COMPARISON OF GROWTH, AGE-AT-MATURITY, AND FECUNDITY FOR BROAD WHITEFISH (*COREGONUS NASUS*) IN THE LOWER MACKENZIE DELTA, NWT AND EVALUATION OF THE PEEL RIVER FISH-MONITORING PROGRAM

BY

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A Thesis
Submitted to the Faculty of Graduate Studies
In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE

Department of Zoology
University of Manitoba
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Comparison Of Growth, Age-At-Maturity, and Fecundity For Broad Whitefish (*Coregonus Nasus*) In The Lower Mackenzie Delta, NWT and Evaluation Of The Peel River Fish-Monitoring Program

BY

Melanie Van Gerwen-Toyne

A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University

of Manitoba in partial fulfillment of the requirements of the degree

of

MASTER OF SCIENCE

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Abstract

This study compared life history traits in three populations of broad whitefish (*Coregonus nasus*) from the Mackenzie Delta, Canada and evaluated the Peel River fish-monitoring program. First, size-at-age, reproductive investment (fecundity and egg size), and the age when growth (inferred from otoliths) slowed were compared between two anadromous populations, the Peel River and Arctic Red River, and a population from Travaillant Lake. Age-at-maturity for the anadromous populations were estimated, but an estimate for whitefish from Travaillant Lake could not be made. Therefore, a general comparison was made using information from a previous study.

Broad whitefish size-at-age was significantly different at younger ages among the anadromous populations, but were not significantly different by age 15 and beyond. Fish from Travaillant Lake were significantly larger than fish from the Peel River at all ages. Fish from the Arctic Red River and Travaillant Lake were significantly different at ages 2 and 3, not significantly different from ages 4 to 9, and significant again from age 10 and beyond. The youngest spawning whitefish in the Peel River and Arctic Red River were ages 7 and 6 years, respectively, while those in Travaillant Lake have been observed to spawn at age ~ 5.5 years. Broad whitefish from the two anadromous populations were not significantly different in estimates of reproductive investment or the age when growth slowed, but both differed significantly from the broad whitefish of Travaillant Lake.

Next, to determine the potential of using adult length-at-age and fecundity to monitor for effects of exploitation in broad whitefish from the Peel River, I evaluated the Peel River fish-monitoring program and simulated alternative designs. Each design was modeled for effects of exploitation and the statistical power was determined via computer simulation. My simulation results were compared to exploitation experiments from the literature. Estimates of length-at-age were unaffected by the monitoring design, but fecundity could vary due to the influence of a supervisor and monitoring location. The statistical power of all monitoring designs initially increased proportionally when more fish were included in the sample and when the effect size was large. However, the benefits of improved sensitivity in the design, by increasing the sample size, diminished after approximately 50 fish were included in the sample. The predicted results of my simulations for broad whitefish from the Peel River matched most outcomes of exploitation experiments from the literature.

Acknowledgements

I would like to thank my primary advisors, Dr. D. Gillis and Dr. R. Tallman for providing me with the independence to make my own mistakes, but then stepping in to help when my strength was weakening. I have learnt more than I ever imagined possible.

I would also like to thank my committee members, Dr. R. Riewe and Dr. D. Bodaly for their suggestions and guidance. Many other people assisted greatly in this research. Particularly all the staff (present and past) of the Gwich'in Renewable Resource Board, Inuvik, and the Department of Fisheries & Oceans, Inuvik. I thank the monitors from the Peel River Fish Study, Walter Alexie, Robert Elias, Fred Koe, William Teya, and Leslie Snowshoe for allowing me the pleasure of working with, and learning from, them. I thank all the Gwich'in beneficiaries in Fort McPherson for their infinite kindness. Lianne Conyers and Tracey Loewen, thank you for all your help and also for your friendship. I thank my family and friends for their unending love and support. Darryl Chudobiak provided much of the data for broad whitefish from the Arctic Red River and Travaillant Lake. Financial and logistic support for this research was provided by the Tetlit Renewable Resource Council, the Gwich'in Renewable Resource Board, the Department of Fisheries & Oceans, and the University of Manitoba.

Dedication

To my husband,

I thank you.

For without you, I would have failed long ago.

To my family and friends,

I thank you.

For without you, I would not have enjoyed life.

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CHAPTER 1. GENERAL INTRODUCTION

Life history traits, such as age-at-maturity, fecundity, and growth rate, are important factors in population regulation and persistence, and also in fishery population assessment models (Stearns 1992, Beverton & Holt 1957). Investigating life history traits can aid in understanding the dynamics of fish populations, and can also be used to monitor populations for changes.

Both anadromous and lacustrine populations of broad whitefish are believed to exist in the Mackenzie Delta (Freeman 1997). Since anadromous fish generally undergo a much greater migration than lacustrine fish, it is expected that their life history traits will differ (Roff 1992). Description of these traits in the different populations is important for independent management of these populations.

Chudobiak (1995) investigated life history traits of broad whitefish from the Mackenzie River and Travaillant Lake to determine if there were differences between the populations. He further questioned whether the differences were likely attributable to the energetic cost of migration (life history difference) or exploitation pressure (environmental difference). Chudobiak investigated reproductive investment (fecundity and GSI) and mean size (mm) and found that broad whitefish from the Mackenzie River had a significantly higher average fecundity, but no significant difference in mean size (mm) than broad whitefish from Travaillant Lake. He concluded that the differences found in life history traits of broad whitefish from the Mackenzie River were more likely due to exploitation pressure than migration. However, he did not report the exploitation pressure for either population.

Describing the life history traits of broad whitefish can also be useful in detecting changes in fish populations, for example, from exploitation. Anadromous broad whitefish migrate extensively throughout their lives and traverse many aboriginal settlement areas where they are subjected to fishing exploitation (Treble 1996, Reist & Treble 1998). For this reason, and because the Gwich'in community expressed concerns that development on or near the Peel River may affect the fish stocks, the Peel River fish-monitoring program was initiated.

Fish-monitoring programs are an important aspect of fisheries management and can provide information on reactions of a population to environmental or anthropogenic effects (Skalski & McKenzie 1982). However, monitoring programs are not always tailored to a specific stock. Instead, general rules may be applied to all stocks in an area which can result in inefficient collection of data and less than optimal management. The calculation of statistical power before the implementation of a project can provide resource managers with valuable information on the allocation of sample effort and the reliability of the results as indicators of the true parameters being studied (Peterman 1990).

Thesis objectives

Chapter 2 elaborates on previous research (Chudobiak 1995) by including broad whitefish from an additional anadromous population (the Peel River). I refined the data selection and analysis, limiting the data to winter samples from the Peel River, Arctic

Red River, and Travaillant Lake. I also compared two additional traits, age-at-maturity and the age when growth slowed (based on otolith annuli growth).

I hypothesize that the life history traits of broad whitefish from the Peel River and Arctic Red River will be similar to one another because they share a common migratory pattern. I then compare these populations to broad whitefish from Travaillant Lake.

In chapter 3, I utilize the information gained on variation in broad whitefish fecundity and length-at-age, and apply it to the design of the Peel River fish-monitoring program. I evaluate the effectiveness of the present, and alternative, monitoring designs by simulating variation in the Peel River fish-monitoring program based upon field data on broad whitefish fecundity and size-at-age. Each design is modeled for effects of exploitation and the statistical power is determined via computer simulations.

This thesis combines potential uses for life history traits to improve our understanding of broad whitefish in the Mackenzie Delta. My results provide the Gwich'in with information to aid in the management of broad whitefish populations and demonstrates the importance of proper experimental design in fish-monitoring programs.

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CHAPTER 2. COMPARISON OF GROWTH, AGE-AT-MATURITY, AND FECUNDITY FOR BROAD WHITEFISH (*COREGONUS NASUS*) IN THE LOWER MACKENZIE DELTA, NWT

Abstract

Population structure of broad whitefish (*Coregonus nasus*) was examined during the winter of 1993, 1998, and 1999 in the lower Mackenzie River System, NWT, Canada. Size-at-age, reproductive investment (fecundity and egg size), and the age when growth slowed were compared between two anadromous populations, the Peel River and Arctic Red River, and a population from Travaillant Lake whose life history type is unclear. Age-at-maturity for the anadromous populations were estimated and compared to an estimate for Travaillant Lake from a previous study.

Broad whitefish size-at-age was significantly different at younger ages in the anadromous populations, but were increasingly more similar and not significantly different by age 15 and beyond. Fish from Travaillant Lake were significantly larger than fish from the Peel River at all ages. Fish from the Arctic Red River and Travaillant Lake were significantly different in size at ages 2 and 3, not significantly different from ages 4 to 9, and significant again from age 10 and beyond. Estimated age-at-maturity for spawning whitefish in the Peel River and Arctic Red River were ages 7 and 6 years, respectively. Broad whitefish from the two anadromous populations were not significantly different in estimates of reproductive investment (fecundity and egg size), but both had a significantly higher reproductive investment than broad whitefish from

Travaillant Lake. Similarly, the anadromous populations were not significantly different in estimates of the age when growth slowed, but growth in both of these populations slowed at a significantly earlier age than whitefish from Travaillant Lake. While these results are not conclusive, it appears that the broad whitefish in Travaillant Lake are different from the anadromous populations and do not appear to be anadromous themselves.

Introduction

Broad whitefish life history in the Mackenzie Delta

Broad whitefish (*Coregonus nasus*) can be found in fresh and brackish waters of northwestern North America and northern Eurasia. Within North America, they inhabit Alaskan Rivers, the headwaters of the Yukon River, and the Northwest Territories. Within the Northwest Territories, they inhabit waters from the Perry River east to the Coppermine River (Scott & Crossman 1973). Broad whitefish is an important species in the Mackenzie Delta because they are fished by Gwich'in, Inuvialuit, Sahtu Dene, Metis, and Inuit communities for food, local sale, and cultural tradition (Bond 1982, Treble 1996). Therefore, identification and description of different life history types of broad whitefish is necessary for proper management. Anadromous broad whitefish migrate between the sea and freshwater at some point in their lives, while lacustrine broad whitefish spend their entire life cycle within or near lakes (Reist & Chang-Kue 1997).

Anadromous broad whitefish

Broad whitefish from the Peel River and Arctic Red River rarely enter wholly marine waters, therefore Reist & Chang-Kue (1997) suggested a more appropriate description is semi-anadromous. For simplicity, I will use the term anadromous in this paper.

Life for anadromous broad whitefish begin when eggs hatch in spring at upstream river spawning areas (Reist & Bond 1988). The young-of-the-year migrate or are washed downstream into the outer Mackenzie delta and Tuktoyaktuk Peninsula with the spring flood (Reist & Bond 1988, Reist & Chang-Kue 1997). The young-of-the-year and small juveniles later migrate upstream to extensive lake systems within the Tuktoyaktuk Peninsula and the outer delta to over-winter (Bond 1982, Bond & Erickson 1985, 1992, Chang-Kue & Jessop 1991, 1992). These fish remain in the lakes and streams to over-winter and feed for several years before re-entering coastal waters (Reist & Bond 1988, Chang-Kue & Jessop 1991). The large juveniles then begin an annual migratory cycle consisting of a downstream migration to coastal feeding areas and a return upstream migration to over-winter in the lakes of the Tuktoyaktuk Peninsula (Bond 1982). In late summer, fish ready to spawn for the first time (age 7 to 9, Bond 1982, Bond & Erickson 1985, 1987) leave the coastal feeding grounds to join mature fish in the pre-spawn migration upstream to the inner delta (Chang-Kue & Jessop 1983). Spawning occurs in mid October or early November further upstream in the Mackenzie River or its two main tributaries, the Peel River and Arctic Red River (Reist & Bond 1988, Stein et al. 1973, Jessop et al. 1974, Change-Kue & Jessop 1983). Shortly after spawning, the adults migrate downstream to over-winter in the outer delta (Stein et al. 1973, Chang-Kue & Jessop 1997).

Alternative life histories

Some fish may spend most of their lives in or near a particular lake. Short migrations may occur to reach feeding or spawning areas, but long migrations to coastal or brackish waters does not occur (Reist & Chang-Kue 1997). The local water bodies must therefore contain all critical habitats such as spawning, nursery, feeding, and over-wintering areas.

Travaillant Lake has many features that may permit it to contain a local population of broad whitefish. The lake has deep and shallow areas that provide good feeding, rearing, and over-wintering areas (Craig 1989). Also, areas in Travaillant River contain high water clarity and gravel substrate that is ideal spawning habitat (Dryden et al. 1973, Chudobiak 1995). Further, ripe and spent broad whitefish have been caught in the lake, although these individuals may have come from an anadromous population (Reist & Bond 1988). However, in the fall, Travaillant River freezes to the bottom in areas which may prevent migrating anadromous individuals from entering Travaillant Lake (Hatfield et al. 1972), except possibly in high water years. Young-of-the-year broad whitefish have also been captured in Travaillant Lake, suggesting that nursery areas are nearby (Strange & MacDonell 1985, Chudobiak 1995).

There is also genetic, biochemical, and morphological evidence which suggests that Travaillant Lake may contain an unusual population of broad whitefish. Using polymorphic enzyme analysis, Reist (1997) found that the frequency of alternative forms of variable enzymes for broad whitefish from Travaillant Lake were distinctly different from two known anadromous populations (the Peel River & Arctic Red River). Also, Babaluk & Reist (1996) found that the strontium concentration in otoliths of spawning broad whitefish from Travaillant Lake were low and constant, concluding that the fish remained in freshwater throughout life. Finally, aboriginal harvesters differentiate river and lake forms of broad whitefish via morphological variation (Freeman 1997) and have observed that broad whitefish from Travaillant Lake appear lacustrine in morphology.

Conversely, Hesslein et al. (1991) tested the $\delta^{34}S$ isotopic ratio of broad whitefish from Travaillant Lake and found that the fish were feeding on sources outside the local food base. The $\delta^{34}S$ isotopic ratio of broad whitefish was highly variable and ranged from – 10.7 % to – 15.8 %. The ratio for all other fish species in the lake ranged from – 8.2 % to – 10.2 %, which was higher (less negative) and less variable than the broad whitefish. They concluded that it was impossible for the flesh of broad whitefish to have been produced from sulfur-containing amino acids found in Travaillant Lake and that those fish were migrant visitors to the lake. Also, no tracking studies have yet been performed on broad whitefish from Travaillant Lake. Therefore it is uncertain whether this system contains anadromous or lacustrine broad whitefish, or perhaps both.

Life history related to migration

Life history traits (or vital rates) are those traits that influence the fitness of an individual or population (Stearns 1992). These include age-at-maturity, reproductive investment, length-at-age, and others. These traits are shaped by natural selection and often involve phenotypic, genetic, and behavioral trade–offs (Stearns 1992). Variations in these characteristics occur widely in both inter- and intra-specific situations (Roff 1992).

Hypotheses regarding life history theory suggest that the selection of migration in fish will correspond with larger relative size, later age-at-maturity, and increased reproductive effort (Roff 1988). A large cost of migration is the use of energy contained in tissue (Roff 1992). Larger fish expend less energy relative to smaller fish to travel the same distance, and therefore suffer less relative tissue depletion (Glebe & Leggett 1981, Roff 1992). Consequently, the energetic cost of migration is inversely proportional to body size (length) and a larger size is expected in migrants relative to non-migrants (Roff 1988). Obtaining a larger size to minimize the costs of migration leads to direct or indirect energetic trade-offs in other life history traits (Roff 1991). Life history theory predicts that migratory individuals will direct more energy into growth by delaying sexual maturation. This results in a larger size-at-age and later age-at-maturity. Since size (length) is commonly correlated to fecundity (Hocutt & Stauffer 1980), it is expected that larger anadromous fish will also be more fecund (Roff 1988).

Theories regarding growth, age-at-maturity, and reproductive investment have been well developed in the literature. However, few studies have recognized the age when growth slowed. It is commonly accepted that fish growth in length slows after sexual maturation, but few researchers have distinguished the age when growth slowed from the age-at-maturity (Jensen 1985). To my knowledge, no studies have been performed to determine the age when growth slowed in different populations of fish. Also, only Jensen (1985) differentiated between the age when growth slowed (described as the inflection point in the growth curve by Jensen) and the age-at-maturity. It is likely that different fish populations would display differences in the age when growth slowed, and it also possible that the amount of time between the age when growth slowed and the age-at-maturity may differ between populations.

In this paper, I compare life history traits between known anadromous broad whitefish populations in the Peel River and Arctic Red River, and broad whitefish caught in Travaillant Lake. I hypothesize that life history traits of the Peel River and Arctic Red River populations will be similar because they share a common migratory pattern. In saying this, I am assuming that the constraints of meeting the demands of a long distance migration will mask any local population differences in the life history traits. The broad whitefish caught in Travaillant Lake could also be similar to the Peel River and Arctic Red River populations based on the conclusion of Hesslein et al. (1991) that the broad whitefish are incorporating $\delta^{34}S$ from outside the system. If these broad whitefish have extensive migrations out of Travaillant Lake (for example, to the coast) then their life history traits will probably match those of the known anadromous populations. Conversely, if these fish do not have extensive migrations out of Travaillant Lake then their life history traits will probably be significantly different from the anadromous populations.

Methods and Materials

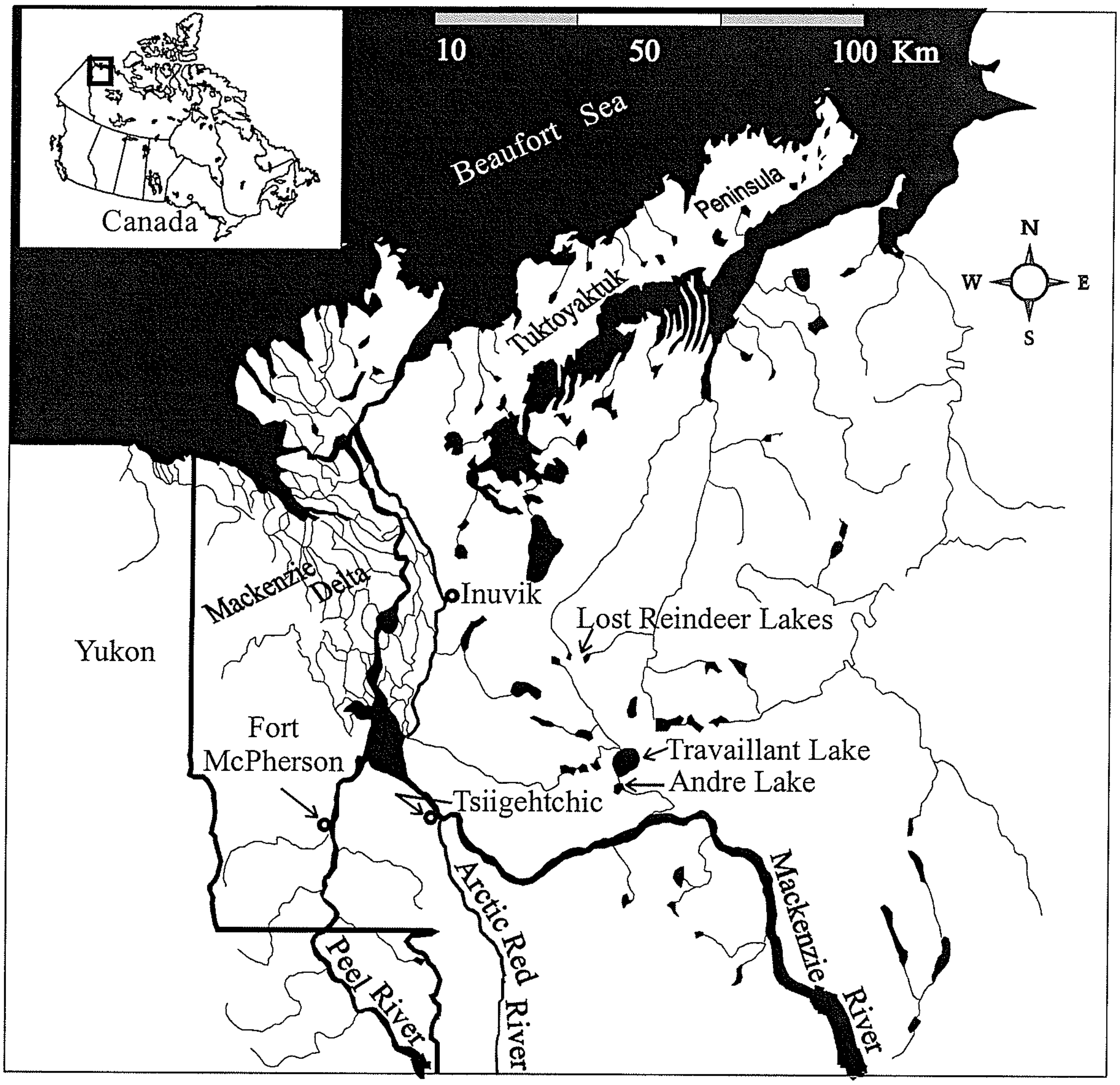
Study Area

The Peel River and Arctic Red River are large tributaries of the Mackenzie River in the lower Mackenzie Delta (Figure 2.1). The Peel River diverts from the Mackenzie River downstream from Fort McPherson. The Arctic Red River diverts from the Mackenzie River at the town of Arctic Red River (Tsiigehtchic). The Peel River and Arctic Red River have total lengths of 440 km and 357 km, with total drainage areas of 110,149 km^2 and 31,707 km^2 respectively (Hatfield et al. 1972, Dryden et al. 1973). Both Rivers contain coarse and fine gravel substrate upstream, which provides ideal spawning habitat for broad whitefish (Hatfield et al. 1972, Dryden et al. 1973).

Travaillant River originates at the Lost Reindeer Lakes and empties into the Mackenzie River (Figure 2.1). It has a length of 126 km and a total drainage area of 308 km^2 (Dryden et al. 1973). The substrate is coarse and fine gravel with a low silt load, good spawning habitat for broad whitefish (Hatfield et al. 1972, Dryden et al. 1973). The depth of this river ranges from 0.1 m to 5.0 m (Hatfield et al. 1972, Chudobiak 1995).

Travaillant Lake is approximately 40 km northeast of the Mackenzie – Travaillant River confluence (Figure 2.1). It has an area of 115 km^2 (Hesslein et al. 1991) that contains both deep and shallow areas that are suitable for broad whitefish rearing and feeding (Craig 1989). The west shore contains a littoral zone, but the east shore is made up of gravel shoals in deep water. Broad whitefish spawning has occurred on the eastern shoal and the sandy southern region (Chudobiak 1995).

Figure 2.1. Map of the Mackenzie Delta, Canada, illustrating the Peel River, Arctic Red River, and Travaillant Lake.


Canada
10
50
100 Km
Beaufort Sea
Tuktoyaktuk Peninsula
N
W
E
S
Mackenzie Delta
Inuvik
Lost Reindeer Lakes
Yukon
Fort McPherson
Travaillant Lake
Andre Lake
Tsiigehtchic
Arctic Red River
Peel River
Mackenzie River

Data Collection

Broad whitefish were collected from the Peel River in the fall of 1998 and 1999. The Peel River fish-monitoring program was a co-management project between the Gwich'in Renewable Resource Board (GRRB), the Department of Fisheries & Oceans, Freshwater Institute (DFO), and the Tetlit Renewable Resource Council (RRC). Broad whitefish from the Arctic Red River and Travaillant Lake were collected in the summer and fall of 1993, as part of a study performed by DFO (Chudobiak 1995). In all studies, fish were caught most commonly by 12.7 cm (5 inch) stretched-mesh gill nets, as well as experimental gill nets with panels of 3.8 cm (1.5 inch) to 10.1cm (4 inch) stretched-mesh size. Gill nets were set perpendicular to shore in eddies and left in the water continuously, except during ice freeze-up. After ice freeze-up, the nets were set under the ice. All fish were sampled by measuring fork length (mm), round weight (kg), sex, maturity stage, gonad weight, and collecting the sagittal otoliths. Female gonads from broad whitefish were also collected and frozen. Sampling locations for each study are shown in Figures 2.2, 2.3, and 2.4. For this paper, I restricted the data from the Arctic Red River to winter samples (September to mid-November) to maintain consistency with the data of broad whitefish from the Peel River.

Biological Sampling

Sex of all broad whitefish were assigned based on the presence or absence of eggs. Qualitative assessments of maturity for fish were assigned based on definitions by Bond & Erickson (1985). All fish were aged using two sagittal otoliths via the 'break and

Figure 2.2. Map of the Peel River indicating sampling locations (X) at Cutoff (1999), Scrapper Hill (1998 & 1999), Road River (1999), and Trail River (1998), and on the Peel Channel at Basook Creek (1998). Filled circles indicate towns. See Figure 2.1 for geographic context.

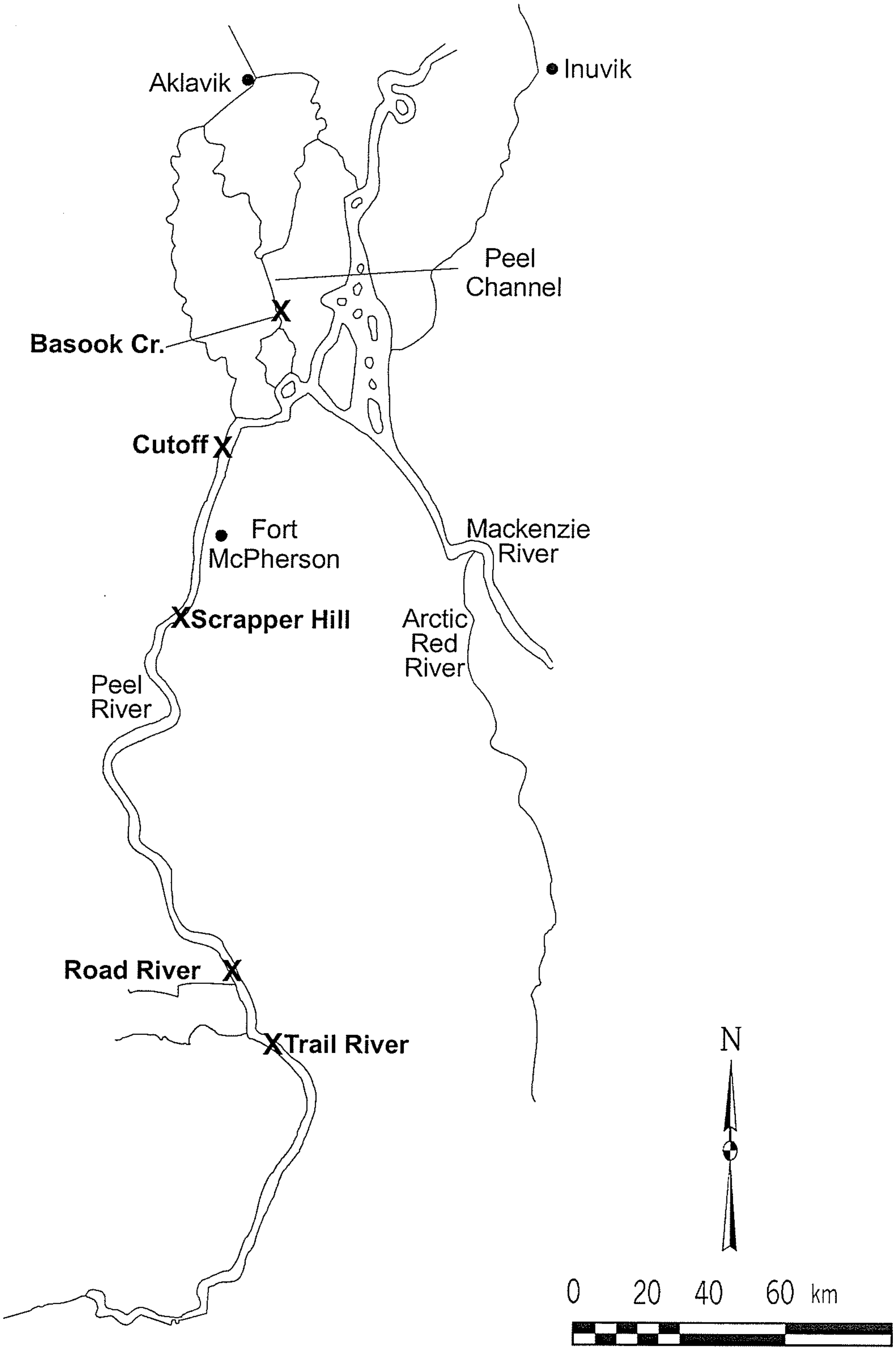

Aklavik
Inuvik
Peel
Channel
Basook Cr.
Cutoff
Fort
McPherson
Mackenzie
River
Arctic
Red
River
Scrapper Hill
Peel
River
Road River
Trail River
N
0 20 40 60 km

Figure 2.3. Map of the Arctic Red River indicating sampling locations (X) (Chudobiak 1995). See Figure 2.1 for geographic context.

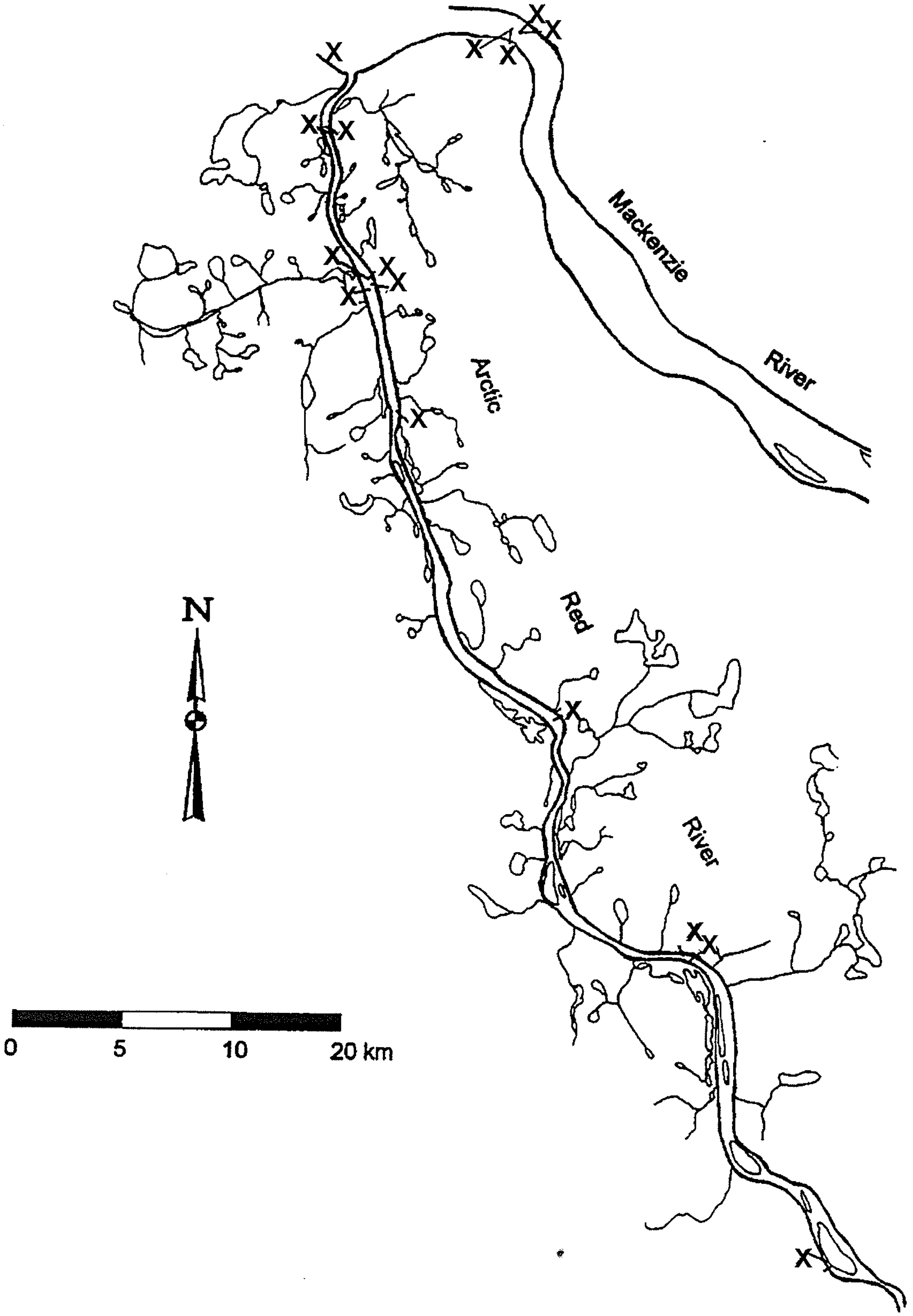
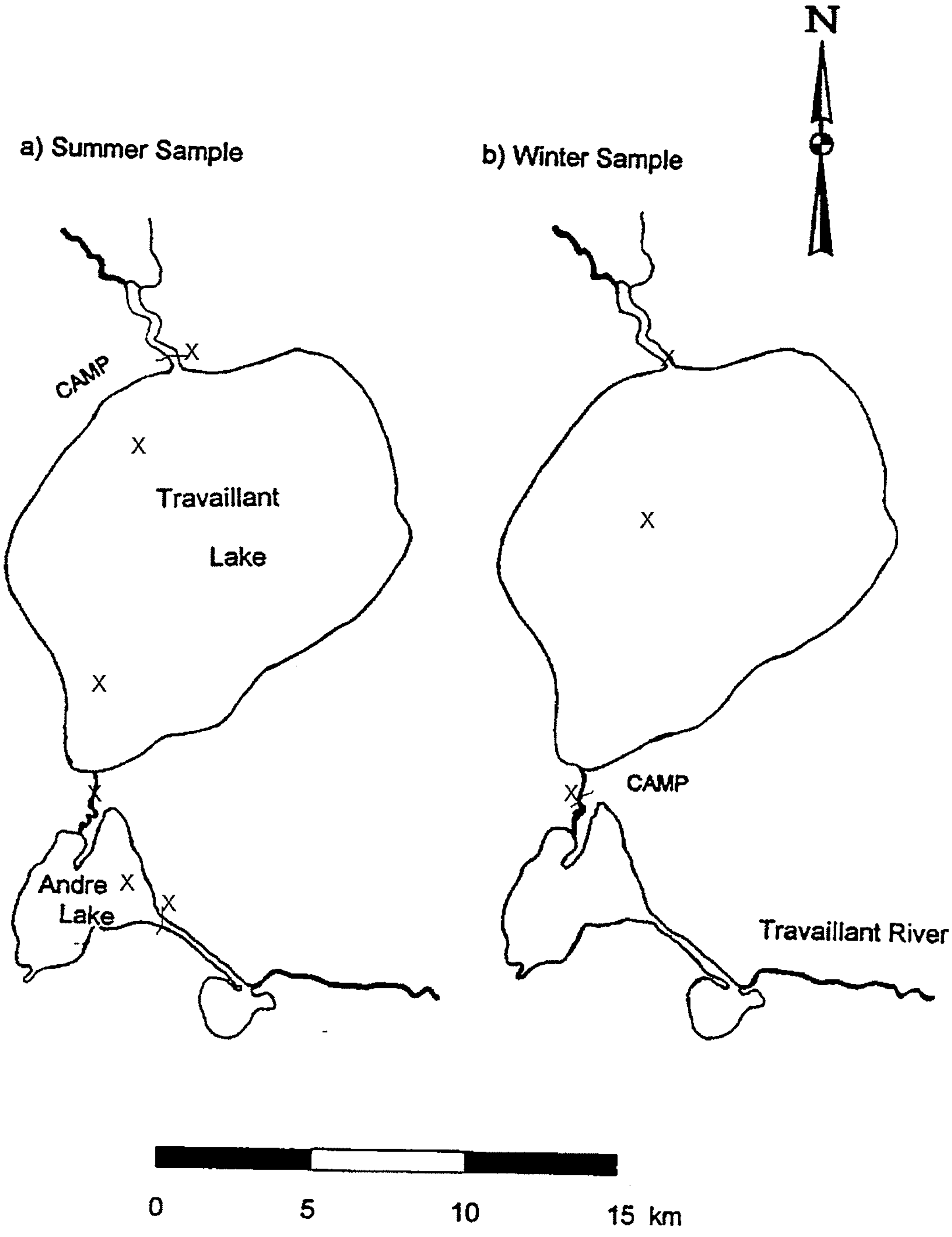

Mackenzie River
Arctic Red River
N
0
5
10
20 km
X

Figure 2.4. Map of Travaillant Lake indicating sampling locations (X) (Chudobiak 1995). See Figure 2.1 for geographic context.


