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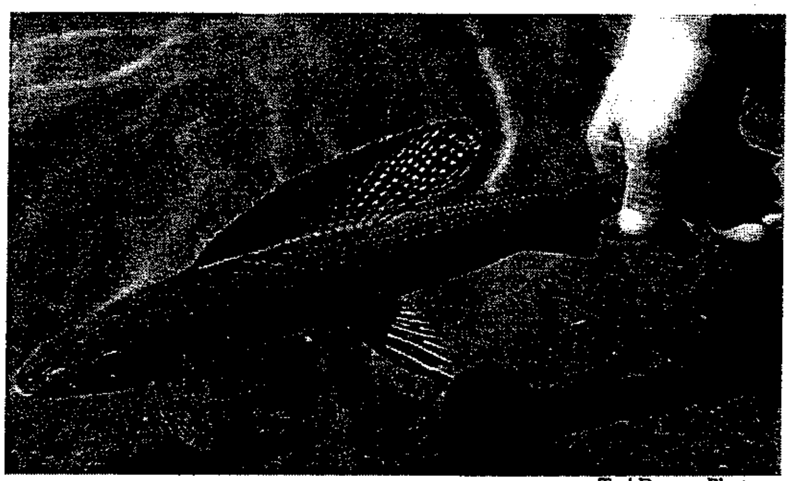
A Stock Assessment of the Kakwa River Arctic Grayling (*Thymallus arcticus*) Population, Fall 1997.

by

Travis Ripley



Ted Downne Photo

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Alberta Conservation Association
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Northwest Boreal Region

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Executive Summary

Arctic grayling (*Thymallus arcticus*) were captured using a 5.0 GPP float electrofishing unit within a 32 km study section of the Kakwa River, Alberta, in 1997. In combination with electrofishing, angling as a capture method was also used to collect grayling within deeper pools, often where electrofishing was less effective. The stock assessment was accomplished using population estimates, length distribution and age composition. The long section of river was chosen to determine the validity of all assumptions associated with population estimates and to accurately predict Arctic grayling abundance. Movement probabilities were tested and the population structure was stratified when necessary. A Peterson mark-recapture technique was used to calculate population estimates. The population abundance whithin the study area was 482 (SE = 34) for the combined (angling and electrofishing) estimate, 603 (SE = 96) for electrofishing only and 185 (SE = 19) for angling. The length frequency distribution ranged from 149 mm to 410 mm fork length which spanned 3 to 11 years of age with age five comprising the majority of the sample. No significant differences in size distribution between each capture method was observed. The comparison of these capture methods leads to unique conclusions about the effectiveness of each method for conducting stock assessments on Arctic grayling.

1.0 Introduction

Arctic grayling (*Thymallus arcticus*) is a unique species found within northern Alberta lakes and streams, and has been currently categorised as a priority management species. Berry (1998) refers to this species as "uniquely attractive", "beautiful to look at", and "the peacock of the trout family", due to its brilliant coloration and distinct dorsal fin. Arctic grayling has been noted as a species of concern because of its ease of capture, late maturity, and slow growth, combined with it's need for clear, cold, unpolluted water (Scott and Crossman 1973). Biology of this species has been described in detail in many other reports (Bishop 1971, Brown 1943, Northcote 1995).

Stock assessments (Clark *et al* 1994) involve the use of various mathematical and statistical calculations, which enable the quantitative predictions about the reactions of fish populations to alternative management decisions or habitat changes (Hilborn and Walters 1992). In the recent past, increased development and improved access throughout northern Alberta have placed Arctic grayling populations at risk of overharvest and adverse population declines. The ever evolving role of fisheries managers is to decisively determine the effects this increase in exploitation has on the population and manage this species appropriately to prevent loss of population abundance and health.

To address this concern, the goal of this assessment was to collect information on the status of Arctic grayling in the Kakwa River, with a design that can be easily repeated in the future. This river was chosen for the study due to its relatively unexploited drainage characteristics and lack of current information. Future habitat alterations and proposed regulation changes on length limits for grayling will be monitored based on the results of this baseline information. With repeated visits, a trend in population structure will enhance our abilities to actively maintain the population for future recreational use.

Specific objectives of this stock assessment were to: (1) supplement the database of historic Arctic grayling population characteristics in order to determine gaps in our knowledge base and focus our monitoring efforts where sufficient baseline data exists; (2) collect current information the status of Arctic grayling in this geographically distinct site; and (3) estimate the size of the population, including a host of biological information (age composition, length frequency) on the health of this species.

2.0 Study Area

The Kakwa River (54°N, 118 °W) originates at Kakwa Lake in British Columbia and flows approximately 210 km in a northeasterly direction to its confluence with the Smoky River. It is situated in the upper and lower foothills ecoregion, characterised by the boreal cordilleran climate (Strong and Leggat 1992), figure 1. The Lower Kakwa and South Kakwa falls are barriers to fish passage and form the upper boundary while the lower is dictated by a large mass wasting which affects the clarity of the river. All data collected and presented includes that portion of the river from the Lower Kakwa falls to approximately 32 river kilometers downstream. For the purposes of this stock assessment, this section of river was separated into three distinct areas to form the "upper", "middle" and "lower" study areas (Figure 2).

Current industrial activities in the drainage include hydrocarbon extraction, seismograph exploration and timber harvesting (Hvenegaard and Fairless 1998). These activities are expected to intensify in the future with the addition of coal mining. Angling, hunting, hiking, canoeing, kayaking, rafting, camping, trail-riding and off-highway vehicle use dominate the recreational activities. These pressures on the resource all play a role in the need to determine important Arctic grayling management strategies. Effects of industrial activity vary in the responses of fish populations and therefore it is appropriate to evaluate this population of Arctic grayling for future comparisons. A wealth of literature currently exists on these potential impacts which this report will not restate (Jones and Grant 1996, Beechie *et al* 1994, D.A. Westworth and Assoc. 1992)

This drainage, although not free from industrial and recreational impacts, can still be described as "pristine" when compared with the remainder of the province. No man made barriers to fish passage or deleterious contributions to water quality occur within the drainage, i.e. hydro-dams and pulp mills (Hvenegaard and Fairless 1998).

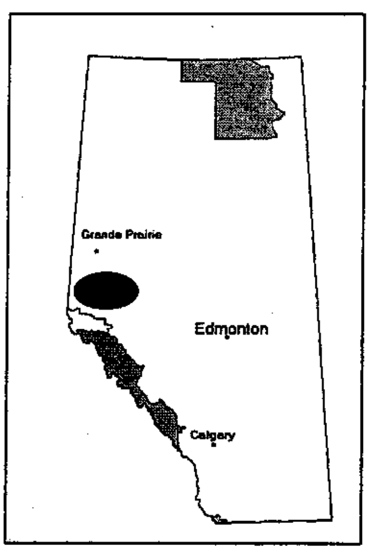

Figure 1. Location of study area.

