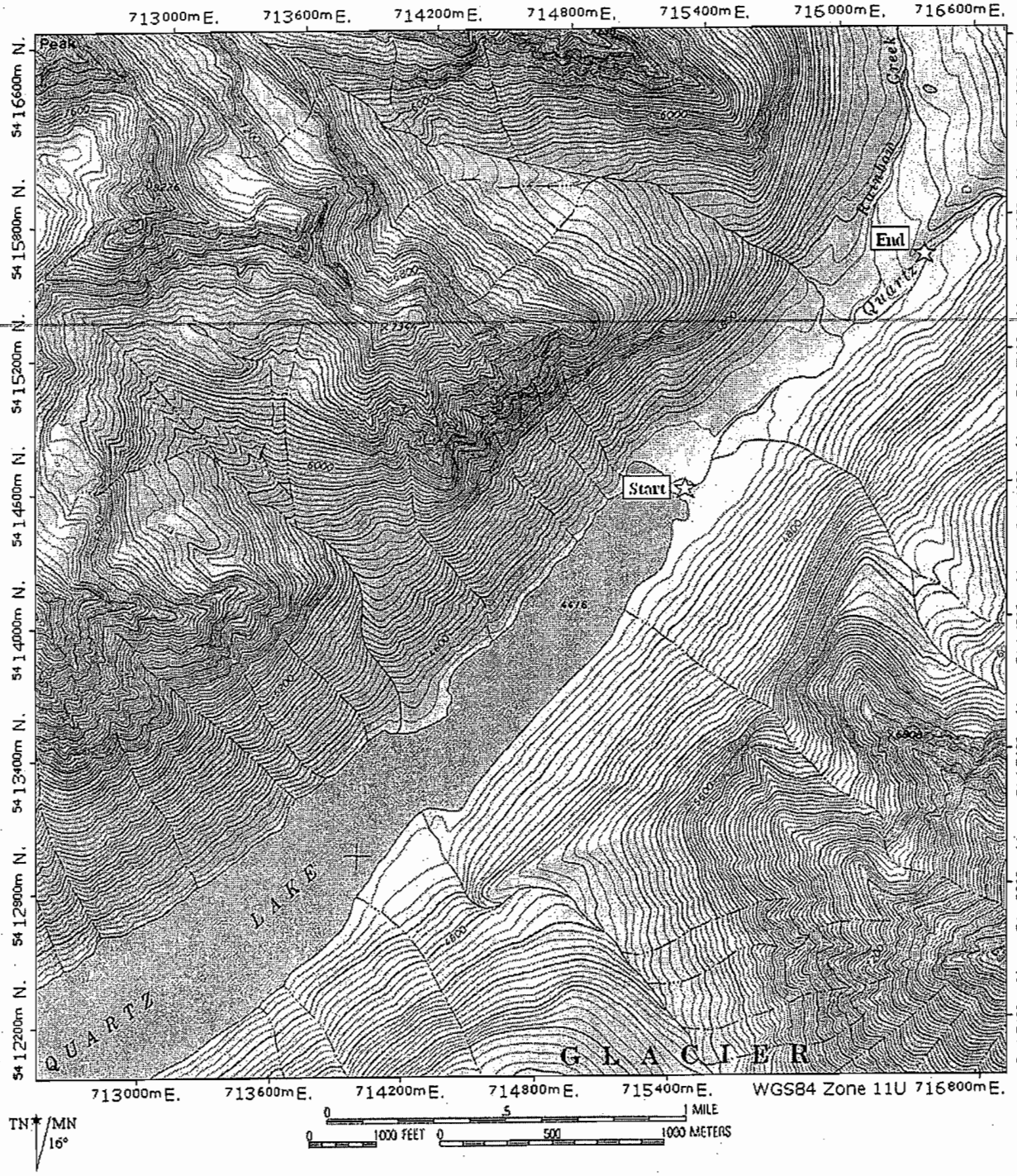

713000mE.
713600mE.
714200mE.
714800mE.
715400mE.
716000mE.
716600mE.
5416600m N.
5415800m N.
5415200m N.
5414600m N.
5414000m N.
5413400m N.
5412800m N.
5412200m N.
5416800m N.
5416000m N.
5415400m N.
5414800m N.
5414200m N.
5413600m N.
5413000m N.
5412400m N.
Peak
Green Jon Creek
End
Quartz
Start
LAKE
QUARTZ
GLACIER
WGS84 Zone 11U
TN
MN
16°
0
5
MILE
0
1000 FEET
0
500
1000 METERS

Figure 7. Location of redd survey reach on Quartz Creek upstream of Quartz Lake.

