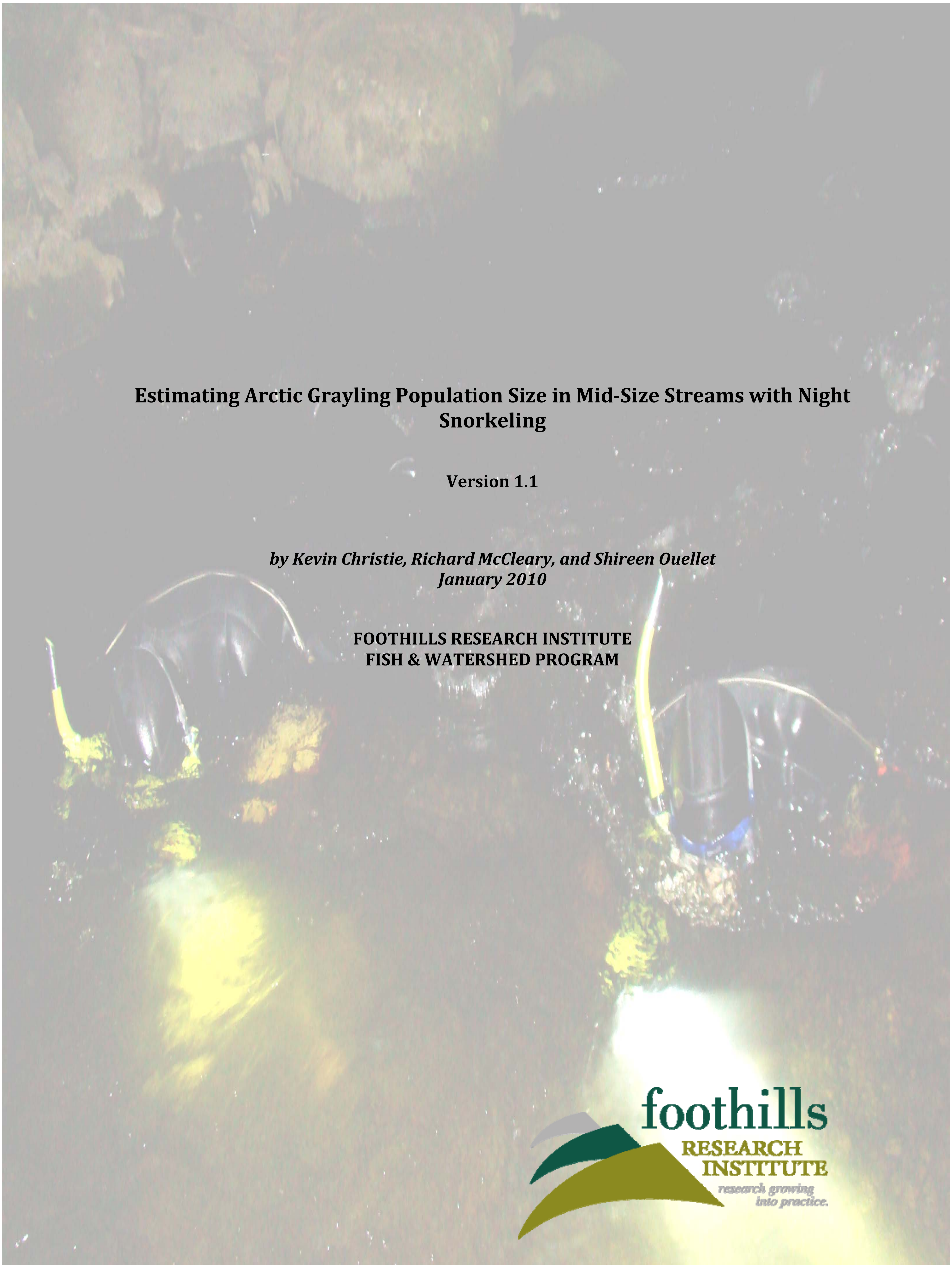

Estimating Arctic Grayling Population Size in Mid-Size Streams with Night Snorkeling

Version 1.1

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EXECUTIVE SUMMARY

Arctic grayling (*Thymallus arcticus*) is listed as "Sensitive" in the province of Alberta. Its conservation requires implementation of long-term monitoring programs and development of field methods to address specific knowledge gaps. For example, little is known about the population status of Arctic grayling in mid-sized streams because these water bodies are not suited for traditional sampling procedures. They are too deep to backpack electrofish and too shallow for boat-based electrofishing. The goal of this research was to determine whether or not snorkeling in intermediate sized streams is a feasible and safe technique for estimating Arctic grayling population size.

In our pilot project, six stream reaches were selected for Arctic grayling population size estimates using mark-recapture techniques, with angling used for the mark survey, and night snorkeling used for the recapture survey. Day and night snorkeling was employed at the first three sample sites, however only night snorkeling was effective. For example, at one reach, eight fish were counted during the day compared to 210 fish at night. Average visibility in the tannin stained boreal streams was less than optimal at 1.5 m, but still feasible for snorkeling. Given the visibility, additional snorkelers should be considered for future studies in the region.

Numbers of fish were sufficient to estimate Arctic grayling population size in three of the six and rainbow trout (*Oncorhynchus mykiss*) at one of the six reaches. In two reaches in Hightower Creek, no Arctic grayling were captured while angling or observed while snorkeling. In the Sundance Creek reach, Arctic grayling greater than >100 mm total length were counted during angling and night snorkeling, but numbers were not sufficient to generate a population estimate and confidence interval. Large numbers of juvenile fish were observed while snorkeling, however fish less than 100 mm cannot be determined specifically as Arctic grayling or mountain whitefish while snorkeling. Given the importance of the Sundance Creek reach for juvenile rearing, other techniques, such as seining or trapping, are advised. The two reaches in Beaver Creek, a tributary to the Berland River, had the highest estimated populations of Arctic grayling > 100 mm total length with 265 fish/200 m (with 95% confidence, between 105 and 636) in Reach 1 and 126 fish/200 m (with 95% confidence, between 1 and 366) in Reach 2. The Lambert Creek reach supported an estimated Arctic grayling population of 12 fish/200m (with 95% confidence, between 1 and 32).

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1.0 INTRODUCTION

1.1 Background

Arctic grayling (*Thymallus arcticus*) is currently listed as *"Sensitive"* in the province of Alberta (Alberta Environment and Alberta Sustainable Resource Development, 2000). This means special management considerations are needed to mitigate effects of natural as well as human caused disturbances to prevent loss of the species. Factors contributing to the decline of Arctic grayling in Alberta include over harvest by anglers, habitat fragmentation at stream crossings, climate change and land-use (Tchir et al., 2004; Walker, 2005). However these impacts likely occur at varying levels across the range of the fish.