N
a) Summer Sample
b) Winter Sample
CAMP
X
Travaillant
Lake
Andre
Lake
CAMP
Travaillant River
0
5
10
15 km

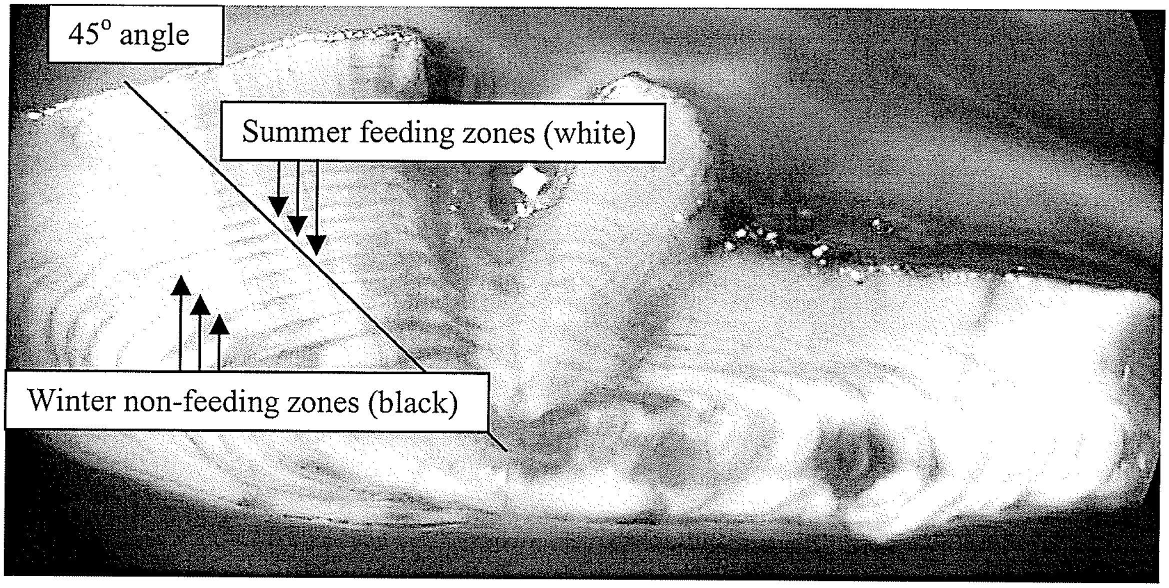
burn" procedure of Chilton & Beamish (1982). A sub-sample of sagittal otoliths from Arctic Red River and Travaillant Lake were re-aged to quantify consistency with previous researchers (Chudobiak 1995).

The gonads of female broad whitefish from the Peel River were collected and frozen in the field. In the lab, they were thawed in preservative for 2 days. The gonads were then rinsed under tap water and the eggs were manually separated from the connective tissue. Eggs were either dried in an oven at a low temperature, or air-dried under a fume hood, until the total egg weight was consistent (+/- 5g). Three sub-samples of 200 eggs were counted and weighted to the nearest 0.001g. Fecundity was calculated as the average weight of the sub-sample / weight of all eggs * size of sub-sample.

Chudobiak (1995) estimated fecundity for broad whitefish from the Arctic Red River and Travaillant Lake using similar methods. However, Chudobiak counted and weighed one sub-sample of 1000 eggs rather than averaging three sub-samples of 200 eggs.

A procedure similar to back-calculation was used to obtain estimates of size-at-age for broad whitefish from the Peel River, Arctic Red River, and Travaillant Lake. The information on the estimated growth curve produced was also used to determine the age when growth slowed. To do so, a digital image of a broken and burnt otolith was taken using a Kodak® DC120 Zoom Digital camera attached with a Kodak® MDS120 Universal Adapter to a Zeiss® dissecting microscope at a magnification of 50X. Scion Image® was used to measure the distance from the otolith nucleus to each annulus along a 45^{O} angle of the slow growing portion of the otolith (Figure 2.5).

Figure 2.5. Cross section of a broken and burnt sagittal otolith from a broad whitefish illustrating measurement angle of 45°, plus summer feeding zones and winter non-feeding zones.


45° angle
Summer feeding zones (white)
Winter non-feeding zones (black)

Scion Image® was calibrated to 0.001 mm with a micrometer slide, and then reported distance in millimeters to three decimal places. In my analysis of the age when growth slowed, 'size' refers to the distance from the otolith nucleus to each annulus and 'age' refers to the number of annuli from the otolith nucleus.

This technique is similar to back calculation in that as a first step I determined if there was a relationship between otolith growth and body length growth via analysis of covariance (ANCOVA). Back calculation techniques plot the otolith size: body size relationship for individuals of all age classes and a formula is used to predict the length of the fish at younger ages (Ricker 1975). I was unable to do this because I did not have representatives of younger age classes to produce the completed otolith: body relationship, therefore I focused analysis on the distance between annuli within each otolith.

Statistical Analysis

To ensure that broad whitefish otolith growth is proportional to fish growth in my analysis of size-at-age, I regressed otolith size on fork length for each population and calculated the Pearson Correlation Coefficient (r). To ensure that the relationship between otolith size and fish fork length is equal in all populations I tested for equality of slopes via ANCOVA. Next, to compare male and female broad whitefish growth within each population, I tested for differences in mean size via two tailed t-tests.

Finally, to compare broad whitefish growth between populations, I tested for differences in size-at-age via analysis of variance (ANOVA) and the post hoc Bonferonni test. Broad whitefish size-at-age was tested independently for fish aged 2-17.

Anadromous broad whitefish use the Peel River and Arctic Red River solely for spawning, therefore representatives of the young (immature) age classes were not available. Consequently, population age-at-maturity was estimated by the youngest mature age which constituted more than 5% of the total sample age-frequency distribution. However, there was not adequate samples of all age classes of mature broad whitefish from Travaillant Lake (almost 50% were age 16 and some age classes had no fish), rendering the age-frequency method futile. Age-at-maturity for broad whitefish from Travaillant Lake was therefore not included in my statistical analysis. Since the age- frequency method for the Peel River and Arctic Red River data did not provide a distribution of individual ages-at-maturity, broad whitefish age-at-maturity could not be compared statistically.

To ensure the procedures for estimating fecundity used by Chudobiak (1995) and this study produce equivalent results, I estimated fecundity for 10 (whole gonads stored in preservative) broad whitefish from the Arctic Red River, using sub-samples of both 1000 eggs as well as averaging three sub-samples of 200 eggs. Next, I tested for differences in mean fecundity due to methodology using a two tailed paired t-test. I compared the regression of broad whitefish fecundity on fork length for Chudobiak's data and the samples I analyzed from Arctic Red River to determine if the data could be pooled to increase the number of broad whitefish represented in the Arctic Red River. A relationship commonly exists between fecundity and fork length (Hocutt & Stauffer 1980), therefore I used ANCOVA to ensure the regression estimates of fecundity on fork length I analyzed were within the observed data from Chudobiak (1995) for broad whitefish from the Arctic Red River and could therefore be pooled. Fecundity was the dependent variable, fork length was the continuous variable (covariate), and both were transformed to natural logarithms.

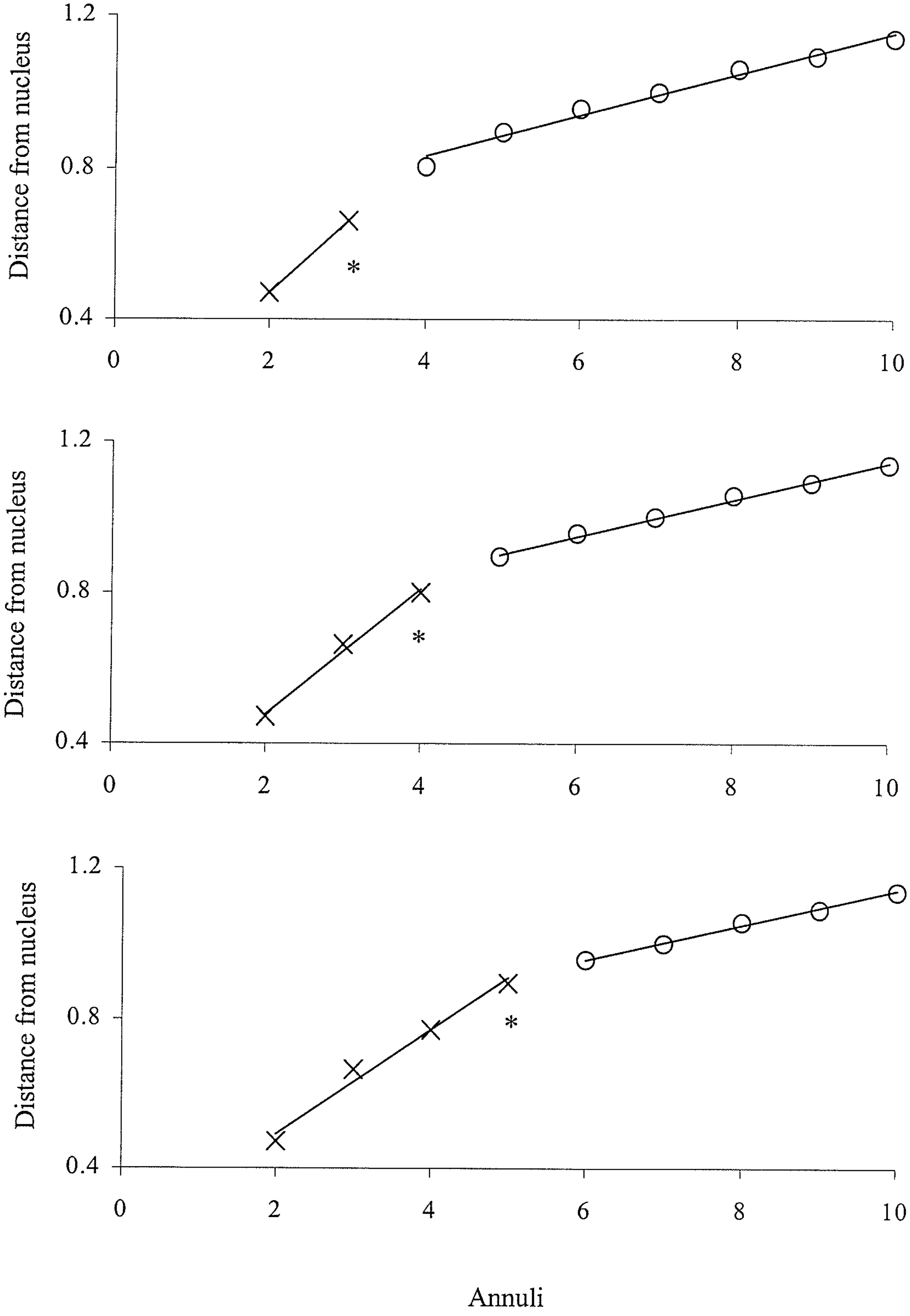
I also compared the size (g/egg) of broad whitefish eggs between Chudobiak's samples and the samples I analyzed from Arctic Red River to determine if they could also be pooled to increase the data for broad whitefish from the Arctic Red River. A relationship commonly exists between size of eggs and size of fish (Hocutt & Stauffer 1980), therefore I used ANCOVA to test for differences in the size of eggs between Chudobiak's (1995) samples and the samples I analyzed from the Arctic Red River. The size of eggs was the dependent variable and fork length was the continuous variable (transformed to natural logarithms).

Covariance analysis was then used to test for differences in fecundity between broad whitefish populations from the Peel River, Arctic Red River, and Travaillant Lake. However, comparing fecundity could only determine if there was a difference in the number of eggs per individual in each population, not if the overall reproductive investment was different. Therefore, to determine if the size (g) per egg was similar in all populations, I compared the ratio of gonad weight (g) to fecundity between each population, via ANCOVA with ln fork length as the covariate.

To estimate the age when female broad whitefish growth slowed, I performed a sequence of paired linear regressions comparing the distance of each annulus from the otolith nucleus (Figure 2.6). For example, for a 10 year old fish the first linear regression was for ages 2-3 and the second for ages 4-10. I then fit both regressions independently via least squares and calculated the total residual sum of squares. Next, I performed another pair of linear regressions, the first for ages 2-4 and the second for ages 5-10. Again, I fit the regressions with least squares and calculated the total residual sum of squares for this group. I repeated this procedure through all possible age groups (i.e. to ages 2-8 and 9-10). The age when growth slowed was then classified as the oldest age of the first linear regression from the pair of regressions with the lowest total residual sum of squares. This procedure was repeated for each otolith independently for broad whitefish from the Peel River, Arctic Red River, and Travaillant Lake. To ensure stability in the data, I limited the ages from 2-12 years, as suggested by J. Babb of the Statistical Advisory Service, University of Manitoba.

To determine if an otolith growth pattern was better represented by a continuous curvilinear line, I also fit each otolith growth pattern using the Von Bertalanaffy Growth Equation (VBGE). I compared the total resSS from the 2 linear regressions and the VBGE via paired t-test to determine if there was a significant difference between the two methods. If so, only the data in which the 2 linear regressions produced a better fitting model was used in further analysis. The average age when growth slowed from each population was then compared statistically using ANOVA and the post hoc Bonferonni test.

Figure 2.6. Example of the paired linear regressions used to determine the age when growth slowed for broad whitefish from the Peel River, Arctic Red River, and Travaillant Lake. The asterisks (*) indicate the potential age when growth slowed for each pair of regressions.


1.2
0.8
0.4
Distance from nucleus
*
0
2
4
6
8
10
1.2
0.8
0.4
Distance from nucleus
*
0
2
4
6
8
10
1.2
0.8
0.4
Distance from nucleus
*
0
2
4
6
8
10
Annuli

Results

Size-at-age

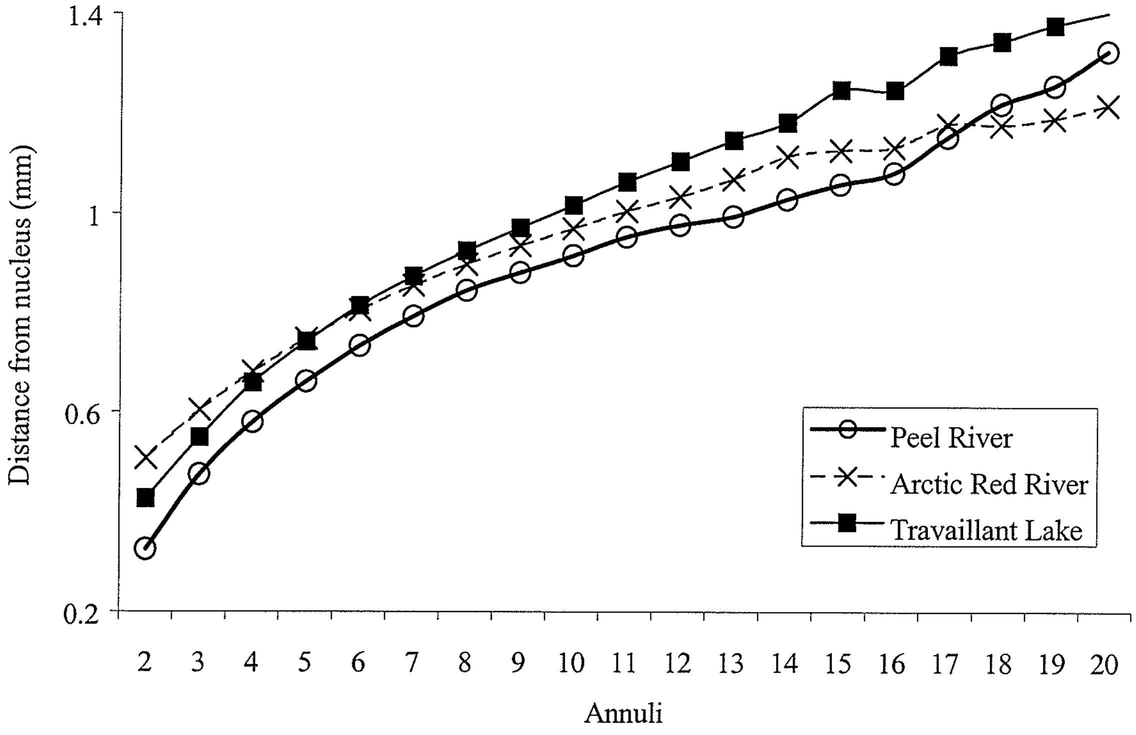
Otolith size was significantly correlated to fork length for broad whitefish from the Peel River ($r = 0.52$, $p < 0.000$), the Arctic Red River ($r = 0.544$, $p < 0.000$), and Travaillant Lake ($r = 0.42$, $p < 0.000$). The slope of the regressions for otolith size on fork length was not significantly different for broad whitefish in any population ($df = 2$, $F = 1.979$, $p = 0.142$). No significant difference was found between the size of male and female broad whitefish in any population (Peel River $t = 1.00$, $p = 0.31$, power = 95.2 % for an effect size of 0.015 mm, Arctic Red River $t = 0.89$, $p = 0.37$, power = 98.2 % for an effect size of 0.015 mm, and Travaillant Lake $t = 0.92$, $p = 0.35$, power = 81.2 % for an effect size of 0.015 mm). Therefore, I pooled male and female data within each population.

At all ages, broad whitefish from the Peel River were significantly smaller than those from Travaillant Lake (Table 2.1 and Figure 2.7). Broad whitefish from the Peel River were significantly smaller than those from Arctic Red River at younger ages, but were increasingly more similar, and were not significantly different at age 15 and beyond. Broad whitefish from Arctic Red River were significantly smaller than those from Travaillant Lake after age 10.

Table 2.1. Summary of results from the post-hoc Bonferonni test of an analysis of variance for size-(distance from nucleus) at-age (annuli) of broad whitefish from the Peel River, Arctic Red River, and Travaillant Lake. Significant results are indicated by an asterisk (*).

Annuli	Bonferonni test (p-value)		
	Peel – Arctic Red	Peel – Travaillant	Arctic Red – Travaillant
2	0.000*	0.000*	0.000*
3	0.000*	0.000*	0.000*
4	0.000*	0.000*	0.188
5	0.000*	0.000*	1.000
6	0.000*	0.000*	1.000
7	0.000*	0.000*	0.587
8	0.001*	0.000*	0.195
9	0.001*	0.000*	0.063
10	0.005*	0.000*	0.014*
11	0.014*	0.000*	0.003*
12	0.013*	0.000*	0.000*
13	0.007*	0.000*	0.001*
14	0.019*	0.000*	0.012*
15	0.232	0.000*	0.000*
16	0.940	0.000*	0.004*
17	1.000	0.000*	0.013*

Figure 2.7. Mean size-at-age (distance from nucleus to annuli) for broad whitefish from the Peel River (o), Arctic Red River (×), and Travaillant Lake (■). Trend lines are shown for the Peel River (thick solid line), Arctic Red River (dashed line), and Travaillant Lake (thin solid line).


1.4
1
0.6
0.2
Distance from nucleus (mm)
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Annuli
Peel River
Arctic Red River
Travaillant Lake

Age-at-maturity

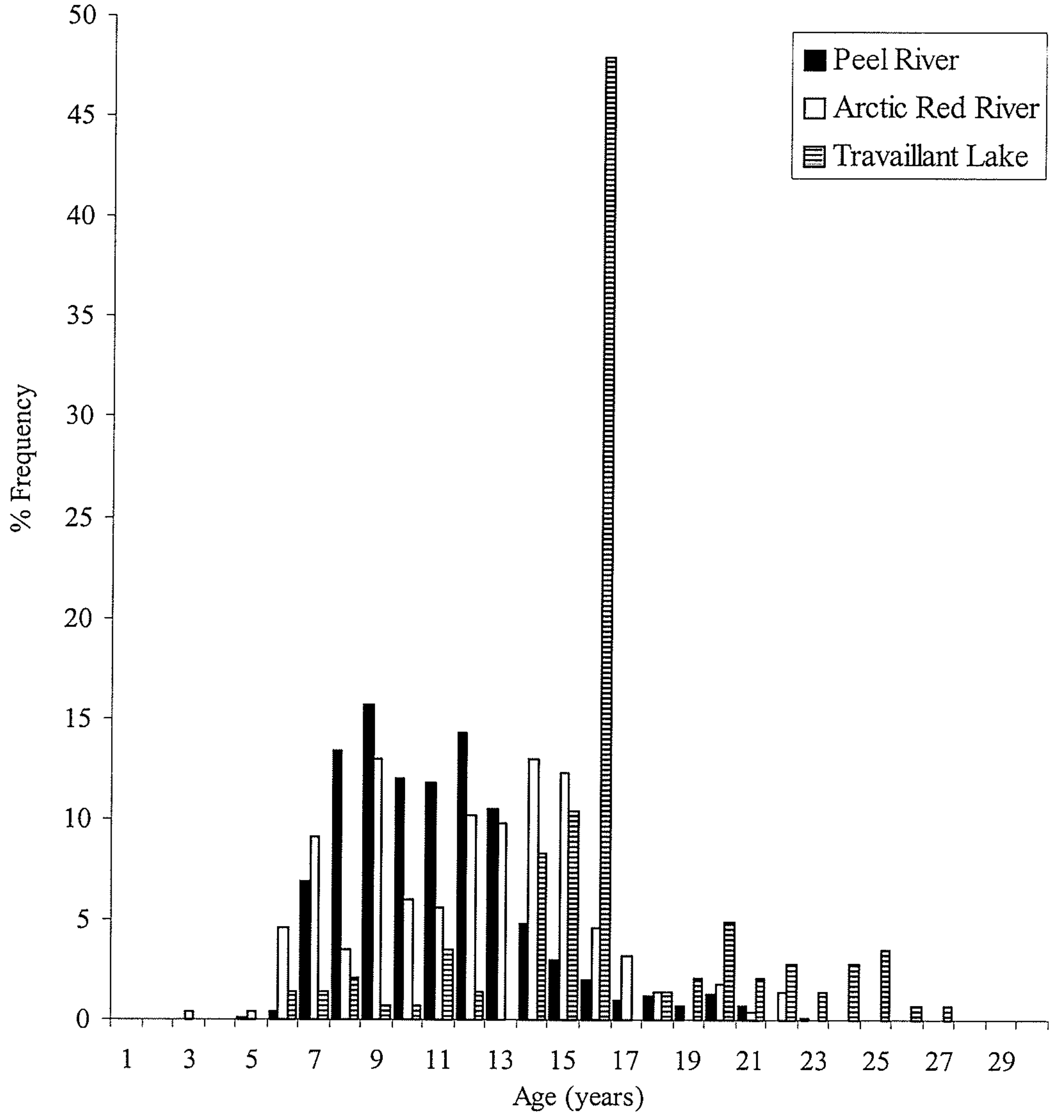
All broad whitefish caught in the Peel River and Arctic Red River during the sampling period used in this paper were sexually mature. The youngest broad whitefish caught in the Peel River (n = 694) and Arctic Red River (n = 286) were ages 5 and 3 respectively (Figure 2.8). The youngest ages which constituted more than 5% of each population were ages 7 & 6 respectively (Figure 2.8). Therefore, the estimated age-at-maturity for broad whitefish in the Peel River and Arctic Red River populations were 7 & 6 years respectively.

Both mature and immature broad whitefish were caught in Travaillant Lake during the sampling period used in this paper. The youngest immature broad whitefish caught in Travaillant Lake was 1 year old and the youngest mature broad whitefish was 6 years old (Figure 2.8). The youngest age which constituted more than 5% of the total mature age-frequency distribution was age 14 years (Figure 2.8). However, this can not be considered to be an accurate estimate of age-at-maturity for broad whitefish in Travaillant Lake because not all ages of mature fish were adequately represented and almost 50% of the fish caught were 16 years old (Figure 2.8).

Reproductive Investment

The methods of counting different sub-samples of eggs to estimate fecundity used in this study and by Chudobiak (1995) produced equivalent estimates for broad whitefish mean fecundity (df = 11, t = 2.20, p = 0.788, power = 80.0% for an effect size of ~ 3000

Figure 2.8. Age-frequency distribution for broad whitefish from a) the Peel River, b) the Arctic Red River, and c) Travaillant Lake.

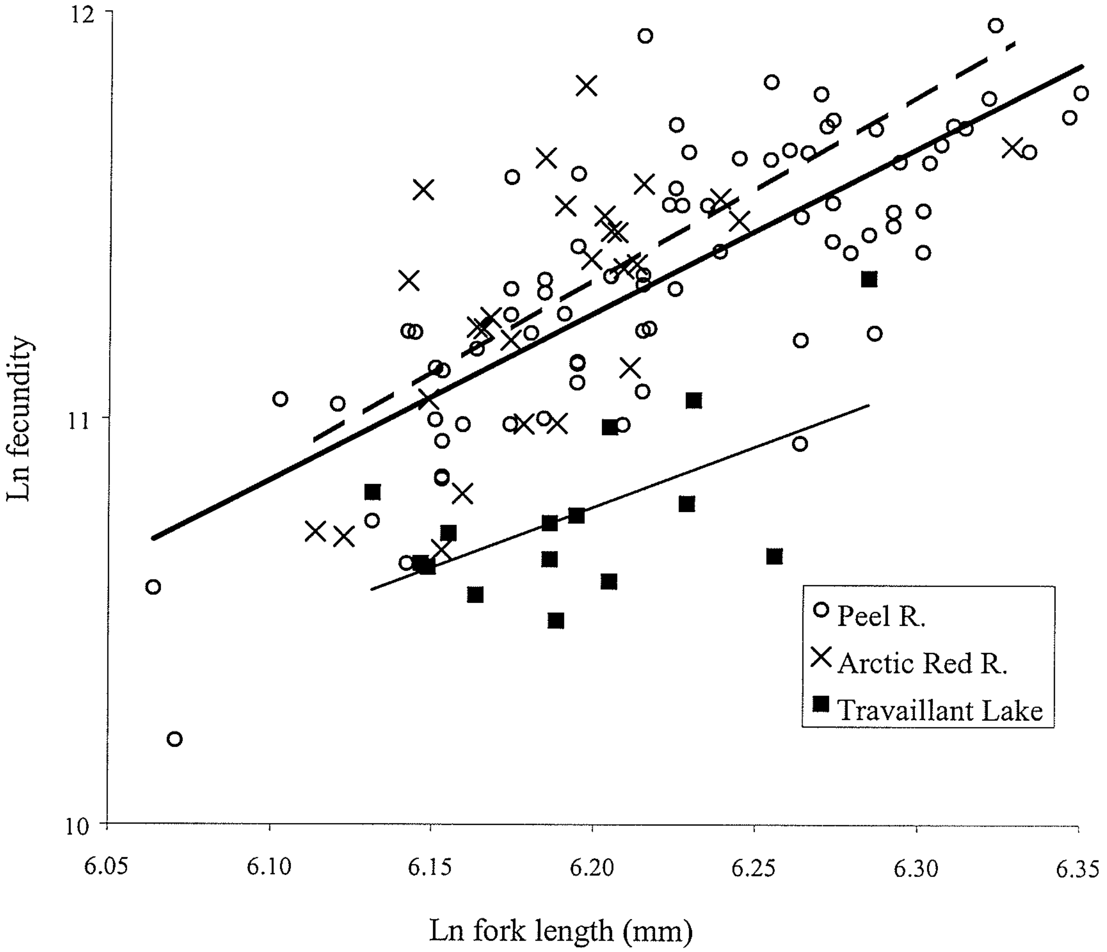

50
45
40
35
30
25
20
15
10
5
0
% Frequency
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
Age (years)
■ Peel River
☐ Arctic Red River
▤ Travaillant Lake

eggs). Also, there was no significant difference between the regressions for the samples I analyzed and Chudobiak's samples (df = 1, F = 0.607, p = 0.443, power = 80% for an effect size of ~ 6000 eggs). Therefore the new fecundity data for broad whitefish from the Arctic Red River was added to Chudobiak's data for the comparison of the regression of fecundity on fork length between populations. However, the size of broad whitefish eggs from the Arctic Red River estimated from Chudobiak's (1995) data were significantly larger than the samples I analyzed from Arctic Red River (df = 20, t = 2.08, p = 0.003). Therefore, the samples I analyzed from Arctic Red River were not included in the analysis of gram per egg between populations.

As expected, fecundity was significantly correlated to fork length in all cases (Peel – ARR: df = 1, F = 79.057, p < 0.000, Peel – Travaillant: df = 1, F = 60.974, p < 0.000, ARR – Travaillant: df = 1, F = 22.756, p < 0.000, Figure 2.9). No significant difference in fecundity was found between broad whitefish from the Peel River and Travaillant Lake (df = 1, F = 14.76, p < 0.000 and df = 1, F = 44.92, p < 0.000 respectively).

Broad whitefish egg size was not significantly related to fork length (df = 1, F = 2.838, p = 0.095) and no significant difference was found in the size of eggs (g/egg) between populations (df = 2, F = 1.35, p = 0.263, power > 80.0% with an effect size of ~ 0.0008 g). Arctic Red River (df = 1, F = 3.79, p = 0.078, power > 80.0% for an effect size of ~ 4000 eggs). However, both were significantly more fecund than broad whitefish from Travaillant Lake (df = 1, F = 14.76, p < 0.000 and df = 1, F = 44.92, p < 0.000 respectively).

Figure 2.9. Regression of natural log (ln) fecundity on ln fork length for broad whitefish from the Peel River (o), Arctic Red River (×), and Travaillant Lake (■). Trendlines are presented for broad whitefish from the Peel River (thick solid line), Arctic Red River (dashed line), and Travaillant Lake (thin solid line).


12
11
10
Ln fecundity
6.05
6.10
6.15
6.20
6.25
6.30
6.35
Ln fork length (mm)
○ Peel R.
× Arctic Red R.
■ Travaillant Lake

Age when growth slowed

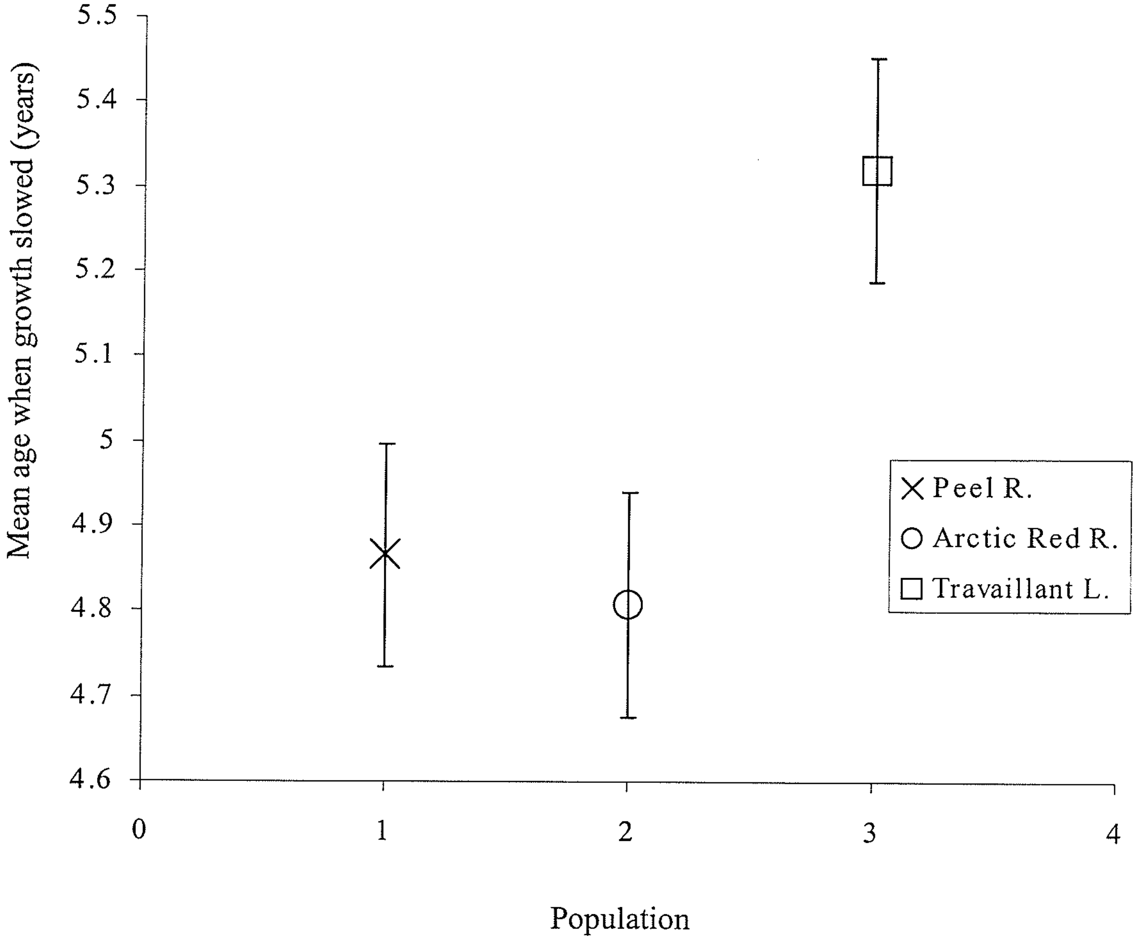
The 2 linear regression method to estimate the growth pattern for broad whitefish otoliths produced significantly smaller resSS than the VBGE (Table 2.2). Therefore, only the data in which the 2 linear regressions produced a smaller resSS were used to determine the mean age when growth slowed.