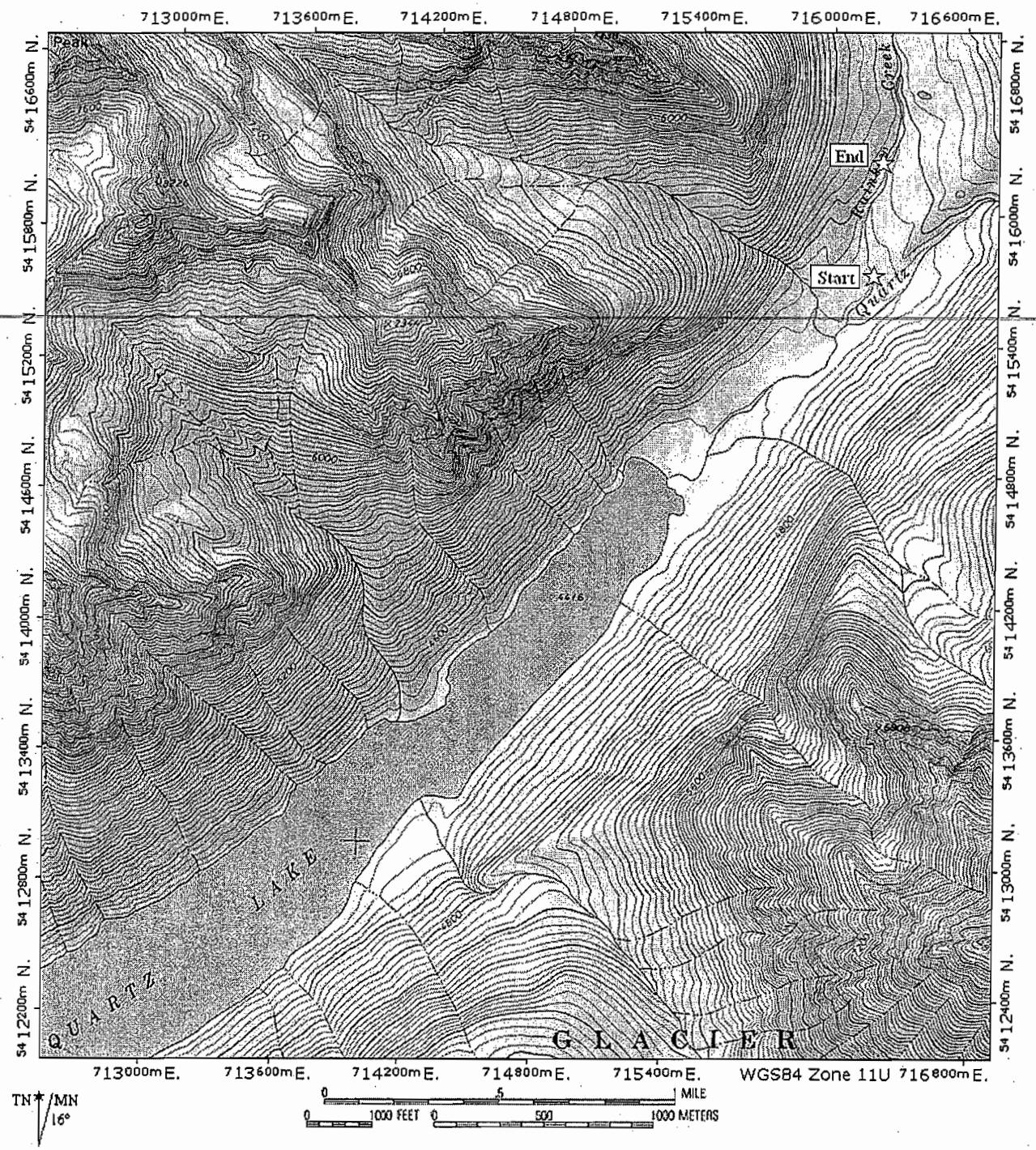

713000mE.
713600mE.
714200mE.
714800mE.
715400mE.
716000mE.
716600mE.
5416600m N.
5416800m N.
5415800m N.
5416000m N.
5415200m N.
5415400m N.
5414600m N.
5414800m N.
5414000m N.
5414200m N.
5413400m N.
5413600m N.
5412800m N.
5413000m N.
5412200m N.
5412400m N.
Peak
End
Start
Creek
Quartz
LAKE
QUARTZ
GLACIER
WGS84 Zone 11U
TN
MN
16°
0
5
MILE
0
1000 FEET
0
500
1000 METERS

Figure 8. Location of redd survey reach on Rainbow Creek from its confluence with Quartz Creek upstream approximately 0.50 km.