Arctic grayling typically are found in northern freshwater drainages of Canada, Alaska and Eurasia with a small isolated population in Montana, U.S.A (Scott and Crossman, 1973). Populations in Alberta inhabit the Hay, Peace, and Athabasca river drainages, which flow into the Mackenzie River and eventually into the Arctic Ocean (Nelson and Paetz, 1992).

Optimal riverine habitat is characterized by cold water with abundant pool habitat, as Arctic grayling are found almost exclusively in pools and seldom in riffles (Vascotto and Morrow, 1973). Grayling inhabit three varieties of streams including spring-fed streams, rapid-runoff streams, and muskeg-fed tannin stained streams with irregular flow (Hubert et al., 1985). Spring-fed streams tend to be cold and clear, have constant flow, pH of 7.0 to 7.8, and there is abundant clean gravel. Most Arctic grayling streams in Alberta are of the bog-fed tannin stained variety. Generally these streams have warmer summer temperatures, pH of 6.4 to 7.4, and a streambed of mud and sand.

1.2 Study Objectives

Due to the limitations of backpack and float electro shocking there is a gap in the knowledge of Arctic grayling status in medium sized streams (order 4-5). In small shallow streams (order 3 and less), backpack electrofishing is the preferred method for determination of population size; in larger, deeper systems, boat/float shockers are currently the method of choice. Intermediate sized streams however are difficult to sample using electro shockers; the water is too deep to backpack shock and too shallow for a watercraft to float. The goal of this research is to determine whether or not snorkeling in the intermediate sized streams is feasible. That is, can these streams actually be snorkeled safely and are confidence levels associated with population estimates suitable for management applications.

Arctic grayling populations are in serious decline throughout its range in Alberta (Walker, 2005). Population estimates that use snorkeling in intermediate sized streams could supplement catchment scale status assessments across the historic range of this fish. Such assessments have application in habitat restoration efforts including those of the Foothills Stream Crossing Program, whose projects include fish passage remediation in mid-sized streams. Population estimates may help set priorities and evaluate biological benefits from infrastructure investment.

1.3 Study Area

We evaluated the usefulness of snorkeling counts within six different site units at four different streams (Table 1) within the Forest Management Area (FMA) of Hinton Wood Products, a division of West Fraser Mills Ltd. (Figure 1).

TABLE 1: UTM locations of streams sampled.

Stream ID	Drainage Area (km^2)	Easting	Northing
Hightower Creek Unit 1	141	436 640	5 956 518
Hightower Creek Unit 2	141	436 416	5 956 332
Beaver Creek Unit 1	241	474 491	5 983 648
Beaver Creek Unit 2	241	474 491	5 983 648
Lambert Creek	179	509 687	5 913 865
Sundance Creek	398	527 474	5 933 992

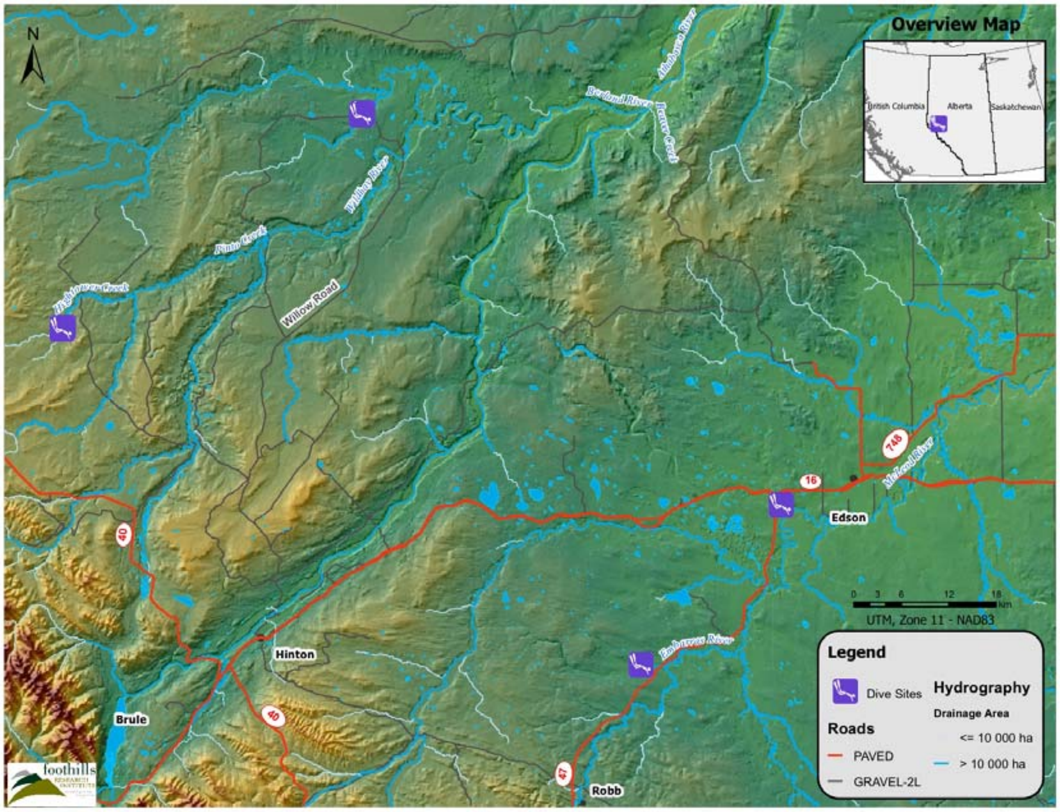

FIGURE 1: LOCATIONS OF STUDY SITES THROUGHOUT THE WEST FRASER MILLS FOREST MANAGEMENT AREA (FMA).

2.0 METHODS

2.1 Site Selection

Sites were selected based on historical data suggesting presence of Arctic grayling. Streams were queried using ArcMap GIS software based on drainage area. Potential sites were visited to confirm a fit within the criteria of being too large to backpack shock all sections and too small to float shock. The stream was also inspected for suitable habitat. Optimal Arctic grayling riverine habitat is characterized by cold water with abundant pools. Arctic grayling are seldom found in riffles (Hubert et al., 1985), but to maximize food intake they often position themselves close to features associated with swifter flow (Stanislawski, 1997).