The mean age when growth slowed for broad whitefish from the Peel River (4.86 years) and Arctic Red River (4.81 years) were not significantly different (df = 55, p = 1.00, power > 80.0 % for an effect size of 0.5 years). However, broad whitefish from both of these populations slowed growth in length at a significantly younger age than that of broad whitefish from Travaillant Lake (5.30 years) (Peel-Travaillant df = 68, p = 0.045, Arctic Red-Travaillant df = 64, p = 0.026, Figure 2.10).

Table 2.2. Comparison of methods to determine growth of broad whitefish otoliths. The asterisks (*) indicate a significant difference in a paired t-test between resSS for each method.

Location	n	# with lower resSS		Paired t-test (p)
		2 linear regressions	VBGE	
Peel River	43	30 (70 %)	13 (30 %)	0.002 *
Arctic Red River	40	26 (65 %)	14 (35 %)	< 0.000 *
Travaillant Lake	46	39 (85 %0	7 (15 %)	< 0.000 *

Figure 2.10. Mean age when growth slowed for broad whitefish from the Peel River (×) (n = 30), Arctic Red River (o) (n = 26) and Travaillant Lake(☐) (n = 39). Bars represent 1 standard error.


5.5
5.4
5.3
5.2
5.1
5
4.9
4.8
4.7
4.6
Mean age when growth slowed (years)
0
1
2
3
4
Population
× Peel R.
○ Arctic Red R.
□ Travaillant L.

Discussion

I compared life history traits between known anadromous broad whitefish populations in the Peel River and Arctic Red River, and broad whitefish caught in Travaillant Lake. I hypothesized that the life history traits of the Peel River and Arctic Red River populations would be similar because they share a common migratory pattern. The life history of broad whitefish from Travaillant Lake is uncertain, but I hypothesized that these fish could be similar to the anadromous populations based on the conclusion of Hesslein et al. (1991) that the broad whitefish are a migrant population which incorporated $\delta^{34}S$ from outside the Travaillant system. I suggested that if these broad whitefish had extensive migrations out of Travaillant Lake then their life history traits would probably match those of the known anadromous populations.

As predicted, the anadromous broad whitefish from the Peel River and Arctic Red River were similar to one another in estimates of reproductive investment and the age when growth slowed. However, these populations were significantly different in estimates of size-at-age, except for ages 15 and beyond. Broad whitefish caught in Travaillant Lake had an earlier age-at-maturity (Tallman, R., Department of Fisheries & Oceans, Freshwater Institute, 501 University Cres., Winnipeg, MB., R3T 2N6, personal communication) than the anadromous populations, but this was not analyzed statistically. Somewhat consistent with prediction, the whitefish caught in Travaillant Lake were similar in size to those from Arctic Red River up to and including age 9, but were significantly different in subsequent ages. Contrary to prediction, the whitefish from the Peel River and Travaillant Lake were significantly different at all ages. Also contrary to prediction, the whitefish caught in Travaillant Lake were significantly different than both anadromous populations in estimates of reproductive investment and the age when growth slowed.

Size-at-age

At ages 3-9, (presumably immature) broad whitefish from the Arctic Red River and Travaillant Lake were not significantly different in size. However, young broad whitefish from the Peel River were significantly smaller than those from both Travaillant Lake and Arctic Red River. Change-Kue and Jessop (1997) proposed that broad whitefish which spawn in the Peel River remain on the western side of the delta while broad whitefish which spawn in the Arctic Red River remain on the eastern side of the delta. If so, my results suggest that feeding areas in the eastern Mackenzie delta may be more productive than those in the west, resulting in a larger size-at-age in the Travaillant Lake and Arctic Red River populations.

At older ages (presumably after sexual maturity), the size of the anadromous broad whitefish in the Peel River and Arctic Red River converged and were not significantly different by age 15, and beyond. This may reflect the life history of the population since the mature portion of life is presumably more energetically demanding. That is, after sexual maturity the fish migrate long distances, against the current, to spawning areas (Change-Kue & Jessop 1997). Also, the spawning migration seems energetically costly since the fish are fat with firm tissue initially during the upstream migration, but then skinny with soft tissue as they return downstream (Fred Koe, local fisherman, Fort McPherson, NWT, personal communication).

However, this was not consistent with observation of the broad whitefish from Arctic Red River and Travaillant Lake. These populations were initially similar in size (age 4-9), but diverged in similarity, and were significantly different by age 10 and beyond. Possible reasons for the differences in size at older ages in these two populations may be due to differences in local food availability, population density, or exploitation pressure.

Babaluk & Reist (1996) found that broad whitefish caught in Travaillant Lake were unlikely to have moved between freshwater and marine or brackish waters, because analysis of otolith microchemistry showed that they had remained in an area with a relatively stable concentration of strontium. Therefore, it is also possible that the fish caught in Travaillant Lake may not be migrating as extensively as the known anadromous populations. Although, if these fish migrated less extensively than the known anadromous populations, they would be expected to be smaller than the anadromous populations (Hutchings & Morris 1985, Gross 1987, Roff 1988, 1991, Snyder & Dingle 1989, 1990). This was not the case. After age 9, the fish in Travaillant Lake were larger than the anadromous populations. Chudobiak (1995) suggested that broad whitefish from Travaillant Lake might continue feeding during the spawning migration. In conjunction with a potentially better feeding habitat, this may suggest that the larger size observed in broad whitefish from Travaillant Lake may be due to better feeding habitat or longer feeding duration.

My analysis of size-at-age was based on measurements from sagittal otoliths; therefore, effects of Lee's phenomena (Ricker 1969, Ricker 1975) are possible. However, instead of using a formula (based on a fitted trend line) to back-calculate fork length, I directly measured the distance from the nucleus to each annuli. By measuring otoliths individually, I have included the natural variation in the population. Gear selectivity also influences effects of Lee's phenomena, but all studies included in my analysis used the same equipment. Further, for the 2 anadromous populations, no broad whitefish were caught in mesh size smaller than 4-inch, therefore variation in size of fish is due to natural causes and not gear selectivity. Also, in all populations I used older fish (age 7 and beyond) for the annulus measurements, and the same estimation technique. Therefore, bias introduced by Lee's phenomena should be approximately equal in all populations and result in minimal repercussions for my analyses.

Age-at-maturity

The youngest mature broad whitefish which constituted more than 5% of the age-frequency distribution from the Peel River and Arctic Red River were approximately ages 7 years and 6 years, respectively. These estimates are consistent with (Peel River) and slightly less than (Arctic Red River) age-at-maturity estimates reported for anadromous broad whitefish in the Mackenzie Delta (age 7 to 9 years) (Bond 1982, Bond & Erickson 1985, 1987). My data did not permit an estimate of the age-at-maturity for broad whitefish from Travaillant Lake. However, (Tallman, R., Department of Fisheries & Oceans, Freshwater Institute, 501 University Cres., Winnipeg, MB., R3T 2N6, personal communication) estimated the age-at-maturity for this population to be approximately 5.5 years (using the methods described by DeMaster (1978) in which age-at-maturity is based on the calculated probability of spawning). This age is younger than the age reported for anadromous broad whitefish populations in this study, and the above mentioned studies.

The fish caught in Travaillant Lake may be reaching sexual maturity at an earlier age since they are larger than those from the anadromous populations. However, the fish from Arctic Red River were similar in size until age 9, but still exhibited a relatively delayed age-at-maturity. Fish that undertake a longer migration have been shown to delay sexual maturity with respect to non-migratory or lesser migratory counterparts (Tallman et al. 1996, Gross 1987, Hutchings & Morris 1985). However, this comparison of age-at-maturity in broad whitefish from the Peel River, Arctic Red River, and Travaillant Lake is restricted to general comment and not scientific analysis due to differences in the methods used to estimate it among studies.

Reproductive Investment

Fecundity data for broad whitefish from the Arctic Red River and Travaillant Lake used in this study were from Chudobiak (1995). This may introduce bias due to differences in methods or sampling precision. However, I tested the data for these potential problems and found no significant difference in estimates of fecundity due to either of the above mentioned factors.

The estimated fecundity for the anadromous broad whitefish populations from the Peel River and Arctic Red River were not significantly different from one another, yet both were significantly more fecund than broad whitefish caught in Travaillant Lake. In other studies, it has been found that populations which migrate extensively have a higher average fecundity than populations that do not migrate as far (Snyder & Dingle 1989, 1990, Tallman et al. 1996).

However, higher fecundity is not synonymous with higher reproductive effort. For example, a fish may have more eggs and therefore higher fecundity, but egg mass may be smaller. In this situation, the overall reproductive effort has not increased, but simply altered its form. Egg size for broad whitefish from the Peel River, Arctic Red River, and Travaillant Lake were not significantly different, therefore the anadromous populations did appear to have higher reproductive effort than the broad whitefish caught in Travaillant Lake.

Age when growth slowed

It is commonly accepted that fish growth slows after sexual maturation, and this can be reflected in the distance between otolith annuli. Jensen (1985) identified the inflection point in the growth curve and found that it was slightly before or corresponded with age-at-maturity of individual fish. However, these conclusions were reached through manipulation of the Von Bertalanaffy Growth Equation and biological considerations were not discussed. Therefore, I investigated individual annulus increments in otoliths of broad whitefish from the Peel River, Arctic Red River, and Travaillant Lake.

I found no significant difference in the age when growth slowed for the anadromous broad whitefish populations in the Peel River (4.86) and Arctic Red River (4.81). Further, in both of these populations, growth in length slowed approximately one to two years before the estimated age-at-maturity (7 & 6 years respectively), not at or slightly before as suggested by Jensen (1985). Bond (1982) also reported that growth of broad whitefish caught in the Tuktoyaktuk Harbor (a nursery area for anadromous populations) slowed after age 4 years, but that the age-at-maturity was 7-9 years.

When the anadromous populations were compared to fish caught in Travaillant Lake, those from the lake were different in two ways. First, the growth of the anadromous populations slowed a significantly earlier age than the broad whitefish from Travaillant Lake (5.30 years). Second, contrary to the anadromous populations but in support of Jensen (1985), the broad whitefish caught in Travaillant Lake slowed growth at approximately age 5.30 years which was near the age-at-maturity of 5.5 years (Tallman, R., Department of Fisheries & Oceans, Freshwater Institute, 501 University Cres., Winnipeg, MB., R3T 2N6, personal communication).

There may be many possible reasons why the anadromous fish slowed growth at an earlier age than the fish in Travaillant Lake including differences in environment, behavior, or physiological energy input, diversion, or storage.

Environmental factors influence all aspects of fish life and could certainly influence the growth pattern. Such factors may include food availability or local climate condition. Fish behavior could also influence the growth pattern. For example, a shift in diet may occur as the fish grows and can ingest larger prey items. However, this alone would likely result in the fish growth increasing and not decreasing.

Explanation for the differences between the anadromous broad whitefish and those caught in Travaillant Lake may also be hypothesized based on life history theory in conjunction with physiological energy. Fish eat and therefore obtain energy. This energy can then be used for growth in length, body maintenance, reproductive development, stored as fat (potentially for migration), or other uses. Broad whitefish continue to feed as adults, but I found that growth in length was minimal. Therefore, I questioned if the energy was being diverted from growth and into reproductive investment and storage for migration. Using my estimates of age-at-maturity for anadromous broad whitefish from the Peel River and Arctic Red River, the estimated age-at-maturity for broad whitefish from Travaillant Lake (Tallman, R., Department of Fisheries & Oceans, Freshwater Institute, 501 University Cres., Winnipeg, MB., R3T 2N6, personal communication), and my estimated age when growth slowed for all three populations, I estimated the amount of time potentially spent in preparation for sexual maturation and migration to spawning areas. Based upon the annuli growth pattern in the otoliths, the anadromous broad whitefish potentially diverted energy from growth (growth slowed and distance between annuli decreased) approximately one or two years before spawning occurred. However, broad whitefish from Travaillant Lake slowed in growth less than half a year before the population age-at-maturity. Since fish from the Peel River and Arctic Red River spent more time hypothetically preparing for maturation, life history theory can be used to hypothesize that the activities for which they were preparing were more demanding than those for fish from Travaillant Lake. If so, this may suggest that the broad whitefish caught in Travaillant Lake are different from the anadromous populations. I hypothesize that the anadromous broad whitefish spent more time, and energy, preparing for a longer migration to spawning areas and, as I've shown previously, had a larger reproductive output. A longer period of reproductive investment and lipid storage may also explain how the broad whitefish from the anadromous populations were able to presumably migrate further and have higher reproductive effort even though their adult size-at-age was smaller than those of broad whitefish from Travaillant Lake.

General summary

The broad whitefish caught in Travaillant Lake appear to be different than the anadromous populations in the Peel River and Arctic Red River. Initially the fish from the Arctic Red River and Travaillant Lake were similar in size, but the trend in size-at-age diverged after age 9 years (presumable after sexual maturation). The fish from Travaillant lake were then significantly larger that the anadromous populations. Broad whitefish caught in Travaillant Lake also had an earlier relative age-at-maturity (based upon previous estimates and not statistically analyzed), lower reproductive effort, later age when growth slowed, and they had a shorter time between the age when growth slowed and the age-at-maturity. While this study suggests that broad whitefish in Travaillant Lake are not similar to the anadromous populations, more research including tagging or tracking studies would be useful to clarify the activities of these fish.

Broad whitefish is an important species in the Mackenzie Delta because many aboriginal communities rely on these fish for consumption, local sale, and cultural tradition (Treble 1996). However, management of this species is difficult because different life history types may exist (Reist 1997) and anadromous populations traverse Aboriginal Settlement Areas (Bond & Erickson 1985, 1987, 1992, Change-Kue & Jessop 1991, 1992, Reist & Bond 1988, Reist and Change-Kue 1997). This study has provided information on the variation in growth, age-at-maturity, reproductive investment, and age when growth slowed for anadromous broad whitefish populations in the Peel River and the Arctic Red River, and broad whitefish caught in Travaillant Lake. This information can be used by resource managers in the Mackenzie Delta to enhance the understanding of the broad whitefish population dynamics, compare to future data to detect potential changes in the populations, and generally aid in management decisions for the populations.

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CHAPTER 3. EVALUATION OF THE PEEL RIVER FISH-MONITORING PROGRAM

Abstract

Monitoring life history traits provides useful information for management decisions. However, variability of the information collected can mask natural or anthropogenic trends. To evaluate the effectiveness of different monitoring designs, I simulated variation in the Peel River fish-monitoring program based upon field data on broad whitefish fecundity and length-at-age. Length-at-age estimates were found to be unaffected by the design, but fecundity could vary due to the influence of a supervisor and location. Each design was modeled for effects of exploitation and the statistical power was determined via computer simulations. Sites that deviated from the general trend were removed from subsequent monitoring designs. The statistical power of all monitoring designs initially increased proportionally when more fish were included in the sample and when the effect size was large. However, the benefits of improved sensitivity in the design, by increasing the sample size, diminished after approximately 50 fish were included in the sample. The results of my simulations on fecundity of broad whitefish from the Peel River correctly predicted the outcomes of exploitation experiments from Healey (1978) with lake whitefish and lake trout, and Baccante & Reid (1988) with walleye. The results of my simulations on length-at-age of broad whitefish from the Peel River coincided with the outcomes of exploitation experiments from Chevalier (1977) with walleye, Healey (1980) for 7 of 11 populations of lake whitefish, and Amundsen (1988) for 2 of 4 stunted populations of common whitefish.

Introduction

Fish-monitoring programs are an important aspect of fisheries management and can provide information on reactions of a population to environmental or anthropogenic effects (Skalski & McKenzie 1982). However, many programs examine several stocks simultaneously over broad geographical ranges. Fish-monitoring programs can be improved if they consider factors involved with specific projects. Fisheries research in the Arctic involves consideration for co-management, the biology of the species in question, environmental and logistic constraints, and proper experimental design (Reist & Treble 1998, Peterman 1990).

Historically, aboriginal groups and western scientists have not worked together in the management of renewable resources (Agrawal 1995, Oakes & Riewe 1996). In 1989, 1992, and 1993 aboriginal land claims were settled in the Canadian Arctic with the Inuvialuit, Gwich'in, and Sahtu and Metis, respectively (Reist & Treble 1998). This gave aboriginal resource boards the responsibility of resource management in their communities. From this, co-management projects have developed between many aboriginal groups and the Canadian federal government. Today, many aboriginal groups and western scientists realize that partnership is the key to maintaining healthy wildlife populations. One example is the development of co-managed fish-monitoring projects in the Canadian Arctic.

Northern aboriginal communities rely upon fish as an important source for food and cultural tradition (Treble 1996). Gwich'in, Inuvialuit, Sahtu Dene, and Metis communities in the lower Mackenzie delta rely upon broad whitefish (*Coregonus nasus*) for this purpose. However, ensuring the population is not depleted is complex due to the biology of the species. Anadromous and lacustrine populations of broad whitefish are believed to occur in the Mackenzie delta (Freeman 1997, Reist 1997). Lacustrine populations do not venture far from their resident lake; therefore, over-exploitation should be easily detected. However, the anadromous broad whitefish migrate extensively throughout their lives and traverse many settlement areas (Bond 1982, Bond & Erickson 1985, 1987, 1992, Chang-Kue & Jessop 1991, 1992, Reist & Bond 1988, Reist & Chang-Kue 1997). The spatial and temporal congregation of anadromous broad whitefish subjects them to fishing exploitation at several points along their migration routes (Treble 1996, Reist & Treble 1998). The ability to detect over-exploitation of these fish is therefore more problematic. For this reason, fish-monitoring projects have been established to study important fish species such as arctic charr and broad whitefish (Gillman & Sparling 1985, Sandstrom & Harwood 1997). To ensure that the fish sampled are from discreet genetic populations, monitoring programs in the Mackenzie delta generally occur while the fish are migrating to spawning areas. For broad whitefish, this migration occurs in the fall just after the spawning river freezes (Stein et al. 1973, Jessop et al. 1974).

Executing a fish-monitoring program in the Arctic during the fall introduces many problems beyond working outdoors in -30^{O}C temperatures. Fishing must cease for a period when the river ice is freezing. Fish may pass by the monitoring stations during this time and therefore may not be represented in the analysis. Also, monitoring stations are often isolated Aboriginal family camps, which lack electricity and heat. The lack of electricity means that the processing of fish and data collection must be performed using natural light or gas lanterns. However, daylight hours are dramatically reduced in the fall, limiting the time available for processing the fish, and gas lanterns do not provide sufficient light. Rushing to complete processing of the fish caught for a day or working in non-optimal lighting can lead to incorrect measurement of biological traits, mis-identification between sexes, or inability to locate aging structures. Further, the lack of heat in monitoring stations, coupled with cold temperatures, can cause the fish to freeze before processing is complete. In such cases, the fish must be thawed before processing and measurement of length and weight may be underestimated due to drying of the fish. Also, roads are often non-existent along rivers in the Arctic, which limits mobility to boat, snow machine, or helicopter. This can cause delays in sampling due to lack of equipment or imprecise data collection from use of available, but non-optimal, equipment. Finally, communications with co-workers or supervisors may be limited to two-way radio and orally relayed messages, leading to lack of or mis-interpretation of suggestions, required supplies, or the progress of the monitoring program.

Monitoring fish populations during a concerted spawning migration also produces difficulties with subsequent data analysis. The effects of exploitation are often examined through the analysis of catch-per-unit-effort (CPUE). Catch and effort can provide a useful indicator of population changes and are often incorporated in more complex populations analysis (i.e. virtual population analysis) (Hocutt & Stauffer 1980). However, when populations are aggregated, such as during migrations, CPUE will not decrease noticeably until the population has been dramatically reduced in size (Ricker

1975, Swain & Sinclair 1994, Mackinson et al. 1997, Tallman 1997). Thus, it may appear that the population is stable through a period of decline.

Monitoring of life history traits provide an alternative to CPUE for studying the impacts of exploitation. Life history theory predicts that reduced adult survival selects for increased fecundity and larger size-at-age (Silliman et al. 1958, Stearns 1983, Reznick et al. 1990). This can result from a decrease in density of the population, thus providing more food for the survivors, or evolutionary selection of traits (Borisov 1978). Increased mortality later in life reduces the costs of reproducing now (Gadgil and Bossert 1970). Therefore, if the probability of reproducing in future years is uncertain, it can be advantageous to put more effort into each reproductive event (increase fecundity).

Once identification has been made as to what will be monitored, the next step is to identify possible sources of variation (or error) in the experimental design. In a monitoring program that contains different monitors with unique sampling locations, biases are likely. Monitoring programs must also consider the annual variation in the biology of the population being studied, and the experience of the monitors. Finally, when working collaboratively on a project, the results must be presented in a way that will be useful for all contributors.

Once the relevant factors involved in designing a monitoring program have been identified, the next critical (and often omitted) step is to ensure the design has adequate statistical power. While most scientists report the Type I error (probability of falsely rejecting the H_o), few report the Type II error (probability of falsely accepting the $H_{o)}$, or the statistical power (probability of correctly rejecting the H_o) (Peterman 1990, McClave

& Dietrich II 1994). Statistical power reveals the ability of an experiment to detect an effect if one does occur (McAllister et al. 1992). It is still uncommon to see statistical power reported in literature studies in ecology, but awareness of it's importance is growing (Bernstein & Zalinski 1983, de la Mare 1984, Green 1988, Peterman 1989, Peterman 1990, Osenberg et al. 1994, Van Strien et al. 1997). Generally, an experiment with a large effect, large number of observations in the sample, and small variability among observations will yield a more powerful test and require less sampling effort (Osenberg et al. 1994). Power analysis is therefore a useful tool in planning and assessing experiments or programs. The calculation of statistical power before the implementation of a project can provide project managers with valuable information on the allocation of sample effort and the reliability of the results as indicators of the true parameter (Peterman 1990). This requires preliminary data to estimate the variability in the factors being studied. For many classical experimental designs, expected power can be read from published power tables (Cohen 1988, Dixon & Massey 1969). An alternative method for novel designs, such as those likely to be employed in field studies, is to use preliminary data from the field to construct power tables with simulations based on the observed variation. This method is more complicated and computer intensive. However, it can be used with non-normal data and can tailor the results to a specific fish population.

In this paper, I evaluate the efficiency of the Peel River fish-monitoring program. Specifically, I identify sources of variation in the program and simulate alternative fish-monitoring designs. The effects of exploitation on life history variables are modeled to determine the statistical power of the various designs. Finally, I compare the results of my simulations to results of exploitation experiments in the literature.

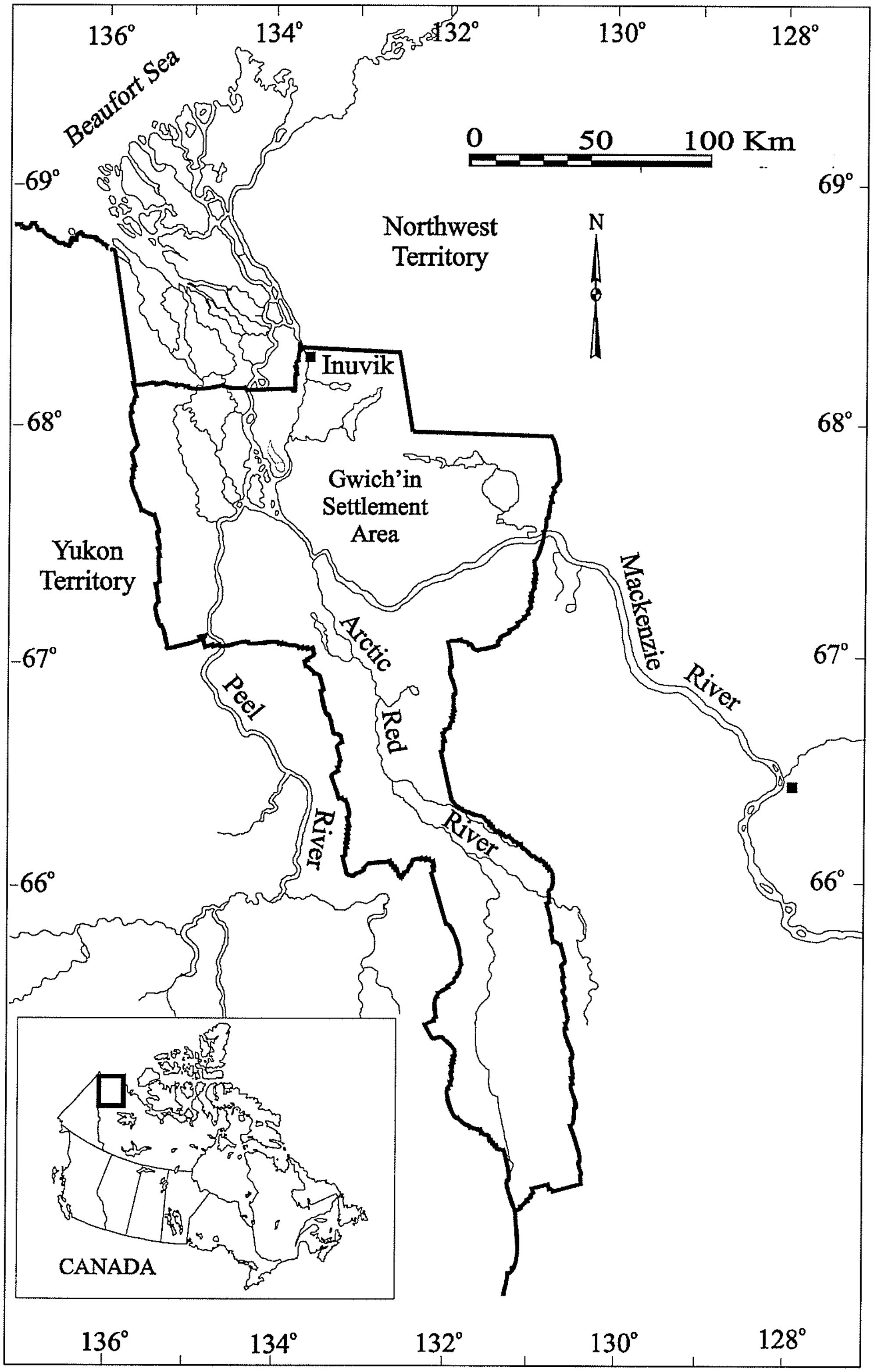
Methods and Materials

The Peel River Fish-Monitoring Program

The sampling of broad whitefish and other species in the Peel River was the basis for the Peel River fish-monitoring program, a co-management project between the Gwich'in Renewable Resource Board (GRRB), the Department of Fisheries & Oceans, Freshwater Institute (DFO), and the Tetlit Renewable Resource Council (RRC). The Gwich'in Settlement area spans 57,000 km^2 (Gwich'in Tribal Council 1992), encompassing a portion of the Peel River (Figure 3.1). The Peel River fish-monitoring project was initiated to monitor the broad whitefish population for effects of exploitation, and because the Gwich'in community expressed concerns that potential developments near the Peel River could cause declines in broad whitefish stocks. The objectives of this study were to: 1) collect an ongoing series of biological data on broad whitefish in the Peel River and 2) test different monitoring designs to assess their sensitivity to changes in broad whitefish fecundity and length-at-age.

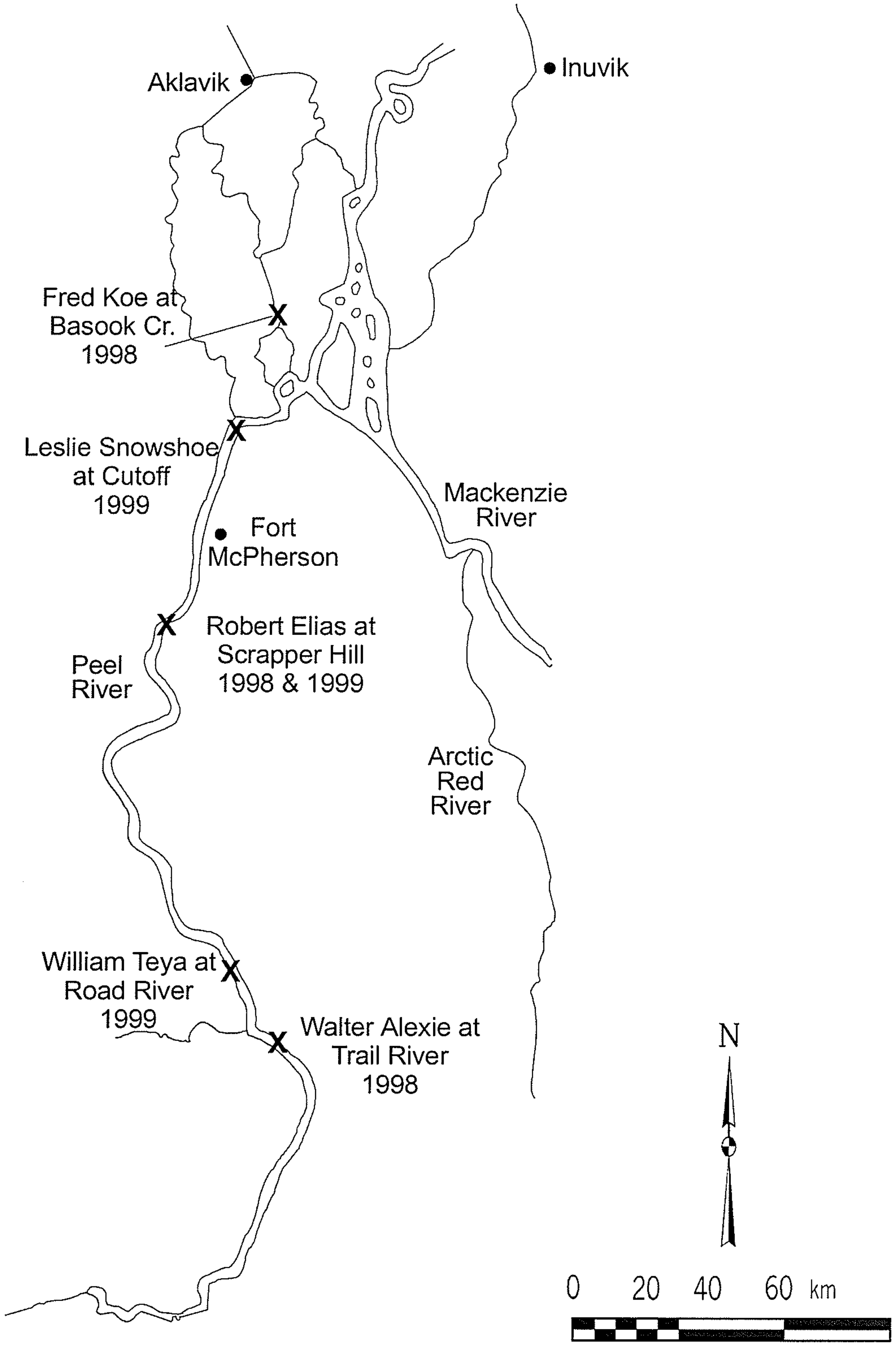
To ensure mutually beneficial results and community involvement, personnel from the GRRB and DFO met with the RRC and community members of Fort McPherson on several occasions to decide, as a group, the procedural details for the field study. Three monitoring stations were chosen at various points along the Peel River to

Figure 3.1. Map of the Mackenzie Delta, Canada, indicating the Gwich'in Settlement Area and the Peel River.


136°
134°
132°
130°
128°
Beaufort Sea
0
50
100 Km
N
69°
Northwest Territory
Inuvik
68°
Gwich'in Settlement Area
Yukon Territory
Mackenzie River
67°
Arctic Red River
Peel River
66°
CANADA

identify migration timing of the fish as they passed by on their upstream spawning migration (an objective in the project not discussed in this paper). The Tetlit RRC selected three men from Fort McPherson based on their camp location, experience, financial need, and interest in the project. Monitoring stations (Figure 3.2) in 1998 included the Peel Channel at Basook Creek (67°44.42N, 134°38.33W), Peel River at Scrapper Hill (67°15.72N, 134°53.16W), and Peel River at Trail River (66°40.30N, 134°33.55W). In 1999, a monitoring station on the Peel River at Cutoff (67°38.955N, 134°38.89W) replaced Basook. Basook was located near the mouth of the Peel River and caught many more fish than the other two locations. This raised concern that the fish caught in the Peel River may have come from the Mackenzie River or the Arctic Red River populations. A monitoring station on the Peel River at Road River (66°52.79N, 135°00.122W) replaced the monitoring station at Trail River because the monitor at Trail River was not interested in continuing with the study. Scraper Hill continued to be a monitoring station in 1999. The field portion of the study occurred in the fall (September to November) of 1998 and 1999. During the study, fish were caught primarily using a 45 m long, 2.4 m deep and 12.7 cm stretched mesh multi-filament nets, but a 45 m long and 2.4 m deep, multi-filament experimental mesh net with panels of 3.8 cm to 10.1 cm stretched-mesh size was also used. Gill nets were set perpendicular to the shore in eddies and left in the water continuously, excluding periods of ice freeze-up. After ice freeze-up, the nets were set under the ice.

Figure 3.2. Map of the Peel River indicating sampling locations (X), name of monitor, and year of sampling. Dots indicate towns.


Aklavik
Inuvik
Fred Koe at Basook Cr. 1998
Leslie Snowshoe at Cutoff 1999
Mackenzie River
Fort McPherson
Robert Elias at Scrapper Hill 1998 & 1999
Peel River
Arctic Red River
William Teya at Road River 1999
Walter Alexie at Trail River 1998
N
0 20 40 60 km

Biological sampling

Monitors checked the nets and processed fish once or twice a day, 3 times a week, to allow time for necessary camp responsibilities (such as chopping wood for a fire and collecting water). Information collected from each fish included fork length (mm), weight (g), sex, maturity stage, gonad weight, and otoliths. Sex and maturity designated for each fish depended on the presence or absence of eggs, and on gonadal development (modification of Bond & Erickson 1985). Age determination of broad whitefish was performed using both sagittal otoliths via the "break and burn" procedure (Chilton & Beamish 1982). Both gonads of female broad whitefish were removed and frozen immediately for fecundity analysis. The eggs were thawed in formalin preservative, rinsed, dried, and weighed. Three sub-samples of 200 eggs were then counted and weighed to the nearest 0.001g. Fecundity was calculated as the average weight of sub-sample / weight of all eggs • size of sub-sample.