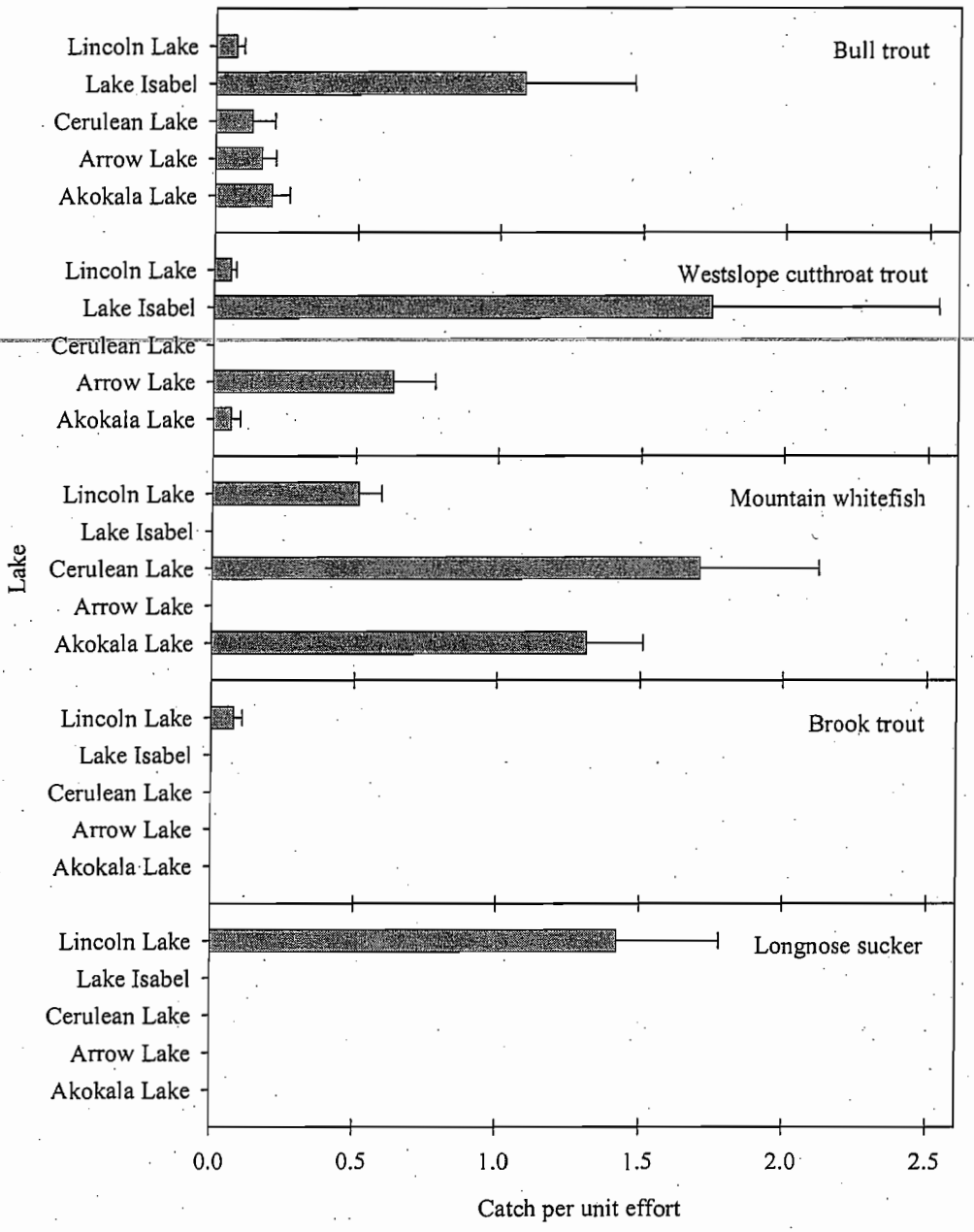

Bull trout
Westslope cutthroat trout
Mountain whitefish
Brook trout
Longnose sucker
Lincoln Lake
Lake Isabel
Cerulean Lake
Arrow Lake
Akokala Lake
Lake
0.0
0.5
1.0
1.5
2.0
2.5
Catch per unit effort

Figure 9. Mean (± 1 SD) catch per unit effort for five species of fish encountered during sampling with sinking, experimental gill nets in five lakes in Glacier National Park. Mountain whitefish were only present in Lincoln Lake, Cerulean Lake, and Akokala Lake. Brook trout and longnose sucker were only present in Lincoln Lake. Westslope cutthroat trout were present in Cerulean Lake (determined from angling surveys), but were not sampled using gill nets.