The four creeks selected for the study were Hightower, Beaver, Lambert and Sundance (Table 1). On both Hightower and Beaver creek, two reaches were surveyed.

2.2 Site Layout

Following the selection of suitable creeks, a string box was used to mark out a 300m long stream reach. Biodegradable ribbon was hung at 50m increments along the bank and each ribbon was marked with a unit identifier as well as the station number. Stations located at 0+50m were marked as the point of commencement (POC) and a UTM using Map Datum NAD83 was recorded using a handheld Garmin GPSmap 60CSx. The upper limit of the unit located at 0+250m was marked as the end of traverse (EOT) and a UTM was also recorded.

2.3 Assuming a Closed Population

A closed population is assumed for Peterson method of mark-recapture population estimate (Everhart and Youngs, 1981). In smaller streams, block nets are typically employed to isolate an area to meet this assumption (Thurow et al., 2006). However, due to stream size, block nets were not feasible and two other measures were used to meet this assumption. First, our surveys were timed to correspond to the summer season when Arctic grayling display a tendency to be relatively stationary while occupying feeding locations (Tack, 1980; Decker et al., 2007; Fitzsimmons and Blackburn, 2009), and we avoided mobile periods including spring and autumn migrations (Stanislawski, 1997). Second, angling was limited to the 200 m long section between the POC and EOT. However to monitor for emigration and immigration, the snorkel survey was completed over the entire 300 m length of the survey site. Marked fish located outside the 200 m section were recorded, but not included in the population estimate. Unmarked fish outside the 200 m section were not recorded.

2.4 Angling

Angling was used to capture fish for marking. Anglers were instructed which type of mark to use (Figures 2 and 3). Fin clips were utilized due to their relative ease of use and low cost (Hoffman et al., 2005). Anglers used a field data sheet to record method (spin or fly casting), total time angling, species, total length of fish, type of mark, and comments (Appendix I).

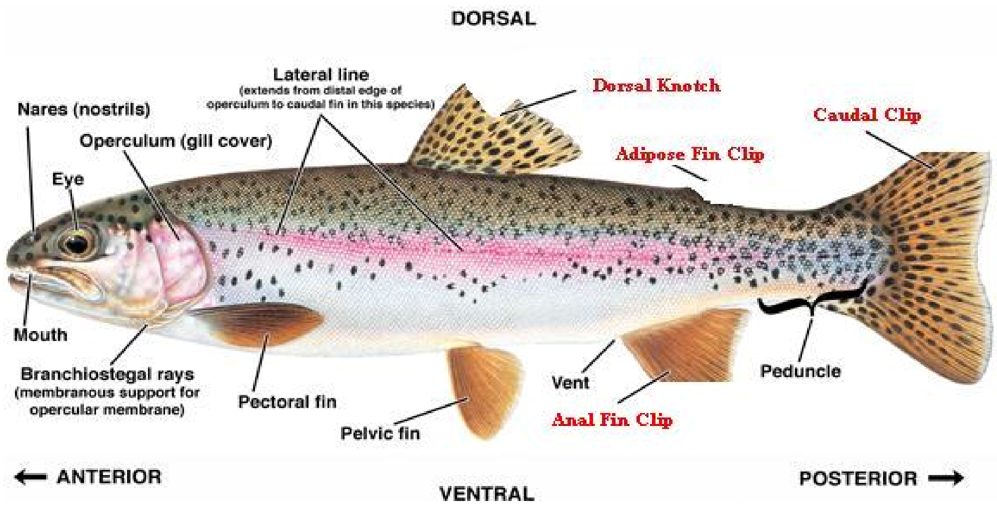

FIGURE 2. TYPES OF FIN CLIPS USED (http://aquaticpath.epi.ufl.edu/lesionguide/).

FIGURE 3. AN ARCTIC GRAYLING WITH A DORSAL FIN CLIP TO DISTINGUISH ITS CAPTURE THROUGH ANGLING.

Spin casting was used more often than fly-casting because of lack of angler experience. Following marking, fish were returned to original place of capture. Fish recaptured during angling were not recorded and simply returned to the stream. In Hightower and Beaver Creek where two units were sampled in each, different fin clips were used in each unit to monitor migration between sites.

2.5 Habitat

Immediately following the angling, habitat information was collected and entered into a Juniper Systems, Inc. Allegro Cx field computer. Habitat information collected consisted of the wetted width, rooted width, substrate composition, % undercut banks, % in-stream cover, overhead cover, dominant vegetation, pool depth and width, water temp and turbidity. Measurements were taken at 0+50m Point of Commencement (POC), 0+100m, 0+150m, 0+200m and 0+250m End of Traverse (EOT).

2.6 Snorkel Survey

After a 24-hour waiting period, a night snorkel survey was made in each sample unit no earlier than one hour after dark. This allowed for the fish to return to a natural state and distribute naturally throughout the unit (Hoffman et al., 2005; Decker et al., 2007).

The snorkel surveys were conducted with two individuals wearing neoprene dry suits, hoods, gloves, mask and snorkel. Prior to commencement of the night snorkel, two measurements of underwater visibility or water transparency for each snorkeler were taken via a method adapted from the use of a Secchi disk in lentic systems (Thurow, 1994). A plastic silhouette of an Arctic grayling was suspended in the water column in front of the snorkeler who moved away until the spotting on the silhouette could not be distinguished. The snorkeler then moved back toward the silhouette until the spotting reappeared clearly, and that distance was measured. Visibility was estimated as the average of the two measurements and was evaluated in an area downstream of the start point 0+000 where a snorkeler had the longest unobstructed underwater view. Snorkelers then agreed upon which side of the stream to sample either left or right and remained on that side for the duration of the snorkel. Remaining parallel to one another and perpendicular to the shore, both snorkelers moved upstream zig- zagging on their side of the unit, ensuring all areas were observed. To record fish while snorkeling, a cuff cut from a piece of PVC plastic pipe 10 cm in diameter and 20 cm long was used (Helfman, 1983). The pipe is cut in half, creating two equal halves each 20 cm long. Four holes are then drilled; one in each corner of the cuff and surgical tubing was fed through each pair of holes. The cuff then fits on the snorkeler's forearm allowing for both hands to be used. A pencil can be stored in the end of one of the surgical tubing tails. A ruler was also scribed on to both the top and bottom of the cuff to aid in length measurements underwater (Figure 4).

FIGURE 4. A SNORKELER DEMONSTRATING THE USE OF AN ARM CUFF TO RECORD FISH OBSERVED.