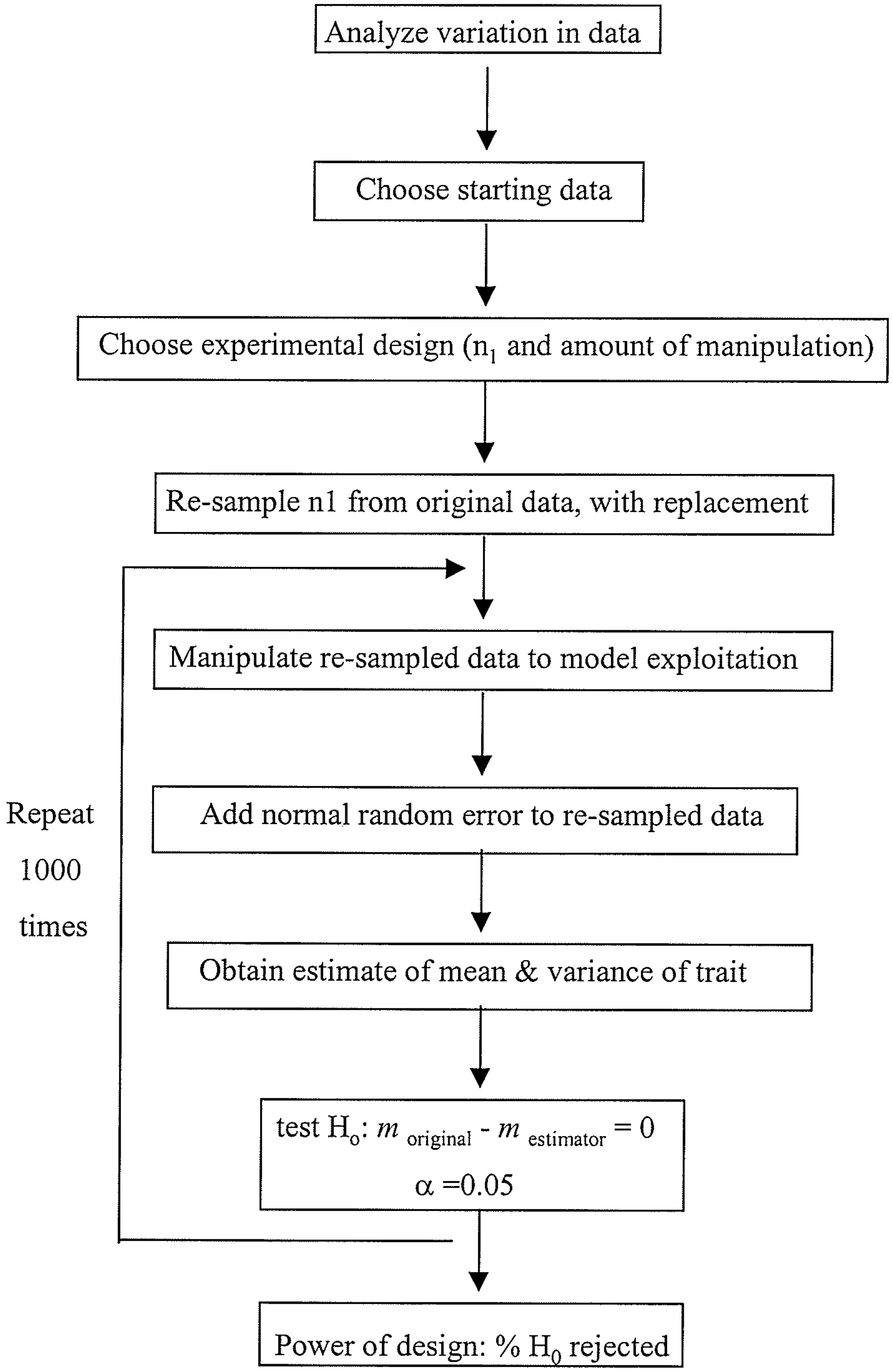
Broad whitefish life history traits

Broad whitefish fecundity and length-at-age were chosen for analyses because the raw materials for these are easily obtained in a fish-monitoring program. In addition, the effects of increased adult mortality (as occurs with size-selective exploitation) on these traits has been well established in the literature (Silliman et al. 1958, Stearns 1983, Reznick et al. 1990). Broad whitefish in the Mackenzie Delta reach sexual maturity between the ages of 7 & 9 (Bond 1982, Bond & Erickson 1985, 1987). Full recruitment to the fishery can therefore be expected by age 9. My analyses of length-at-age included broad whitefish age 9, but also age 11 and 13 to reduce bias of specific age classes.

Sources of variation

The first step in the analysis of the Peel River fish-monitoring program was to investigate sources of variation in the estimates of fecundity and length-at-age (Figure 3.3). To determine if inter-annual variation in the spawning stock composition would influence the results, I compared variation in the data collected in 1998 and 1999. The broad whitefish which spawn in the same year can represent a sub-population that may have experienced different environmental influences and therefore exhibit different fecundity and length-at-age. To determine if the presence of a supervisor influenced the results, I compared the variation found in the data for broad whitefish fecundity and length-at-age at times of supervisor presence or absence during data collection. The supervisor (M. Van Gerwen-Toyne) trained the monitors before the initiation of the study and then moved among the camps throughout the study. The training was brief, and in 1999 occurred three weeks before the study initiated. Consequently, there was potential sampling error introduced during times of no supervision. Third, to determine if the location of the monitoring station or monitor bias influenced the resulting estimates of fecundity and length-at-age, I compared variation in the data for broad whitefish fecundity and length-at-age between monitoring stations. With five monitors at unique locations, there was potential for sampling bias due to both location and monitor performance. Finally, to determine if there were differences in growth between the male

Figure 3.3. Flow diagram illustrating the steps in evaluating an experimental design that tests for a specific effect of exploitation on fecundity or length-at-age.


Analyze variation in data
Choose starting data
Choose experimental design (n_1 and amount of manipulation)
Re-sample n1 from original data, with replacement
Manipulate re-sampled data to model exploitation
Repeat 1000 times
Add normal random error to re-sampled data
Obtain estimate of mean & variance of trait
test H_o: $m_{\text{original}} - m_{\text{estimator}} = 0$
$\alpha = 0.05$
Power of design: % H_0 rejected

and female broad whitefish, I compared variation in broad whitefish length-at-age data between sexes.

Since there is commonly a correlation between fecundity and size (Hocutt & Stauffer 1980), I tested each hypothesis for fecundity using dummy variable regression. Fecundity was the dependent variable and fork length was the continuous variable (covariate). Both variables were transformed to natural logarithms. The dummy variable was a categorical variable specific to the hypothesis (i.e. year of sampling, supervisor's presence, and individual camp). The regression equation was,

$$Y = \beta_0 + \beta_1 X + \beta_2 D + \beta_3 (X \bullet D) \tag{3.1}$$

Where Y = ln fecundity (dependent variable)

X = ln fork length (mm) (covariate)

D = dummy variable

The test for determining the influence of the supervisor on fecundity estimates at Scrapper Hill 1998 could not be performed due to insufficient data ($n = 4$). The data for fecundity which were not significantly different were pooled and used to estimate variability in field data when testing different monitoring designs (Figure 3.3).

All hypotheses for broad whitefish length-at-age were tested using two-tailed t-tests. Within each general hypothesis, I compared mean fork length independently for broad whitefish aged 9, 11, and 13. Tests for determining the influence of the supervisor on mean fork length could not be performed on broad whitefish age 9, 11, and 13 from

Scrapper Hill, and from broad whitefish age 9 and 13 from Trail River, due to insufficient data (n = 0 for one variable). The data for length-at-age which were not significantly different were pooled as starting data for testing different monitoring designs (Figure 3.3).

Experimental design

My procedures for simulating and testing different experimental monitoring designs followed a sequence of events modified from McAllister et al. (1992). The evaluation of each monitoring design consisted of 6 steps (Figure 3.3): 1) choosing the experimental design to be used (the number of fish and amount of manipulation that will be simulated), 2) simulating new data, by re-sampling with replacement from the original data, 3) manipulating the simulated data to model effects of exploitation, 4) adding normal random error to the simulated data, 5) testing the null hypothesis of no difference between the original and simulated data, and 6) estimating the power of the monitoring design.

The simulated data included a predetermined number of fish. The number of fish in a single sample reported in various fecundity studies ranged from n = 1 to almost 100 fish (Bell et al. 1977, Healey 1978, Healey & Heard 1984, Baccante & Reid 1988, Snyder & Dingle 1989). Therefore, my experimental designs for fecundity simulated samples ranging in size from n = 10 to 150. Length-at-age data collected in various studies resulted in n = 1 to over 1000 individuals at one age (Healey 1980, Prasolov 1989, Lockwood et al. 1991, Bond & Erickson 1992, Griffiths et al. 1992, Treble & Tallman

1997). However, only in Treble & Tallman (1997) and Griffiths et al. (1992) did samples exceed 50 fish per year of one age group. Therefore, my experimental designs for length-at-age also simulated samples ranging in size from n = 10 to150 fish.

The simulated data were then manipulated to model effects of exploitation. Manipulation included adding a predetermined amount of change (i.e. an addition of 1000 eggs, or 10 mm). Healey (1978) experimentally exploited lake whitefish from four lakes in the Northwest Territories and found that fecundity increased from an addition of 1000 to 7000 eggs per individual. Therefore, in my experimental designs, I manipulated the simulated data by adding increments of 1000 eggs, starting with no change. However, I did not limit the manipulations to an increase of 7000 eggs. I continued to increase the manipulations until at least 80% power of detection was observed (manipulations from no change to a maximum addition of 14000 eggs per individual). Healey (1980) found a mean increase in length-at-age up to 44 mm, depending on the level of exploitation. Therefore, I manipulated the simulated data by adding from 0 to a maximum addition of 45 mm, at 5 mm increments, until at least 80% power of detection was observed.

To introduce variability to the simulated data, a computer generated normal random error was added to individual estimates of fecundity and fork length in the simulated data. For fecundity monitoring designs, the residuals from the regression of ln fecundity on ln fork length were calculated and tested for normality. The standard deviation of the residuals were then used to generate a random number from a normal distribution. This randomly generated number represented error in fecundity which was added to individual estimates of fecundity in the simulated data. For length-at-age monitoring designs, the residuals from the mean fork length at age 9, 11, and 13 were calculated and tested for normality. The standard deviation of the residuals were then used to generate a random number from a normal distribution. The randomly generated number represented error which was added to each fork length in the simulated data.

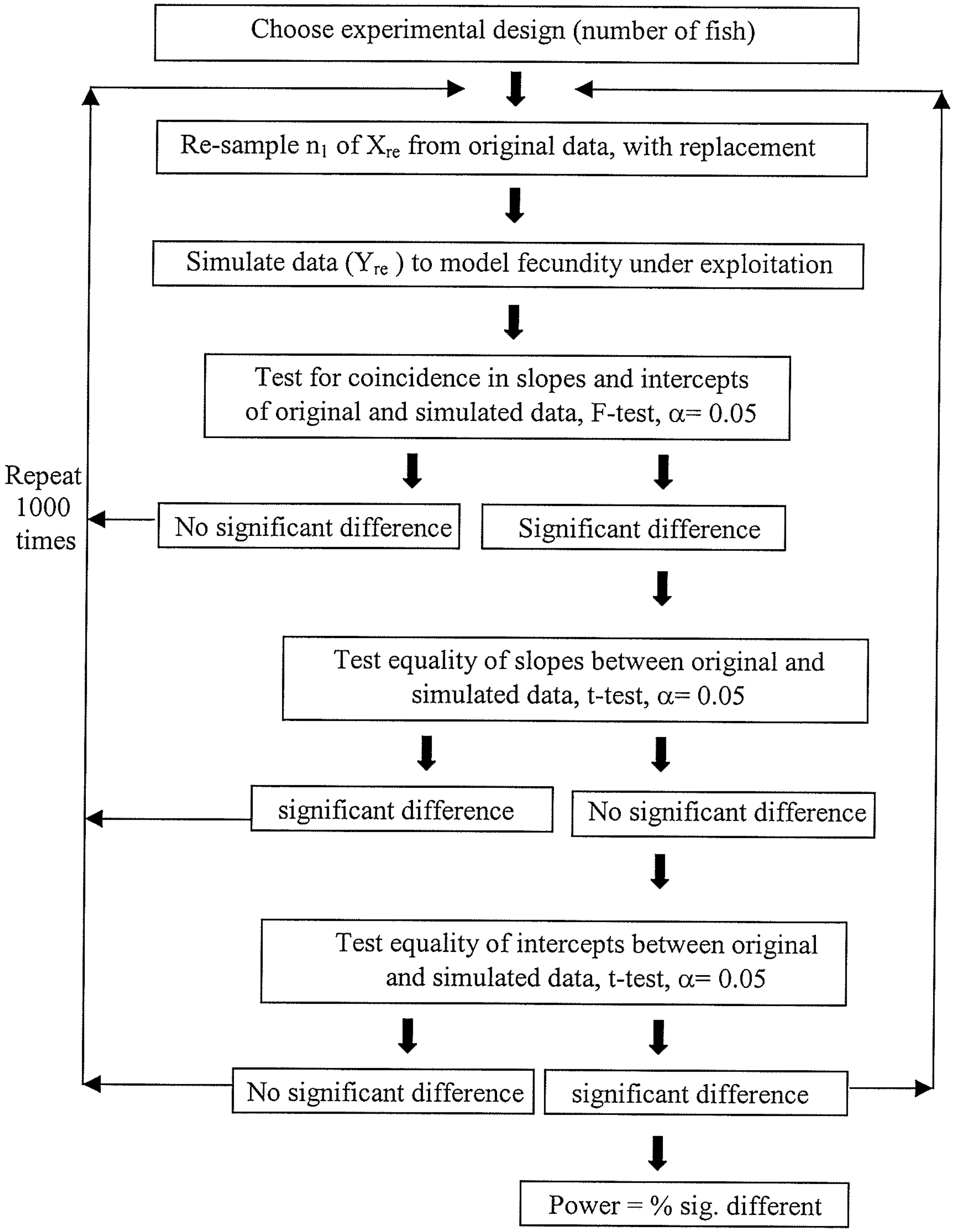
The specific experimental design for fecundity (Figure 3.4) included all of the above steps, plus additional procedures. After the monitoring design to be tested was selected (number of fish and amount of manipulation in simulated data) the original fecundity and fork length were regressed to determine the slope and intercept. New fork lengths (X_{re}) were then re-sampled from the original broad whitefish data. The re-sampled fork lengths were used to estimate simulated fecundity (Y_{re}) of each individual (n_{re}) from the regression of the original data. The simulated fecundity (Y_{re}) was then manipulated to model effects of exploitation and a normal random error term was added (Equation 3.2).

$$(3.2) \qquad Y_{re} = \beta_0' + \beta_1'(X_{re}) + \varepsilon + \text{manipulation}$$

Where β_0' and β_1' are estimated from the original data, X_{re} is a re-sampled fork length, and ε is a normal random variable with mean 0 and standard deviation estimated from the residuals of the regression of the original field data.

After generating Y_{re}, the simulated fecundities (Y_{sim}) were regressed on the re-sampled fork length (X_{re}). The original and simulated regression were then compared for equality of slopes and intercepts using an F-test for coincidence (Zar 1996). If the test for coincident regressions was significant the simulation continued to test for a change in

Figure 3.4. Flow diagram illustrating the steps in evaluating an experimental design that tests for a specific effect of exploitation on fecundity.

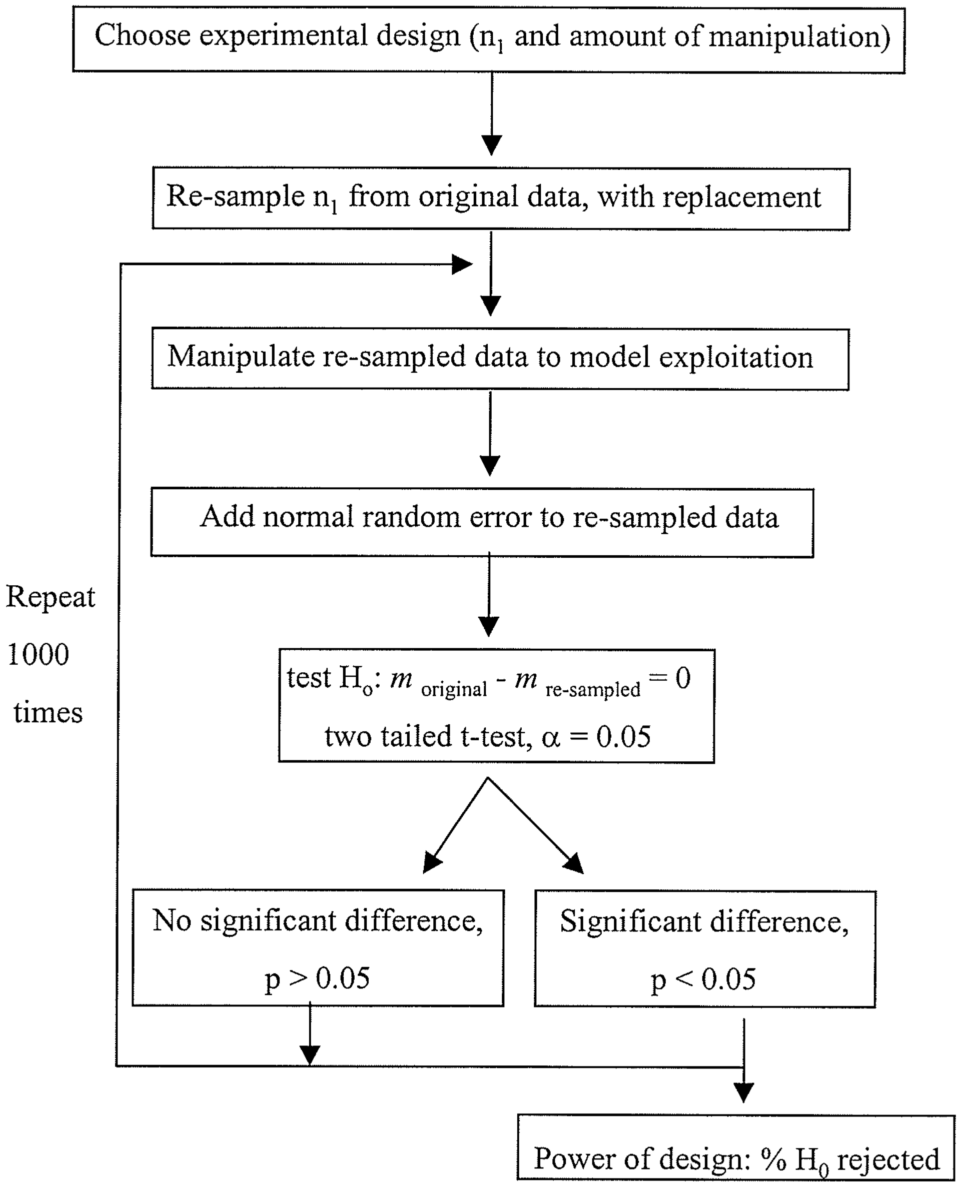

Choose experimental design (number of fish)
Re-sample n_1 of X_{re} from original data, with replacement
Simulate data (Y_{re}) to model fecundity under exploitation
Test for coincidence in slopes and intercepts of original and simulated data, F-test, α= 0.05
Repeat 1000 times
No significant difference
Significant difference
Test equality of slopes between original and simulated data, t-test, α= 0.05
significant difference
No significant difference
Test equality of intercepts between original and simulated data, t-test, α= 0.05
No significant difference
significant difference
Power = % sig. different

slope. If the slopes were not significantly different, the simulation again continued to test for differences in the intercepts of the original and simulated data. However, if the test for coincident regressions was not significant, or the test for equality of slopes was significant, that simulation was stopped. Each monitoring design was repeated 1000 times. Since I created and manipulated the simulated data, the null hypothesis of no change is false. The 'power' of that design was therefore calculated as the percent of times, out of 1000, a significant difference was found between the intercepts of the original and simulated data.

Testing the power of different monitoring designs in detecting changes in length-at-age of broad whitefish from the Peel River, was less complicated (Figure 3.5). The experimental design (number of fish and amount of manipulation in simulated data) was chosen and new fork length data was re-sampled with replacement from the original data. The re-sampled data was manipulated to model effects of exploitation and normal random error was added. A two-tailed t-test was then used to test for differences in mean length-at-age. As before, each monitoring design was repeated 1000 times, and the power of that design to detect changes in mean fork length was determined as the percent of times, out of 1000, a significant t-test was found between the original and simulated data. This procedure was repeated independently for broad whitefish aged 9, 11, and 13.

For graphical purposes, linear interpolation was used to determine the exact increase in fecundity and mean fork length that was required to produce statistical power of 30%, 50%, and 80%. This was performed for each design with the number of fish in

Figure 3.5. Flow diagram illustrating the steps in evaluating an experimental design that tests for a specific effect of exploitation on length-at-age.


Choose experimental design (n_1 and amount of manipulation)
Re-sample n_1 from original data, with replacement
Manipulate re-sampled data to model exploitation
Add normal random error to re-sampled data
Repeat 1000 times
test H_o: $m_{\text{original}} - m_{\text{re-sampled}} = 0$
two tailed t-test, $\alpha = 0.05$
No significant difference, $p > 0.05$
Significant difference, $p < 0.05$
Power of design: % H_0 rejected

each sample ranging from n = 10 to 150 fish. For length-at-age, this was performed independently for broad whitefish aged 9, 11, and 13. Also, for the three age classes in the length-at-age analyses, the estimates of the statistical power at each size of sample were averaged among the age classes. This was performed independently for power of 30%, 50%, and 80%.

Finally, I compared the results of my simulations on broad whitefish fecundity and length-at-age (averaged for age 9, 11, and 13 year old broad whitefish) to exploitation experiments in the literature. The data from the literature were converted to percent increase in the mean for each trait (i.e. percent increase in mean fecundity or percent increase in mean fork length). The percentage was then used to determine the same relative increase (# eggs or mm) in the trait for broad whitefish from the Peel River.

Though many papers discussed exploitation effects on fish fecundity and growth, few provided the detail of information that was required to compare with my work. Therefore, the results of my fecundity simulations were compared to Healey (1978) for lake whitefish (*Coregonus clupeaformis*) and lake trout (*Salvelinus namycush*) from 3 lakes in the Northwest Territories, and Baccante & Reid (1988) for walleye (*Stizostedion vitreum*) from 2 lakes in Ontario. My averaged length-at-age results were compared to results from Healey (1980) for lake whitefish (*Coregonus clupeaformis*) from 3 lakes in the Northwest Territories, Chevalier (1977) for walleye (*Stizostedion vitreum*) from 1 lake in Ontario, and Amundsen (1988) for a stunted population of the common whitefish (*Coregonus lavaretus* L. *s.l.*) from 1 lake in Norway.

Results

Broad whitefish life history traits

Fecundity was significantly correlated to fork length in general (Table 3.1), and at each monitoring station when examined separately (Table 3.2). This correlation was also observed when testing the influence of a supervisor at Basook Creek and Scraper Hill 1999. However, when testing the influence of a supervisor at Trail River, Cutoff, and Road River the correlation between fecundity and fork length was not significant (Table 3.3).

Year of sampling did not contribute significantly to explaining fecundity (Table 3.1). The presence of the supervisor significantly contributed to observed fecundity at Basook Creek (Table 3.2). When the influence of each camp was compared to all other camps independently at $\alpha = 0.05$, no single camp was found to contribute significantly to observed fecundity (Table 3.3). However, Cutoff was close to significant ($p = 0.056$), and the regression was visibly lower than all other camps (Figure 3.6). Therefore, fecundity data from Basook Creek and Cutoff were omitted from further analyses, and all other data were pooled.

No significant difference was found between male and female broad whitefish mean fork length, for any age (Table 3.4). Mean fork length of broad whitefish was also consistent in 1998 and 1999, for all ages (Table 3.5). Differences in mean fork length of broad whitefish caught during the presence and absence of the supervisor were not significant for any monitoring station, at any age (Table 3.6). Mean fork length of broad whitefish was not different between any of the stations, in any age class (Table 3.7).

Table 3.1. Results from dummy variable regression to test the contribution of ln fork length, year of sampling (1998 and 1999), and the interaction of ln fork length • year of sampling, to explaining fecundity. df is the hypothesis degrees of freedom. Residual degrees of freedom is 85 for all factors. The statistical power of the test is also given where the null hypothesis was not rejected.

Factor	df	F	p	Power
Ln fork length	1	33.170	0.000	N/A
Year	1	0.446	0.506	0.101
Ln fork length • year	1	0.413	0.522	0.097

Table 3.2. Results for dummy variable regression for testing the contribution of natural log (ln) fork length, individual camps, and the interaction of ln fork length • individual camps, in describing fecundity. df is the hypothesis degrees of freedom.

Camp	df	Ln fork length		Camp		Ln fork length• camp	
		F	p	F	p	F	p
Scraper Hill 1998	1	9.965	0.002	0.036	0.850	0.040	0.842
Trail R.	1	8.687	0.004	0.153	0.696	0.145	0.704
Cutoff	1	30.344	0.000	3.400	0.056	4.340	0.051
Scraper Hill 1999	1	48.404	0.000	0.072	0.788	0.064	0.801
Road R.	1	15.921	0.000	0.319	0.574	0.329	0.568

Table 3.3. Results from dummy variable regression to test the contribution of natural log (ln) fork length, the supervisor, and the interaction of ln fork length • the supervisor, in contributing to explain fecundity. df is the hypothesis degrees of freedom.

Camp	Ln fork length			Supervisor		Ln fork length • Supervisor	
	df	F	p	F	p	F	p
Basook	1	9.11	0.01	9.72	0.01	0.73	0.01
Scraper Hill 1998	1	N/A	N/A	N/A	N/A	N/A	N/A
Trail R.	1	0.41	0.53	0.15	0.70	0.15	0.70
Cutoff	1	0.47	0.50	0.14	0.71	0.14	0.71
Scraper Hill 1999	1	10.08	0.00	0.04	0.83	0.04	0.82
Road R.	1	4.90	0.06	0.00	0.95	0.00	0.95

Figure 3.6. Comparison of the regression of ln fecundity on ln fork length (mm) for broad whitefish sampled from monitoring stations at Basook Creek (BC), Scrapper Hill 1998 (SH 98), Trail River 1998 (TR), Cutoff 1999 (CO), Scrapper Hill 1999 (SH 99), and Road River 1999 (RR).

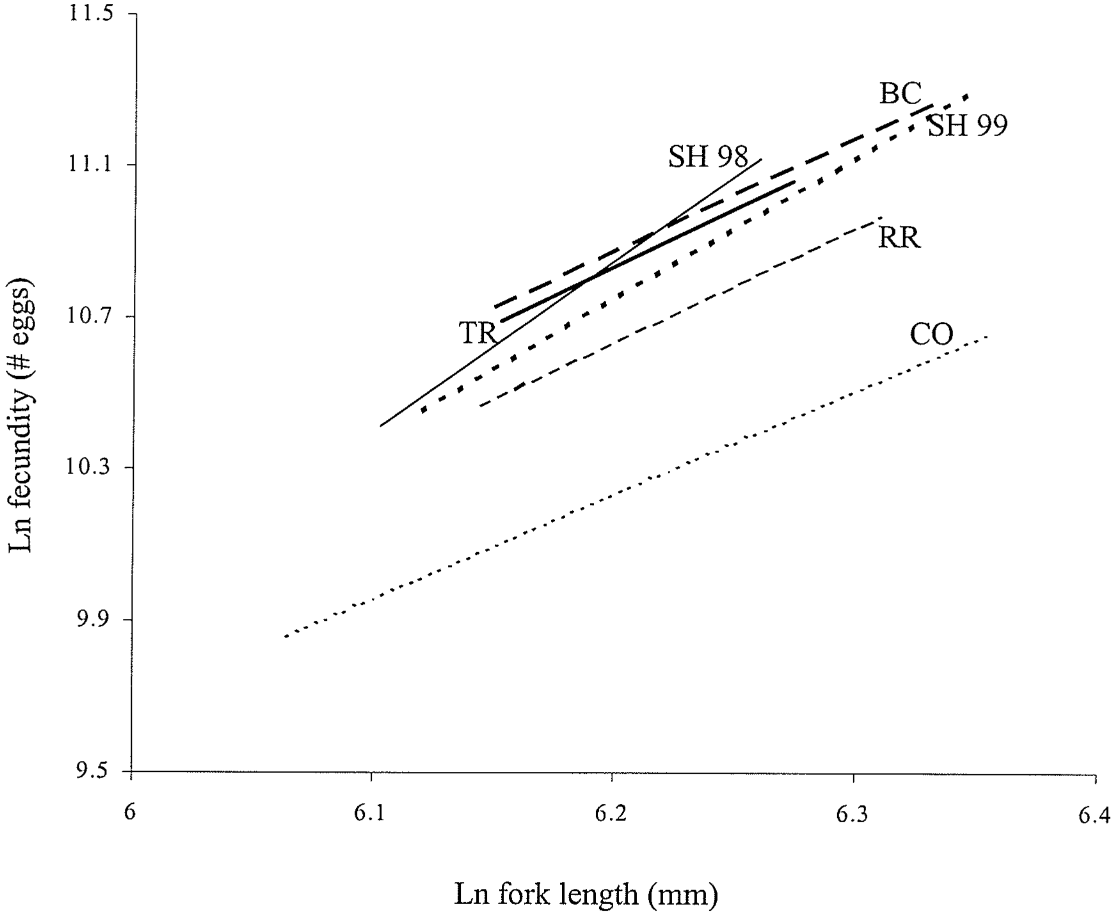

11.5
11.1
10.7
10.3
9.9
9.5
Ln fecundity (# eggs)
6
6.1
6.2
6.3
6.4
Ln fork length (mm)
BC
SH 99
SH 98
RR
TR
CO

Table 3.4. Results of two-tailed t-test ($\alpha = 0.05$) for the hypothesis that mean fork length (mm) is not significantly different between female and male broad whitefish from the Peel River. Broad whitefish aged 9, 11, and 13 are represented. Standard deviations of the mean fork lengths (mm) are given in brackets.

Age	Descriptives				Two-tailed students t-test	
	Female		Male			
	n	Mean length	n	Mean length	t	p
9	39	499 (33)	68	504 (31)	1.98	0.38
11	25	503 (29)	47	513 (38)	2.00	0.30
13	33	512 (38)	51	504 (38)	2.00	0.26

Table 3.5. Two tailed t-test for the hypothesis of equivalence of broad whitefish mean fork length (mm) between 1998 and 1999. Standard deviations for mean fork lengths (mm) are given in brackets. Results for broad whitefish age 9, 11, and 13 are represented.

Age	Descriptives				Two-tailed student's t-test	
	1998		1999			
	n	Mean length	n	Mean length	t	p
9	50	503 (26)	56	504 (34)	0.067	0.947
11	58	510 (23)	25	509 (22)	0.155	0.877
13	38	516 (34)	34	503 (42)	1.458	0.150

Table 3.6. Two-tailed t-test comparing the supervisors influence on mean fork length (mm) of broad whitefish caught at Basook Creek, Scraper Hill 1998, Trail River, Cutoff, Scraper Hill 1999, and Road River. Results are presented for broad whitefish age 9, 11, and 13. Standard deviations of the mean fork lengths (mm) are given in brackets.

Camp	Supervisor present		Supervisor not present		t	p
	n	Mean length	n	Mean length		
Age 9						
Basook Cr.	7	512(28)	20	507(30)	0.36	0.73
Scraper Hill 1998	0	-	21	-	-	-
Trail R.	0	-	2	-	-	-
Cutoff	9	496(32)	20	510(44)	0.96	0.34
Scraper Hill 1999	12	504(31)	9	500(21)	0.34	0.73
Road R.	2	509(26)	4	492(24)	0.73	0.53
Age 11						
Basook Cr.	8	485(88)	26	511(25)	1.37	0.17
Scraper Hill 1998	0	-	21	-	-	-
Trail R.	1	525(0)	3	495(18)	1.44	0.28
Cutoff	7	506(19)	3	524(12)	1.46	0.18
Scraper Hill 1999	6	505(30)	6	503(19)	0.09	0.92
Road R.	2	525(28)	1	530(0)	0.14	0.91
Age 13						
Basook Cr.	4	549(41)	12	523(27)	1.17	0.30
Scraper Hill 1998	0	-	19	-	-	-
Trail R.	3	-	0	-	-	-
Cutoff	3	502(53)	12	492(58)	0.27	0.80
Scraper Hill 1999	10	511(29)	2	498(11)	1.09	0.32
Road R.	2	502(14)	5	517(35)	0.82	0.44

Table 3.7. Two-tailed t-test comparing each individual camp's influence on mean fork length (mm) of broad whitefish caught at Basook Creek, Scraper Hill 1998, Trail River, Cutoff, Scraper Hill 1999, and Road River. Results are presented for broad whitefish age 9, 11, and 13. Standard deviations of the mean fork lengths (mm) are given in brackets.

Camp	Camp in question		All other camps		t	p
	n	Mean length	n	Mean length		
Age 9						
Basook Cr.	27	509(29)	79	502(31)	1.00	0.32
Scraper Hill 1998	21	496(22)	85	506(31)	1.68	0.10
Trail R.	2	515(7)	104	504(31)	1.94	0.20
Cutoff	29	506(40)	77	502(26)	0.42	0.68
Scraper Hill 1999	21	503(26)	85	504(31)	0.21	0.84
Road R.	6	497(24)	100	504(31)	0.65	0.54
Age 11						
Basook Cr.	34	505(48)	50	509(23)	0.42	0.67
Scraper Hill 1998	21	509(24)	63	507(38)	0.35	0.73
Trail R.	4	503(21)	80	508(35)	0.48	0.65
Cutoff	10	512(19)	74	507(36)	0.59	0.56
Scraper Hill 1999	12	505(24)	72	508(36)	0.45	0.66
Road R.	3	527(20)	81	507(35)	1.60	0.23
Age 13						
Basook Cr.	16	519(32)	56	504(38)	1.70	0.11
Scraper Hill 1998	19	501(30)	52	513(41)	1.35	0.18
Trail R.	3	538(31)	68	509(38)	1.50	0.25
Cutoff	15	494(55)	57	514(32)	1.35	0.19
Scraper Hill 1999	12	508(27)	59	510(40)	0.20	0.84
Road R.	7	513(30)	65	510(39)	0.27	0.79

Experimental monitoring designs

The monitoring designs for testing for changes in broad whitefish life history traits resulted in the usual relationship between power, effect size, and the number of fish in a sample. The statistical power increased when more fish were included in the sample and when larger changes in the traits were added (Figure 3.7).