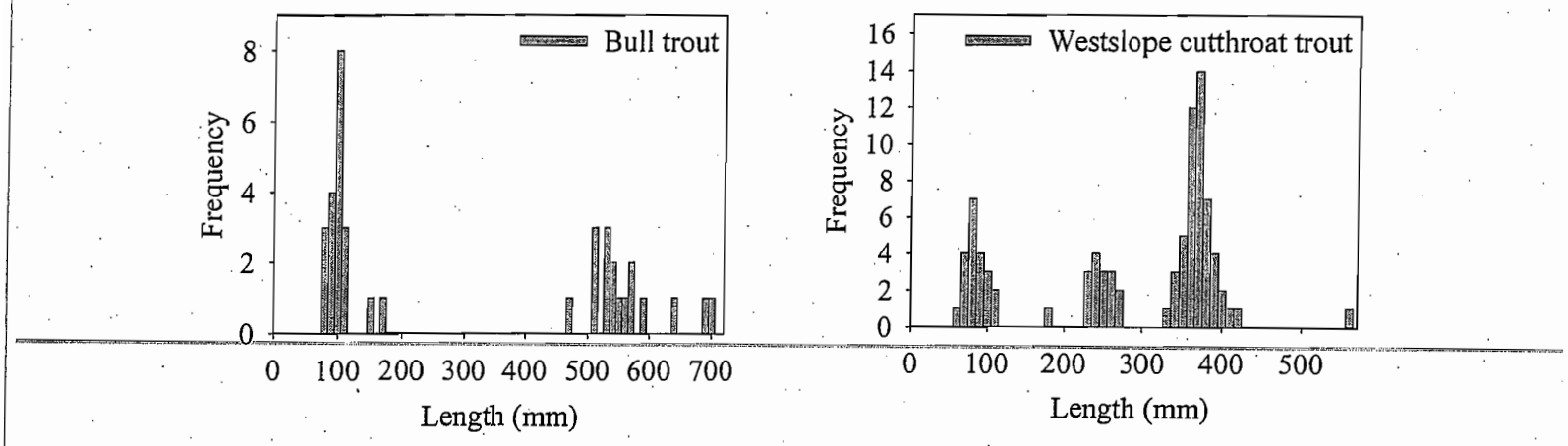
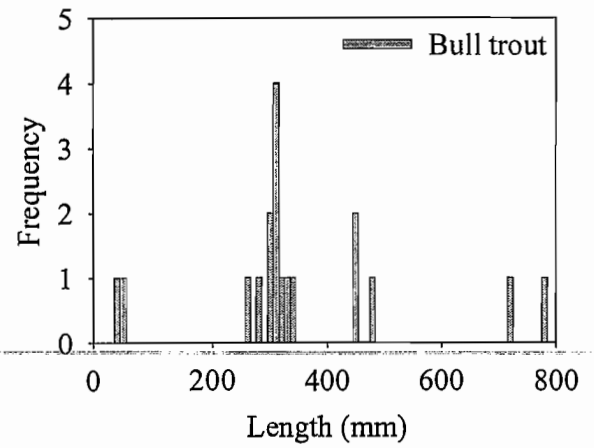
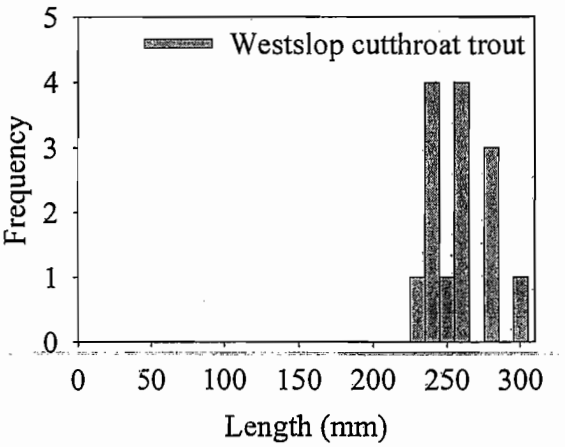


Figure 10. Length-frequency histograms of fish species sampled using the combination of gill net surveys, angling surveys, and shoreline electrofishing surveys at Arrow Lake.