Objects viewed underwater are magnified about 1.3 times (Thurow, 1994), therefore it takes some time to become accustomed to this difference. Snorkelers had previously measured the distance between their thumb and forefinger to provide another means of measurement. Another useful approach was to take note of the locations of underwater features such as rocks at the tip of the nose and the end of the tail and once the fish moved away the snorkeler would measure that distance. To see through the water at night required the use of an underwater dive light; the one used on this project was a UK Sunlight C4 eLED. As snorkelers encountered fish they were not recorded until the fish was passed – this was to reduce the chance of recounting individual fish (Thurow, 1994; Hoffman et al., 2005). In shallow riffle sections of the stream it was often necessary and more efficient to stand up in the area and look for fish from above, out of the water providing better visibility than from within the water. Shallow riffles are more difficult to snorkel than pools (Hankin and Reeves, 1988; Hillman et al., 1992) and snorkel surveys are also known to under estimate fish abundance in shallow water, particularly when fish are less than 50 or 60 mm (Griffith, 1981; Hillman et al., 1992).

The Arctic grayling's distinguishing dorsal fin is not visible to a snorkeler until fish reach 100 mm in total length. Furthermore, juvenile Arctic grayling and juvenile mountain whitefish both display an adipose fin and relatively large scales and therefore cannot be distinguished. Therefore, all fish < 100 mm were excluded from population estimates.

A shore-person ensured safety of all people on site at all times and recorded all information relayed by the snorkelers onto a field data sheet (Appendix II).

2.7 Statistical Analysis

The Petersen method can be used to estimate population size if two visits are made to the study site (Nichols, 1992; Schaub et al., 2007). Assumptions of the Peterson method are the following:

1. the population was closed (no change in the number or composition of fish during the experiment);
2. all fish had the same probability of capture during the marking event or the same probability of capture during the recapture event, or marked and unmarked fish mixed completely between the marking and recapture events;
3. marking of fish did not affect their probability of capture in the recapture event;
4. fish did not lose their mark between events; and,
5. all marked fish were reported when recovered in the recapture event.

Measures to address assumption one were described in section 2.3. Assumption two was met because we excluded fish < 100 mm from the population estimate. In addition to the problem with identification, these smaller fish likely had different angling vs. snorkeling capture probabilities. Assumption three was met because marking techniques were selected that did not make the fish more visible and susceptible to predation, such as Floy tagging. Fin clips were also thought to be less likely to injure smaller fish than Floy tagging. Furthermore, after marking, all angled fish were held within the water column long enough for them to recover and swim away under their own power. To meet assumption 4, fish were marked with two distinct clips in different locations. Assumption five was met by confirming fish length with the use of an arm cuff and relaying all sightings to the shore person for recording.

Given those conditions, population size was estimated using $N = MC/R$ where: N = estimated abundance of fish at the time of marking, M = the number of fishes marked and released alive during the marking event; C = number of fish examined for marks during the recapture event; and R = the number of fish recaptured during the recapture event (Everhart and Youngs, 1981). Variance of the abundance estimate (V) was calculated using the formula for binomial sampling, which applies for survey types including snorkeling where a fish is examined for a mark and not removed from the population:

$$V[N] = \frac{M^2 C(C-R)}{R^3}$$

Confidence intervals (α=0.95) were placed around the estimate of N as follows: $N \pm 1.96\ ((V\ (N))^{-2})$

2.8 Safety

Safety was our first priority. Working in and around water at night presented numerous hazards. Our safety plan included training, using well-suited equipment, and establishing procedures. Prior to the commencement of the study the crew spend two days in Canmore, Alberta completing swift water rescue training. We were trained on:

1. Rescue philosophy and attitude
2. Hydrology of river systems
3. Self rescue
4. Throw bag use
5. Rescue equipment
6. Swimming in swift water
7. Mechanical advantage systems
8. Use of rescue crafts
9. Emergency care of individuals experiencing hypothermia or drowning

All crew members were certified with basic first aid. The crew was encouraged to express any safety concerns and was not required to perform any task they were not comfortable with. As we were working in bear country and the possibility of an encounter did exist, we received bear awareness training through the Grizzly Bear Program at the Foothills Research Institute from Wildlife Biologist, Karen Graham. While performing the study, the shore person was responsible for carrying bear spray. One member of the team was also licensed to carry a side arm and opted to carry his firearm as protection during his rotation as shore watch. Shore watch was responsible for the safety of the crew members performing the snorkel survey at all times due to the limited ability to hear or see anything in the area around them.

Shore watch would relay relevant information on wildlife in the area such as bats flying close to the snorkelers, beavers or beaver dams coming up, or any other animals observed in the area. Hazards that were difficult to see from the water level, such as overhanging vegetation or debris, were relayed to the snorkelers.

Start and end points of the study were chosen in areas of low velocity to avoid entering or exiting the water in dangerous areas. When encountering debris jams, snorkelers were instructed to remain alert to ensure that they did not become entangled in debris.

3.0 RESULTS

3.1 Angling

Angling was used on all six sites and effort varied between streams (Table 2) due to time constraints and availability of volunteer anglers. No fish were captured in the Hightower Creek Units. All Arctic grayling and rainbow trout (*Oncorhynchus mykiss*) that were captured were marked. In general, Arctic grayling that were observed rising were captured.

TABLE 2. FISH CAPTURED AND MARKED DURING ANGLING.

Stream ID	Fish Species	Effort (minutes)	# Captured
Hightower Creek Unit 1	No fish captured	720	0
Hightower Creek Unit 2	No fish captured	720	0
Beaver Creek Unit 1	Arctic grayling	1800	24
	Rainbow Trout		7
Beaver Creek Unit 2	Arctic grayling	1020	20
Lambert Creek	Arctic grayling	1200	3
Sundance Creek	Arctic grayling	900	8
	Rainbow Trout		3

Due to the relative inexperience of most of the anglers, spin casting was the preferred method. However, when it became apparent that spin-casting was not as successful as fly-fishing, the anglers re-rigged their gear. Spin-casting gear was rigged with a float to suspend the line atop the water and a dry fly attached about 2 m from the float. After the switch, angler catch rate increased, though not to the level of those using fly-fishing gear. Few fish were captured in riffle sections, and most were caught in pools or deeper run sections. The most active locations were where a riffle entered a pool.

3.2 Snorkeling

Wetted widths were similar at all reaches, ranging between 9.1 and 11.5 m. Visibility ranged from 1.1 to 1.8 m and averaged 1.5 m (TABLE 3). Therefore, snorkelers were required to use a zig-zag pattern to view the entire channel width. This limited visibility made it difficult at times to visualize fish, though more fish were counted while snorkeling with less effort than were captured with angling (Tables 2 and 4).