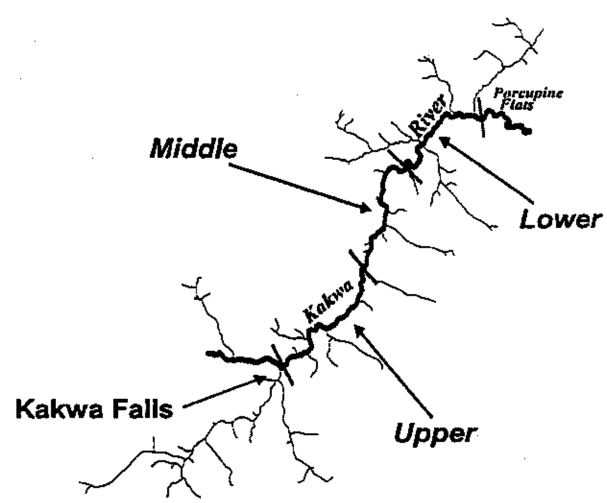

Figure 2. Study sections on the Kakwa River

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3.0 Methods

3.1 Estimation of Abundance

Methodologies have been developed to estimate abundance of fish species in runoff streams. Inherent within each methodology are certain assumptions that must be made in order to quantitatively predict population size. Advances in electrofishing equipment and techniques have made these methods much easier to accomplish. Conversely, many authors make reference to bias in fish capture from electrofishing such as: size-selectivity and mortality (Dwyer and White 1995, Hudy 1985, Reynolds 1983, Hollender and Carline 1994). In recognition of this, angling was used in addition to electrofishing to help offset this bias (Merkowsky 1989). Long study sections were also employed to minimise emigration of grayling during the experiment (Clark *et al* 1991).

Population abundance of Arctic grayling within the Kakwa River was estimated with mark-recapture methods (Ricker 1975), which assume:

1. The population is closed (no change in the number of Arctic grayling in the population during the experiment);
2. All Arctic grayling have the same probability of capture during the first sampling event or in the second sampling event and marked and unmarked Arctic grayling mix randomly between the first and second sampling events;
3. Marking of Arctic grayling does not affect their probability of capture in the second sampling event;
4. Arctic grayling do not lose their mark between sampling events; and,
5. All marked Arctic grayling are reported when recovered in the second sampling event.

Assumption 1 was not tested directly, but movement of grayling out of the river section was inferred from analysis of movements of grayling between the three study sections (Clark *et al* 1991). A log-likelihood ratio test (G-test) was performed to determine the significance of movement between study sections. The log-likelihood ratio test was chosen in view of the considerable advantages over the traditional chi-square test (Sokal and Rohlf 1997). This test compares the observed movement of mark and recapture data with that of recapture data expected if no movement had occurred. Due to the narrow time frame between sampling events, other factors, which could possibly contribute to violation of this assumption, such as recruitment or mortality, were considered insignificant.

To assure the validity of assumption 2, a Kolmogorov-Smirnov two sample statistical test was conducted between both sampling events. The statistical inferences are noted in Clark *et al* (1991), and restated here. Two tests were performed: first was the comparison of length frequency distributions between marked Arctic grayling in the first event with the distribution of grayling recaptured in the second event. Second, the length frequency distribution of marked grayling during the first event was compared with the distribution of grayling captured (unmarked) in the second event. Resulting from the outcome of these two tests, the null hypothesis (there is no size selectivity during each event) was either rejected or not rejected in each instance. The summary of statistical inferences used to alleviate bias are those noted by Clark *et al* (1991).

Assumption 3 was tested by employing the chi square contingency table test comparing the recovery rates of grayling from each study section and during each event (mark run and recapture run). Employing the use of FLOY™ tags combined with clipping the adipose fin (double marked) was felt adequate to meet assumption 4. For grayling too small to be tagged with FLOY™ tags (<200 mm fork length), various fin clips were used relative to the different study sections (upper, middle, lower). Finally, assumption 5 was assumed to be met since no other individuals other than those participating in the study examined the grayling for marks.

The Peterson mark and recapture estimation technique was used for the study. An opportunity was available to conduct two marking events and two recapture events on the same section of stream to better estimate the number of grayling present. It should be mentioned that each marking event and recapturing event were treated separately during the data analysis, and only those grayling captured with marks during the recapture event were included in the estimate (i.e. no grayling captured with tags during the marking event in the second estimate were considered a recapture from the first estimate). The basic formula from Ricker (1975) was:

$$\frac{M(C+1)}{(R+1)}$$

Where: M is the number of Arctic grayling marked,
C is the number of Arctic grayling captured without marks, and
R is the number of Arctic grayling recaptured with marks

In the event that assumption 2 was found to be violated, grayling were stratified by length into separate categories until this assumption was met. In this event, the estimates were calculated based on the stratified sample rather than the overall grouping.
Associated error was calculated by bootstrapping the estimate 1000 times using the program SPAS - Stratified Population Analysis System (Arnason *et al* 1996). Variance was calculated by bootstrapping the estimate using a simulation analysis based on marked and recapture grayling probabilities for all captured grayling within each study section (Arnason *et al* 1996). Once again, variance was calculated for stratified samples as well.

3.2 Age and Size Distribution

A sample of grayling from the recapture run had scales removed for ageing. It was felt that scale removal during the recapture run would reduce the risk of added mortality, and therefore not affect the recovery rate of grayling had scales been removed during the marking run, and mortality incurred. Despite some evidence that scales are not as accurate as otoliths to age northern populations of Arctic grayling, it was the preferred choice to minimise the loss of grayling from this area rather than the option of using a lethal method (Sikstrom 1983). Scales were collected by trained personnel from the preferred area (Mackay *et al* 1990). Because of the difficulty in reading Arctic grayling scales, two scale readers were used to calculate an index of reader agreement (Sikstrom 1983).

Age composition was estimated with the proportion:

$$\hat{P}_k = \frac{X_k}{n}$$

Where:

$\hat{P}_k$ = the proportion of Arctic grayling that are age k,
X_k = the number of Arctic grayling sampled at age k, and
N = then total number of Arctic grayling sampled that are aged.

Variance of this estimate was then calculated with:

$$V(\hat{P}_k) = \frac{P_k\ (1 - P_k)}{\sqrt{(n-1)}}$$

Catch curves were calculated for those grayling that were aged (Ricker 1975). From these catch curves, grayling annual survivability, annual mortality, and instantaneous mortality were calculated for comparison with future stock assessments. Instantaneous mortality (Z) is calculated from the slope of the line on the descending limb. Survivability (S) is then determined from the inverse logarithmic distribution of the slope of the curve (e^{-z}) and annual mortality (A) is 1-S. Therefore, the equation is (1-A) = S = e^{-z}.
Length distribution was calculated using a length frequency histogram. Relationship between fork length and total length was also calculated to be used in comparison with other Arctic grayling assessments and to report on regulation changes.

4.0 Results

4.1 Population Abundance

The population abundance of Arctic grayling was calculated from the combination of data accumulated from both sampling events, September 4-9 and September 26-30, 1997. The latter event did not produce enough grayling captures to facilitate two independent estimates. Due to the close proximity of each sampling event, it was deemed that both events combined did not violate earlier assumptions. Individual section lengths for the upper, middle and lower sections were 12 km, 11 km and 9 km, respectively. These lengths were chosen based on stream locators and availability to cover all habitat types (Lyons 1992.) A total of 239 Arctic grayling were marked and 209 grayling were examined for marks of which 69 were recaptured with marks. One immediate mortality (0.22%) was evident from the catches of all grayling. The population estimate for the combined trips in 32 km of the Kakwa River was 482.43 (SE = 34.26) showing 95% confidence limits at 415.27 – 549.59 (Table 1). On average, this correlates to 15.1 Arctic grayling per kilometer. Movements of grayling among study sections (Table 2) were not significant ($G = 1.7$, $df = 2$, $p<0.05$), therefore no effort was made to modify the Peterson estimate. In addition, the capture probabilities when tested between study areas indicates no difference in the recapture rate of Arctic grayling ($\chi^2 = 10.951$, $df = 2$, $p < 0.05$).