The results of the monitoring designs for fecundity are summarized in Figure 3.8. The increase in fecundity required for 80% detection power ranged from ~ 5200 to ~ 13000 eggs (10% to 25% of mean fecundity) with samples including n = 150 to n = 10 fish, respectively. For the same number of fish, the increase in fecundity for 50% power ranged from ~ 4300 to ~ 9900 (~ 8% to ~ 19% of mean fecundity), and for 30% power ranged from ~ 3500 to ~ 7900 (~ 7% to ~ 15% of mean fecundity).

The results of my simulations for broad whitefish fecundity from the Peel River were compatible with the outcome of previous exploitation experiments on lake whitefish and lake trout from 3 lakes in the Northwest Territories (Healey 1978), and on walleye from 2 lakes in Ontario (Baccante & Reid 1988). Three out of 4 populations that were found to have significantly increased fecundity after exploitation were above my 80% power of detection line, given the number of fish in the sample. In 2 populations Healey (1978) did not find a significant increase in fecundity after exploitation, both of which were below my 80% power of detection line.

Figure 3.7. Statistical power of detecting simulated exploitation to broad whitefish with an addition of no eggs to 14000 eggs. Representatives are given for simulations containing 10, 50, 100, and 150 fish per sample.

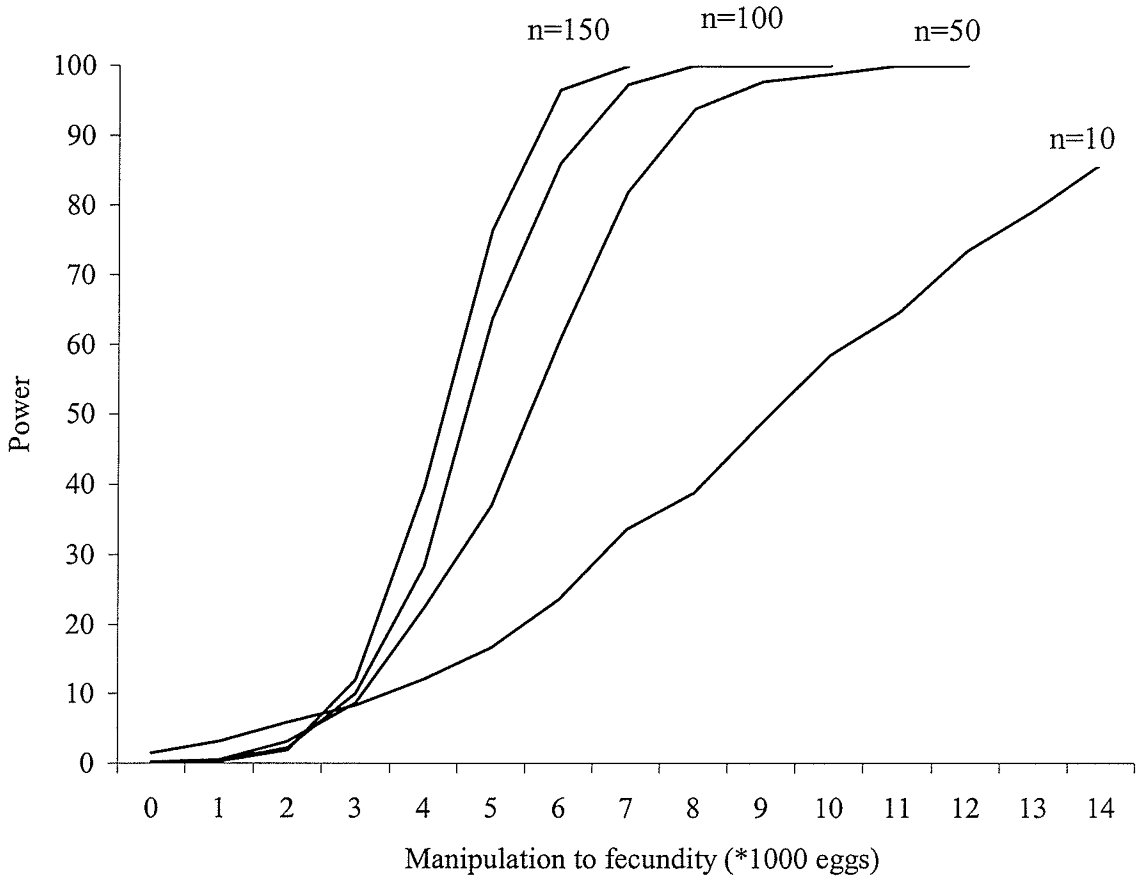
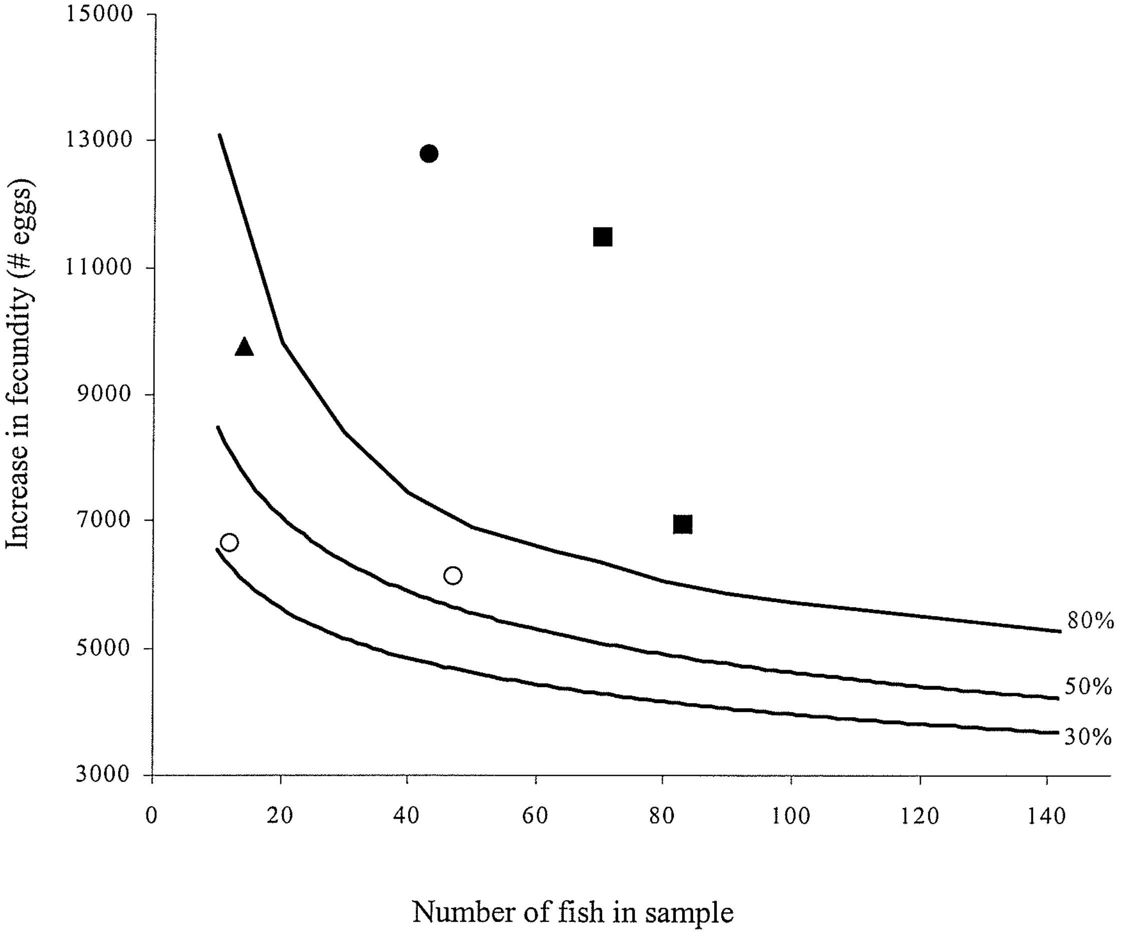

n=150
n=100
n=50
n=10
100
90
80
70
60
50
40
30
20
10
0
Power
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Manipulation to fecundity (*1000 eggs)

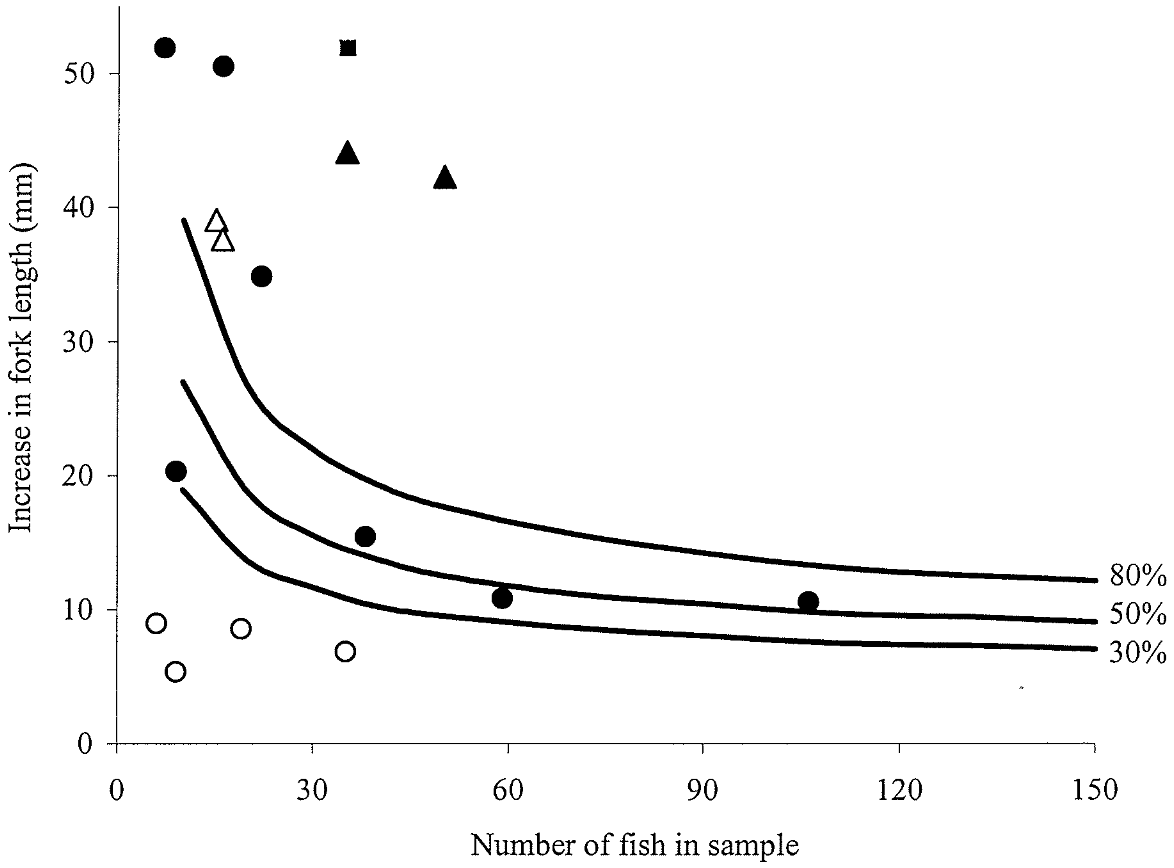
Figure 3.8. The amount of increase in broad whitefish fecundity (# eggs) required for detection with various numbers of fish included in the simulated data. Lines refer to my simulation results for ability to detect changes in fecundity with a power of 80%, 50%, and 30%. Data points refer to exploitation experiments from the literature. Circles are from Healey (1978) with lake whitefish, squares are from Baccante & Ried (1988) for walleye, the triangle is from Healey (1978) with lake trout. Filled data points indicate a statistically significant increase in fecundity after exploitation. Open data points indicate no significant difference was found in fecundity after exploitation.


15000
13000
11000
9000
7000
5000
3000
0
20
40
60
80
100
120
140
Increase in fecundity (# eggs)
Number of fish in sample
80%
50%
30%

The results of the monitoring design for broad whitefish length-at-age differed for each age group. Broad whitefish of age 13 required the greatest manipulation for 80% detection regardless of the number of fish in the sample. Broad whitefish of age 9 followed, and broad whitefish of age 11 required the least amount of manipulation for 80% detection. The averaged results of the monitoring designs for detecting changes in length-at-age are summarized in Figure 3.9. The increase in fork length required for 80% detection power ranged from ~ 12 to ~ 39 mm (~ 2% to ~ 8% of mean fork length) with samples including n = 150 to n = 10 fish, respectively. For the same number of fish, the increase in fork length for 50% power ranged from ~ 9 to ~ 27 mm (~ 2% to ~ 5% of mean fork length) and for 30% power ranged from ~ 7 to ~ 19 mm (~ 1% to ~ 4% of mean fork length).

The results of my simulations for broad whitefish length-at-age corresponded with the results of exploitation experiments from Healey (1980) for lake whitefish from 3 lakes in the Northwest Territories, Chevalier (1977) for walleye from 1 lake in Ontario, and Amundsen (1988) for a stunted population of the common whitefish from 1 lake in Norway. However, in 1 population Healey (1980) detected a significant increase in lake whitefish length-at-age which the results of my simulations predicted would have had about a 30% chance of being detected. In 2 populations, Amundsen (1988) found no significant increase in mean fork length of stunted common whitefish, even though the fish grew almost 4 cm larger after exploitation. My results estimated that this stunted whitefish population had over 80% probability of detecting the increase.

Figure 3.9. The relative amount of increase in broad whitefish fork length (mm) required for detection with the number of fish in a sample ranging from 10 to 150. Contour lines are my simulation results for ability to detect changes in fork length with a power of 80%, 50%, and 30%. Data points are exploitation experiments from the literature. Circles are from Healey (1980) with lake whitefish, squares are from Chevalier (1977) with walleye, and the triangles are from Amundsen (1988) with stunted whitefish. Filled data points indicate a statistically significant increase in fork length after exploitation. Open data points indicate no significant difference was found in fork length after exploitation.


Increase in fork length (mm)
0
10
20
30
40
50
Number of fish in sample
0
30
60
90
120
150
80%
50%
30%

Discussion

The predictions of my simulations for broad whitefish length-at-age and fecundity after exploitation were consistent with the observed outcome of most exploitation experiments for a variety of lacustrine species in the literature. In most cases where non-significant results were found, the data were below my simulated results for 80% power of detection. However, there were three cases in my comparison of length-at-age where my results were not able to predict the results of experiments from the literature. This may be attributed to many possible causes. It is plausible that the disagreements demonstrate a difference between the species. Different species or populations may have different relative plasticity for exploitation effects on length-at-age. Also, the data may not have the same pattern of variability that is assumed by this comparison. This difference in results may also be due to the comparison of anadromous (current study) and lacustrine (all other studies) populations. Instead, given these differences, it is interesting that the powers simulated correspond well with the literature results.

While many authors have investigated increases in growth and fecundity after experimental exploitation in fish populations (Bell et al. 1977, Chevalier 1977, Healey 1978, Healey 1980, Baccante & Reid 1988, Snyder & Dingle 1989), most studies are performed for lake dwelling populations of fish. Some studies on non-lake-dwelling populations have not found increases in growth and fecundity after exploitation. Knutsen & Ward (1999) experimentally exploited northern pikeminnow (*Ptychocheilus oregonensis*) in the lower Columbia River and Snake River. The experiment ran from 1991 to 1996 and the average annual rate of removal was 12.1% of the initial population.

They reported that even though catch rate decreased and mortality rate increased, fecundity and growth did not increase. They suggested that the relationship between fecundity and abundance was not density dependent. However, the statistical power was not reported. Similarly, Gyselman & Broughton (1991) studied anadromous arctic charr (*Salvelinus alpinus*) from Nauyuk Lake that were exploited from 1974-1981. Again, no increase in fecundity or growth was observed, nor was statistical power reported.

In lake populations, fecundity and growth may be limited to food availability and the density of the population. Gyselman (1997) suggested that in anadromous populations, feeding often occurs in the marine environment where food is not a limiting factor. Therefore, growth might not be a good indicator for detecting effects of exploitation in anadromous broad whitefish. Conversely, Healey & Heard (1984) found that the level of anadromy did not contribute significantly to variation in fecundity of chinook salmon (*Oncorhynchus tshauytscha*). Silliman et al. (1958) found that there was an optimal rate of exploitation on laboratory reared guppies (*Lebistes reticulatus*) that enabled the population to adapt with increased survival and growth rates.

When investigating changes in fecundity one must acknowledge that an increase in fecundity may not represent an increase in reproductive effort. For example, a fish may have more eggs and therefore higher fecundity, but egg mass may be smaller. In this situation, the overall reproductive effort has not increased, but simply altered its form.

My simulations were based on exploitation experiments from the literature, which only addressed an increase in fecundity as the number of eggs. Likewise, my results will apply to broad whitefish in the Peel River only if they compensate for effects of exploitation via increasing total reproductive effort and not just fecundity (i.e. the eggs are of equal mass, but more plentiful). To address this, measurements should be made each year to determine if egg mass (diameter or weight) remains constant though time.

Understanding the life history of the species being fished is important to fisheries management. Likewise, proper experimental design and power analysis are also important to prevent misinformed decisions. Many authors have reviewed the statistical power of previously published research and found that decisions were being made based on the inability to reject the null hypothesis (de la Mare 1984, Peterman 1989). Note that contrary to common practice, the inability to reject the null hypothesis does not infer that the null hypothesis is true (Peterman 1990). The purpose of the Peel River project was to prepare for changes in the fish populations due to exploitation or potential developments near the Peel River. In the case of development, the statistical power of the monitoring program becomes crucial. Often when development occurs in Aboriginal Settlement Areas (or elsewhere), an agreement is made for some level of compensation due to effects of the development. These may include rebuilding habitat for the population affected or financial compensation for the community. If the power of the test is not high, one may mistakenly conclude that no adverse effects have occurred and therefore no compensation would be paid (i.e. make a Type II error of hypothesis testing). The negative repercussions of this are obvious and managers should therefore design management actions so that true responses can be detected with high probability (McAllister & Peterman 1992).

The Peel River fish-monitoring program enabled the Gwich'in community to address their concerns about the fish populations and participate in all decisions for the field study. The project began as a co-management study, but has since continued independently by the Gwich'in in 2000.

Many logistic constraints were encountered during the implementation of the monitoring project, but I will mention those with the greatest potential impact on the data. Uncertain environmental conditions limited the amount of time each monitor could fish. For example, one net was lost in running ice slush and poor ice conditions restricted safe travel and work on the ice. Logistic hurdles also included limited communication between monitors and supervisors. Also, distributing equipment was hampered by lack of roads and limited travel by boat, snow machine, or helicopter. In spite of these difficulties, the Peel River project has (and will continue to) collect valuable information that can be compared to fish population data collected in the future.

My simulations to determine the power of the Peel River monitoring program were guided by effects of exploitation. But potential development on or near the Peel River is not limited to exploitation. Therefore it should be noted that my simulations, while guided by exploitation, were simple increases in fecundity and length-at-age. Due to this general approach my results can be applied to other areas in which an increase in the life history traits may be expected. For example, Reist (1994) hypothesized the possible increase in growth resulting from global warming and the associated increases in water temperature.

Recommendation to resource managers for the Peel River broad whitefish

With the issues of life history in mind, the results of my evaluation of the Peel River fish-monitoring program suggest that the Gwich'in resource managers continue to investigate both fecundity and length-at-age trends, but with informed caution. The results of my simulations suggest that approximately 50 fish should be sampled for fecundity analyses. I recognize that the financial cost of obtaining fecundity information may be a limiting factor in the project, and 50 fish is often more than is normally collected (Bell et al. 1977, Healey 1978, Healey & Heard 1984, Snyder & Dingle 1989). For the present study, 30 pair of gonads from broad whitefish were collected in 1998 and 59 in 1999, 30 of which were purchased from an Aboriginal fisherman from the area. But according to the results of my simulations for broad whitefish from the Peel River, the benefit of increasing the number of samples collected improves the statistical power greatly until the sample reaches approximately 50 fish. In the same manner, the collection of more than 50 fish would provide minimal improvement in power. Making a recommendation for monitoring length-at-age is slightly more complex. One can not plan to catch a certain number of specific age classes of broad whitefish. However, the results of my simulations can be used post-hoc to establish the strength of the observed results from the broad whitefish monitoring program in the Peel River. This will provide the managers with an idea of how reliable the observed results are before acting upon them.

To summarize, this research has provided information on the Peel River fish-monitoring program which can be directly used by Resource Managers in the Gwich'in

Settlement Area. But the benefits of this research expand to illustrate the importance of proper experimental design and statistical power in fish-monitoring programs in general.

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GENERAL SUMMARY

The Peel River, Arctic Red River, and Travaillant Lake populations of broad whitefish have been genetically differentiated by Reist (1997), but no comparison of whether their life history traits reflect that genetic distinctness is yet published. I have provided information on natural variation in broad whitefish length-at-age, age-at-maturity, reproductive investment (fecundity and egg size), and the age when growth slowed. I further defined differences in these traits between anadromous broad whitefish populations in the Peel River and Arctic Red River and broad whitefish caught in Travaillant Lake.

I also provided the Gwich'in community with information on the ability of the Peel River fish-monitoring program to detect changes in broad whitefish fecundity and length-at-age. I provided an explanation of exploitation effects on the life history traits and estimated the sample effort required for detecting changes in fecundity and length-at-age that could be expected with exploitation. A model of this type can be modified to assess other arctic broad whitefish populations, such as those in the Arctic Red River and Mackenzie River.

This research will enhance the scientific knowledge of broad whitefish in the lower Mackenzie Delta and provide practical information on monitoring techniques useful to the Gwich'in and surrounding communities. Further research should involve elaboration on the examination of life history traits for broad whitefish in the Mackenzie Delta, clarification on the life history of the Travaillant Lake population, and ensuring that fish-monitoring programs are designed with adequate statistical power.

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APPENDIX I. Biological data for broad whitefish (BDWT) caught in the Peel River in 1998 and 1999 as part of the Peel River fish-monitoring program. S# = sample number, FL = fork length (mm), WT = round weight (g), GW = gonad weight (g).

S#	DATE	Camp	FL (mm)	WT (g)	sex	maturity	GW (g)	AGE (yr)	Fecundity
1	25-Sep-98	Basook Creek	270	1600	M	7	16	11	
2	25-Sep-98	Basook Creek	530	2200	M	7	16	13	
3	24-Sep-98	Basook Creek	565	3050	M	8	32	13	
4	24-Sep-98	Basook Creek	504	1800	F	3	310	13	
5	24-Sep-98	Basook Creek	493	2150	M	7	24	9	
6	24-Sep-98	Basook Creek	545	2350	M	7	22	11	
7	24-Sep-98	Basook Creek	490	1950	M	7	20	10	
8	24-Sep-98	Basook Creek	485	1750	F	4	37	7	
9	24-Sep-98	Basook Creek	490	1800	M	6	17	10	
10	25-Sep-98	Basook Creek	512	2500	F	3	675	11	
11	25-Sep-98	Basook Creek	515	2500	M	7	46	8	
12	25-Sep-98	Basook Creek	490	1800	F	3	300	10	
13	25-Sep-98	Basook Creek	535	2650	F	4	600	15	
14	25-Sep-98	Basook Creek	490	1700	M	5	14	9	
15	25-Sep-98	Basook Creek	515	2350	M	6	26	11	
16	25-Sep-98	Basook Creek	500	1750	F	3	350	14	
17	25-Sep-98	Basook Creek	522	2250	F	2	400	12	
18	25-Sep-98	Basook Creek	490	1750	M	7	16	10	
19	25-Sep-98	Basook Creek	490	1650	M	7	16	12	
20	28-Sep-98	Basook Creek	573	3600	F	4	1000	11	
21	30-Sep-98	Basook Creek	506	2050	F	4	500	11	61443
22	30-Sep-98	Basook Creek	493	1600	F	4	200	12	
23	30-Sep-98	Basook Creek	500	1750	M	7	17	10	
24	02-Oct-98	Basook Creek	580	1600	M	7	14	13	
25	05-Oct-98	Basook Creek	487	1650	M	8	18	7	
26	07-Oct-98	Basook Creek	504	1850	M	7	29	11	
27	07-Oct-98	Basook Creek	557	3150	F	4	271	9	95912
28	15-Oct-98	Basook Creek	527	2580	F	3	310	12	
29	15-Oct-98	Basook Creek	477	1700	F	3	320	12	
30	15-Oct-98	Basook Creek	558	2940	F	3	414	12	
31	15-Oct-98	Basook Creek	523	2300	M	2	27	11	
32	15-Oct-98	Basook Creek	556	3090	F	3	343	15	80045
33	15-Oct-98	Basook Creek	507	2050	M	9	24	12	
34	15-Oct-98	Basook Creek	515	2010	M	8	33	10	
35	15-Oct-98	Basook Creek	530	2400	M	9	34	12	
36	15-Oct-98	Basook Creek	525	2200	M	9	29	15	
37	15-Oct-98	Basook Creek	530	1950	M	9	24	12	
38	15-Oct-98	Basook Creek	483	1400	M	9	16	12	
39	15-Oct-98	Basook Creek	499	2000	M	7	26	9	
40	15-Oct-98	Basook Creek	515	2200	M	7	34	11	
41	15-Oct-98	Basook Creek	523	1780	M	9	27	8	

42	15-Oct-98	Basook Creek	662	3050	M	7	50		
43	15-Oct-98	Basook Creek	535	2250	M	7	37		
44	15-Oct-98	Basook Creek	549	2340	M	9	39	9	
45	15-Oct-98	Basook Creek	880	2850	M	9	27	14	
46	15-Oct-98	Basook Creek	469	1680	F	3	410	10	41102
47	15-Oct-98	Basook Creek	500	2200	M	9	26	11	
48	15-Oct-98	Basook Creek	460	1500	M	9	20	7	
49	15-Oct-98	Basook Creek	506	1970	M	9	27	12	
50	15-Oct-98	Basook Creek	544	2540	M	8	33	12	
51	15-Oct-98	Basook Creek	505	2120	F	4	439	8	49969
52	15-Oct-98	Basook Creek	555	2250	M	9	31	12	
53	15-Oct-98	Basook Creek	540	2590	M	9	33	12	
54	15-Oct-98	Basook Creek	497	1940	M	8	26	9	
55	15-Oct-98	Basook Creek	598	3350	M	9	44	13	
56	15-Oct-98	Basook Creek	467	1550	M	9	19	8	
57	15-Oct-98	Basook Creek	600	3200	M	9	74	18	
58	15-Oct-98	Basook Creek	500	1850	M	9	13	9	
59	15-Oct-98	Basook Creek	460	1100	M	9	10	7	
60	15-Oct-98	Basook Creek	515	2300	M	7	29	10	
61	18-Oct-98	Basook Creek	507	2400	F	4	163	9	70058
62	18-Oct-98	Basook Creek	535	2460	M	9	27	9	
63	18-Oct-98	Basook Creek	543	2670	M	9	14	12	
64	18-Oct-98	Basook Creek	508	2040	M	9	21	11	
65	18-Oct-98	Basook Creek	500	1990	M	9	29	14	
66	18-Oct-98	Basook Creek	535	2400	M	9	36	15	
67	18-Oct-98	Basook Creek	494	1920	M	8	30	11	
68	18-Oct-98	Basook Creek	493	1660	M	7	19	11	
69	18-Oct-98	Basook Creek	462	1520	F	4	349	11	
70	18-Oct-98	Basook Creek	488	1790	M	7	23	7	
71	18-Oct-98	Basook Creek	543	1950	M	9	23	16	
72	18-Oct-98	Basook Creek	490	1640	M	7	14	14	
73	18-Oct-98	Basook Creek	509	1990	M	8	26	11	
74	18-Oct-98	Basook Creek	555	2290	M	9	24	12	
75	18-Oct-98	Basook Creek	472	1550	M	9	14	16	
76	18-Oct-98	Basook Creek	539	2950	M	9	31	13	
77	18-Oct-98	Basook Creek	480	1750	M	9	21	12	
78	18-Oct-98	Basook Creek	507	1970	M	9	24	8	
79	18-Oct-98	Basook Creek	497	1950	M	9	23	8	
80	18-Oct-98	Basook Creek	535	2500	M	9	39	9	
81	18-Oct-98	Basook Creek	485	1630	M	9	19	9	
82	18-Oct-98	Basook Creek	487	1950	M	7	29	7	
83	18-Oct-98	Basook Creek	502	2020	M	9	31	8	
84	19-Oct-98	Basook Creek	597	3250	M	9	54	12	
85	19-Oct-98	Basook Creek	523	2250	M	9	21	8	
86	19-Oct-98	Basook Creek	529	2500	F	2	163	12	74698
87	19-Oct-98	Basook Creek	512	1700	M	7	21	11	
88	19-Oct-98	Basook Creek	530	2350	M	7	30	8	
89	19-Oct-98	Basook Creek	510	1920	M	9	6	8	
90	19-Oct-98	Basook Creek	520	2050	M	9	24	8	

91	19-Oct-98	Basook Creek	510	2060	M	9	26	10	
92	19-Oct-98	Basook Creek	473	1600	M	9	17	7	
93	19-Oct-98	Basook Creek	523	2400	M	7	41	13	
94	19-Oct-98	Basook Creek	536	2430	M	9	39	11	
95	19-Oct-98	Basook Creek	520	2020	M	9	27	8	
96	19-Oct-98	Basook Creek	518	1750	M	9	20	12	
97	19-Oct-98	Basook Creek	513	1920	M	9	19	11	
98	19-Oct-98	Basook Creek	512	1870	M	9	14	15	
99	19-Oct-98	Basook Creek	670	3100	M	9	41	20	
100	19-Oct-98	Basook Creek	472	1340	M	9	14	16	
101	19-Oct-98	Basook Creek	485	1090	M	9	23	7	
102	19-Oct-98	Basook Creek	542	2540	M	9	36	13	
103	19-Oct-98	Basook Creek	508	2390	M	9	36	11	
104	19-Oct-98	Basook Creek	486	1050	M	9	23	11	
105	19-Oct-98	Basook Creek	518	2150	M	9	36	7	
106	21-Oct-98	Basook Creek	504	2080	F	4	153	13	
107	21-Oct-98	Basook Creek	535	2590	F	4	106	12	
108	21-Oct-98	Basook Creek	738	3100	M	9	47	21	
109	21-Oct-98	Basook Creek	577	2140	M	9	27	10	
110	21-Oct-98	Basook Creek	506	2340	M	9	37	8	
111	21-Oct-98	Basook Creek	515	1990	F	4	381	10	
112	21-Oct-98	Basook Creek	540	2540	M	9	43	12	
113	21-Oct-98	Basook Creek	512	2230	M	9	37	9	
114	21-Oct-98	Basook Creek	518	2170	M	9	23	13	
115	21-Oct-98	Basook Creek	480	1350	M	9	16	11	
116	21-Oct-98	Basook Creek	549	2640	M	7	37	13	
117	21-Oct-98	Basook Creek	502	1640	M	9	26	18	
118	21-Oct-98	Basook Creek	537	2850	F	4	211	10	74189
119	21-Oct-98	Basook Creek	493	1880	M	9	26	10	
120	21-Oct-98	Basook Creek	507	2110	M	9	37	7	
121	21-Oct-98	Basook Creek	628	3400	M	10	10	21	
122	21-Oct-98	Basook Creek	530	2490	M	9	33	12	
123	21-Oct-98	Basook Creek	488	1920	F	4	54	16	
124	21-Oct-98	Basook Creek	533	2350	M	9	39	17	
125	21-Oct-98	Basook Creek	485	1780	M	9	23	8	
126	21-Oct-98	Basook Creek	490	1800	M	9	24	11	
127	21-Oct-98	Basook Creek	482	1640	M	7	29	13	
128	21-Oct-98	Basook Creek	480	1950	M	7	31	9	
129	21-Oct-98	Basook Creek	461	1560	M	9	24	9	
130	21-Oct-98	Basook Creek	482	1450	M	9	17	12	
131	21-Oct-98	Basook Creek	469	1370	M	7	24		
132	21-Oct-98	Basook Creek	503	1760	M	9	27	12	
133	23-Oct-98	Basook Creek	546	2290	M	9	31	12	
134	23-Oct-98	Basook Creek	488	1600	M	9	17	15	
135	23-Oct-98	Basook Creek	491	1750	M	9	24	11	
136	23-Oct-98	Basook Creek	493	1870	M	9	19	7	
137	23-Oct-98	Basook Creek	585	2690	M	9	41	9	
138	23-Oct-98	Basook Creek	484	1690	M	9	26	8	
139	23-Oct-98	Basook Creek	520	2520	M	9	37	10	