TABLE 3. DESCRIPTION OF VISIBILITY USING A MODIFIED SECCHI DISK APPROACH AND THE WATER TEMPERATURES PRIOR TO NIGHTTIME SNORKELING.

Stream ID	Wetted width (m)	Rooted width (m)	Visibility (m)	Temp (˚C)
Hightower Creek Unit 1	10.5	12.0	1.5	9.2
Hightower Creek Unit 2	10.3	12.2	1.5	9.1
Beaver Creek Unit 1	10.2	10.3	1.5	12.3
Beaver Creek Unit 2	9.5	10.5	1.5	10.7
Lambert Creek	9.1	9.4	1.8	13.4
Sundance Creek	11.5	13.9	1.1	14.6

During the first sampling event in Hightower Creek, a day snorkel, we only observed sculpin (*Cottidae spp.*) in both units (Table 4). During the night snorkel, rainbow trout and sucker (*Catostomus spp.*) were observed in the first unit and in the second unit, rainbow trout and sculpin were seen (Table 5). At Beaver creek, a total of eight fish were observed during the day snorkel, in comparison to 210 during the night. Due to this limited success, day snorkels were abandoned in the three remaining sites.

Juvenile salmonids that were observed included rainbow trout (FIGURE 7) and large scaled fish that could not be positively identified as either Arctic grayling (ARGR) or mountain whitefish (MNWH) (TABLE 4). Four of the sites that were visited supported juvenile ARGR/MNWH, with the greatest densities in Sundance Creek – a tributary to the McLeod River that is a known Arctic grayling spawning stream (R L and L Environmental Services Ltd., 1995).

TABLE 4. SUMMARY OF SNORKEL SURVEYS INCLUDING TIMING, EFFORT, SPECIES, COUNTS, AND EXPANSION TO FISH PER KM.

Stream ID	Time of survey	Effort (minutes)	Fish Species[1]	# fish/ 200m	# fish/ km
Hightower Creek Unit 1	day	100	Sculpin spp.	2	10
	night	100	Rainbow trout	2	10
			Sucker spp.	1	5
Hightower Creek Unit 2	day	70	Sculpin spp.	1	5
	night	130	Sculpin spp.	1	5
Beaver Creek Unit 1	day	240	Juvenile ARGR / MNWH	1	5
			Arctic grayling	2	10
			Rainbow trout	2	10
			Sucker spp.	1	5
			Sculpin spp.	3	15
	night	284	Juvenile ARGR / MNWH	22	110
			Arctic grayling	108	540
			Rainbow trout	38	185
			Sucker spp.	12	60
			Burbot	2	10
			Sculpin spp.	50	250
Beaver Creek Unit 2	night	148	Juvenile ARGR / MNWH	3	15
			Arctic grayling	61	270
			Mountain Whitefish	10	50
			Rainbow trout	1	5
			Sculpin spp.	22	110
Lambert Creek	night	170	Juvenile ARGR / MNWH	12	60
			Arctic grayling	4	15
			Mountain Whitefish	2	10
			Rainbow trout	14	70
			Sucker spp.	4	20
			Sculpin spp.	5	25
Sundance Creek	night	240	Juvenile ARGR / MNWH	327	1635
			Arctic grayling	5	25
			Mountain Whitefish	44	355
			Rainbow trout	27	135
			Sucker spp.	28	140
			Sculpin spp.	2	10
			Pearl Dace	27	135
			Burbot	2	10

[1] ARGR = Arctic grayling and MNWH = mountain whitefish

In the six sections sampled, no marked fish, including Arctic grayling and rainbow trout, were observed within the 50 m upstream and downstream buffer zones. This finding supports the closed population assumption required for the Peterson method.

Sample size was sufficient to estimate populations and associated confidence intervals for Arctic grayling at three sites and rainbow trout at one site (TABLE 5). The Beaver Creek units had larger estimated populations than Lambert Creek.

TABLE 5. PETERSON MARK-RECAPTURE POPULATION ESTIMATES AND 95% CONFIDENCE INTERVALS (CI) BY LOCATION AND SPECIES.

Stream ID	Species	M[1]	C[2]	R[3]	Population estimate / 200 m	Lower Cl (95%)	Upper Cl (95%)
Beaver Creek Unit 1	Arctic grayling	24	107	8	265	105	636
	Rainbow trout	7	18	1	126	1	366
Beaver Creek Unit 2	Arctic grayling	20	61	7	174	53	296
Lambert Creek	Arctic grayling	3	4	1	12	1	32

[1] M = Number of fish marked and released.
[2] C = recapture sample size including both marked and unmarked fish .
[3] R = number of marked fish recaptured.

Size of Arctic grayling in Beaver Creek – Unit 1 were left skewed (FIGURE 5), with median size class of 100 – 149 mm. Maximum fish size at this site was the 200 - 249 mm class. Arctic grayling in Beaver Creek – Unit 2 also had a left skewed size distribution (FIGURE 6), however it had a larger median size class of 150 – 199 mm and a greater maximum fish size class of greater than 250 mm. The four Arctic grayling that were observed in Lambert Creek ranged in size between 100 and 200 mm.

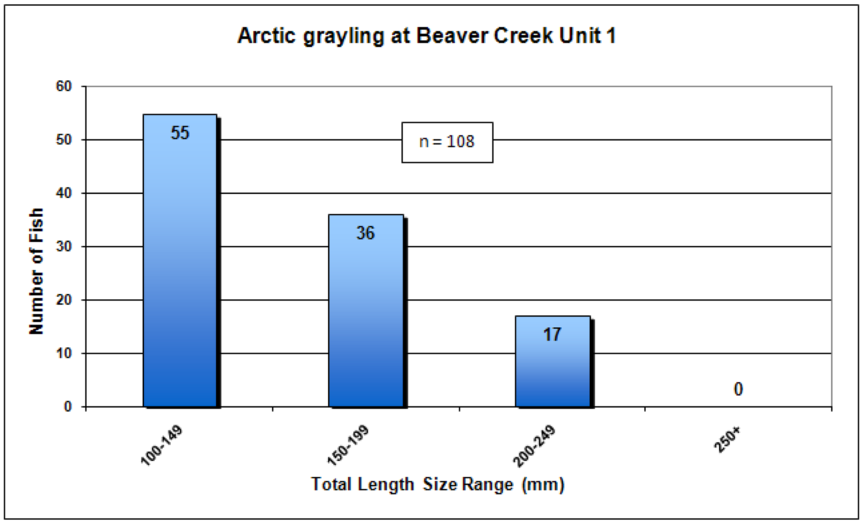

FIGURE 5. DISTRIBUTION OF VARIOUS SIZE CLASSES OF ARCTIC GRAYLING OBSERVED DURING THE NIGHT SNORKEL SURVEY IN UNIT ONE - BEAVER CREEK. ARCTIC GRAYLING UNDER 100 MM WERE NOT INCLUDED AS IT WAS DIFFICULT TO DISTINGUISH BETWEEN GRAYLING AND MOUNTAIN WHITEFISH OF THE SAME SIZE CATEGORIES.