Table 1. Population estimates of Arctic grayling in 32 km of the Kakwa River

Type	Number Marked	Number Captured (without marks)	Number Recaptured (with marks)	Estimate	S.E.	95% Confidence Limits
Angling	103	51	28	185.48	19.23	147.79-223.17
Electro-fishing	141	101	23	602.50	96.22	413.91-791.09
Small grayling (<295 mm)	122	78	16	570.59	110.80	353.43-787.75
Large grayling (=>295 mm)	117	62	53	136.70	5.17	126.54-146.79
Combined Trips[a]	239	140	69	482.43	34.26	415.27-549.59

[a] Includes two individual marking runs and recapture runs calculated from September 4-9 and September 26-30, 1997.

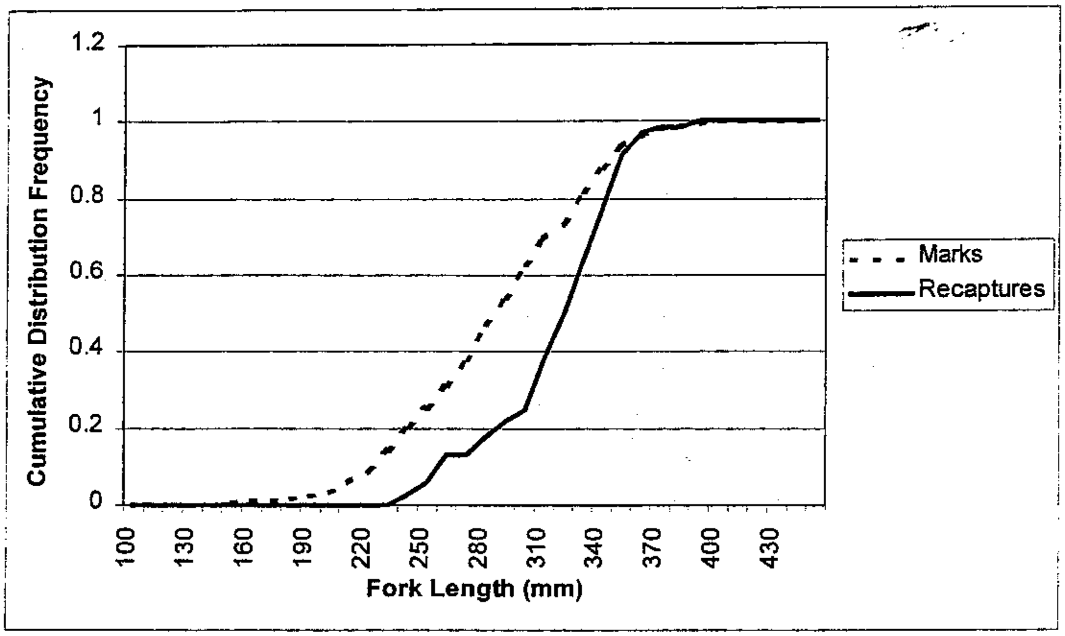
However, when tested for assumption 3, the first test (length distribution between marked grayling and recaptured grayling) showed a detectable difference in sizes of grayling between the two runs ($D=0.3812>D_{0.05}$). Figure 3 shows the cumulative distribution function of lengths for both marked vs. recaptured and marked vs. captured. The difference between the two samples indicates the sizes at which the discrepancy occurs.

Table 2. Movements of Arctic grayling among study sections for all known recaptures from both sampling events .

Section

Marked	Km	Upper												Middle											Lower														
		165	164	163	162	161	160	159	158	157	156	155	154	153	152	151	150	149	148	147	146	145	144	143	142	141	140	139	138	137	136	135	134	Rnm	Rm	Total R	Total M	R/M Ratio	Recapture Rate
1	165																			■														0	1	1	2	0.50	
2	164			2																														0	2	2	5	0.40	
6	163		1	9			1																											9	2	11	22	0.50	
0	162																																	0	0	0	0	0.00	
1	161						1																											0	1	1	5	0.20	
15	160			8			5	1	1		1																■							5	12	17	29	0.59	
2	159						1	1	1																									1	2	3	4	0.75	
3	158								2				1																					2	1	3	17	0.18	
0	157																																	0	0	0	0	0.00	
0	156																																	0	0	0	0	0.00	
2	155										1	1												■										1	2	3	14	0.21	
2	154												1	■																				1	2	3	9	0.33	0.411214953
3	153													4																				4	0	4	18	0.22	
0	152																																	0	0	0	0	0.00	
0	151																																	0	0	0	2	0.00	
1	150																			2														0	2	2	5	0.40	
6	149													1		4				2														0	7	7	13	0.54	
2	148																			2												■		0	3	3	8	0.38	
0	147																																	0	0	0	5	0.00	
1	146																					3												0	3	3	1	3.00	
1	145																							1										0	1	1	13	0.08	
0	144																																	0	0	0	0	0.00	
0	143																																	0	0	0	12	0.00	0.25974026
0	142																																	0	0	0	0	0.00	
3	141																											3						0	3	3	9	0.33	
0	140																																	0	0	0	4	0.00	
0	139																																	0	0	0	4	0.00	
0	138																																	0	0	0	9	0.00	
1	137																																1	0	1	1	11	0.09	
0	136																																	0	0	0	0	0.00	
0	135																																	0	0	0	0	0.00	
1	134																																1	1	0	1	18	0.06	0.090909091

Denotes ± 1 km
Denotes intra-area movement
Rnm - Recaptures with no movement
Rm - Recaptures with movement
Total R - Total number of recaptures
Total M - Total number marked fish



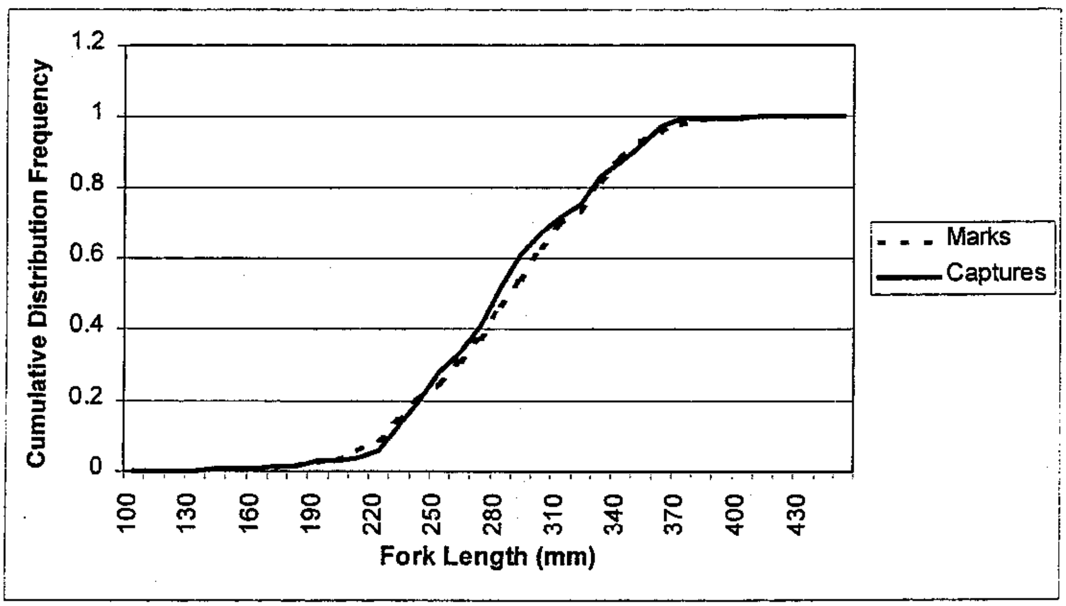


Figure 3. Cumulative distribution function of lengths of Arctic grayling marked vs. lengths of Arctic grayling recaptured (top) and vs. lengths of Arctic grayling captured (bottom) from the Kakwa River, 1997.