Bull trout
Frequency
0
1
2
3
4
5
0
200
400
600
800
Length (mm)


Westslop cutthroat trout
Frequency
0
1
2
3
4
5
0
50
100
150
200
250
300
Length (mm)

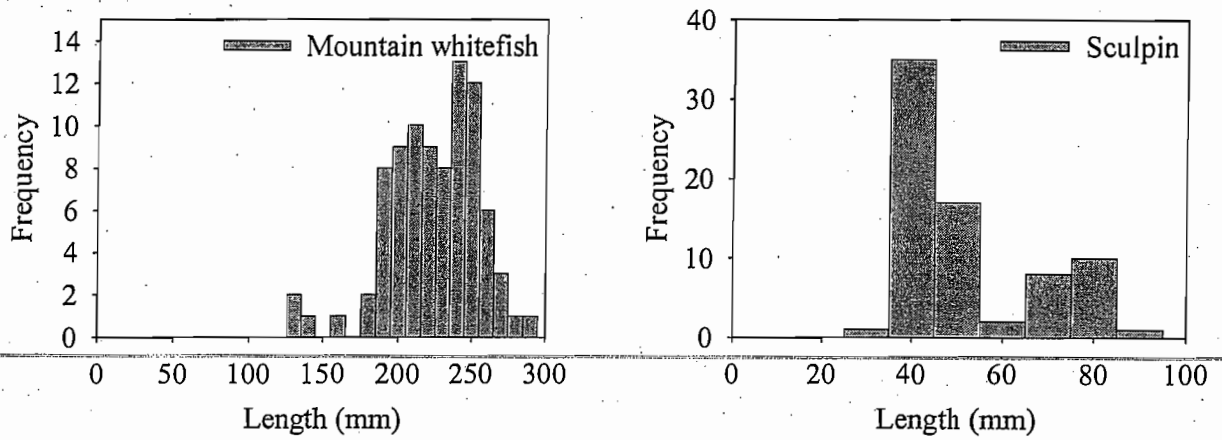
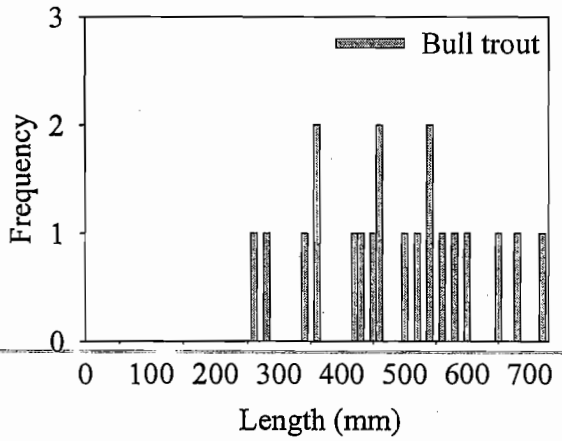
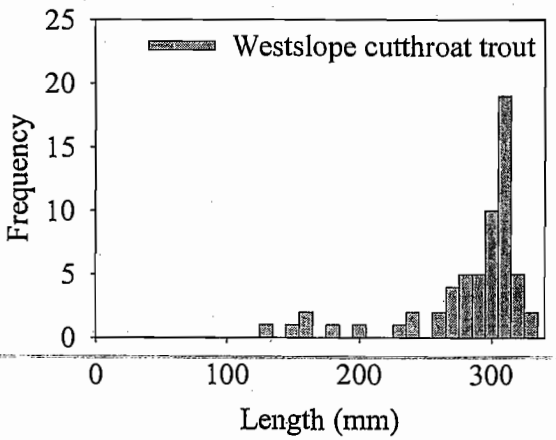


Figure 11. Length-frequency histograms of fish species sampled using the combination of gill net surveys, angling surveys, and shoreline electrofishing surveys at Akokala Lake.