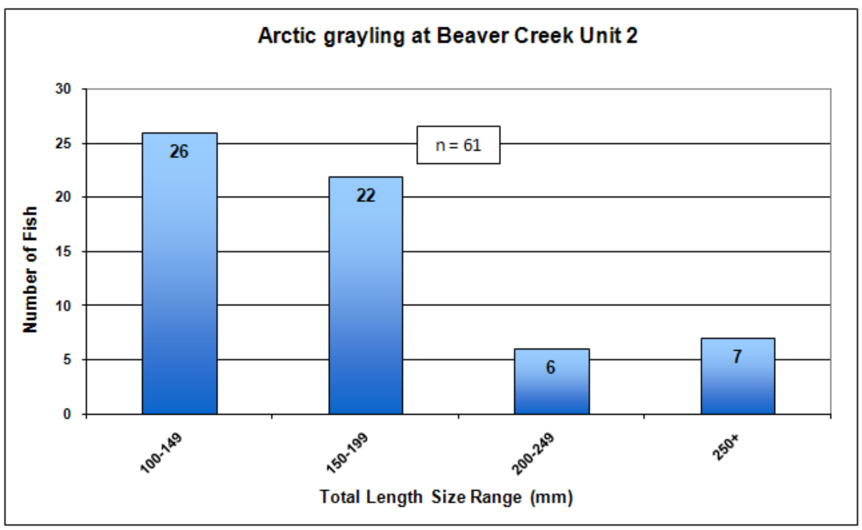

FIGURE 6. DISTRIBUTION OF VARIOUS SIZE CLASSES OF ARCTIC GRAYLING OBSERVED DURING THE NIGHT SNORKEL SURVEY IN UNIT TWO - BEAVER CREEK.

Beaver Creek – Unit 1 supported rainbow trout with a wide range of size classes (Figure 7). Of the fish that were included in the population estimate (i.e. greater than 99 mm), the median size class was 100 – 149 mm, and the largest fish observed were within the 200 – 249 mm class.

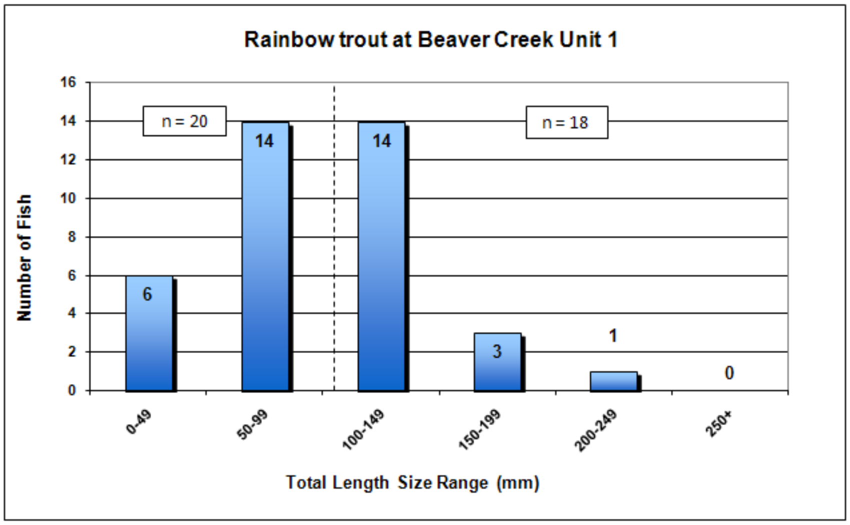

FIGURE 7. DISTRIBUTION OF VARIOUS SIZES CLASSES OF RAINBOW TROUT OBSERVED DURING THE NIGHT SNORKEL SURVEY IN UNIT ONE - BEAVER CREEK.

4.0 DISCUSSION

4.1 Safety and Site Selection

The Foothills receive more precipitation in the summer months than any other region in Alberta. As a result, the creeks are susceptible to high water during any given week. For example, during one summer rainy period, water levels rose up to 1.5 meters in places, causing many streams to overflow their banks and inundate their floodplains. When using this method in regional assessments, accounting for water level will remain one of the most important concerns. Surveys should be completed during base flow conditions when fish are more concentrated within a narrower channel and underwater visibility is best. Targeting base flow conditions will also be important for maintaining consistency across years. Ideally, initial site evaluation and fish capture / recapture surveys should be completed during base flow. Summer water level fluctuations mandate a flexible sampling schedule.

4.2 Angling

Experience of most of anglers was limited and catch rates were likely lower than those of experienced fly-fishers. Due to the relative ease at which Arctic grayling can be captured, there is no need for individuals to master the skill of fly-casting – they only need to learn the basics prior to commencement of sampling, including use of a spin-casting rod with a float and fly. Difficulty recruiting volunteers was a problem due to the timing; many potential volunteers were unavailable during mid-week due to work responsibilities. More time should be spent in the future securing experienced volunteers and establishing a schedule that will accommodate their responsibilities.

4.3 Snorkeling

Snorkeling in mid-sized Foothills steams is feasible. At times, crewmembers struggled to get through faster moving riffle sections, but if we are concerned with determining population estimates for Arctic grayling this is of little concern. Once they have reached summer feeding grounds, Arctic grayling spend most of their time within pools and deeper runs (Hubert et al., 1985; Stanislawski, 1997). Shallow riffle sections were also difficult and time consuming for the snorkelers and snorkel surveys are also known to underestimate fish abundance in shallow water, particularly when fish are less than 50 or 60mm (Roni and Fayram, 2000).

Visibility was limited within the survey streams. The recommended minimum visibility is around 1.5m (Thurow, 1994), and we were typically working at or below this minimum (FIGURE 8). The water must be clear enough to see the bottom in the deepest locations, identify fish to species and detect fish trying to avoid the snorkeler.