Therefore, distributions of Arctic grayling were stratified by length into small grayling (<295 mm) and large grayling (=>295 mm) to meet this assumption. Calculated estimates for small and large grayling were 570.59 (SE = 110.8) and 136.7 (SE = 5.17), respectively (Table 1). However, due to limited number of samples available for analysis, the estimates based on both sizes were chosen for further analysis applied to this report, acknowledging the violation of this assumption. Furthermore, the above population abundance's stratified by size reflects recapture rates between estimates, very low for small grayling and very high for large grayling. It was felt that these estimates do not accurately reflect the true population abundance of Arctic grayling within the Kakwa River.

More importantly, the differences between estimates for grayling captured by angling and electrofishing individually, provides greater insight into size selectivity bias for this type of analysis (Table 1). Angling marked 103 grayling, and captured 79 grayling in the recapture run of which 28 were marked previously. This high proportion of recaptures is reflected a low estimate of 185.48 (SE = 19.23) showing 95% confidence limits of 148 - 223. Once again, the Kolmogorov-Smirnov test for length distribution between marked and recaptured grayling indicates size selectivity bias greater than the total estimate calculated previously ($D=0.3131>D_{0.05}$). In comparison, electrofishing marked 141 grayling, captured 124 grayling of which only 23 were recaptures from the marking event. Therefore the estimate of 602.5 (SE = 96.22, 95% CI 414 - 791), while much higher, seems a better indicator of population size. It should be noted however that similar to angling, length distribution of recaptured Arctic grayling were also biased with respect to recapture probabilities of marked grayling ($D=0.4765>D_{0.05}$), but less so.

In both, the angling and electrofishing estimates, the inter-area movement was found to be insignificant ($G = 0.064$, $df = 2$, $p < 0.05$ *and* $G = 0.59$, $df = 2$, $p < 0.05$). This was also true of the recovery rate between sampling ($\chi^2 = 8.40$, $df = 2$, $p < 0.05$ *for angling and* $\chi^2 = 8.93$, $df = 2$, $p < 0.05$ *for electrofishing*), respectively (Tables 3 and 4).

4.2 Effort

4.2.1 Angling

In total, 9001 minutes (150 hrs) were expended to catch a total of 182 Arctic grayling for a catch rate of 1.21 grayling per hour. This includes all captures of fish whether marked, captured or recaptured. Comparatively, this is a rather low catch rate when contrasted with similar rivers within the area, such as the Little Smoky River having a catch rate of 5.58 grayling/hour (Sullivan and Johnson 1994). Differences of effort between mark run and recapture run (4735 min vs. 4266 min) were not notably different throughout the study (Table 5). Often, environmental factors such as weather, can alter rate of catch between study days and hence between study sections and runs. Figure 4 displays a monthly meteorological summary for September 1997 in the Grande Prairie area (Environment Canada 1997). Fluctuations in the efficiency of angling can be linked to

Table 3. Movements of Arctic grayling among study sections for all known angling recaptures from both sampling events .

Section

		Upper												Middle											Lower														
Marked	Km	165	164	163	162	161	160	159	158	157	156	155	154	153	152	151	150	149	148	147	146	145	144	143	142	141	140	139	138	137	136	135	134	Rnm	Rm	Total R	Total M	R/M Ratio	Recapture Rate
1	165																																	0	1	1	2	0.50	
2	164																																	0	0	0	3	0.00	
8	163		1	4																														4	1	5	13	0.38	
0	162																																	0	0	0	0	0.00	
1	161																																	0	0	0	0	0.00	
15	160			7			4																											4	7	11	24	0.46	
2	159							1																										1	0	1	4	0.25	
3	158																																	0	0	0	9	0.00	
0	157																																	0	0	0	0	0.00	
0	156																																	0	0	0	0	0.00	
2	155																																	0	0	0	8	0.00	
2	154												1																					1	0	1	4	0.25	0.28358209
3	153													3																				3	0	3	9	0.33	
0	152																																	0	0	0	0	0.00	
0	151																																	0	0	0	0	0.00	
1	150																																	0	0	0	0	0.00	
6	149															4																		0	4	4	13	0.31	
2	148																																	0	0	0	0	0.00	
0	147																																	0	0	0	0	0.00	
1	146																					2												0	2	2	1	2.00	
1	145																																	0	0	0	2	0.00	
0	144																																	0	0	0	0	0.00	
0	143																																	0	0	0	1	0.00	0.346153846
0	142																																	0	0	0	0	0.00	
3	141																																	0	0	0	0	0.00	
0	140																																	0	0	0	0	0.00	
0	139																																	0	0	0	1	0.00	
0	138																																	0	0	0	0	0.00	
1	137																																	0	0	0	8	0.00	
0	136																																	0	0	0	0	0.00	
0	135																																	0	0	0	0	0.00	
1	134																																	0	0	0	3	0.00	0

Table 4. Movements of Arctic grayling among study sections for all known electrofishing recaptures from both sampling events .

Section

		Upper												Middle											Lower														
Marked	Km	165	164	163	162	161	160	159	158	157	156	155	154	153	152	151	150	149	148	147	146	145	144	143	142	141	140	139	138	137	136	135	134	Rnm	Rm	Total R	Total M	R/M Ratio	Recapture Rate
1	165																																	0	0	0	0	0.00	
2	164			1																														0	1	1	2	0.50	
8	163			3																														3	0	3	10	0.30	
0	162																																	0	0	0	0	0.00	
1	161						1																											0	1	1	5	0.20	
15	160						1	1			1																							1	3	4	5	0.80	
2	159																																	0	0	0	0	0.00	
3	158								2																									2	0	2	8	0.25	
0	157																																	0	0	0	0	0.00	
0	156																																	0	0	0	0	0.00	
2	155										1																							0	1	1	6	0.17	
2	154																																	0	1	1	5	0.20	0.317073171
3	153																			1														0	1	1	10	0.10	
0	152																																	0	0	0	0	0.00	
0	151																																	0	0	0	2	0.00	
1	150																			1														0	2	2	5	0.40	
6	149																																	0	0	0	0	0.00	
2	148																			1														0	3	3	8	0.38	
0	147																																	0	0	0	5	0.00	
1	146																																	0	0	0	0	0.00	
1	145																																	0	0	0	12	0.00	
0	144																																	0	0	0	0	0.00	
0	143																																	0	0	0	13	0.00	0.109090909
0	142																																	0	0	0	0	0.00	
3	141																											1						0	2	2	9	0.22	
0	140																																	0	0	0	4	0.00	
0	139																																	0	0	0	3	0.00	
0	138																																	0	0	0	9	0.00	
1	137																																1	0	1	1	5	0.20	
0	136																																	0	0	0	0	0.00	
0	135																																	0	0	0	0	0.00	
1	134																																1	1	0	1	15	0.07	0.066666667

Denotes ± 1 km
Denotes intra-area movement
Rnm - Recaptures with no movement
Rm - Recaptures with movement
Total R - Total number of recaptures
Total M - Total number marked fish

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Table 5. Effort and catch of angled Arctic grayling from both sampling events.