140	23-Oct-98	Basook Creek	517	2020	M	9	30	18	
141	23-Oct-98	Basook Creek	493	1680	M	9	20	13	
142	23-Oct-98	Basook Creek	476	1420	M	7	20	20	
143	23-Oct-98	Basook Creek	563	3100	F	4	203	11	70227
144	23-Oct-98	Basook Creek	495	1360	F	4	244	9	
145	23-Oct-98	Basook Creek	504	2180	M	9	29	11	
146	23-Oct-98	Basook Creek	498	2000	M	9	27	9	
147	23-Oct-98	Basook Creek	570	2920	M	9	33	12	
148	23-Oct-98	Basook Creek	520	2180	M	9	33	9	
149	23-Oct-98	Basook Creek	533	2930	M	9	36	8	
150	23-Oct-98	Basook Creek	492	1840	M	9	36	11	
151	23-Oct-98	Basook Creek	506	1760	F	4	161	12	
152	23-Oct-98	Basook Creek	462	1400	M	9	21	9	
153	23-Oct-98	Basook Creek	489	1800	M	7	31	8	
154	23-Oct-98	Basook Creek	503	1680	M	9	26		
155	23-Oct-98	Basook Creek	514	2900	M	9	36	12	
156	23-Oct-98	Basook Creek	550	2380	M	9	51	8	
157	26-Oct-98	Basook Creek	534	2360	F	4	259	10	
158	26-Oct-98	Basook Creek	527	2230	M	9	31	11	
159	26-Oct-98	Basook Creek	522	2220	M	9	20	8	
160	26-Oct-98	Basook Creek	506	2560	F	4	174	11	
161	26-Oct-98	Basook Creek	530	2450	M	9	34	12	
162	26-Oct-98	Basook Creek	503	2010	M	9	30	9	
163	26-Oct-98	Basook Creek	515	2510	F	4	176	13	69025
164	26-Oct-98	Basook Creek	518	2420	M	9	51	10	
165	26-Oct-98	Basook Creek	536	2400	F	4	157	14	
166	26-Oct-98	Basook Creek	516	2090	M	9	21	10	
167	26-Oct-98	Basook Creek	539	2370	F	4	54	11	
168	26-Oct-98	Basook Creek	545	2490	M	9	34	9	
169	26-Oct-98	Basook Creek	493	2150	M	7	26	10	
170	26-Oct-98	Basook Creek	485	1720	M	9	23	9	
171	26-Oct-98	Basook Creek	573	1920	M	7	26	12	
172	26-Oct-98	Basook Creek	515	1980	M	9	14	9	
173	26-Oct-98	Basook Creek	553	2490	M	9	33	19	
174	26-Oct-98	Basook Creek	535	2440	M	9	22	11	
175	26-Oct-98	Basook Creek	468	1300	M	9	13	12	
176	26-Oct-98	Basook Creek	505	2800	M	9	23	9	
177	26-Oct-98	Basook Creek	483	1820	M	7	21	12	
178	26-Oct-98	Basook Creek	512	2080	M	9	27	9	
179	26-Oct-98	Basook Creek	472	1430	M	9	10	12	
180	26-Oct-98	Basook Creek	504	1920	M	9	31	8	
181	26-Oct-98	Basook Creek	479	1820	M	9	29	12	
182	26-Oct-98	Basook Creek	537	2600	M	9	49	9	
183	26-Oct-98	Basook Creek	464	1600	M	9	16	7	
184	26-Oct-98	Basook Creek	438	1230	F	4	41	17	
185	28-Oct-98	Basook Creek	506	2300	M	7	26	14	
186	28-Oct-98	Basook Creek	460	1350	F	4	164	12	
187	28-Oct-98	Basook Creek	495	1930	M	9	16	12	
188	28-Oct-98	Basook Creek	502	1950	M	9	27	11	

189	28-Oct-98	Basook Creek	503	1930	M	9	16	13	
190	28-Oct-98	Basook Creek	512	2020	M	9	31	8	
191	28-Oct-98	Basook Creek	545	2600	F	4	81	11	54781
192	28-Oct-98	Basook Creek	578	2840	M	9	36	20	
193	28-Oct-98	Basook Creek	518	2330	F	4	17	8	
194	28-Oct-98	Basook Creek	388	960	M	9	14	15	
195	28-Oct-98	Basook Creek	512	1720	F	9	133	11	
196	28-Oct-98	Basook Creek	482	1730	M	7	16	14	
197	28-Oct-98	Basook Creek	573	2400	M	9	24	12	
198	28-Oct-98	Basook Creek	469	1450	M	9	14	8	
199	28-Oct-98	Basook Creek	476	1720	M	9	23	9	
200	30-Oct-98	Basook Creek	533	2700	M	9	29	8	
201	30-Oct-98	Basook Creek	533	2720	F	4	129	13	54704
202	30-Oct-98	Basook Creek	488	1700	F	4	373	16	
203	30-Oct-98	Basook Creek	523	1890	M	9	27	12	
204	30-Oct-98	Basook Creek	516	2350	F	4	99	11	
205	30-Oct-98	Basook Creek	540	2450	M	9	29	12	
206	30-Oct-98	Basook Creek	508	2230	M	9	39	7	
207	30-Oct-98	Basook Creek	444	1330	F	4	304	10	
208	30-Oct-98	Basook Creek	525	2060	M	9	20	14	
209	30-Oct-98	Basook Creek	470	1600	F	4	406	15	
210	31-Oct-98	Basook Creek	480	1600	F	4	36	8	
211	31-Oct-98	Basook Creek	607	2890	M	9	21	17	
212	31-Oct-98	Basook Creek	475	1500	M	9	16	10	
213	31-Oct-98	Basook Creek	487	1870	M	9	26	8	
214	31-Oct-98	Basook Creek	546	3000	F	4	199	14	68288
215	22-Sep-98	Scraper Hill 1998	510	1850	M	7	23	8	
216	22-Sep-98	Scraper Hill 1998	480	1150	M	7	18	13	
217	22-Sep-98	Scraper Hill 1998	490	1750	M	7	29	13	
218	23-Sep-98	Scraper Hill 1998	439	1100	F	2	50		
219	23-Sep-98	Scraper Hill 1998	520	1950	M	7	20		
220	23-Sep-98	Scraper Hill 1998	470	1550	F	2	100		
221	26-Sep-98	Scraper Hill 1998	510	2500	F	3	475	8	61418
222	26-Sep-98	Scraper Hill 1998	474	1650	F	3	450	7	
223	27-Sep-98	Scraper Hill 1998	505	2500	M	7	24	14	
224	27-Sep-98	Scraper Hill 1998	447	1400	F	3	264	10	38008
225	27-Sep-98	Scraper Hill 1998	529	2230	F	3	520	21	
226	30-Sep-98	Scraper Hill 1998	515	2100	M	7	40	11	
227	30-Sep-98	Scraper Hill 1998	495	1850	M	7	20	7	
228	01-Oct-98	Scraper Hill 1998	523	2250	F	3	500	12	70459
229	07-Oct-98	Scraper Hill 1998	510	2000	M	7	28	12	
230	12-Oct-98	Scraper Hill 1998	513	1900	M	9	30	17	
231	12-Oct-98	Scraper Hill 1998	501	2200	M	9	30	12	
232	13-Oct-98	Scraper Hill 1998	480	1750	M	9	26	7	
233	13-Oct-98	Scraper Hill 1998	500	1950	M	9	31	8	
234	14-Oct-98	Scraper Hill 1998	495	1800	M	9	21	13	
235	19-Oct-98	Scraper Hill 1998	500	2000	M	9	31	13	
236	19-Oct-98	Scraper Hill 1998	562	2650	M	9	30	14	
237	19-Oct-98	Scraper Hill 1998	460	1250	M	10	10	15	

238	19-Oct-98	Scraper Hill 1998	492	2000	M	9	27	9	
239	19-Oct-98	Scraper Hill 1998	460	1400	M	10	16	12	
240	19-Oct-98	Scraper Hill 1998	456	1500	M	10	11	8	
241	19-Oct-98	Scraper Hill 1998	500	1800	M	9	26	11	
242	19-Oct-98	Scraper Hill 1998	493	1800	M	9	36	20	
243	19-Oct-98	Scraper Hill 1998	499	1900	M	10	31	10	
244	19-Oct-98	Scraper Hill 1998	520	2000	M	10	30	13	
245	19-Oct-98	Scraper Hill 1998	520	2150	M	9	23	13	
246	19-Oct-98	Scraper Hill 1998	500	2000	M	9	36	12	
247	19-Oct-98	Scraper Hill 1998	528	2100	M	10	20	10	
248	19-Oct-98	Scraper Hill 1998	500	1800	M	10	19	14	
249	20-Oct-98	Scraper Hill 1998	495	1600	M	9	16	9	
250	20-Oct-98	Scraper Hill 1998	520	2100	M	9	30	10	
251	20-Oct-98	Scraper Hill 1998	475	1500	M	10	21	13	
252	20-Oct-98	Scraper Hill 1998	474	1600	M	9	19	9	
253	20-Oct-98	Scraper Hill 1998	475	1550	M	9	26	20	
254	20-Oct-98	Scraper Hill 1998	515	2000	M	9	33	8	
255	20-Oct-98	Scraper Hill 1998	505	1800	M	10	20	11	
256	21-Oct-98	Scraper Hill 1998	480	1750	M	9	27		
257	21-Oct-98	Scraper Hill 1998	504	1800	M	9	26		
258	21-Oct-98	Scraper Hill 1998	470	1400	M	10	16	14	
259	21-Oct-98	Scraper Hill 1998	478	1550	M	9	24	14	
260	21-Oct-98	Scraper Hill 1998	509	1750	M	9	30	13	
261	21-Oct-98	Scraper Hill 1998	505	2100	M	9	37	8	
262	21-Oct-98	Scraper Hill 1998	520	2400	M	9	40	11	
263	21-Oct-98	Scraper Hill 1998	470	1300	F	4	253	10	34361
264	25-Oct-98	Scraper Hill 1998	524	1950	M	9	17	10	
265	25-Oct-98	Scraper Hill 1998	453	1400	M	9	16	8	
266	25-Oct-98	Scraper Hill 1998	506	1900	M	9	33	18	
267	25-Oct-98	Scraper Hill 1998	500	1900	M	9	33	9	
268	25-Oct-98	Scraper Hill 1998	458	1600	M	9	29	9	
269	25-Oct-98	Scraper Hill 1998	520	2100	M	9	30	11	
270	25-Oct-98	Scraper Hill 1998	493	1850	M	9	20	9	
271	25-Oct-98	Scraper Hill 1998	475	1800	F	4	327	12	
272	26-Oct-98	Scraper Hill 1998	495	2000	M	9	30	11	
273	26-Oct-98	Scraper Hill 1998	489	1900	M	9	20	8	
274	26-Oct-98	Scraper Hill 1998	495	2000	M	9	39	10	
275	26-Oct-98	Scraper Hill 1998	520	1950	M	9	29	11	
276	26-Oct-98	Scraper Hill 1998	514	2150	M	9	36	9	
277	26-Oct-98	Scraper Hill 1998	470	1450	M	9	16	9	
278	26-Oct-98	Scraper Hill 1998	485	1650	M	9	23	7	
279	26-Oct-98	Scraper Hill 1998	470	1450	M	9	20	7	
280	26-Oct-98	Scraper Hill 1998	485	1700	M	9	24	11	
281	26-Oct-98	Scraper Hill 1998	485	1500	M	9	17	13	
282	26-Oct-98	Scraper Hill 1998	480	1900	F	4	431	9	
283	27-Oct-98	Scraper Hill 1998	510	1950	M	9	19	12	
284	27-Oct-98	Scraper Hill 1998	475	1650	F	4	359	8	
285	02-Nov-98	Scraper Hill 1998	500	7900	M	8	NO	13	
286	02-Nov-98	Scraper Hill 1998	500	1920	M	8	NO	15	

287	02-Nov-98	Scraper Hill 1998	500	1900	F	5	NO	7	
288	02-Nov-98	Scraper Hill 1998	460	1690	M	8	NO	8	
289	02-Nov-98	Scraper Hill 1998	490	1700	F	1	NO	10	
290	02-Nov-98	Scraper Hill 1998	520	2200	F	3	NO	7	
291	02-Nov-98	Scraper Hill 1998	540	2500	M	8	NO	13	
292	02-Nov-98	Scraper Hill 1998	550	2100	F	1	NO	11	
293	02-Nov-98	Scraper Hill 1998	450	1400	M	8	NO	8	
294	02-Nov-98	Scraper Hill 1998	510	1800	M	8	NO	9	
295	02-Nov-98	Scraper Hill 1998	500	1660	F	2	NO	7	
296	02-Nov-98	Scraper Hill 1998	470	1800	F	3	NO	11	
297	02-Nov-98	Scraper Hill 1998	440	1200	F	4	NO	13	
298	02-Nov-98	Scraper Hill 1998	490	1600	F	3	NO	11	
299	02-Nov-98	Scraper Hill 1998	510	2000	M	8	NO	11	
300	02-Nov-98	Scraper Hill 1998	500	1500	F	5	NO	9	
301	02-Nov-98	Scraper Hill 1998	480	1800	M	7	NO	8	
302	02-Nov-98	Scraper Hill 1998	520	1850	M	8	NO	8	
303	02-Nov-98	Scraper Hill 1998	490	1900	M	8	NO	12	
304	02-Nov-98	Scraper Hill 1998	490	1700	M	8	NO	12	
305	02-Nov-98	Scraper Hill 1998	480	1300	M	6	NO	12	
306	02-Nov-98	Scraper Hill 1998	550	1900	F	1	NO	11	
307	02-Nov-98	Scraper Hill 1998	530	1900			NO	12	
308	02-Nov-98	Scraper Hill 1998	500	2160	M	8	NO	9	
309	03-Nov-98	Scraper Hill 1998	540	1990	F	4	NO	10	
310	03-Nov-98	Scraper Hill 1998	470	1470	M	6	NO	12	
311	03-Nov-98	Scraper Hill 1998	510	1720	F	5	NO	8	
312	03-Nov-98	Scraper Hill 1998	480	1900	F	5	NO	13	
313	03-Nov-98	Scraper Hill 1998	550	2100	F	5	NO	9	
314	03-Nov-98	Scraper Hill 1998	490	1990	M	8	NO	11	
315	03-Nov-98	Scraper Hill 1998	500	1700	F	2	NO	12	
316	03-Nov-98	Scraper Hill 1998	510	1500	F	1	NO	12	
317	03-Nov-98	Scraper Hill 1998	500	2000	F	5	NO	7	
318	03-Nov-98	Scraper Hill 1998	500	1800	M	8	NO	12	
319	03-Nov-98	Scraper Hill 1998	510	2000	F	3	NO	13	
320	05-Nov-98	Scraper Hill 1998	490	1500	F	1	NO	15	
321	05-Nov-98	Scraper Hill 1998	500	1700	F	3	NO	8	
322	05-Nov-98	Scraper Hill 1998	530	1880	F	3	NO	7	
323	05-Nov-98	Scraper Hill 1998	500	2160	F	5	NO	9	
324	05-Nov-98	Scraper Hill 1998	480	1500	F	5	NO	8	
325	05-Nov-98	Scraper Hill 1998	470	1400	F	5	NO	12	
326	07-Nov-98	Scraper Hill 1998	510	1900	F	1	NO	8	
327	07-Nov-98	Scraper Hill 1998	500	1600	M	10	NO	12	
328	07-Nov-98	Scraper Hill 1998	540	2300	M	10	NO	11	
329	07-Nov-98	Scraper Hill 1998	500	1900	F	5	NO	12	
330	07-Nov-98	Scraper Hill 1998	470	1250	F	3	NO	12	
331	08-Nov-98	Scraper Hill 1998	460	1300	F	1	NO	9	
332	07-Nov-98	Scraper Hill 1998	480	1700	F	5	NO	11	
333	08-Nov-98	Scraper Hill 1998	470	1500	F	3	NO	6	
334	08-Nov-98	Scraper Hill 1998	510	1900	M	8	NO	18	
335	08-Nov-98	Scraper Hill 1998	520	2200	F	5	NO	10	

336	08-Nov-98	Scraper Hill 1998	540	2300	M	8	NO	8	
337	08-Nov-98	Scraper Hill 1998	530	2000	F	5	NO	11	
338	08-Nov-98	Scraper Hill 1998	500	1580	M	8	NO	11	
339	08-Nov-98	Scraper Hill 1998	530	2500	M	8	NO	14	
340	12-Nov-98	Scraper Hill 1998	470	1650	F	5	NO	13	
341	12-Nov-98	Scraper Hill 1998	550	2400			NO	10	
342	12-Nov-98	Scraper Hill 1998	490	1800	F	5	NO	9	
343	12-Nov-98	Scraper Hill 1998	550	2900	M	10	NO	12	
344	12-Nov-98	Scraper Hill 1998	470	1500	F	3	NO	12	
345	12-Nov-98	Scraper Hill 1998	500	1700	F	5	NO	12	
346	12-Nov-98	Scraper Hill 1998	450	1450	M	8	NO	8	
347	12-Nov-98	Scraper Hill 1998	470	1640	F	5	NO	8	
348	12-Nov-98	Scraper Hill 1998	500	1490	F	3	NO	15	
349	12-Nov-98	Scraper Hill 1998	520	1700	F	3	NO	9	
350	12-Nov-98	Scraper Hill 1998	470	1500	M	6	NO	11	
351	12-Nov-98	Scraper Hill 1998	490	1580	F	3	NO	12	
352	12-Nov-98	Scraper Hill 1998	520	2250	M	8	NO	9	
353	13-Nov-98	Scraper Hill 1998	560	2900	M	8	NO	13	
354	13-Nov-98	Scraper Hill 1998	540	2500	M	10	NO	11	
355	13-Nov-98	Scraper Hill 1998	510	2400	M	8	NO	9	
356	13-Nov-98	Scraper Hill 1998	530	2500	M	8	NO	8	
357	13-Nov-98	Scraper Hill 1998	520	2400	F	3	NO	10	
358	13-Nov-98	Scraper Hill 1998	470	1460	F	3	NO	12	
359	13-Nov-98	Scraper Hill 1998	480	1600	M	8	NO	9	
360	13-Nov-98	Scraper Hill 1998	520	2100	M	8	NO		
361	13-Nov-98	Scraper Hill 1998	500	1500	F	5	NO	12	
362	13-Nov-98	Scraper Hill 1998	470	1400	F	1	NO	10	
363	13-Nov-98	Scraper Hill 1998	470	1800			NO	12	
364	14-Nov-98	Scraper Hill 1998	510	2100	M	6	NO	10	
365	14-Nov-98	Scraper Hill 1998	520	2500	M	10	NO	13	
366	14-Nov-98	Scraper Hill 1998	480	1580	M	8	NO	10	
367	14-Nov-98	Scraper Hill 1998	530	2200	M	8	NO	12	
368	14-Nov-98	Scraper Hill 1998	500	1500	F	5	NO	12	
369	14-Nov-98	Scraper Hill 1998	480	1500	M	8	NO	19	
370	14-Nov-98	Scraper Hill 1998	540	2400	F	5	NO	12	
371	14-Nov-98	Scraper Hill 1998	520	2000	F	3	NO	11	
372	15-Nov-98	Scraper Hill 1998	440	1200	F	5	NO	20	
373	15-Nov-98	Scraper Hill 1998	470	1680	M	8	NO	7	
374	15-Nov-98	Scraper Hill 1998	500	1900	M	6	NO	9	
375	15-Nov-98	Scraper Hill 1998	540	2080	M	10	NO	10	
376	15-Nov-98	Scraper Hill 1998	475	1700	F	5	NO	8	
377	15-Nov-98	Scraper Hill 1998	490	1560	F	5	NO	8	
378	15-Nov-98	Scraper Hill 1998	550	2200	F	5	NO	13	
379	15-Nov-98	Scraper Hill 1998	550	1800	F	2	NO	16	
380	15-Nov-98	Scraper Hill 1998	500	2000	F	5	NO	12	
381	17-Nov-98	Scraper Hill 1998	500	1860	M	8	NO	14	
382	17-Nov-98	Scraper Hill 1998	470	1280	F	5	NO	12	
383	17-Nov-98	Scraper Hill 1998	480	1380			NO	13	
384	13-Nov-98	Scraper Hill 1998	540	2600			NO	10	

385	02-Nov-98	Scraper Hill 1998	530	2300	M	6	NO	14	
386	25-Sep-98	Trail River 1998	505	2100	M	8	25	6	
387	26-Sep-98	Trail River 1998	520	2200	F	3	43	10	
388	27-Sep-98	Trail River 1998	515	2500	M	8	27	7	
389	27-Sep-98	Trail River 1998	540	2700	F	3	66	10	
390	28-Sep-98	Trail River 1998	530	2350	M	9	21	8	
391	29-Sep-98	Trail River 1998	520	1950	M	8	17	13	
392	01-Oct-98	Trail River 1998	544	2500	M	8	31	8	
393	01-Oct-98	Trail River 1998	539	2100	M	8	22	12	
394	03-Oct-98	Trail River 1998	520	2820	F	3	580		83283
395	03-Oct-98	Trail River 1998	480	2030	F	3	8	8	65781
396	03-Oct-98	Trail River 1998	525	2600	F	3	910	14	59749
397	05-Oct-98	Trail River 1998	520	1850	F	2	900	13	
398	05-Oct-98	Trail River 1998	575	2180	M	8	29	13	
399	05-Oct-98	Trail River 1998	490	1800	F	2	800	12	41547
400	05-Oct-98	Trail River 1998	525	1800	M	7	25	11	
401	07-Oct-98	Trail River 1998	520	3500	M	8	31	9	
402	07-Oct-98	Trail River 1998	500	2600	F	2	650	8	93270
403	07-Oct-98	Trail River 1998	520	2200	M	6	24	8	
404	07-Oct-98	Trail River 1998	435	1050	M	6	12	18	
405	13-Oct-98	Trail River 1998	515	2000	M	8	30	11	
406	13-Oct-98	Trail River 1998	470	1450	F	2	330	8	40816
407	13-Oct-98	Trail River 1998	550	2350	M	8	20	10	
408	13-Oct-98	Trail River 1998	520	2200	F	2	550	8	68768
409	13-Oct-98	Trail River 1998	495	1850	M	7	20	10	
410	13-Oct-98	Trail River 1998	485	1650	F	2	400	21	49472
411	13-Oct-98	Trail River 1998	490	1820	F	2	330	11	39665
412	15-Oct-98	Trail River 1998	450	1950	F	2	300	10	
413	15-Oct-98	Trail River 1998	520	2450	M	7	33	8	37092
414	15-Oct-98	Trail River 1998	540	1950	F	2	300	10	34341
415	15-Oct-98	Trail River 1998	535	2200	M	7	19	12	
416	19-Oct-98	Trail River 1998	535	2300	M	8	23	10	
417	19-Oct-98	Trail River 1998	510	2300	M	8		9	
418	19-Oct-98	Trail River 1998	500	2000	M	8	30	7	
419	19-Oct-98	Trail River 1998	490	1800	M	7	14	8	
420	19-Oct-98	Trail River 1998	480	1600	F	2	26	11	35828
421	19-Oct-98	Trail River 1998	530	2400	F	2	3	10	56238
422	11-Oct-99	Cutoff 1999	416	1600	F	2	26	16	
423	11-Oct-99	Cutoff 1999	500	1800	F	3	407	9	51720
424	11-Oct-99	Cutoff 1999	480	1700	M	1	23	7	
425	11-Oct-99	Cutoff 1999	500	1800	M	3	14	18	
426	15-Oct-99	Cutoff 1999	502	1900	M	5	20	8	
427	15-Oct-99	Cutoff 1999	543	2600	M	5	22	9	
428	15-Oct-99	Cutoff 1999	560	2800	M	5	36	9	
429	15-Oct-99	Cutoff 1999	540	2100	M	5	27	13	
430	15-Oct-99	Cutoff 1999	500	1800	M	5	16	16	
431	15-Oct-99	Cutoff 1999	490	1800	M	5	18	9	
432	18-Oct-99	Cutoff 1999	530	2500	M	5	36	7	
433	18-Oct-99	Cutoff 1999	540	2800	F	3	305	15	24958

434	18-Oct-99	Cutoff 1999	595	1800	M	5	23	9	
435	18-Oct-99	Cutoff 1999	433	1800	F	3	194	10	16426
436	18-Oct-99	Cutoff 1999	430	1700	F	3	207	9	23906
437	18-Oct-99	Cutoff 1999	470	1700	M	5	?	8	
438	18-Oct-99	Cutoff 1999	570	3100	M	5	26	13	
439	18-Oct-99	Cutoff 1999	445	2600	M	5	49	9	
440	18-Oct-99	Cutoff 1999	525	2600	M	5	37	10	
441	18-Oct-99	Cutoff 1999	535	2850	M	5	34	11	
442	18-Oct-99	Cutoff 1999	495	1800	M	5	24	14	
443	18-Oct-99	Cutoff 1999	485	1750	M	5	19	7	
444	18-Oct-99	Cutoff 1999	464	1950	M	5	18	9	
445	18-Oct-99	Cutoff 1999	428	1600	M	5	22	8	
446	18-Oct-99	Cutoff 1999	425	1550	M	5	18	17	
447	18-Oct-99	Cutoff 1999	490	1700	F	3	181	11	
448	20-Oct-99	Cutoff 1999	540	2700	M	5	39	7	
449	20-Oct-99	Cutoff 1999	460	1500	M	5	5	8	
450	20-Oct-99	Cutoff 1999	518	2200	M	5	29	9	
451	22-Oct-99	Cutoff 1999	450	1600	M	5	9	?	
452	22-Oct-99	Cutoff 1999	480	1700	F	3	161	7	18421
453	22-Oct-99	Cutoff 1999	490	2200	F	3	92	10	
454	22-Oct-99	Cutoff 1999	480	1300	F	3	90	14	10070
455	22-Oct-99	Cutoff 1999	504	1600	F	3	241	20	26561
456	22-Oct-99	Cutoff 1999	484	1700	F	3	215	?	
457	22-Oct-99	Cutoff 1999	470	1800	M	5	7	15	
458	22-Oct-99	Cutoff 1999	490	1600	M	5	6	8	
459	25-Oct-99	Cutoff 1999	550	2600	M	5	28	9	
460	27-Oct-99	Cutoff 1999	550	2950	F	2	48	10	
461	27-Oct-99	Cutoff 1999	515	2300	M	5	30	10	
462	27-Oct-99	Cutoff 1999	514	1700	F	2	26	7	
463	27-Oct-99	Cutoff 1999	455	1400	M	5	21	7	
464	27-Oct-99	Cutoff 1999	518	1550	F	2	43	11	
465	27-Oct-99	Cutoff 1999	505	2500	F	3	664	10	74903
466	29-Oct-99	Cutoff 1999	485	1600	F	3	37	7	
467	29-Oct-99	Cutoff 1999	517	1900	F	2	50	8	
468	29-Oct-99	Cutoff 1999	540	2200	M	1	24	13	
469	29-Oct-99	Cutoff 1999	576	3000	F	3	377	10	36716
470	29-Oct-99	Cutoff 1999	400	800	M	1	3	13	
471	29-Oct-99	Cutoff 1999	420	900	F	2	14	13	
472	29-Oct-99	Cutoff 1999	536	2000	F	3	50	20	
473	29-Oct-99	Cutoff 1999	530	2000	F	2	59	9	
474	29-Oct-99	Cutoff 1999	512	1850	M	5	15	12	
475	01-Nov-99	Cutoff 1999	480	1600	F	2	37	8	
476	01-Nov-99	Cutoff 1999	495	1500	F	2	37	9	
477	01-Nov-99	Cutoff 1999	530	2500	F	2	61	?	
478	01-Nov-99	Cutoff 1999	475	1300	F	2	37	13	
479	01-Nov-99	Cutoff 1999	500	1850	F	2	6	13	
480	01-Nov-99	Cutoff 1999	545	2600	M	5	15	9	
481	01-Nov-99	Cutoff 1999	530	2250	M	5	10	13	
482	01-Nov-99	Cutoff 1999	550	2400	F	2	40	13	

483	01-Nov-99	Cutoff 1999	430	1400	F	2	33	?	
484	01-Nov-99	Cutoff 1999	514	1600	F	2	42	13	
485	01-Nov-99	Cutoff 1999	500	1700	F	2	45	11	
486	03-Nov-99	Cutoff 1999	495	2000	M	5	9	7	
487	03-Nov-99	Cutoff 1999	540	1900	M	5	47	14	
488	03-Nov-99	Cutoff 1999	490	1800	M	5	15	?	
489	03-Nov-99	Cutoff 1999	480	1500	F	2	48	12	
490	03-Nov-99	Cutoff 1999	503	1400	F	2	35	9	
491	03-Nov-99	Cutoff 1999	540	2400	M	5	11	9	
492	03-Nov-99	Cutoff 1999	427	1900	M	5	33	13	
493	03-Nov-99	Cutoff 1999	506	1600	F	2	35	9	
494	03-Nov-99	Cutoff 1999	432	1600	F	2	39	9	
495	03-Nov-99	Cutoff 1999	480	1500	F	2	41	11	
496	03-Nov-99	Cutoff 1999	500	1550	F	2	35	9	
497	05-Nov-99	Cutoff 1999	525	1900	F	2	43	9	
498	05-Nov-99	Cutoff 1999	492	1700	F	2	46	8	
499	05-Nov-99	Cutoff 1999	440	900	F	2	18	13	
500	05-Nov-99	Cutoff 1999	490	1500	F	2	31	15	
501	05-Nov-99	Cutoff 1999	500	1300	F	2	16	?	
502	05-Nov-99	Cutoff 1999	520	2200	M	5	7	11	
503	08-Nov-99	Cutoff 1999	555	2400	M	5	16	12	
504	08-Nov-99	Cutoff 1999	533	2400	M	5	12	11	
505	08-Nov-99	Cutoff 1999	488	1350	F	2	36	10	
506	08-Nov-99	Cutoff 1999	480	1500	F	3	35	12	
507	10-Nov-99	Cutoff 1999	500	1950	F	4	451	10	35815
508	10-Nov-99	Cutoff 1999	520	2000	M	4	23	?	
509	10-Nov-99	Cutoff 1999	429	1800	M	4	12	9	
510	10-Nov-99	Cutoff 1999	496	1650	M	4	25	9	
511	10-Nov-99	Cutoff 1999	490	1700	M	4	9	10	
512	10-Nov-99	Cutoff 1999	535	2600	M	4	25	8	
513	10-Nov-99	Cutoff 1999	520	1700	M	4	17	9	
514	10-Nov-99	Cutoff 1999	470	1500	M	4	7	8	
515	10-Nov-99	Cutoff 1999	510	1950	F	3	49	11	
516	10-Nov-99	Cutoff 1999	525	2200	M	4	19	12	
517	10-Nov-99	Cutoff 1999	516	2150	M	4	15	7	
518	10-Nov-99	Cutoff 1999	446	1300	M	4	12	8	
519	15-Nov-99	Cutoff 1999	542	2200	M	5	26	9	
520	15-Nov-99	Cutoff 1999	530	1800	M	5	11	12	
521	15-Nov-99	Cutoff 1999	500	1600	M	5	10	11	
522	15-Nov-99	Cutoff 1999	490	1900	M	5	12	7	
523	17-Nov-99	Cutoff 1999	545	2700	M	5	11	12	
524	17-Nov-99	Cutoff 1999	490	1850	M	5	10	12	
525	17-Nov-99	Cutoff 1999	514	1550	M	5	14	8	
526	07-Oct-99	Scraper Hill 1999	479	1300	F	1	13	11	
527	07-Oct-99	Scraper Hill 1999	500	1950	M	2	23	17	
528	07-Oct-99	Scraper Hill 1999	490	2050	M	2	22	10	
529	07-Oct-99	Scraper Hill 1999	492	1850	M	2	21	14	
530	07-Oct-99	Scraper Hill 1999	506	2350	M	2	33	10	
531	08-Oct-99	Scraper Hill 1999	507	2250	M	2	29	7	

532	08-Oct-99	Scraper Hill 1999	468	1700	M	2	21	7	
533	08-Oct-99	Scraper Hill 1999	532	2200	M	2	25	10	
534	08-Oct-99	Scraper Hill 1999	495	1850	M	2	29	7	
535	08-Oct-99	Scraper Hill 1999	527	2050	M	2	26	10	
536	09-Oct-99	Scraper Hill 1999	490	1800	M	2	24	13	
537	09-Oct-99	Scraper Hill 1999	510	2100	M	2	26	8	
538	09-Oct-99	Scraper Hill 1999	505	2300	F	3	547	13	64079
539	11-Oct-99	Scraper Hill 1999	460	1600	M	4	20	?	
540	11-Oct-99	Scraper Hill 1999	472	1650	M	4	22	8	
541	11-Oct-99	Scraper Hill 1999	455	1400	F	3	309	15	37587
542	13-Oct-99	Scraper Hill 1999	484	1800	M	3	25	6	
543	13-Oct-99	Scraper Hill 1999	460	1500	M	4	19	9	
544	13-Oct-99	Scraper Hill 1999	483	1800	M	4	26	10	
545	13-Oct-99	Scraper Hill 1999	517	2500	M	4	28	9	
546	13-Oct-99	Scraper Hill 1999	488	1750	F	3	374	8	46954
547	15-Oct-99	Scraper Hill 1999	469	1700	M	4	25	8	
548	15-Oct-99	Scraper Hill 1999	510	1800	M	4	33	16	
549	18-Oct-99	Scraper Hill 1999	455	1500	M	4	19	5	
550	18-Oct-99	Scraper Hill 1999	480	1800	M	4	24	7	
551	18-Oct-99	Scraper Hill 1999	493	1750	M	4	28	15	
552	18-Oct-99	Scraper Hill 1999	490	1850	M	4	19	12	
553	18-Oct-99	Scraper Hill 1999	520	2000	M	4	25	13	
554	18-Oct-99	Scraper Hill 1999	490	1900	M	4	24	9	
555	20-Oct-99	Scraper Hill 1999	490	2150	M	4	21	8	
556	20-Oct-99	Scraper Hill 1999	480	1700	M	4	26	13	
557	20-Oct-99	Scraper Hill 1999	515	2150	M	4	36	12	
558	20-Oct-99	Scraper Hill 1999	518	2350	M	4	37	10	
559	20-Oct-99	Scraper Hill 1999	520	2050	M	4	22	8	
560	20-Oct-99	Scraper Hill 1999	500	2100	M	4	33	11	
561	20-Oct-99	Scraper Hill 1999	485	1850	M	4	27	10	
562	20-Oct-99	Scraper Hill 1999	527	2350	M	4	32	10	
563	20-Oct-99	Scraper Hill 1999	500	1850	M	4	29	14	
564	20-Oct-99	Scraper Hill 1999	516	2050	M	4	16	13	
565	20-Oct-99	Scraper Hill 1999	464	1350	M	4	11	11	
566	22-Oct-99	Scraper Hill 1999	485	1650	M	4	24	12	
567	22-Oct-99	Scraper Hill 1999	500	2000	F	3	513	19	50491
568	22-Oct-99	Scraper Hill 1999	552	3050	F	4	728	11	74391
569	22-Oct-99	Scraper Hill 1999	513	2250	M	4	26	13	
570	22-Oct-99	Scraper Hill 1999	560	2550	M	4	25	12	
571	22-Oct-99	Scraper Hill 1999	477	1850	M	4	34	10	
572	25-Oct-99	Scraper Hill 1999	489	1700	F	5	39	11	
573	27-Oct-99	Scraper Hill 1999	530	1750	F	5	39	14	
574	27-Oct-99	Scraper Hill 1999	490	2150	F	4	469	14	41748
575	29-Oct-99	Scraper Hill 1999	467	1550	F	5	29	7	
576	29-Oct-99	Scraper Hill 1999	510	1450	F	5	38	12	
577	01-Nov-99	Scraper Hill 1999	470	1350	F	5	22	19	
578	01-Nov-99	Scraper Hill 1999	524	2150	F	5	43	9	
579	01-Nov-99	Scraper Hill 1999	490	1450	F	5	26	14	
580	03-Nov-99	Scraper Hill 1999	520	2750	M	4	36	11	