Bull trout
Frequency
3
2
1
0
0 100 200 300 400 500 600 700
Length (mm)


Westslope cutthroat trout
Frequency
25
20
15
10
5
0
0 100 200 300
Length (mm)

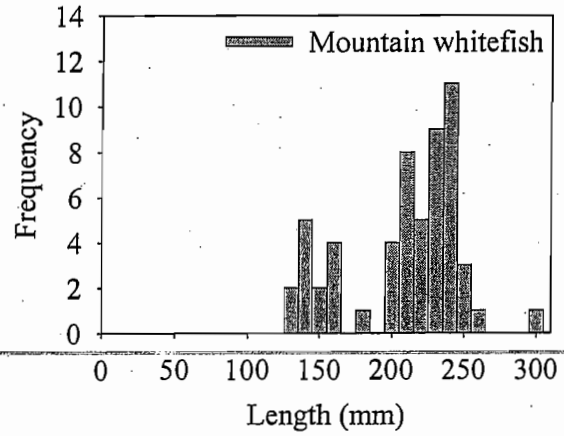
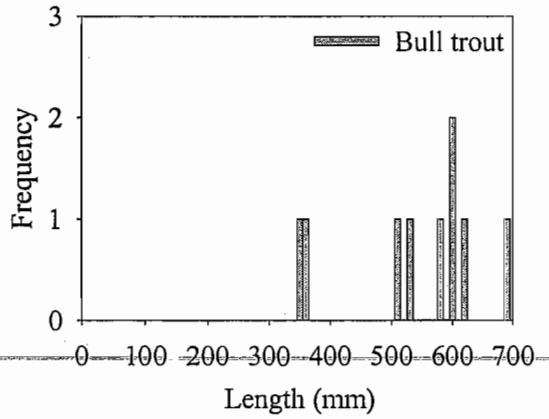
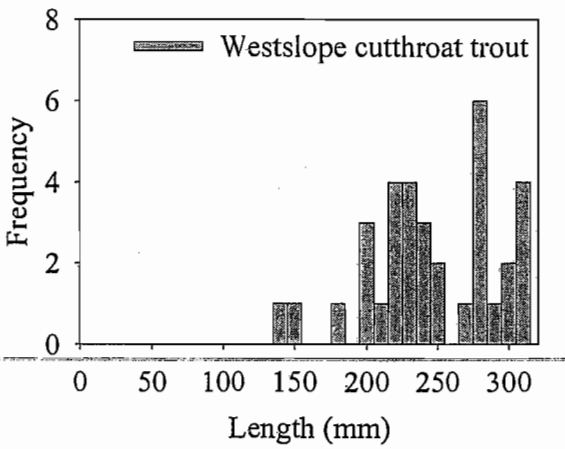
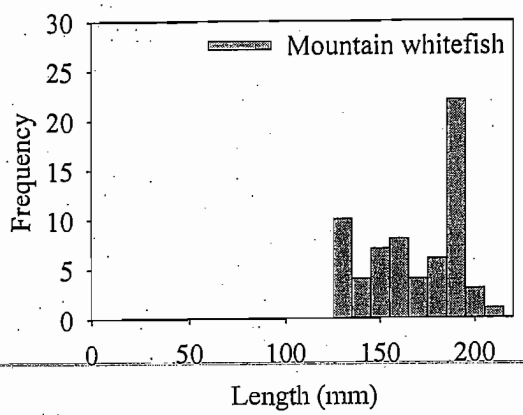
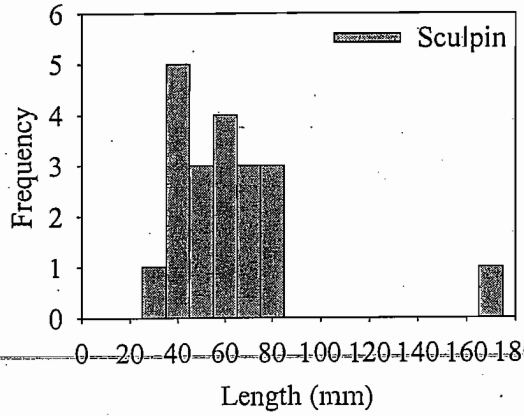


Figure 12. Length-frequency histograms of fish species sampled using the combination of gill net surveys and angling surveys at Cerulean Lake.


Bull trout
Frequency
0
1
2
3
0 100 200 300 400 500 600 700
Length (mm)


Westslope cutthroat trout
Frequency
0
2
4
6
8
0 50 100 150 200 250 300
Length (mm)


Mountain whitefish
Frequency
30
25
20
15
10
5
0
0
50
100
150
200
Length (mm)


Sculpin
Frequency
6
5
4
3
2
1
0
0
20
40
60
80
100
120
140
160
180
Length (mm)