FIGURE 8: DAY SNORKEL ON HIGHTOWER CREEK DEMONSTRATING THE TANNIN STAINED WATER WITH AN UNDERWATER VISIBILITY OF 1.5M.

Our intent was to use direct enumeration and count the total number of fish within the sampling unit. This method assumes that snorkelers are able to see all areas and each other at all times. This was not the case during this study due to low visibility. To get around this problem more snorkelers could have been added to fill the gaps. Otherwise if total enumeration is not feasible due to visibility, an expansion estimate could be considered. This method assumes counts are accurate and the density of fish in each snorkeler's lane represents the unsampled area. One snorkeler counts the fish observed within their lane and that number is expanded to include the unsampled area. If counts within individual lanes are replicated, the mean density, variance and confidence limits can be calculated (Slaney and Martin, 1987). Limitations of the snorkel-expansion method however are that fish are not actually handled, and true length measurements are not possible to obtain by this method (Zubik and Fraley, 1988). Slaney and Martin (1987) felt that the accuracy of snorkel-expansion estimates varies among different stream types or hydraulic conditions. The snorkel-expansion method is more time and cost-effective than Petersen mark-recapture methods (Zubik and Fraley, 1988). Because the snorkel-expansion estimate can be accomplished in 1 day, researchers do not have to meet many of the assumptions of a mark-recapture estimate relating to immigration and emigration. Zubik and Fraley (1988) concluded that the snorkel-expansion method provided an accurate and precise estimate of fish densities. For night snorkeling, it will remain imperative that a hazard assessment be completed in full daylight prior to the sampling.

In some instances, population estimates derived from underwater observations may be more cost-effective and reliable than those obtained from electrofishing or other techniques. Underwater observation offers a quick, inexpensive, and nondestructive census technique that is not limited by deep water, as is electrofishing (Hillman et al., 1992). Slaney & Martin (1987) demonstrated that snorkeling required about 6% of the time required covering the same area as angling. Snorkeling required 2 hours to cover 3.25 km of river or 0.4 hour/hectare and angling required 7 hours of effort per hectare. Their study was performed on Cutthroat trout (*Oncorhynchus clarki*) which also display a high vulnerability to angler harvest as do Arctic grayling (McPhee, 1966).

Our fish inventory training included observing Foothills fish species in the aquariums at the Royal Alberta Museum in Edmonton prior to project commencement. Photographs and pictures were also studied. Stream margins could be electrofished after the snorkel surveys to collect juvenile salmonids, cyprinids, and other species that are difficult to identify. Future studies should continue to emphasize identification fish size enumeration skills. Griffith (1981) reported that five observers were tested on their ability to estimate lengths of 15 fish underwater. Prior to training, 52 to 72 percent of estimates were within 25 mm of the actual length; after one hour accuracy improved to 90 percent.

4.4 Recommendations for improvements in future studies

This project was a co-operative effort between a project biologist, fisheries technicians, GIS/database specialists, and the Fish & Wildlife Resource Data Management Specialist from Alberta Sustainable Resource Development. Considerations for improving future studies from all participants are summarized in several categories:

1. Field work:
    - 1.1. Continue to emphasize safety first through First Aid and Swift water Rescue Training.
    - 1.2. Use longer sites to increase confidence in population estimates.
    - 1.3. Use fish size intervals of equal 50 mm size intervals.
    - 1.4. Designate size class cutoffs that correspond to juvenile/adult fish.
    - 1.5. Continue to improve skills on underwater fish species identification and collect photographs where possible.
    - 1.6. Use standard fin clips that are included in the provincial database.
    - 1.7. The day after snorkeling, revisit all sites where fish were not positively identified to species and use backpack electrofishing in channel margins and other shallow areas to confirm fish species. Fish identified as sucker spp., sculpin spp., cyprinid, ARGR/MNWH juvenile cannot be entered into the provincial database.
    - 1.8. Continue to assess closed population assumption by recording only marked fish within the first and last 50 m section of stream.
2. Data management
    - 2.1. Invest in the use of field PC and associated data management programs for recording all field data.
    - 2.2. Expand an ACCESS database to include snorkeling tables and output programs to populate provincial database digital load forms.
    - 2.3. Provide sufficient training for all staff. This investment will pay off during analysis, reporting and data transfer to the provincial database.

5.0 CONCLUSION

Snorkeling proved to be an effective technique for estimating Arctic grayling population sizes in several mid-sized streams. Streams dominantly used by juvenile fish should be sampled using other methods that allow for positive fish species identification. Three considerations for future applications are: (1) set minimum numbers for marked fish number and for fish examined for marks and increase reach length or effort to achieve these numbers; (2) set minimum visibility requirements in relation to number of snorkelers available; and (3) complete day time safety assessments on a site by site basis before expanding night snorkeling to larger water bodies.

Quantitative population estimate methods on a watershed-by-watershed basis could support regional assessments of Arctic grayling status. These larger projects should strive to identify areas where management intervention is required to ensure viable populations are conserved. Regional initiatives should also try to identify factors that have impacted populations such as over harvest, fragmentation, sedimentation, on a catchment by catchment basis. For example, the status of Arctic grayling in tributaries to the Berland River appeared to be different from tributaries to the Embarras River. This catchment scale knowledge is required so that specific corrective measures can be applied. Quantitative techniques will continue to be important for monitoring the results of any completed restoration activities.

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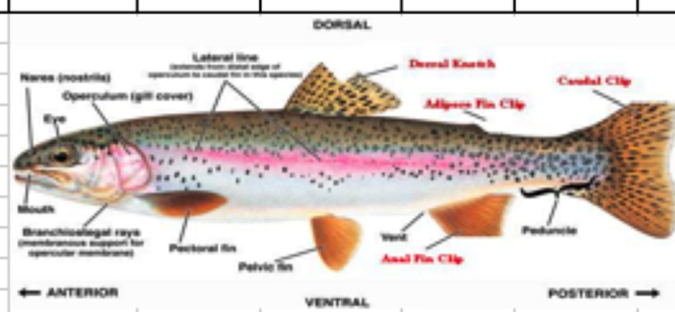
APPENDIX I. Angling Survey Data Sheet

Angling Survey Data Sheet

Date:				
Waterbody Name:		Time:	Start	End
Clip ID (see below):				
Reach ID:		Angler Names:		
Visit #				
Method (fly/spin cast)				
Lure Used:				
Location UTM Lower:		Weather:		
Location UTM Upper:				