581	03-Nov-99	Scraper Hill 1999	479	1500	F	5	34	8	
582	03-Nov-99	Scraper Hill 1999	518	1450	F	5	46	9	
583	03-Nov-99	Scraper Hill 1999	489	1350	F	5	20	8	
584	03-Nov-99	Scraper Hill 1999	490	1300	F	5	36	9	
585	03-Nov-99	Scraper Hill 1999	540	1700	M	5	5	7	
586	05-Nov-99	Scraper Hill 1999	504	1700	F	5	39	9	
587	05-Nov-99	Scraper Hill 1999	480	1550	F	5	30	7	
588	05-Nov-99	Scraper Hill 1999	466	1600	M	5	7	10	
589	05-Nov-99	Scraper Hill 1999	517	2150	M	5	14	9	
590	05-Nov-99	Scraper Hill 1999	517	1700	F	5	41	11	
591	05-Nov-99	Scraper Hill 1999	500	2500	M	5	17	7	
592	08-Nov-99	Scraper Hill 1999	515	2100	M	5	16	8	
593	08-Nov-99	Scraper Hill 1999	510	1850	M	5	9	10	
594	08-Nov-99	Scraper Hill 1999	499	1850	M	5	14	10	
595	10-Nov-99	Scraper Hill 1999	510	2000	M	5	32	10	
596	10-Nov-99	Scraper Hill 1999	520	2150	M	5	13	12	
597	10-Nov-99	Scraper Hill 1999	484	1500	M	5	9	12	
598	12-Nov-99	Scraper Hill 1999	512	2050	M	4	21	11	
599	12-Nov-99	Scraper Hill 1999	494	2100	M	4	21	10	
600	12-Nov-99	Scraper Hill 1999	560	2350	M	4	19	14	
601	12-Nov-99	Scraper Hill 1999	515	2000	M	4	14	11	
602	12-Nov-99	Scraper Hill 1999	485	1300	F	5	23	9	
603	15-Nov-99	Scraper Hill 1999	490	1900	M	4	59	9	
604	15-Nov-99	Scraper Hill 1999	480	1700	F	5	35	8	
605	17-Nov-99	Scraper Hill 1999	480	1400	M	4	6	12	
606	19-Oct-99	Road River 1999	513	1120	M	2	34	10	
607	19-Oct-99	Road River 1999	545	2600	F	3	543	10	60684
608	19-Oct-99	Road River 1999	483	1900	F	3	421	?	44784
609	19-Oct-99	Road River 1999	495	1600	M	2	0	12	
610	19-Oct-99	Road River 1999	500	1550	M	2	0	16	
611	20-Oct-99	Road River 1999	532	2100	F	3	380	?	33410
612	20-Oct-99	Road River 1999	525	2100	F	3	351	10	34232
613	20-Oct-99	Road River 1999	540	2800	M	3	33	10	
614	20-Oct-99	Road River 1999	534	2300	M	3	70	14	
615	20-Oct-99	Road River 1999	500	1900	M	2	63	15	
616	20-Oct-99	Road River 1999	474	1400	M	2	56	9	
617	20-Oct-99	Road River 1999	475	1700	M	3	61	15	
618	20-Oct-99	Road River 1999	501	2100	M	3	67	7	
619	20-Oct-99	Road River 1999	530	1650	F	5	0	11	
620	20-Oct-99	Road River 1999	537	2500	M	3	66	8	
621	22-Oct-99	Road River 1999	533	2350	M	3	37	14	
622	22-Oct-99	Road River 1999	478	1400	M	2	?	14	
623	22-Oct-99	Road River 1999	470	1500	M	?	?	?	
624	22-Oct-99	Road River 1999	550	2850	F	4	737	10	74822
625	22-Oct-99	Road River 1999	470	1700	F	3	523	9	31315
626	22-Oct-99	Road River 1999	475	1450	M	2	49	21	
627	25-Oct-99	Road River 1999	535	2650	M	3	37	10	
628	25-Oct-99	Road River 1999	560	1850	F	4	?	10	
629	25-Oct-99	Road River 1999	505	2500	M	3	24	9	

630	25-Oct-99	Road River 1999	490	1700	M	?	49	13	
631	25-Oct-99	Road River 1999	536	1950	F	4	?	8	
632	25-Oct-99	Road River 1999	545	2200	M	3	67	13	
633	25-Oct-99	Road River 1999	448	1200	M	2	49	8	
634	25-Oct-99	Road River 1999	515	2000	M	2	59	13	
635	25-Oct-99	Road River 1999	560	2100	F	5	?	13	
636	25-Oct-99	Road River 1999	535	1800	F	5	?	10	
637	25-Oct-99	Road River 1999	394	1850	F	5	?	9	
638	25-Oct-99	Road River 1999	525	2000	M	2	54	12	
639	27-Oct-99	Road River 1999	512	2250	F	4	576	13	54832
640	27-Oct-99	Road River 1999	548	2800	F	4	819	16	71383
641	27-Oct-99	Road River 1999	466	1650	F	4	357	7	44857
642	27-Oct-99	Road River 1999	497	1900	F	4	423	12	35815
643	27-Oct-99	Road River 1999	480	1450	F	5	25	8	
644	29-Oct-99	Road River 1999	530	2050	F	5	40	8	
645	29-Oct-99	Road River 1999	490	1600	F	5	38	9	
646	05-Nov-99	Road River 1999	550	2050	M	5	14	12	
647	05-Nov-99	Road River 1999	492	1950	F	5	96	13	
648	05-Nov-99	Road River 1999	545	2000	F	5	40	11	
649	05-Nov-99	Road River 1999	505	1650	F	5	37	11	
650	05-Nov-99	Road River 1999	536	2900	F	4	791	?	57170
651	08-Nov-99	Road River 1999	550	2300	M	5	45	16	
652	08-Nov-99	Road River 1999	520	2350	M	5	51	9	
653	08-Nov-99	Road River 1999	477	1500	M	5	7	13	
654	08-Nov-99	Road River 1999	440	1250	M	5	8	15	
655	08-Nov-99	Road River 1999	500	1900	M	3	29	?	
656	10-Nov-99	Road River 1999	550	2600	M	5	7	?	
657	10-Nov-99	Road River 1999	525	2550	M	5	8	?	
658	10-Nov-99	Road River 1999	510	2300	M	5	8	8	
659	19-Oct-99	Scraper Hill 1999	500	2100	M	4	41	11	
660	20-Oct-99	Scraper Hill 1999	526	2600	F	4	516	11	69995
661	20-Oct-99	Scraper Hill 1999	450	1200	M	4	14	9	
662	20-Oct-99	Scraper Hill 1999	495	1700	M	4	23	13	
663	20-Oct-99	Scraper Hill 1999	530	2600	M	4	25	12	
664	20-Oct-99	Scraper Hill 1999	480	1900	F	4	408	12	49932
665	24-Oct-99	Scraper Hill 1999	540	3200	F	4	875	9	74944
666	29-Oct-99	Road River 1999	527	1650	F	5	41	9	
667	29-Oct-99	Road River 1999	483	1650	F	5	42	16	
668	09-Nov-99	Cutoff 1999	535	3000	M	4	30	13	
669	09-Nov-99	Cutoff 1999	485	1800	F	4	339	10	36333
670	09-Nov-99	Cutoff 1999	490	1650	M	4	7	14	
671	09-Nov-99	Cutoff 1999	478	1600	F	4	291	9	21755
672	09-Nov-99	Cutoff 1999	511	1950	M	4	20	12	
673	09-Nov-99	Cutoff 1999	476	1650	M	4	8	8	
674	09-Nov-99	Cutoff 1999	529	2150	M	4	15	11	
675	09-Nov-99	Cutoff 1999	440	1000	M	4	5	13	
676	09-Nov-99	Cutoff 1999	490	1700	M	4	7	8	
677	10-Nov-99	Cutoff 1999	520	2000	M	4	15	15	
678	10-Nov-99	Cutoff 1999	492	1750	M	4	12	8	

679	10-Nov-99	Cutoff 1999	533	2500	M	4	12	9	
680	10-Nov-99	Cutoff 1999	487	1750	M	4	16	17	
681	10-Nov-99	Cutoff 1999	519	2200	M	4	18	9	
682	10-Nov-99	Cutoff 1999	500	2200	M	4	28	9	
683	10-Nov-99	Cutoff 1999	479	1650	M	4	13	9	
684	10-Nov-99	Cutoff 1999	489	1600	M	4	17	?	
685	11-Nov-99	Cutoff 1999	510	2200	M	4	20	7	
686	11-Nov-99	Cutoff 1999	530	2000	M	4	23	13	
687	11-Nov-99	Cutoff 1999	517	2100	M	4	17	9	
688	11-Nov-99	Cutoff 1999	533	2450	M	3	29	16	
689	11-Nov-99	Cutoff 1999	482	1550	M	3	14	8	
690	12-Nov-99	Cutoff 1999	455	1300	M	3	7	10	
691	12-Nov-99	Cutoff 1999	480	1550	M	4	12	8	
692	12-Nov-99	Cutoff 1999	529	2100	M	4	17	10	
693	20-24oct	Scraper Hill 1999	473	2000	F	4	465	10	35795
694	20-24oct	Scraper Hill 1999	541	2800	F	4	800	9	68421
695	20-24oct	Scraper Hill 1999	570	3300	F	4	965	13	76538
696	20-24oct	Scraper Hill 1999	527	2850	F	4	1030	9	
697	20-24oct	Scraper Hill 1999	530	2750	F	4	695	13	75865
698	20-24oct	Scraper Hill 1999	528	2750	F	4	910	13	80865
699	20-24oct	Scraper Hill 1999	572	3450	F	4	940	10	81241
700	20-24oct	Scraper Hill 1999	504	2700	F	4	580	23	61518
701	20-24oct	Scraper Hill 1999	530	2850	F	4	870	19	61837
702	20-24oct	Scraper Hill 1999	540	2300	F	4	600	9	52572
703	20-24oct	Scraper Hill 1999	501	2100	F	4	545	12	45308
704	20-24oct	Scraper Hill 1999	540	2200	F	4	590	8	58442
705	20-24oct	Scraper Hill 1999	490	2400	F	4	640	?	66370
706	20-24oct	Scraper Hill 1999	500	2000	F	4	485	9	45059
707	20-24oct	Scraper Hill 1999	495	2400	F	4	580	18	51541
708	20-24oct	Scraper Hill 1999	500	2350	F	4	765	9	
709	20-24oct	Scraper Hill 1999	490	2100	F	4	515	8	55483
710	20-24oct	Scraper Hill 1999	465	1400	F	4	300	9	25419
711	20-24oct	Scraper Hill 1999	470	1700	F	4	360	12	31500
712	20-24oct	Scraper Hill 1999	525	2400	F	4	610	9	44089
713	20-24oct	Scraper Hill 1999	460	1600	F	4	300	8	28220
714	20-24oct	Scraper Hill 1999	490	2500	F	4	700	10	
715	20-24oct	Scraper Hill 1999	469	2100	F	4	520	13	36241
716	20-24oct	Scraper Hill 1999	500	2300	F	4	485	9	38845
717	20-24oct	Scraper Hill 1999	540	2800	F	4	700	14	60519
718	20-24oct	Scraper Hill 1999	537	2500	F	4	575	20	44837
719	20-24oct	Scraper Hill 1999	480	2000	F	4	565	11	46828
720	20-24oct	Scraper Hill 1999	475	2000	F	4	485	9	43079
721	20-24oct	Scraper Hill 1999	485	2200	F	4	555	13	51091
722	20-24oct	Scraper Hill 1999	465	1900	F	4	475	14	44955

APPENDIX II. Index of sample numbers for broad whitefish (BDWT) caught in the Peel River in 1998 and 1999 as part of the Peel River fish-monitoring program. S# = sample number. Samples numbers as recorded 1) on scale envelopes, 2) all species caught in a single year (1998 or 1999), and 3) only broad whitefish, caught in both 1998 and 1999 (as reported in thesis Appendix I).

Date	Camp #	Camp	S# on envelope	S# for year	BDWT S#
25-Sep-98	1	Basook Creek	6	6	1
25-Sep-98	1	Basook Creek	7	7	2
24-Sep-98	1	Basook Creek	2	73	3
24-Sep-98	1	Basook Creek	4	75	4
24-Sep-98	1	Basook Creek	5	76	5
24-Sep-98	1	Basook Creek	6	77	6
24-Sep-98	1	Basook Creek	7	78	7
24-Sep-98	1	Basook Creek	8	79	8
24-Sep-98	1	Basook Creek	12	83	9
25-Sep-98	1	Basook Creek	15	86	10
25-Sep-98	1	Basook Creek	17	88	11
25-Sep-98	1	Basook Creek	18	89	12
25-Sep-98	1	Basook Creek	19	90	13
25-Sep-98	1	Basook Creek	22	93	14
25-Sep-98	1	Basook Creek	23	94	15
25-Sep-98	1	Basook Creek	24	95	16
25-Sep-98	1	Basook Creek	26	97	17
25-Sep-98	1	Basook Creek	28	99	18
25-Sep-98	1	Basook Creek	29	100	19
28-Sep-98	1	Basook Creek	33	104	20
30-Sep-98	1	Basook Creek	42	113	21
30-Sep-98	1	Basook Creek	46	117	22
30-Sep-98	1	Basook Creek	49	120	23
02-Oct-98	1	Basook Creek	59	130	24
05-Oct-98	1	Basook Creek	75	146	25
07-Oct-98	1	Basook Creek	99	170	26
07-Oct-98	1	Basook Creek	105	176	27
15-Oct-98	1	Basook Creek	111	182	28
15-Oct-98	1	Basook Creek	112	183	29
15-Oct-98	1	Basook Creek	113	184	30
15-Oct-98	1	Basook Creek	114	185	31
15-Oct-98	1	Basook Creek	115	186	32
15-Oct-98	1	Basook Creek	116	187	33
15-Oct-98	1	Basook Creek	117	188	34
15-Oct-98	1	Basook Creek	118	189	35
15-Oct-98	1	Basook Creek	119	190	36
15-Oct-98	1	Basook Creek	120	191	37

15-Oct-98	1	Basook Creek	121	192	38
15-Oct-98	1	Basook Creek	122	193	39
15-Oct-98	1	Basook Creek	123	194	40
15-Oct-98	1	Basook Creek	124	195	41
15-Oct-98	1	Basook Creek	125	196	42
15-Oct-98	1	Basook Creek	126	197	43
15-Oct-98	1	Basook Creek	127	198	44
15-Oct-98	1	Basook Creek	128	199	45
15-Oct-98	1	Basook Creek	129	200	46
15-Oct-98	1	Basook Creek	130	201	47
15-Oct-98	1	Basook Creek	131	202	48
15-Oct-98	1	Basook Creek	132	203	49
15-Oct-98	1	Basook Creek	133	204	50
15-Oct-98	1	Basook Creek	134	205	51
15-Oct-98	1	Basook Creek	135	206	52
15-Oct-98	1	Basook Creek	136	207	53
15-Oct-98	1	Basook Creek	138	209	54
15-Oct-98	1	Basook Creek	141	212	55
15-Oct-98	1	Basook Creek	142	213	56
15-Oct-98	1	Basook Creek	143	214	57
15-Oct-98	1	Basook Creek	144	215	58
15-Oct-98	1	Basook Creek	145	216	59
15-Oct-98	1	Basook Creek	146	217	60
18-Oct-98	1	Basook Creek	148	219	61
18-Oct-98	1	Basook Creek	149	220	62
18-Oct-98	1	Basook Creek	150	221	63
18-Oct-98	1	Basook Creek	151	222	64
18-Oct-98	1	Basook Creek	152	223	65
18-Oct-98	1	Basook Creek	153	224	66
18-Oct-98	1	Basook Creek	154	225	67
18-Oct-98	1	Basook Creek	155	226	68
18-Oct-98	1	Basook Creek	156	227	69
18-Oct-98	1	Basook Creek	157	228	70
18-Oct-98	1	Basook Creek	158	229	71
18-Oct-98	1	Basook Creek	159	230	72
18-Oct-98	1	Basook Creek	160	231	73
18-Oct-98	1	Basook Creek	161	232	74
18-Oct-98	1	Basook Creek	162	233	75
18-Oct-98	1	Basook Creek	163	234	76
18-Oct-98	1	Basook Creek	164	235	77
18-Oct-98	1	Basook Creek	165	236	78
18-Oct-98	1	Basook Creek	166	237	79
18-Oct-98	1	Basook Creek	167	238	80
18-Oct-98	1	Basook Creek	168	239	81
18-Oct-98	1	Basook Creek	169	240	82
18-Oct-98	1	Basook Creek	170	241	83
19-Oct-98	1	Basook Creek	171	242	84
19-Oct-98	1	Basook Creek	172	243	85
19-Oct-98	1	Basook Creek	173	244	86

19-Oct-98	1	Basook Creek	174	245	87
19-Oct-98	1	Basook Creek	175	246	88
19-Oct-98	1	Basook Creek	176	247	89
19-Oct-98	1	Basook Creek	177	248	90
19-Oct-98	1	Basook Creek	178	249	91
19-Oct-98	1	Basook Creek	179	250	92
19-Oct-98	1	Basook Creek	180	251	93
19-Oct-98	1	Basook Creek	181	252	94
19-Oct-98	1	Basook Creek	182	253	95
19-Oct-98	1	Basook Creek	183	254	96
19-Oct-98	1	Basook Creek	184	255	97
19-Oct-98	1	Basook Creek	185	256	98
19-Oct-98	1	Basook Creek	186	257	99
19-Oct-98	1	Basook Creek	187	258	100
19-Oct-98	1	Basook Creek	188	259	101
19-Oct-98	1	Basook Creek	189	260	102
19-Oct-98	1	Basook Creek	190	261	103
19-Oct-98	1	Basook Creek	191	262	104
19-Oct-98	1	Basook Creek	192	263	105
21-Oct-98	1	Basook Creek	193	264	106
21-Oct-98	1	Basook Creek	194	265	107
21-Oct-98	1	Basook Creek	195	266	108
21-Oct-98	1	Basook Creek	196	267	109
21-Oct-98	1	Basook Creek	197	268	110
21-Oct-98	1	Basook Creek	198	269	111
21-Oct-98	1	Basook Creek	199	270	112
21-Oct-98	1	Basook Creek	200	271	113
21-Oct-98	1	Basook Creek	201	272	114
21-Oct-98	1	Basook Creek	202	273	115
21-Oct-98	1	Basook Creek	203	274	116
21-Oct-98	1	Basook Creek	204	275	117
21-Oct-98	1	Basook Creek	205	276	118
21-Oct-98	1	Basook Creek	206	277	119
21-Oct-98	1	Basook Creek	207	278	120
21-Oct-98	1	Basook Creek	208	279	121
21-Oct-98	1	Basook Creek	209	280	122
21-Oct-98	1	Basook Creek	210	281	123
21-Oct-98	1	Basook Creek	211	282	124
21-Oct-98	1	Basook Creek	212	283	125
21-Oct-98	1	Basook Creek	213	284	126
21-Oct-98	1	Basook Creek	214	285	127
21-Oct-98	1	Basook Creek	215	286	128
21-Oct-98	1	Basook Creek	216	287	129
21-Oct-98	1	Basook Creek	217	288	130
21-Oct-98	1	Basook Creek	218	289	131
21-Oct-98	1	Basook Creek	219	290	132
23-Oct-98	1	Basook Creek	220	291	133
23-Oct-98	1	Basook Creek	221	292	134
23-Oct-98	1	Basook Creek	222	293	135

23-Oct-98	1	Basook Creek	223	294	136
23-Oct-98	1	Basook Creek	224	295	137
23-Oct-98	1	Basook Creek	225	296	138
23-Oct-98	1	Basook Creek	226	297	139
23-Oct-98	1	Basook Creek	227	298	140
23-Oct-98	1	Basook Creek	228	299	141
23-Oct-98	1	Basook Creek	229	300	142
23-Oct-98	1	Basook Creek	230	301	143
23-Oct-98	1	Basook Creek	231	302	144
23-Oct-98	1	Basook Creek	232	303	145
23-Oct-98	1	Basook Creek	233	304	146
23-Oct-98	1	Basook Creek	234	305	147
23-Oct-98	1	Basook Creek	235	306	148
23-Oct-98	1	Basook Creek	236	307	149
23-Oct-98	1	Basook Creek	237	308	150
23-Oct-98	1	Basook Creek	238	309	151
23-Oct-98	1	Basook Creek	239	310	152
23-Oct-98	1	Basook Creek	240	311	153
23-Oct-98	1	Basook Creek	241	312	154
23-Oct-98	1	Basook Creek	242	313	155
23-Oct-98	1	Basook Creek	243	314	156
26-Oct-98	1	Basook Creek	244	315	157
26-Oct-98	1	Basook Creek	245	316	158
26-Oct-98	1	Basook Creek	246	317	159
26-Oct-98	1	Basook Creek	247	318	160
26-Oct-98	1	Basook Creek	248	319	161
26-Oct-98	1	Basook Creek	249	320	162
26-Oct-98	1	Basook Creek	250	321	163
26-Oct-98	1	Basook Creek	251	322	164
26-Oct-98	1	Basook Creek	252	323	165
26-Oct-98	1	Basook Creek	253	324	166
26-Oct-98	1	Basook Creek	254	325	167
26-Oct-98	1	Basook Creek	255	326	168
26-Oct-98	1	Basook Creek	256	327	169
26-Oct-98	1	Basook Creek	257	328	170
26-Oct-98	1	Basook Creek	258	329	171
26-Oct-98	1	Basook Creek	259	330	172
26-Oct-98	1	Basook Creek	260	331	173
26-Oct-98	1	Basook Creek	261	332	174
26-Oct-98	1	Basook Creek	262	333	175
26-Oct-98	1	Basook Creek	263	334	176
26-Oct-98	1	Basook Creek	264	335	177
26-Oct-98	1	Basook Creek	265	336	178
26-Oct-98	1	Basook Creek	266	337	179
26-Oct-98	1	Basook Creek	267	338	180
26-Oct-98	1	Basook Creek	268	339	181
26-Oct-98	1	Basook Creek	269	340	182
26-Oct-98	1	Basook Creek	270	341	183
26-Oct-98	1	Basook Creek	271	342	184

28-Oct-98	1	Basook Creek	272	343	185
28-Oct-98	1	Basook Creek	273	344	186
28-Oct-98	1	Basook Creek	274	345	187
28-Oct-98	1	Basook Creek	275	346	188
28-Oct-98	1	Basook Creek	276	347	189
28-Oct-98	1	Basook Creek	277	348	190
28-Oct-98	1	Basook Creek	278	349	191
28-Oct-98	1	Basook Creek	280	351	192
28-Oct-98	1	Basook Creek	281	352	193
28-Oct-98	1	Basook Creek	282	353	194
28-Oct-98	1	Basook Creek	283	354	195
28-Oct-98	1	Basook Creek	284	355	196
28-Oct-98	1	Basook Creek	285	356	197
28-Oct-98	1	Basook Creek	286	357	198
28-Oct-98	1	Basook Creek	287	358	199
30-Oct-98	1	Basook Creek	288	359	200
30-Oct-98	1	Basook Creek	289	360	201
30-Oct-98	1	Basook Creek	290	361	202
30-Oct-98	1	Basook Creek	291	362	203
30-Oct-98	1	Basook Creek	292	363	204
30-Oct-98	1	Basook Creek	293	364	205
30-Oct-98	1	Basook Creek	294	365	206
30-Oct-98	1	Basook Creek	296	367	207
30-Oct-98	1	Basook Creek	297	368	208
30-Oct-98	1	Basook Creek	298	369	209
31-Oct-98	1	Basook Creek	300	371	210
31-Oct-98	1	Basook Creek	301	372	211
31-Oct-98	1	Basook Creek	302	373	212
31-Oct-98	1	Basook Creek	303	374	213
31-Oct-98	1	Basook Creek	304	375	214
22-Sep-98	2	Scrapper Hill 1998	1	376	215
22-Sep-98	2	Scrapper Hill 1998	2	377	216
22-Sep-98	2	Scrapper Hill 1998	3	378	217
23-Sep-98	2	Scrapper Hill 1998	4	379	218
23-Sep-98	2	Scrapper Hill 1998	5	380	219
23-Sep-98	2	Scrapper Hill 1998	6	381	220
26-Sep-98	2	Scrapper Hill 1998	9	384	221
26-Sep-98	2	Scrapper Hill 1998	10	385	222
27-Sep-98	2	Scrapper Hill 1998	15	390	223
27-Sep-98	2	Scrapper Hill 1998	16	391	224
27-Sep-98	2	Scrapper Hill 1998	17	392	225
30-Sep-98	2	Scrapper Hill 1998	18	393	226
30-Sep-98	2	Scrapper Hill 1998	19	394	227
01-Oct-98	2	Scrapper Hill 1998	20	395	228
07-Oct-98	2	Scrapper Hill 1998	52	427	229
12-Oct-98	2	Scrapper Hill 1998	67	442	230
12-Oct-98	2	Scrapper Hill 1998	68	443	231
13-Oct-98	2	Scrapper Hill 1998	72	447	232
13-Oct-98	2	Scrapper Hill 1998	73	448	233

14-Oct-98	2	Scrapper Hill 1998	77	452	234
19-Oct-98	2	Scrapper Hill 1998	80	455	235
19-Oct-98	2	Scrapper Hill 1998	81	456	236
19-Oct-98	2	Scrapper Hill 1998	82	457	237
19-Oct-98	2	Scrapper Hill 1998	83	458	238
19-Oct-98	2	Scrapper Hill 1998	84	459	239
19-Oct-98	2	Scrapper Hill 1998	85	460	240
19-Oct-98	2	Scrapper Hill 1998	86	461	241
19-Oct-98	2	Scrapper Hill 1998	87	462	242
19-Oct-98	2	Scrapper Hill 1998	88	463	243
19-Oct-98	2	Scrapper Hill 1998	89	464	244
19-Oct-98	2	Scrapper Hill 1998	90	465	245
19-Oct-98	2	Scrapper Hill 1998	91	466	246
19-Oct-98	2	Scrapper Hill 1998	92	467	247
19-Oct-98	2	Scrapper Hill 1998	93	468	248
20-Oct-98	2	Scrapper Hill 1998	95	470	249
20-Oct-98	2	Scrapper Hill 1998	96	471	250
20-Oct-98	2	Scrapper Hill 1998	97	472	251
20-Oct-98	2	Scrapper Hill 1998	98	473	252
20-Oct-98	2	Scrapper Hill 1998	99	474	253
20-Oct-98	2	Scrapper Hill 1998	100	475	254
20-Oct-98	2	Scrapper Hill 1998	101	476	255
21-Oct-98	2	Scrapper Hill 1998	103	478	256
21-Oct-98	2	Scrapper Hill 1998	104	479	257
21-Oct-98	2	Scrapper Hill 1998	105	480	258
21-Oct-98	2	Scrapper Hill 1998	106	481	259
21-Oct-98	2	Scrapper Hill 1998	107	482	260
21-Oct-98	2	Scrapper Hill 1998	108	483	261
21-Oct-98	2	Scrapper Hill 1998	109	484	262
21-Oct-98	2	Scrapper Hill 1998	110	485	263
25-Oct-98	2	Scrapper Hill 1998	111	486	264
25-Oct-98	2	Scrapper Hill 1998	112	487	265
25-Oct-98	2	Scrapper Hill 1998	113	488	266
25-Oct-98	2	Scrapper Hill 1998	114	489	267
25-Oct-98	2	Scrapper Hill 1998	115	490	268
25-Oct-98	2	Scrapper Hill 1998	116	491	269
25-Oct-98	2	Scrapper Hill 1998	117	492	270
25-Oct-98	2	Scrapper Hill 1998	118	493	271
26-Oct-98	2	Scrapper Hill 1998	119	494	272
26-Oct-98	2	Scrapper Hill 1998	120	495	273
26-Oct-98	2	Scrapper Hill 1998	121	496	274
26-Oct-98	2	Scrapper Hill 1998	122	497	275
26-Oct-98	2	Scrapper Hill 1998	123	498	276
26-Oct-98	2	Scrapper Hill 1998	124	499	277
26-Oct-98	2	Scrapper Hill 1998	125	500	278
26-Oct-98	2	Scrapper Hill 1998	126	501	279
26-Oct-98	2	Scrapper Hill 1998	127	502	280
26-Oct-98	2	Scrapper Hill 1998	128	503	281
26-Oct-98	2	Scrapper Hill 1998	129	504	282

27-Oct-98	2	Scrapper Hill 1998	130	505	283
27-Oct-98	2	Scrapper Hill 1998	131	506	284
02-Nov-98	2	Scrapper Hill 1998	133	508	285
02-Nov-98	2	Scrapper Hill 1998	135	509	286
02-Nov-98	2	Scrapper Hill 1998	136	510	287
02-Nov-98	2	Scrapper Hill 1998	137	511	288
02-Nov-98	2	Scrapper Hill 1998	138	512	289
02-Nov-98	2	Scrapper Hill 1998	139	513	290
02-Nov-98	2	Scrapper Hill 1998	140	514	291
02-Nov-98	2	Scrapper Hill 1998	141	515	292
02-Nov-98	2	Scrapper Hill 1998	142	516	293
02-Nov-98	2	Scrapper Hill 1998	143	517	294
02-Nov-98	2	Scrapper Hill 1998	144	518	295
02-Nov-98	2	Scrapper Hill 1998	145	519	296
02-Nov-98	2	Scrapper Hill 1998	146	520	297
02-Nov-98	2	Scrapper Hill 1998	147	521	298
02-Nov-98	2	Scrapper Hill 1998	148	522	299
02-Nov-98	2	Scrapper Hill 1998	149	523	300
02-Nov-98	2	Scrapper Hill 1998	150	524	301
02-Nov-98	2	Scrapper Hill 1998	151	525	302
02-Nov-98	2	Scrapper Hill 1998	152	526	303
02-Nov-98	2	Scrapper Hill 1998	153	527	304
02-Nov-98	2	Scrapper Hill 1998	154	528	305
02-Nov-98	2	Scrapper Hill 1998	155	529	306
02-Nov-98	2	Scrapper Hill 1998	156	530	307
02-Nov-98	2	Scrapper Hill 1998	157	531	308
03-Nov-98	2	Scrapper Hill 1998	158	532	309
03-Nov-98	2	Scrapper Hill 1998	159	533	310
03-Nov-98	2	Scrapper Hill 1998	160	534	311
03-Nov-98	2	Scrapper Hill 1998	161	535	312
03-Nov-98	2	Scrapper Hill 1998	162	536	313
03-Nov-98	2	Scrapper Hill 1998	163	537	314
03-Nov-98	2	Scrapper Hill 1998	164	538	315
03-Nov-98	2	Scrapper Hill 1998	165	539	316
03-Nov-98	2	Scrapper Hill 1998	166	540	317
03-Nov-98	2	Scrapper Hill 1998	167	541	318
03-Nov-98	2	Scrapper Hill 1998	168	542	319
05-Nov-98	2	Scrapper Hill 1998	169	543	320
05-Nov-98	2	Scrapper Hill 1998	170	544	321
05-Nov-98	2	Scrapper Hill 1998	171	545	322
05-Nov-98	2	Scrapper Hill 1998	172	546	323
05-Nov-98	2	Scrapper Hill 1998	173	547	324
05-Nov-98	2	Scrapper Hill 1998	174	548	325
07-Nov-98	2	Scrapper Hill 1998	175	549	326
07-Nov-98	2	Scrapper Hill 1998	176	550	327
07-Nov-98	2	Scrapper Hill 1998	177	551	328
07-Nov-98	2	Scrapper Hill 1998	178	552	329
07-Nov-98	2	Scrapper Hill 1998	179	553	330
08-Nov-98	2	Scrapper Hill 1998	180	554	331

07-Nov-98	2	Scrapper Hill 1998	134	555	332
08-Nov-98	2	Scrapper Hill 1998	181	556	333
08-Nov-98	2	Scrapper Hill 1998	182	557	334
08-Nov-98	2	Scrapper Hill 1998	183	558	335
08-Nov-98	2	Scrapper Hill 1998	184	559	336
08-Nov-98	2	Scrapper Hill 1998	185	560	337
08-Nov-98	2	Scrapper Hill 1998	186	561	338
08-Nov-98	2	Scrapper Hill 1998	187	562	339
12-Nov-98	2	Scrapper Hill 1998	188	563	340
12-Nov-98	2	Scrapper Hill 1998	189	564	341
12-Nov-98	2	Scrapper Hill 1998	190	565	342
12-Nov-98	2	Scrapper Hill 1998	191	566	343
12-Nov-98	2	Scrapper Hill 1998	192	567	344
12-Nov-98	2	Scrapper Hill 1998	193	568	345
12-Nov-98	2	Scrapper Hill 1998	194	569	346
12-Nov-98	2	Scrapper Hill 1998	195	570	347
12-Nov-98	2	Scrapper Hill 1998	196	571	348
12-Nov-98	2	Scrapper Hill 1998	197	572	349
12-Nov-98	2	Scrapper Hill 1998	198	573	350
12-Nov-98	2	Scrapper Hill 1998	199	574	351
12-Nov-98	2	Scrapper Hill 1998	200	575	352
13-Nov-98	2	Scrapper Hill 1998	201	576	353
13-Nov-98	2	Scrapper Hill 1998	202	577	354
13-Nov-98	2	Scrapper Hill 1998	203	578	355
13-Nov-98	2	Scrapper Hill 1998	204	579	356
13-Nov-98	2	Scrapper Hill 1998	205	580	357
13-Nov-98	2	Scrapper Hill 1998	206	581	358
13-Nov-98	2	Scrapper Hill 1998	207	582	359
13-Nov-98	2	Scrapper Hill 1998	208	583	360
13-Nov-98	2	Scrapper Hill 1998	209	584	361
13-Nov-98	2	Scrapper Hill 1998	210	585	362
13-Nov-98	2	Scrapper Hill 1998	211	586	363
14-Nov-98	2	Scrapper Hill 1998	212	587	364
14-Nov-98	2	Scrapper Hill 1998	213	588	365
14-Nov-98	2	Scrapper Hill 1998	214	589	366
14-Nov-98	2	Scrapper Hill 1998	215	590	367
14-Nov-98	2	Scrapper Hill 1998	216	591	368
14-Nov-98	2	Scrapper Hill 1998	217	592	369
14-Nov-98	2	Scrapper Hill 1998	218	593	370
14-Nov-98	2	Scrapper Hill 1998	219	594	371
15-Nov-98	2	Scrapper Hill 1998	220	595	372
15-Nov-98	2	Scrapper Hill 1998	221	596	373
15-Nov-98	2	Scrapper Hill 1998	222	597	374
15-Nov-98	2	Scrapper Hill 1998	223	598	375
15-Nov-98	2	Scrapper Hill 1998	224	599	376
15-Nov-98	2	Scrapper Hill 1998	225	600	377
15-Nov-98	2	Scrapper Hill 1998	226	601	378
15-Nov-98	2	Scrapper Hill 1998	227	602	379
15-Nov-98	2	Scrapper Hill 1998	228	603	380