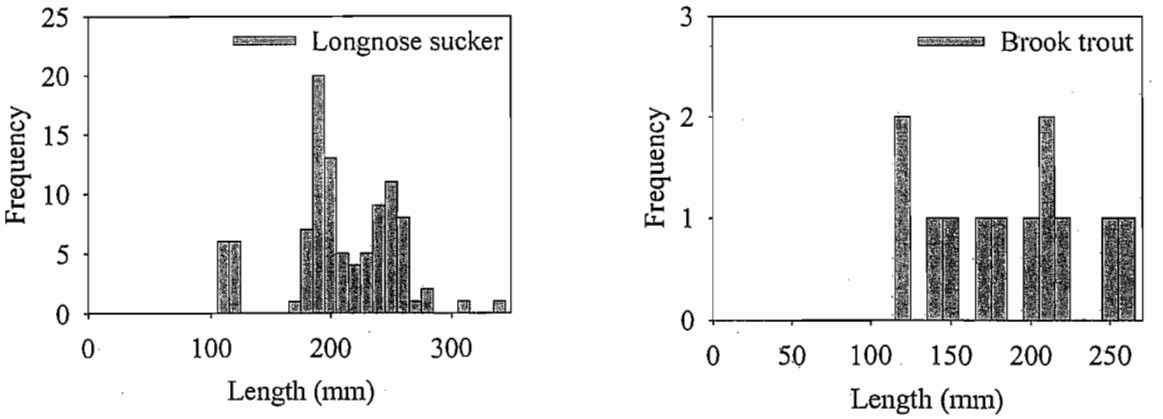


Figure 13. Length-frequency histograms of fish species sampled using the combination of gill net surveys, angling surveys, and shoreline electrofishing surveys at Lincoln Lake.

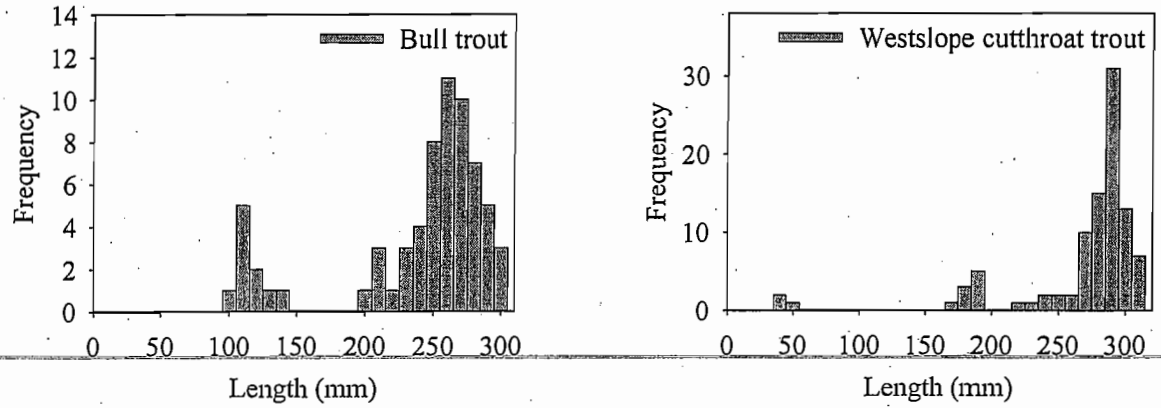
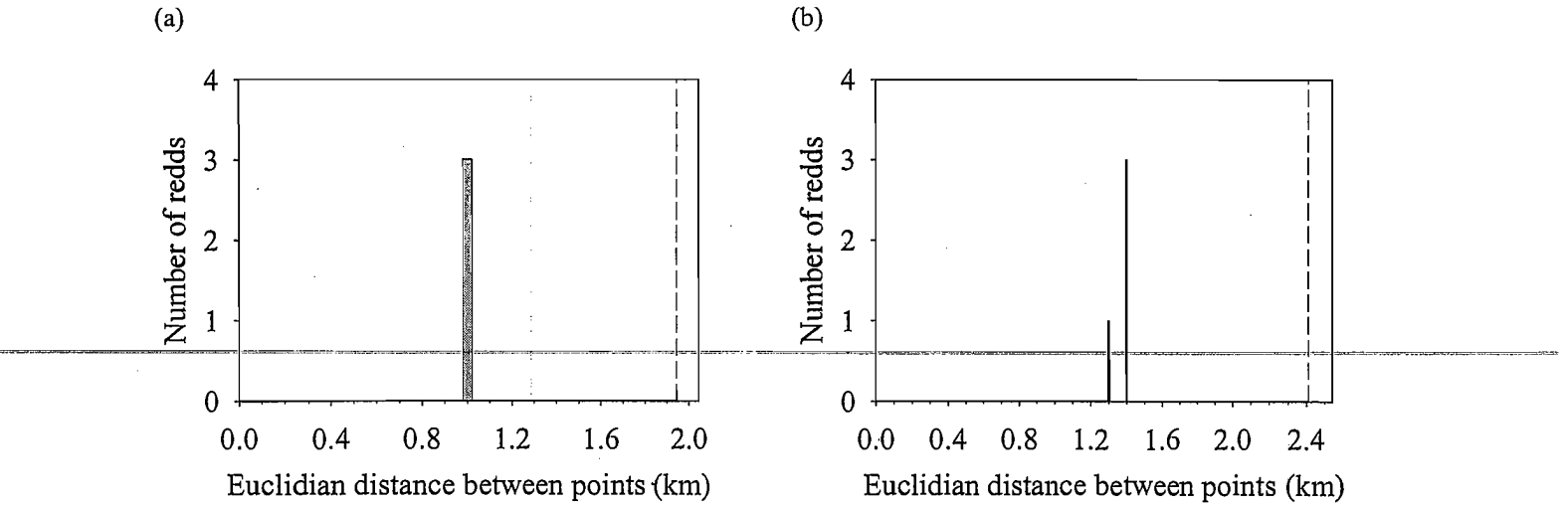