Section	Minutes (hrs)			Difference
	Mark Run	Recapture Run	Total	
Upper	2619 (43.65)	1864 (31.07)	4483 (74.72)	+755 (12.58)
Middle	1145 (19.08)	1410 (23.50)	2555 (42.58)	-265 (0.92)
Lower	971 (16.18)	992 (16.53)	1963 (32.72)	-21 (0.35)
Total	4735 (78.92)	4266 (71.10)	9001 (150.02)	+469 (7.82)

Section	Number of Arctic Grayling			Catch Rate (Arctic Grayling / Hr)		
	Mark Run	Recapture Run	Total	Mark Run	Recapture Run	Total
Upper	67	34	101	1.53	1.09	1.35
Middle	26	29	55	1.36	1.23	1.29
Lower	10	16	26	0.62	0.97	0.79
Total	103	79	182	1.31	1.11	1.21

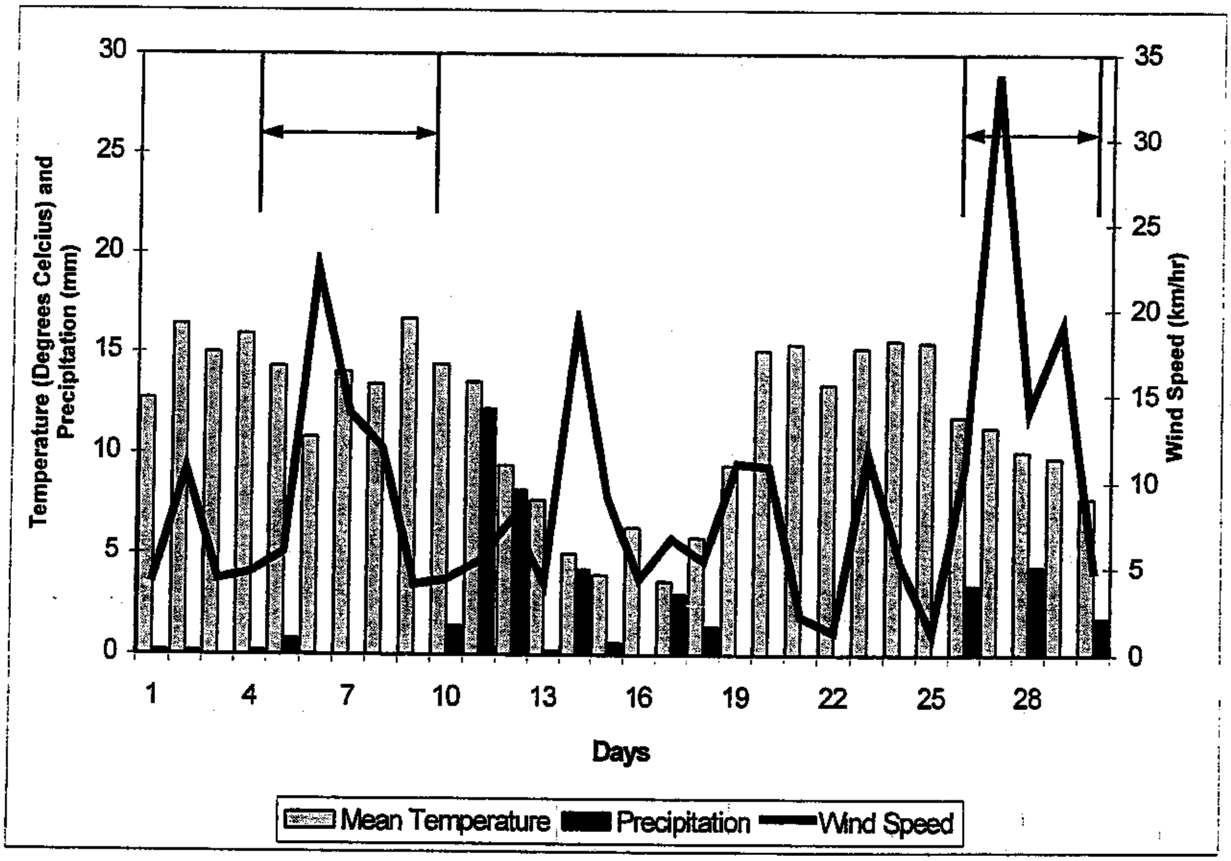

Figure 4. Monthly meteorological summary for the month of September, 1997. Mean air temperature (°C), precipitation (mm) and wind speed (km/hr) are indicated for each day.

temperature, precipitation and often wind speed (Jackson and Davies 1988). It is evident there was a high wind speed during both sampling events. Wind speed peeked on September 27 at 33.8 km/hr. It reached its second highest speed on September 6 at 22.4 km/hr. In addition, precipitation was a factor during the second event in which it peeked at 4.4 mm on September 28.

4.2.2 Electrofishing

Two hundred and sixty five Arctic grayling were captured from a total of 52,051 electrofishing seconds (867.5 min) for a catch rate of 0.31 Arctic grayling per minute. Table 6 illustrates the catch rate between mark and recapture runs by section. It is apparent that once again, there is no detectable difference in effort and catch rates between runs (27,592 vs. 24,459 sec and 0.31 vs. 0.30 fish/min), respectively.

Table 6. Effort and catch from electrofished Arctic grayling from both sampling events.

Section	Seconds (min)			Difference
	Mark Run	Recapture Run	Total	
Upper	10833 (180.55)	8764 (146.07)	19597 (326.62)	+2069 (34.48)
Middle	9090 (151.50)	8288 (138.13)	17378 (289.63)	+802 (13.37)
Lower	7669 (127.82)	7407 (123.45)	15076 (251.27)	+ 262 (4.37)
Total	27592 (459.87)	24459 (407.65)	52051 (867.52)	+3133 (52.22)

Section	Number of Arctic Grayling			Catch Rate (Arctic Grayling / min)		
	Mark Run	Recapture Run	Total	Mark Run	Recapture Run	Total
Upper	40	57	97	0.22	0.39	0.30
Middle	56	39	95	0.37	0.28	0.33
Lower	45	28	73	0.35	0.23	0.29
Total	141	124	265	0.31	0.30	0.31

4.3 Size Composition

Arctic grayling captured during the study and measured for length (N=392) ranged in size from 149 mm to 410 mm fork length (average 294 mm). When tested for differences in size distribution between angling and electrofishing, there was no detectable difference ($D_{0.05} = 1.3581 > D = 0.04605$). Distribution of grayling lengths is presented in figure 5. Total length – fork length relationship among grayling was T.L. = 6.82374 + 1.06114 F.L. This relationship is important for the application of restrictive regulations placed on grayling for harvest. Current regulations do not allow harvest of grayling less than 30 cm in total length (27.6 cm fork length). From this survey, 252 Arctic grayling (64%) would be the number allowed to harvest from the total catch of all grayling. Proposed regulation adjustments which will increase the minimum size limit from 30 cm to 35 cm total length will effectively increase the minimum fork length to 32.3 cm and supply an