Species (mm)	0 to 50	51 to 80	81 to 100	101 to 120	121 to 150	151 to 200	201 to 250	251+
Arctic Grayling								
Rainbow Trout								
Brook Trout								
Cutthroat Trout								
Brown Trout								
Bull Trout								
Whitefish								
Northern Pike Min.								
Sucker								

Dorsal Knotch (DK)
Adipose Fin Clip (AF)
Caudal Fin Clip (CF)
Anal Fin Clip (AC)
Anterior Dorsal Knotch (ADK)



Comments:

APPENDIX II. Snorkeling Survey Data Sheet

Snorkeling Survey Data Sheet

			Start	End	
Date:		Time:			
Waterbody Name:		Snorkeler 1:			
Reach ID:		Distance silhouette visible:		Distance silhouette not	
Visit #:		Snorkeler 2:			
Reach Name:		Distance silhouette visible:		Distance silhouette not visible:	
Lower (Start) UTM:		Snorkeler 1 Avg.			
Upper (Finish) UTM:		Snorkeler 2 Avg.		Total Avg.	
Weather:					

Species (Unmarked)	0 to 50mm	51 to 80	81 to 100	101 to 120	121 to 150	151 to 200	201 to 250	251 +	Total
Arctic Grayling									0
Rainbow									0
Brook Trout									0
Cutthroat Trout									0
Brown Trout									0
Bull Trout									0
Whitefish									0
Northern Pike Minnow									0
Sucker									0
Sculpin									0
									0
									0
									0

Turbidity		Reach Length (m)	

0 = not snorkelable due to high turbidity or hiding cover
1 = high amount of hiding cover and/or poor water clarity
2 = moderate hiding cover and/or moderate water clarity
3 = little hiding cover and good water clarity

Comments:

Dorsal Knotch (DK)
Adipose Fin Clip (AF)
Caudal Fin Clip (CF)
Anal Fin Clip (AC)
Anterior Dorsal Knotch (ADK)

APPENDIX II CONTINUED. SNORKEL SURVEY DATA SHEET PAGE 2.

Species (Marked)	0 to 50mm	51 to 80	81 to 100	101 to 120	121 to 150	151 to 200	201 to 250	251 +	Total
Dorsal Knotch (DK)									
Anterior Dorsal Knotch (ADK)	circle one								
Arctic Grayling									
Rainbow									
Brook Trout									
Cutthroat Trout									
Brown Trout									
Bull Trout									
Whitefish									
Northern Pike Minnow									
Sucker									
Species (Marked)	0 to 50mm	51 to 80	81 to 100	101 to 120	121 to 150	151 to 200	201 to 250	251 +	Total
Adipose Fin Clip (AF)									
Arctic Grayling									
Rainbow									
Brook Trout									
Cutthroat Trout									
Brown Trout									
Bull Trout									
Whitefish									
Northern Pike Minnow									
Sucker									
Species (Marked)	0 to 50mm	51 to 80	81 to 100	101 to 120	121 to 150	151 to 200	201 to 250	251 +	Total
Caudal Fin Clip (CF)									
Arctic Grayling									
Rainbow									
Brook Trout									
Cutthroat Trout									
Brown Trout									
Bull Trout									
Whitefish									
Northern Pike Minnow									
Sucker									
Species (Marked)	0 to 50mm	51 to 80	81 to 100	101 to 120	121 to 150	151 to 200	201 to 250	251 +	Total
Anal Fin Clip (AC)									
Arctic Grayling									
Rainbow									
Brook Trout									
Cutthroat Trout									
Brown Trout									
Bull Trout									
Whitefish									
Northern Pike Minnow									
Sucker									

APPENDIX III. Equipment List.

- Neoprene dry suits with hoods and gloves
- Dive Masks
- Snorkels
- Wet suit cement
- Zipper wax for suits
- Halogen dive lights
- Data recorders – plastic cuff (10 cm PVC pipe in 20 cm lengths with surgical tubing)
- Data forms
- Measuring tape
- Flagging
- Pencils
- Thermometer
- Fly-rods and reels
- Spin-casting rods and reels
- Flies
- Measuring boards
- Scissors for fin clipping
- Pole for measuring water depth
- First-aid kit
- String Box

APPENDIX IV. Snorkeling equipment rental and purchases.

The Dive Outfitters
Scuba Diving & Snorkeling

The Dive Outfitters Ltd.
17826 – 107 Ave
Edmonton, Alberta T5S 1J1
Toll Free 888.483.0049
Fax 780.437.8643
Phone 780.483.0044
www.thediveoutfitters.ca
info@thediveoutfitters.ca

INVOICE

CUSTOMER
Name Foothills Research Institute
Address 1176 Switzer Drive
Hinton, AB T7V 1X6
Phone 780-865-8374
Fax 780-865-8331

SHIP TO
Name Kevin Christie
Address Senior Fisheries Technician

Date August 19, 2009

Qty	Code	Description	Color/Size	Unit Price	Total
3		Drysuit Rental (w/ hood & gloves) - weekly	L	135.00	405.00
3		Drysuit Rental (w/ hood & gloves) - weekly	M	135.00	405.00
3		Drysuit Rental (w/ hood & gloves) - weekly	XXL	135.00	405.00
3	19041D	UK Sunlight C4 eLED	Yellow	155.00	465.00
1	M-M401	Manta Mask	Blue	49.00	49.00
2	M-M101	Butterfly Mask	Yellow	98.00	196.00
3	12473	Silicone Snorkel	Yellow	30.00	90.00
1	28115	Max Wax		8.00	8.00

OTHER DETAILS

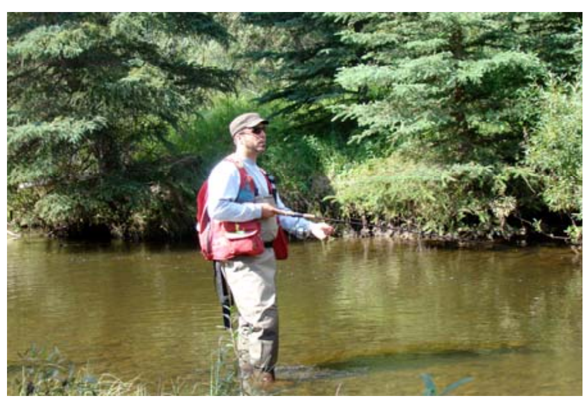
Subtotal	2,023.00
Shipping	
Subtotal	2,023.00
GST	101.15
Total	$ 2,124.15

APPENDIX V. Photographs.






APPENDIX V CONTINUED.



APPENDIX V CONTINUED.

APPENDIX V CONTINUED.






APPENDIX V CONTINUED.