Figure 14. Length-frequency histograms of fish species sampled using the combination of gill net surveys and shoreline electrofishing surveys at Lake Isabel.


(a)
Number of redds
0
1
2
3
4
0.0
0.4
0.8
1.2
1.6
2.0
Euclidian distance between points (km)
(b)
Number of redds
0
1
2
3
4
0.0
0.4
0.8
1.2
1.6
2.0
2.4
Euclidian distance between points (km)

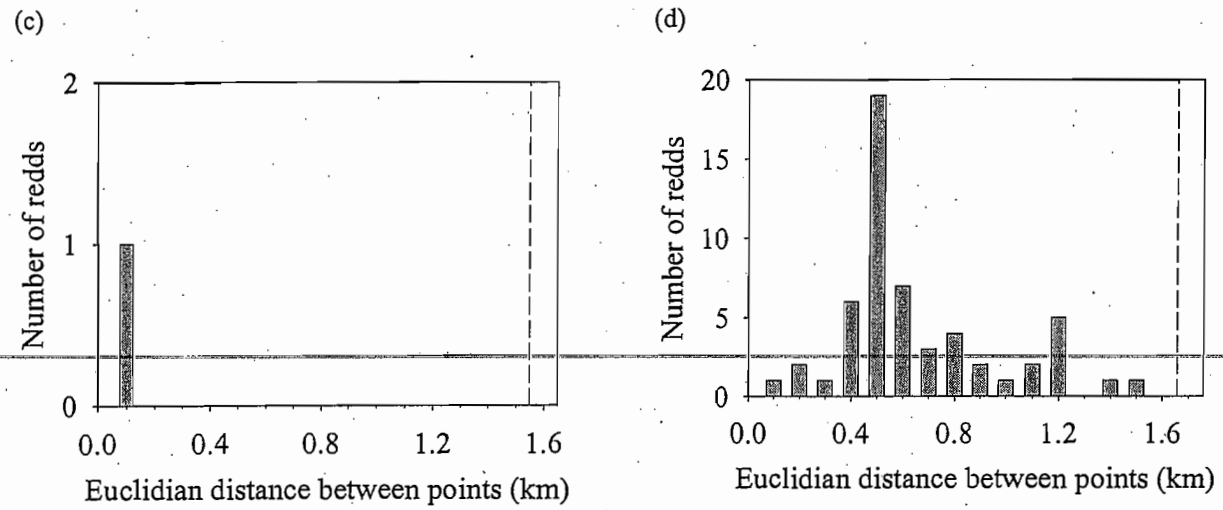


Figure 15. Distribution of bull trout redds observed in four stream sections: (a) Logging Creek from Logging Lake upstream approximately 1.94 km, (b) Harrison Creek from Harrison Lake upstream approximately 2.41 km, (c) Quartz Creek from Lower Quartz Lake upstream approximately 1.55 km, and (d) Quartz Creek from Quartz Lake upstream approximately 1.66 km. The starting point of the survey reach is corresponds to a distance of 0.0 km and the ending point of the reach is represented by a vertical dashed line. A vertical dotted line in plate (a) represents the position of a waterfall observed on Logging Creek.