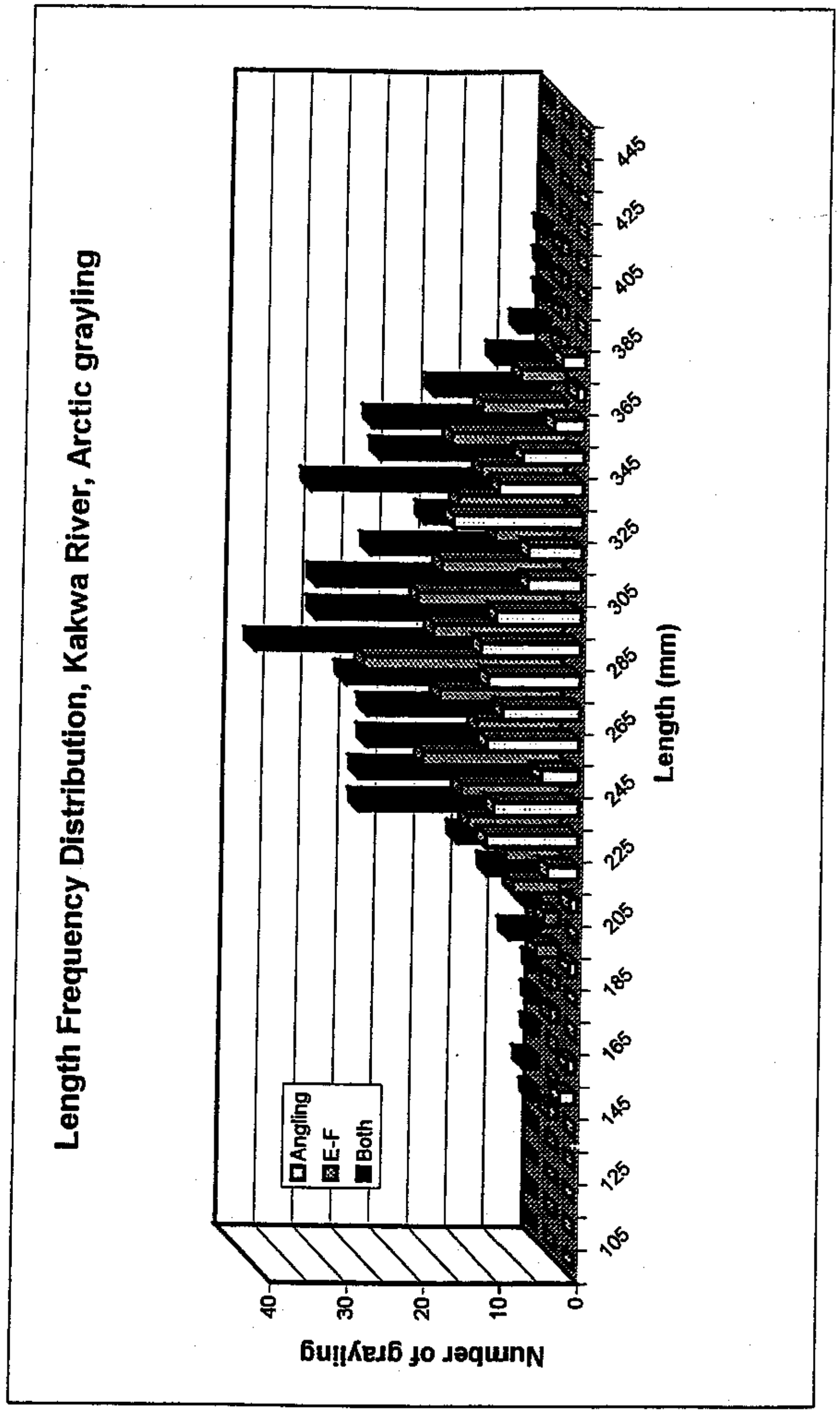

Figure 5. Length distribution of Arctic grayling in the Kakwa River separated by capture method.

allowable surplus of 117 Arctic grayling, reducing the allowable harvest from 64% to 29.8% of the catch.

4.4 Age Composition

Arctic grayling ages ranged from 3 to 11 years of age from a total of 134 sampled for age data. Reader agreement from scales was 70.9%, with those disagreed upon by one age class only. Mean age of all grayling aged was 5.76 with age 5 comprising the majority (30.6%) of the sample (Table 7, Figure 6). Mean length at each age for the Kakwa River Arctic grayling show no significant difference ($D_{0.0244}<D_{0.05}$) with a similar study conducted in Alaska (Clark *et al* 1991).

Table 7. Estimates of age class composition and standard error of Arctic grayling.

Age Class	N[a]	P[b]	SE	Fork Length	
				mean	s.d.
2	0	0.000	0.000	n/a	n/a
3	4	0.030	0.017	188	33.5
4	17	0.127	0.028	246	17.3
5	41	0.306	0.034	284	25.8
6	40	0.299	0.034	314	25.8
7	17	0.127	0.028	334	19.7
8	9	0.067	0.022	360	8.9
9	5	0.037	0.018	376	20.6
10	0	0.000	0.000	n/a	n/a
11	1	0.007	0.000	372	0
12	0	0.000	0.000	n/a	n/a

[a] n = sample size
[b] p = proportion of Arctic grayling in the population

Length at age curves calculated for the Kakwa River are shown in Figure 7. Based on this information, new legal harvest regulations will permit grayling to reach on average the age of 6 before being removed from the population. Based on current maturity data available in the Northwest Boreal region, grayling will be able to spawn at least 2-3 times before being harvested rather than only one spawning event previously allowed under the old regulation (Table 8).

Catch curves resulting from this experiment are shown in Figure 8. Analysis was performed on the descending limb from ages 6 to 11. Resulting instantaneous mortality was 0.79. Survivability calculated from the curve equals 0.46 equating to an annual mortality rate of 0.54.

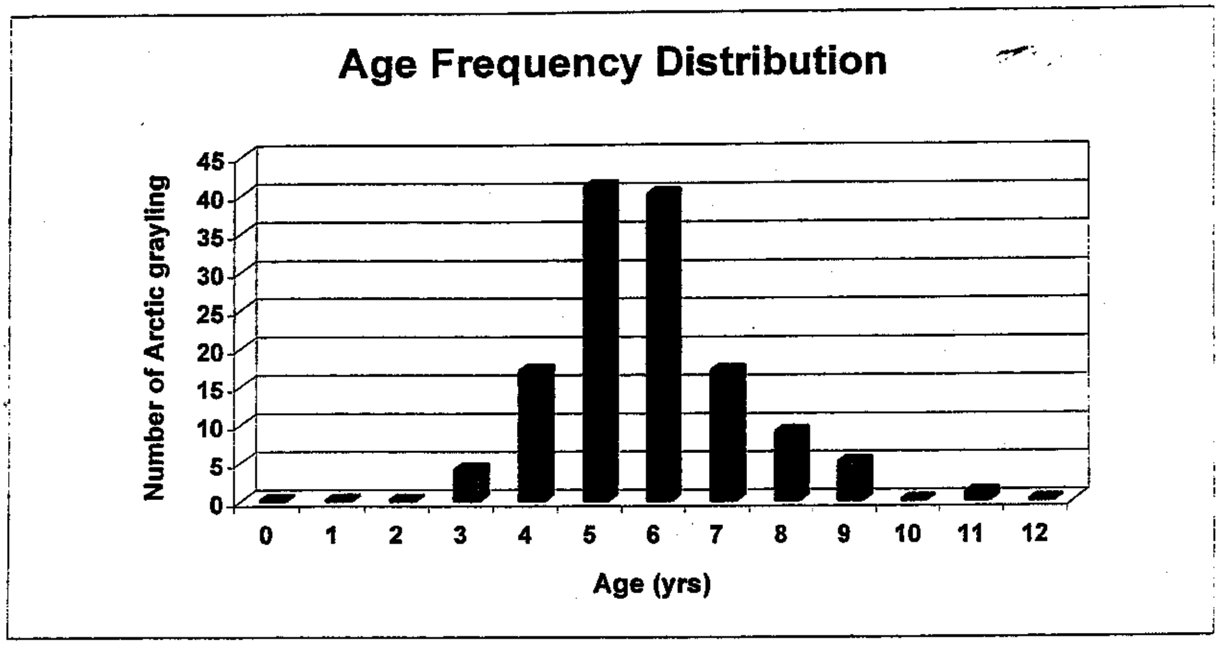

Figure 6. Age distribution of Arctic grayling sampled from the Kakwa River, 1997.

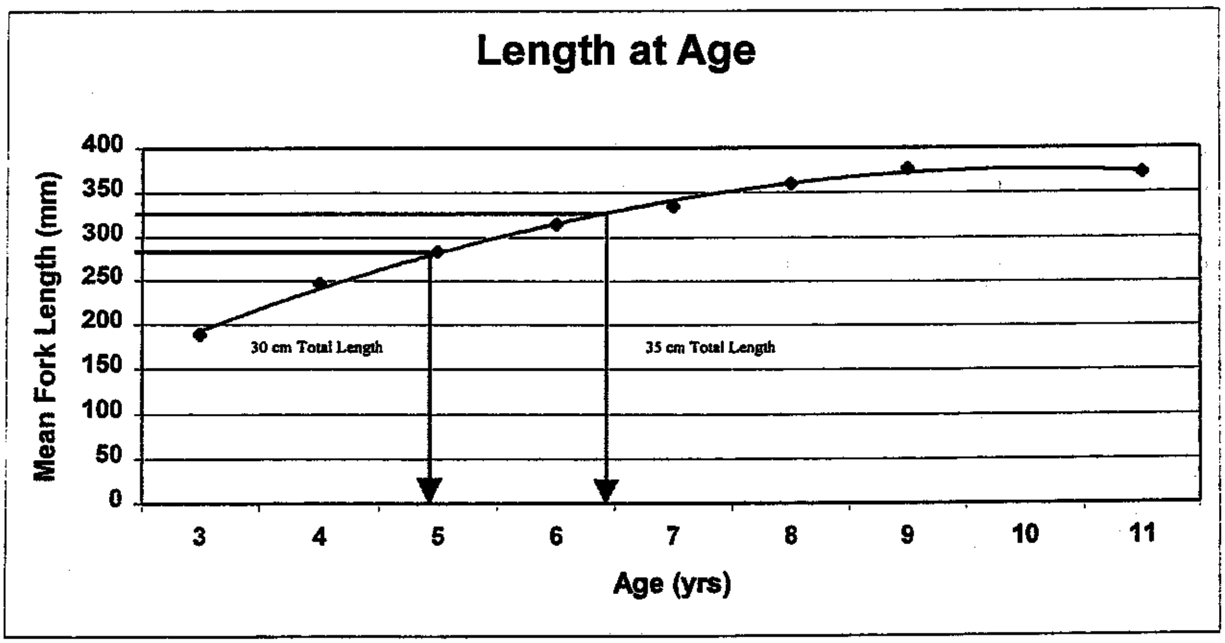

Figure 7. Length at age curve for Arctic grayling sampled from the Kakwa River, 1997. Trendline computed for second order polynomial.

Table 8. Maturity data collected from various streams in the Northwest Boreal Region

Age	# of grayling	# grayling mature at age	Mean F.L. (mm)	Min F.L. (mm)	Max F.L. (mm)	% Mature
0	35	0	64.2	28	103	0
1	42	0	144.8	85	230	0
2	75	34	193.1	119	254	45.3
3	91	65	257.4	168	314	71.4
4	265	262	296.0	170	385	98.9
5	216	216	307.9	215	418	100.0
6	140	140	318.4	200	442	100.0
7	28	28	330.9	288	383	100.0
8	4	4	356.0	340	364	100.0
9	1	1	370.0	370	370	100.0
Total	897	750	319.5			

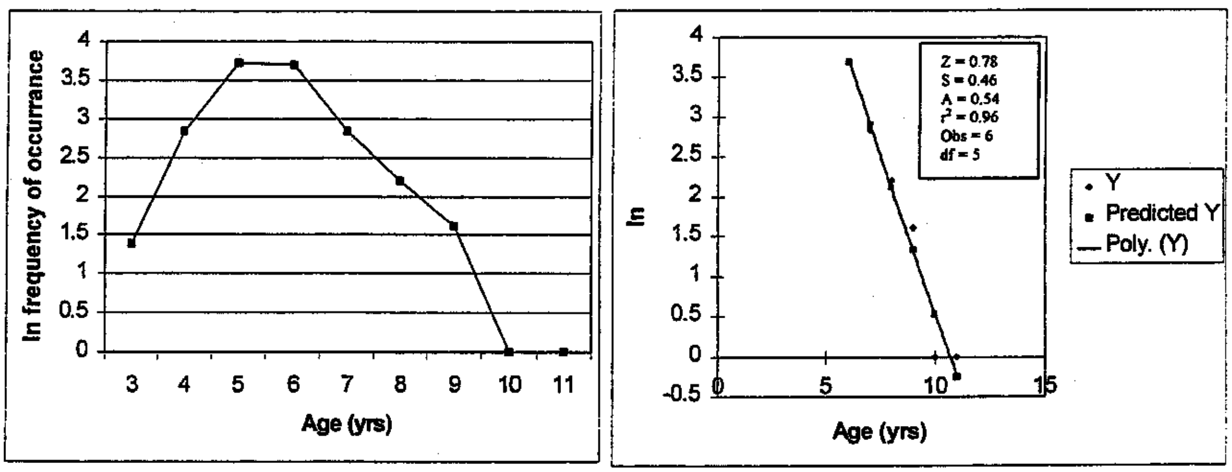

Figure 8. Catch curves calculated for all aged Arctic grayling sampled in the Kakwa River, 1997.

Travis Ripley
Alberta Conservation Association

5.0 Discussion

Estimates calculated from mark-recovery experiments provides us with benchmark information which to compare future grayling population abundance estimates. Future increases or decreases in the estimated population size will provide us with an arbitrary index with which to determine responses of Arctic grayling to regulation changes and impacts of industrial development on the fishery resource.

5.1 Population Estimates

Population estimates calculated from both angling and electrofishing capture methods provides us with an accurate and precise estimate of abundance. Accuracy stems from the validation of each assumption associated with the Peterson mark-recapture technique, while precision of the estimate has been reduced from 96.22 to 34.26 with the added use of angling. Much of this reduction in the standard error is the direct result of angling, which increases the number of recaptures in the recovery sample, while not violating assumptions stated previously. In essence, each assumption met using the electrofishing data alone was also met using angling as a capture technique. This combination only enhances the precision of the estimate. It appears that angling improves numbers of recaptured grayling, due to the ability to target grayling that have been marked during the marking event. This fact centers around the "competition for ranked feeding positions" hypothesis which states that Arctic grayling of larger size dominate those positions within the stream where drift feeding is more successful. Often during this study, we captured and marked grayling which were dominant in these positions and therefore were likely to be recaptured in the following run based on this dominance heirarchy which Arctic grayling display (Hughs and Reynolds 1994). This result has also been shown in other species such as Brook trout (*Salvelinus fontanalis*) and Brown trout (*Salmo trutta*) (Faush and White 1981). Results support this conclusion when there is a higher proportion of recaptures by angling (35.4%) than by electrofishing the same section (18.5%). Often, many grayling captured and marked in numerous pools by angling were recaptured from those same pools, in the same order in which they were marked. With the ability to provide for higher recapture rates with no loss of statistical confidence, there is the benefit of increasing the precision of the overall estimate. However, this increase in precision will only be effective if no added statistical bias is apparent, which is likely the case if too many Arctic grayling are recaptured with respect to the numbers marked.

5.2 Probability of Capture Assumption

Unequal catchability between marked fish and recaptured fish is not an uncommon phenomenon. Of particular importance is the assumption that marked and unmarked fish are equally catchable, and has been the subject of much statistical investigation (Otis *et al* 1978, Mesa and Schreck 1989, Anderson 1995). Recognising the fact that this assumption was not met gives us further warning of future estimates conducted in the Kakwa River. The possible bias which have affected these results likely stems from the larger grayling being recaptured due to their size and ability for personnel to identify them from other species such as Mountain whitefish (*Prosopium williamsoni)*. Simply looking at the probability of not rejecting the null hypothesis (i.e. no selectivity) does not necessarily assume that marginal differences in the cumulative distribution frequency's will be meaningful. Researchers which continue to apply a similar design must set a criteria for appropriate differences and weigh the amount of accuracy wanted with the inevitable loss of precision (Clark 1991). From the results presented, the arbitrary amount of Arctic grayling combined with the precision of this estimate by the combination of electrofishing and angling was felt adequate to determine future directions or responses of this Arctic grayling population to alternative management strategies and unavoidable habitat alterations.

5.3 Closed Population Assumption

Another assumption within this experiment focussed on a closed population (no immigration or emigration) of grayling within the study area. Ideally, the middle section of the study is a control to monitor movements of grayling upstream or downstream from adjacent study sections after marking. Mortality and recruitment within the population was considered negligible due to the limited amount of time between marking and recapturing events. Based on these criteria, it is possible to determine movement rates from the mark-recovery data (Anganuzzi *et al* 1994). However, results have indicated no statistically significant movement of Arctic grayling within any study section. Inferred from this is more a life history indication of range and behaviour. Not only did grayling not move out of designated study sections, but more specifically many did not move out of individual pools from where they were marked and released. Stanislawski (1997) reports that during the time of this study, Arctic grayling move approximately 0.2 km at the most, which identifies possible explanation of grayling behaviour found in the Kakwa River.

Recovery rates of Arctic grayling within study sections as well as between runs was shown to not be significantly different. Equal amounts of effort expended to mark and recapture grayling in both electrofishing and angling accounts for no differences reported in the study. The importance of equal effort cannot be stated enough. Based on this experiment, it can be assumed with equal effort expended which in many cases is the use of the same personnel employed in each event relates to an equal recovery rate over the entire study area.

5.4 Effort and Catch Rates

Catch rates of arctic grayling by angling was similar between study areas during the survey. Based on similar rivers within the area, these catch rates seem low. Sullivan (1997) suggested that a fishery with a catch rate less than 4-7 Arctic grayling per hour might be limited by either habitat or exploitation. However, the catch rates calculated on the Kakwa River may not be indicative of these circumstances, but perhaps that of weather. Fly-fishing and spin casting were the combined methods chosen for angling. Often temperature of the water and wind speed can play an important factor in catches of grayling over time. In addition, the catch rate on the Kakwa River was calculated from total fishing effort throughout the entire study reach and not centered on highly productive pool areas where individual catch rates were high. A more in-depth analysis of these possible limiting factors should be taken into account and adjusted for in future estimates of this nature. Conversely, electrofishing effort and catch rate provide results that are similar to many other studies. Catch rates of Arctic grayling ranged from 0.15 to 0.48 fish per minute in the House River study area in 1995 with an average of 0.29 fish per minute (R.L.& L. 1996). Catch rates on the Kakwa River ranged from 0.30 to 0.31 throughout this study.

5.5 Size and Age Class Distributions

Size and age class composition of Arctic grayling in the Kakwa River reveals important indications of mortality and recruitment of this population. Few small and young fish were captured in the combined sample from both angling and electrofishing. It has been suggested that young grayling often use the upstream areas or tributaries more so than adults (R.L.& L. 1996). Fall and winter migrations to overwintering areas for Arctic grayling appear to be correlated to decreasing water temperatures and formation of ice (Stanislawski 1997). Early September appears to be too soon for any large migrations within the Kakwa River and tributaries. Using air temperature as a relative index of water temperature, no continuous decrease in temperature was apparent, which likely reduced the amount of Arctic grayling movement from tributaries, however additional information is necessary to document this hypothesis. Future assessments of this nature should take into account the juvenile grayling population within headwater streams to report a more extensive distribution of grayling sizes and ages on a broader scale.

Alternative management strategies, which are proposed to increase the minimum size limit from 30 cm to 35 cm total length, seem to be beneficial to this population. Reducing the allowed harvest of grayling by 34% from catches in this study, while increasing the age at harvest to nearly seven allow for more grayling to provide recruitment into this system over the years.

5.6 Catch Curves

The catch curve used to determine mortality and survivability of Arctic grayling indicate an annual mortality rate close to 0.5. Assuming recruitment and mortality within this population are constant and the sub sample is indicative of the true population structure, there appears to be minimal exploitation of the stock. In comparison with Fielding Lake in Alaska which shows a mortality rate of 0.45, this population appears to be relatively stable (Clark 1994), however due to the preliminary conclusions drawn from these results, only future comparisons with Arctic grayling from the Kakwa River will support this assumption.

6.0 Conclusion

The Kakwa River appears to show a relatively stable population of Arctic grayling, however the monitoring of this population is still in its early stages. The population abundance of Arctic grayling was 482 (S.E. = 34) for the 32 km study section. Evidence indicates that despite combining angling and electrofishing as capture methods, overall abundance estimates were not statistically affected. The equal catchability assumption violated by both electrofishing and angling indicate no negative interaction between these capture techniques used in combination. Clearly no other discrepancies appear to conflict with the analysis by using both methods. Arctic grayling captured during this study ranged in size from 149 mm to 410 mm in length, spanning ages 3 through 11. Evidence from the literature suggests the younger grayling not seen in this study remain in the headwater tributaries until late fall movements into overwintering sites. It is also apparent that environmental factors influence the catch rates used in angling and should be accounted for in similar studies of this nature. In summary, future assessments conducted on this and many other Arctic grayling streams using angling as a supplement to electrofishing captures will provide a better indication of population health and the potential pressures of overharvest and exploitation. With repeatability of this experiment, a more concrete foundation with which to examine population decreases or increases from alternatives in management or exploitation will be developed.

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