17-Nov-98	2	Scrapper Hill 1998	232	604	381
17-Nov-98	2	Scrapper Hill 1998	233	605	382
17-Nov-98	2	Scrapper Hill 1998	234	606	383
13-Nov-98	2	Scrapper Hill 1998	229	607	384
02-Nov-98	2	Scrapper Hill 1998	230	608	385
25-Sep-98	3	Trail River	1	609	386
26-Sep-98	3	Trail River	2	610	387
27-Sep-98	3	Trail River	3	611	388
27-Sep-98	3	Trail River	4	612	389
28-Sep-98	3	Trail River	14	622	390
29-Sep-98	3	Trail River	19	627	391
01-Oct-98	3	Trail River	34	642	392
01-Oct-98	3	Trail River	43	651	393
03-Oct-98	3	Trail River	55	663	394
03-Oct-98	3	Trail River	56	664	395
03-Oct-98	3	Trail River	64	672	396
05-Oct-98	3	Trail River	72	680	397
05-Oct-98	3	Trail River	73	681	398
05-Oct-98	3	Trail River	74	682	399
05-Oct-98	3	Trail River	77	685	400
07-Oct-98	3	Trail River	80	688	401
07-Oct-98	3	Trail River	81	689	402
07-Oct-98	3	Trail River	82	690	403
07-Oct-98	3	Trail River	83	691	404
13-Oct-98	3	Trail River	91	699	405
13-Oct-98	3	Trail River	92	700	406
13-Oct-98	3	Trail River	93	701	407
13-Oct-98	3	Trail River	94	702	408
13-Oct-98	3	Trail River	95	703	409
13-Oct-98	3	Trail River	96	704	410
13-Oct-98	3	Trail River	97	705	411
15-Oct-98	3	Trail River	98	706	412
15-Oct-98	3	Trail River	99	707	413
15-Oct-98	3	Trail River	100	708	414
15-Oct-98	3	Trail River	101	709	415
19-Oct-98	3	Trail River	109	717	416
19-Oct-98	3	Trail River	110	718	417
19-Oct-98	3	Trail River	111	719	418
19-Oct-98	3	Trail River	112	720	419
19-Oct-98	3	Trail River	113	721	420
19-Oct-98	3	Trail River	114	722	421
11-Oct-99	4	Cutoff	13	7	422
11-Oct-99	4	Cutoff	14	8	423
11-Oct-99	4	Cutoff	15	9	424
11-Oct-99	4	Cutoff	16	10	425
15-Oct-99	4	Cutoff	33	27	426
15-Oct-99	4	Cutoff	34	28	427
15-Oct-99	4	Cutoff	35	29	428
15-Oct-99	4	Cutoff	36	30	429

15-Oct-99	4	Cutoff	37	31	430
15-Oct-99	4	Cutoff	38	32	431
18-Oct-99	4	Cutoff	57	51	432
18-Oct-99	4	Cutoff	58	52	433
18-Oct-99	4	Cutoff	59	53	434
18-Oct-99	4	Cutoff	60	54	435
18-Oct-99	4	Cutoff	61	55	436
18-Oct-99	4	Cutoff	62	56	437
18-Oct-99	4	Cutoff	63	57	438
18-Oct-99	4	Cutoff	64	58	439
18-Oct-99	4	Cutoff	65	59	440
18-Oct-99	4	Cutoff	66	60	441
18-Oct-99	4	Cutoff	67	61	442
18-Oct-99	4	Cutoff	68	62	443
18-Oct-99	4	Cutoff	69	63	444
18-Oct-99	4	Cutoff	70	64	445
18-Oct-99	4	Cutoff	71	65	446
18-Oct-99	4	Cutoff	72	66	447
20-Oct-99	4	Cutoff	86	80	448
20-Oct-99	4	Cutoff	88	82	449
20-Oct-99	4	Cutoff	89	83	450
22-Oct-99	4	Cutoff	93	87	451
22-Oct-99	4	Cutoff	94	88	452
22-Oct-99	4	Cutoff	95	89	453
22-Oct-99	4	Cutoff	96	90	454
22-Oct-99	4	Cutoff	97	91	455
22-Oct-99	4	Cutoff	98	92	456
22-Oct-99	4	Cutoff	99	93	457
22-Oct-99	4	Cutoff	101	95	458
25-Oct-99	4	Cutoff	104	98	459
27-Oct-99	4	Cutoff	112	106	460
27-Oct-99	4	Cutoff	113	107	461
27-Oct-99	4	Cutoff	114	108	462
27-Oct-99	4	Cutoff	115	109	463
27-Oct-99	4	Cutoff	116	110	464
27-Oct-99	4	Cutoff	117	111	465
29-Oct-99	4	Cutoff	119	113	466
29-Oct-99	4	Cutoff	120	114	467
29-Oct-99	4	Cutoff	121	115	468
29-Oct-99	4	Cutoff	122	116	469
29-Oct-99	4	Cutoff	123	117	470
29-Oct-99	4	Cutoff	124	118	471
29-Oct-99	4	Cutoff	125	119	472
29-Oct-99	4	Cutoff	126	120	473
29-Oct-99	4	Cutoff	127	121	474
01-Nov-99	4	Cutoff	129	123	475
01-Nov-99	4	Cutoff	130	124	476
01-Nov-99	4	Cutoff	131	125	477
01-Nov-99	4	Cutoff	132	126	478

01-Nov-99	4	Cutoff	133	127	479
01-Nov-99	4	Cutoff	134	128	480
01-Nov-99	4	Cutoff	135	129	481
01-Nov-99	4	Cutoff	136	130	482
01-Nov-99	4	Cutoff	137	131	483
01-Nov-99	4	Cutoff	138	132	484
01-Nov-99	4	Cutoff	139	133	485
03-Nov-99	4	Cutoff	140	134	486
03-Nov-99	4	Cutoff	141	135	487
03-Nov-99	4	Cutoff	142	136	488
03-Nov-99	4	Cutoff	143	137	489
03-Nov-99	4	Cutoff	144	138	490
03-Nov-99	4	Cutoff	145	139	491
03-Nov-99	4	Cutoff	146	140	492
03-Nov-99	4	Cutoff	147	141	493
03-Nov-99	4	Cutoff	148	142	494
03-Nov-99	4	Cutoff	149	143	495
03-Nov-99	4	Cutoff	150	144	496
05-Nov-99	4	Cutoff	151	145	497
05-Nov-99	4	Cutoff	153	147	498
05-Nov-99	4	Cutoff	154	148	499
05-Nov-99	4	Cutoff	155	149	500
05-Nov-99	4	Cutoff	156	150	501
05-Nov-99	4	Cutoff	157	151	502
08-Nov-99	4	Cutoff	158	152	503
08-Nov-99	4	Cutoff	159	153	504
08-Nov-99	4	Cutoff	160	154	505
08-Nov-99	4	Cutoff	161	155	506
10-Nov-99	4	Cutoff	163	157	507
10-Nov-99	4	Cutoff	164	158	508
10-Nov-99	4	Cutoff	165	159	509
10-Nov-99	4	Cutoff	166	160	510
10-Nov-99	4	Cutoff	167	161	511
10-Nov-99	4	Cutoff	168	162	512
10-Nov-99	4	Cutoff	169	163	513
10-Nov-99	4	Cutoff	170	164	514
10-Nov-99	4	Cutoff	171	165	515
10-Nov-99	4	Cutoff	172	166	516
10-Nov-99	4	Cutoff	173	167	517
10-Nov-99	4	Cutoff	174	168	518
15-Nov-99	4	Cutoff	175	169	519
15-Nov-99	4	Cutoff	176	170	520
15-Nov-99	4	Cutoff	177	171	521
15-Nov-99	4	Cutoff	178	172	522
17-Nov-99	4	Cutoff	179	173	523
17-Nov-99	4	Cutoff	180	174	524
17-Nov-99	4	Cutoff	181	175	525
07-Oct-99	4	Cutoff	1	176	526
07-Oct-99	5	Scrapper Hill 1999	2	177	527

07-Oct-99	5	Scrapper Hill 1999	3	178	528
07-Oct-99	5	Scrapper Hill 1999	4	179	529
07-Oct-99	5	Scrapper Hill 1999	5	180	530
08-Oct-99	5	Scrapper Hill 1999	9	184	531
08-Oct-99	5	Scrapper Hill 1999	10	185	532
08-Oct-99	5	Scrapper Hill 1999	11	186	533
08-Oct-99	5	Scrapper Hill 1999	12	187	534
08-Oct-99	5	Scrapper Hill 1999	13	188	535
09-Oct-99	5	Scrapper Hill 1999	17	192	536
09-Oct-99	5	Scrapper Hill 1999	18	193	537
09-Oct-99	5	Scrapper Hill 1999	19	194	538
11-Oct-99	5	Scrapper Hill 1999	22	197	539
11-Oct-99	5	Scrapper Hill 1999	23	198	540
11-Oct-99	5	Scrapper Hill 1999	24	199	541
13-Oct-99	5	Scrapper Hill 1999	27	202	542
13-Oct-99	5	Scrapper Hill 1999	28	203	543
13-Oct-99	5	Scrapper Hill 1999	29	204	544
13-Oct-99	5	Scrapper Hill 1999	30	205	545
13-Oct-99	5	Scrapper Hill 1999	31	206	546
15-Oct-99	5	Scrapper Hill 1999	33	208	547
15-Oct-99	5	Scrapper Hill 1999	34	209	548
18-Oct-99	5	Scrapper Hill 1999	36	211	549
18-Oct-99	5	Scrapper Hill 1999	37	212	550
18-Oct-99	5	Scrapper Hill 1999	38	213	551
18-Oct-99	5	Scrapper Hill 1999	39	214	552
18-Oct-99	5	Scrapper Hill 1999	40	215	553
18-Oct-99	5	Scrapper Hill 1999	41	216	554
20-Oct-99	5	Scrapper Hill 1999	44	219	555
20-Oct-99	5	Scrapper Hill 1999	45	220	556
20-Oct-99	5	Scrapper Hill 1999	46	221	557
20-Oct-99	5	Scrapper Hill 1999	47	222	558
20-Oct-99	5	Scrapper Hill 1999	48	223	559
20-Oct-99	5	Scrapper Hill 1999	49	224	560
20-Oct-99	5	Scrapper Hill 1999	50	225	561
20-Oct-99	5	Scrapper Hill 1999	51	226	562
20-Oct-99	5	Scrapper Hill 1999	52	227	563
20-Oct-99	5	Scrapper Hill 1999	53	228	564
20-Oct-99	5	Scrapper Hill 1999	54	229	565
22-Oct-99	5	Scrapper Hill 1999	57	232	566
22-Oct-99	5	Scrapper Hill 1999	58	233	567
22-Oct-99	5	Scrapper Hill 1999	59	234	568
22-Oct-99	5	Scrapper Hill 1999	60	235	569
22-Oct-99	5	Scrapper Hill 1999	61	236	570
22-Oct-99	5	Scrapper Hill 1999	62	237	571
25-Oct-99	5	Scrapper Hill 1999	66	241	572
27-Oct-99	5	Scrapper Hill 1999	70	245	573
27-Oct-99	5	Scrapper Hill 1999	71	246	574
29-Oct-99	5	Scrapper Hill 1999	73	248	575
29-Oct-99	5	Scrapper Hill 1999	74	249	576

01-Nov-99	5	Scrapper Hill 1999	76	251	577
01-Nov-99	5	Scrapper Hill 1999	77	252	578
01-Nov-99	5	Scrapper Hill 1999	78	253	579
03-Nov-99	5	Scrapper Hill 1999	81	256	580
03-Nov-99	5	Scrapper Hill 1999	82	257	581
03-Nov-99	5	Scrapper Hill 1999	83	258	582
03-Nov-99	5	Scrapper Hill 1999	84	259	583
03-Nov-99	5	Scrapper Hill 1999	85	260	584
03-Nov-99	5	Scrapper Hill 1999	86	261	585
05-Nov-99	5	Scrapper Hill 1999	88	263	586
05-Nov-99	5	Scrapper Hill 1999	89	264	587
05-Nov-99	5	Scrapper Hill 1999	90	265	588
05-Nov-99	5	Scrapper Hill 1999	91	266	589
05-Nov-99	5	Scrapper Hill 1999	92	267	590
05-Nov-99	5	Scrapper Hill 1999	93	268	591
08-Nov-99	5	Scrapper Hill 1999	94	269	592
08-Nov-99	5	Scrapper Hill 1999	95	270	593
08-Nov-99	5	Scrapper Hill 1999	96	271	594
10-Nov-99	5	Scrapper Hill 1999	97	272	595
10-Nov-99	5	Scrapper Hill 1999	98	273	596
10-Nov-99	5	Scrapper Hill 1999	99	274	597
12-Nov-99	5	Scrapper Hill 1999	100	275	598
12-Nov-99	5	Scrapper Hill 1999	101	276	599
12-Nov-99	5	Scrapper Hill 1999	102	277	600
12-Nov-99	5	Scrapper Hill 1999	103	278	601
12-Nov-99	5	Scrapper Hill 1999	104	279	602
15-Nov-99	5	Scrapper Hill 1999	105	280	603
15-Nov-99	5	Scrapper Hill 1999	106	281	604
17-Nov-99	5	Scrapper Hill 1999	108	283	605
19-Oct-99	5	Scrapper Hill 1999	1	284	606
19-Oct-99	6	Road River	2	285	607
19-Oct-99	6	Road River	3	286	608
19-Oct-99	6	Road River	4	287	609
19-Oct-99	6	Road River	7	290	610
20-Oct-99	6	Road River	9	292	611
20-Oct-99	6	Road River	10	293	612
20-Oct-99	6	Road River	11	294	613
20-Oct-99	6	Road River	12	295	614
20-Oct-99	6	Road River	13	296	615
20-Oct-99	6	Road River	14	297	616
20-Oct-99	6	Road River	17	300	617
20-Oct-99	6	Road River	18	301	618
20-Oct-99	6	Road River	19	302	619
20-Oct-99	6	Road River	20	303	620
22-Oct-99	6	Road River	22	305	621
22-Oct-99	6	Road River	23	306	622
22-Oct-99	6	Road River	24	307	623
22-Oct-99	6	Road River	25	308	624
22-Oct-99	6	Road River	26	309	625

22-Oct-99	6	Road River	27	310	626
25-Oct-99	6	Road River	28	311	627
25-Oct-99	6	Road River	29	312	628
25-Oct-99	6	Road River	30	313	629
25-Oct-99	6	Road River	31	314	630
25-Oct-99	6	Road River	32	315	631
25-Oct-99	6	Road River	34	317	632
25-Oct-99	6	Road River	35	318	633
25-Oct-99	6	Road River	36	319	634
25-Oct-99	6	Road River	37	320	635
25-Oct-99	6	Road River	38	321	636
25-Oct-99	6	Road River	39	322	637
25-Oct-99	6	Road River	40	323	638
27-Oct-99	6	Road River	44	327	639
27-Oct-99	6	Road River	45	328	640
27-Oct-99	6	Road River	46	329	641
27-Oct-99	6	Road River	47	330	642
27-Oct-99	6	Road River	48	331	643
29-Oct-99	6	Road River	50	333	644
29-Oct-99	6	Road River	51	334	645
05-Nov-99	6	Road River	54	337	646
05-Nov-99	6	Road River	55	338	647
05-Nov-99	6	Road River	56	339	648
05-Nov-99	6	Road River	57	340	649
05-Nov-99	6	Road River	58	341	650
08-Nov-99	6	Road River	60	343	651
08-Nov-99	6	Road River	61	344	652
08-Nov-99	6	Road River	62	345	653
08-Nov-99	6	Road River	63	346	654
08-Nov-99	6	Road River	64	347	655
10-Nov-99	6	Road River	65	348	656
10-Nov-99	6	Road River	66	349	657
10-Nov-99	6	Road River	67	350	658
19-Oct-99	5	Scrapper Hill 1999	1 M	351	659
20-Oct-99	5	Scrapper Hill 1999	15 M	365	660
20-Oct-99	5	Scrapper Hill 1999	16 M	366	661
20-Oct-99	5	Scrapper Hill 1999	17 M	367	662
20-Oct-99	5	Scrapper Hill 1999	18 M	368	663
20-Oct-99	5	Scrapper Hill 1999	19 M	369	664
24-Oct-99	5	Scrapper Hill 1999	29 M	379	665
29-Oct-99	5	Scrapper Hill 1999	36 M	386	666
29-Oct-99	6	Road River	37 M	387	667
09-Nov-99	6	Road River	38 M	388	668
09-Nov-99	4	Cutoff	39 M	389	669
09-Nov-99	4	Cutoff	40 M	390	670
09-Nov-99	4	Cutoff	41 M	391	671
09-Nov-99	4	Cutoff	42 M	392	672
09-Nov-99	4	Cutoff	43 M	393	673
09-Nov-99	4	Cutoff	44 M	394	674

09-Nov-99	4	Cutoff	45 M	395	675
09-Nov-99	4	Cutoff	46 M	396	676
10-Nov-99	4	Cutoff	48 M	398	677
10-Nov-99	4	Cutoff	49 M	399	678
10-Nov-99	4	Cutoff	50 M	400	679
10-Nov-99	4	Cutoff	51 M	401	680
10-Nov-99	4	Cutoff	52 M	402	681
10-Nov-99	4	Cutoff	53 M	403	682
10-Nov-99	4	Cutoff	54 M	404	683
10-Nov-99	4	Cutoff	55 M	405	684
11-Nov-99	4	Cutoff	56 M	406	685
11-Nov-99	4	Cutoff	57 M	407	686
11-Nov-99	4	Cutoff	58 M	408	687
11-Nov-99	4	Cutoff	59 M	409	688
11-Nov-99	4	Cutoff	60 M	410	689
12-Nov-99	4	Cutoff	61 M	411	690
12-Nov-99	4	Cutoff	62 M	412	691
12-Nov-99	4	Cutoff	63 M	413	692
20-24oct	4	Cutoff	1 RF	416	693
20-24oct	5	Scraper Hill 1999	2 RF	417	694
20-24oct	5	Scraper Hill 1999	3 RF	418	695
20-24oct	5	Scraper Hill 1999	4 RF	419	696
20-24oct	5	Scraper Hill 1999	5 RF	420	697
20-24oct	5	Scraper Hill 1999	6 RF	421	698
20-24oct	5	Scraper Hill 1999	7 RF	422	699
20-24oct	5	Scraper Hill 1999	8 RF	423	700
20-24oct	5	Scraper Hill 1999	9 RF	424	701
20-24oct	5	Scraper Hill 1999	10 RF	425	702
20-24oct	5	Scraper Hill 1999	11 RF	426	703
20-24oct	5	Scraper Hill 1999	12 RF	427	704
20-24oct	5	Scraper Hill 1999	13 RF	428	705
20-24oct	5	Scraper Hill 1999	14 RF	429	706
20-24oct	5	Scraper Hill 1999	15 RF	430	707
20-24oct	5	Scraper Hill 1999	16 RF	431	708
20-24oct	5	Scraper Hill 1999	17 RF	432	709
20-24oct	5	Scraper Hill 1999	18 RF	433	710
20-24oct	5	Scraper Hill 1999	19 RF	434	711
20-24oct	5	Scraper Hill 1999	20 RF	435	712
20-24oct	5	Scraper Hill 1999	21 RF	436	713
20-24oct	5	Scraper Hill 1999	22 RF	437	714
20-24oct	5	Scraper Hill 1999	23 RF	438	715
20-24oct	5	Scraper Hill 1999	24 RF	439	716
20-24oct	5	Scraper Hill 1999	25 RF	440	717
20-24oct	5	Scraper Hill 1999	26 RF	441	718
20-24oct	5	Scraper Hill 1999	27 RF	442	719
20-24oct	5	Scraper Hill 1999	28 RF	443	720
20-24oct	5	Scraper Hill 1999	29 RF	444	721
20-24oct	5	Scraper Hill 1999	30 RF	445	722

APPENDIX III. Program for testing experimental design for fecundity, written in Microsoft Visual Basic® for Applications.

```
Sub fecundity()

a1 = Time()
  Range("D4:F496").ClearContents
  Range("H4").ClearContents
  Range("H6").ClearContents
  Range("J4:J522").ClearContents
  Range("L4:L522").ClearContents
  Range("N4:N522").ClearContents
  Range("P4:P522").ClearContents
  Range("R4:R522").ClearContents
  Range("T5:Z8").ClearContents
  Range("AB67:AC587").ClearContents
  Range("AE3:AE4").ClearContents
  Range("AF4:AJ522").ClearContents
  Range("AM21:AM29").ClearContents
  Range("AR3:Ay20800").ClearContents

  No = 63
  Range("AM21") = No
  N = 10
  q = 0
  r = 0


  For sample_size = 1 To 10
    Cells(22, 39) = N 'n1
    manip = 3000

    For trial_manipulation = 1 To 14
      Range("Am23") = manip 'manipulation
      intercept_sig_diff_counter = 0
      rep = 1000
      c_counter = 0
      s_counter = 0
      i_counter = 0

      For Trial = 1 To rep
         Range("D4:F517").ClearContents
        Range("H4").ClearContents
        Range("H6").ClearContents
        Range("J4:J542").ClearContents
        Range("L4:L553").ClearContents
        Range("N4:N503").ClearContents
        Range("P4:P503").ClearContents
        Range("R4:R503").ClearContents
        Range("T5:Z8").ClearContents
        Range("AB67:AC567").ClearContents
```

```
    Range("AE3").ClearContents
    Range("AE4").ClearContents
    Range("AF4:AJ481").ClearContents

' norminv
    Range("D4").Select
    ActiveCell.FormulaR1C1 = "=+NORMINV(RAND()*1,0,11992.91)"
    ' boot_X_predY Macro
    Range("E4").Select
    ActiveCell.FormulaR1C1 = "=+VLOOKUP(INT(RAND()*62+1),R4C1:R66C2,2,FALSE)"
    Range("F4").Select
    ActiveCell.FormulaR1C1 = "=+R9C7*RC[-1]+R12C7+R23C39+RC[-2]"
    Range("D4:F4").Select
    Selection.Copy
    Range(Cells(5, 4), Cells(N + 3, 4)).Select
    ActiveSheet.Paste
    Range(Cells(4, 4), Cells(N + 3, 6)).Select
    Selection.Copy
    Range("D4").Select
    Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, SkipBlanks:= _
    False, Transpose:=False

    ' Xbar_Ybar Macro
    Range("H4").Select
    ActiveCell.FormulaR1C1 = "=+AVERAGE(RC[-3]:R[5000]C[-3])"
    Range("H6").Select
    ActiveCell.FormulaR1C1 = "=+AVERAGE(R[-2]C[-2]:R[5000]C[-2])"
    Range("J4").Select
    ActiveCell.FormulaR1C1 = "=+RC[-5]-R4C8"
    Range("L4").Select
    ActiveCell.FormulaR1C1 = "=+RC[-6]-R6C8"

    ' x2_xy_y2 Macro
    Range("N4").Select
    ActiveCell.FormulaR1C1 = "=+RC[-4]^2"
    Range("P4").Select
    ActiveCell.FormulaR1C1 = "=+RC[-6]*RC[-4]"
    Range("R4").Select
    ActiveCell.FormulaR1C1 = "=+RC[-6]^2"
    Range("I4:R4").Select
    Selection.Copy
    Range(Cells(5, 9), Cells(N + 3, 18)).Select
    ActiveSheet.Paste

    ' sumx2_sumxy Macro
    Range("T5").Select
    ActiveCell.FormulaR1C1 = "=+SUM(R[-1]C[-6]:R[5000]C[-6])"
    Range("U5").Select
    ActiveCell.FormulaR1C1 = "=+SUM(R[-1]C[-5]:R[5000]C[-5])"
    Range("V5").Select
    ActiveCell.FormulaR1C1 = "=+SUM(R[-1]C[-4]:R[5000]C[-4])"
    Range("T7").Select
    ActiveCell.FormulaR1C1 = "=+SUM(R[-3]C:R[-2]C)"
```

```
Range("U7").Select
ActiveCell.FormulaR1C1 = "=+SUM(R[-3]C:R[-2]C)"
Range("V7").Select
ActiveCell.FormulaR1C1 = "=+SUM(R[-3]C:R[-2]C)"

' bi_SS_n_DF Macro
Range("W5").Select
ActiveCell.FormulaR1C1 = "=+RC[-2]/RC[-3]"
Range("X5").Select
ActiveCell.FormulaR1C1 = "=+RC[-2]-RC[-3]^2/RC[-4]"
Range("Y5").Select
ActiveCell.FormulaR1C1 = "=+COUNT(RC[-19]:R[5000]C[-19])"
Range("Z5").Select
ActiveCell.FormulaR1C1 = "=+RC[-1]-2"
Range("W7").Select
ActiveCell.FormulaR1C1 = "=+RC[-2]/RC[-3]"
Range("X7").Select
ActiveCell.FormulaR1C1 = "=+RC[-2]-RC[-3]^2/RC[-4]"
Range("Y7").Select
ActiveCell.FormulaR1C1 = "=+SUM(R[-3]C:R[-2]C)"
Range("Z7").Select
ActiveCell.FormulaR1C1 = "=+RC[-1]-3"
Range("X6").Select
ActiveCell.FormulaR1C1 = "=SUM(R[-2]C:R[-1]C)"
Range("Z6").Select
ActiveCell.FormulaR1C1 = "=SUM(R[-2]C:R[-1]C)"

'calc total X and Y

Range("E4:F500").Copy
Range("AB67").Select
ActiveSheet.Paste
Range("AE3").Select
ActiveCell.FormulaR1C1 = "=AVERAGE(R[1]C[-3]:R[501]C[-3])"
 Range("AE4").Select
 ActiveCell.FormulaR1C1 = "=AVERAGE(RC[-2]:R[500]C[-2])"
Range("AF4").Select
ActiveCell.FormulaR1C1 = "=RC[-4]-R3C31"
Range("AG4").Select
ActiveCell.FormulaR1C1 = "=RC[-4]-R4C31"
Range("AH4").Select
ActiveCell.FormulaR1C1 = "=RC[-2]^2"
Range("AI4").Select
ActiveCell.FormulaR1C1 = "=RC[-3]*RC[-2]"
Range("AJ4").Select
ActiveCell.FormulaR1C1 = "=RC[-3]^2"
Range("AF4:AJ4").Copy
N2 = Range("Y7")
Range(Cells(4, 32), Cells(N2 + 4, 36)).Select
ActiveSheet.Paste

'total SS calcs
Range("T8").Select
```

```
            ActiveCell.FormulaR1C1 = "=SUM(R[-4]C[14]:R[518]C[14])"
            Range("U8").Select
            ActiveCell.FormulaR1C1 = "=SUM(R[-4]C[14]:R[493]C[14])"
            Range("V8").Select
            ActiveCell.FormulaR1C1 = "=SUM(R[-4]C[14]:R[493]C[14])"
            Range("X8").Select
            ActiveCell.FormulaR1C1 = "=RC[-2]-RC[-3]^2/RC[-4]"
            Range("Z8").Select
            ActiveCell.FormulaR1C1 = "=SUM(R[-4]C[-1]:R[-3]C[-1])-2"
           'test power
             If Range("AN6") < 0.05 Then ' coincident diff
               If Range("AN10") > 0.05 Then 'slope equal
                 If Range("AN16") < 0.05 Then intercept_sig_diff_counter = intercept_sig_diff_counter +
1 'intercept different
                 End If
                 End If
             Range("AM24") = intercept_sig_diff_counter

If Range("AL6") < 0.05 Then c_counter = c_counter + 1
If Range("AL10") < 0.05 Then s_counter = s_counter + 1
If Range("AL16") < 0.05 Then i_counter = i_counter + 1
Range("AN7") = c_counter
Range("AN12") = s_counter
Range("AN18") = i_counter

              Next Trial

           Power = intercept_sig_diff_counter / rep * 100
           Range("AM25") = Power

           Range("AM21:AM25").Copy
             If Cells(q + 3, 44) <> "" Then q = q + 1
             Cells(q + 3, 44).Select
             Selection.PasteSpecial Paste:=xlAll, Operation:=xlNone, SkipBlanks:=False _
             , Transpose:=True

           Range("AN7,AN12,AN18").Copy
             If Cells(r + 3, 49) <> "" Then r = r + 1
             Cells(r + 3, 49).Select
             Selection.PasteSpecial Paste:=xlAll, Operation:=xlNone, SkipBlanks:=False _
             , Transpose:=True

           ActiveWorkbook.Save
           manip = manip + 1000
      Next trial_manipulation
      N = N + 10

    Next sample_size
a2 = Time()
Range("AM29") = a2 - a1
MsgBox "Done"
End Sub
```

	A	B	C	D	E	F	G	H	I
1	1	2	3	4	5	6	7	8	9
2	Fecundity								
3	index	FL(X0)	fecundity(Y0)	error	X1	Y1	Xobar	=AVERAGE(B4:B53)	Xo-Xobar = xo
4	1	447	38008.16				X1bar		=B4-H3
5	2	455	37587.3873873874				Yo bar	=AVERAGE(C4:C53)	=B5-H3
6	3	460	28220.4081632653				Y1 bar		=B6-H3
7	4	465	25418.5185185185						=B7-H3
8	5	465	44955				orig slope		=B8-H3
9	6	466	44857.3770491803				=SLOPE(C4:C53,B4:B53)		=B9-H3
10	7	469	36240.7185628742						=B10-H3
11	8	470	34361.07				intercept		=B11-H3
12	9	470	40816.11				=INTERCEPT(C4:C53,B4:B53)		=B12-H3
13	10	470	31500						=B13-H3
14	11	470	31314.7058823529						=B14-H3
15	12	473	35795.2941176471						=B15-H3
16	13	475	43078.527607362						=B16-H3
17	14	480	65781.4						=B17-H3
18	15	480	35827.55						=B18-H3
19	16	480	49932.4137931034						=B19-H3
20	17	480	46827.7456647399						=B20-H3
21	18	483	44784						=B21-H3
22	19	485	49472.09						=B22-H3
23	20	485	51090.6976744186						=B23-H3
24	21	488	46953.9473684211						=B24-H3
25	22	490	41547.17						=B25-H3
26	23	490	39664.67						=B26-H3
27	24	490	41747.5609756097						=B27-H3
28	25	490	66370.4697986577						=B28-H3
29	26	490	55482.6086956522						=B29-H3
30	27	495	51540.6593406594						=B30-H3
31	28	497	35815.3846153846						=B31-H3
32	29	500	93270.37						=B32-H3
33	30	500	50491.0994764398						=B33-H3
34	31	500	45058.8957055215						=B34-H3
35	32	500	38844.6043165468						=B35-H3
36	33	501	45308.1967213115						=B36-H3
37	34	504	61517.880794702						=B37-H3
38	35	505	64078.5714285714						=B38-H3
39	36	510	61418.18						=B39-H3
40	37	512	54831.6455696203						=B40-H3
41	38	520	83283.02						=B41-H3
42	39	520	68767.857						=B42-H3
43	40	520	37091.93						=B43-H3
44	41	523	70459.17						=B44-H3
45	42	525	59749.41						=B45-H3
46	43	525	44089.2857142857						=B46-H3
47	44	525	34232.3353293413						=B47-H3
48	45	526	69995.2380952381						=B48-H3
49	46	528	80865.0887573964						=B49-H3
50	47	530	56238.04						=B50-H3
51	48	530	75864.8275862069						=B51-H3
52	49	530	61837.1134020619						=B52-H3
53	50	532	33409.8591549296						=B53-H3

	J	K	L	M	N	O	P	Q	R	S	T
1	10	11	12	13	14	15	16	17	18	19	20
2											A
3	X1-X1bar = x1	Yo-Yobar = yo	Y1-Y1bar = y1	xo^2	x1^2	xoyo	x1y1	yo^2	y1^2	year	sum x^2
4		=C4-H5		=I4^2		=I4*K4		=K4^2		original	=SUM(M4:M53)
5		=C5-H5		=I5^2		=I5*K5		=K5^2		boot 1	
6		=C6-H5		=I6^2		=I6*K6		=K6^2		pooled	
7		=C7-H5		=I7^2		=I7*K7		=K7^2		common	
8		=C8-H5		=I8^2		=I8*K8		=K8^2		total	
9		=C9-H5		=I9^2		=I9*K9		=K9^2			
10		=C10-H5		=I10^2		=I10*K10		=K10^2			
11		=C11-H5		=I11^2		=I11*K11		=K11^2			
12		=C12-H5		=I12^2		=I12*K12		=K12^2			
13		=C13-H5		=I13^2		=I13*K13		=K13^2			
14		=C14-H5		=I14^2		=I14*K14		=K14^2			
15		=C15-H5		=I15^2		=I15*K15		=K15^2			
16		=C16-H5		=I16^2		=I16*K16		=K16^2			
17		=C17-H5		=I17^2		=I17*K17		=K17^2			
18		=C18-H5		=I18^2		=I18*K18		=K18^2			
19		=C19-H5		=I19^2		=I19*K19		=K19^2			
20		=C20-H5		=I20^2		=I20*K20		=K20^2			
21		=C21-H5		=I21^2		=I21*K21		=K21^2			
22		=C22-H5		=I22^2		=I22*K22		=K22^2			
23		=C23-H5		=I23^2		=I23*K23		=K23^2			
24		=C24-H5		=I24^2		=I24*K24		=K24^2			
25		=C25-H5		=I25^2		=I25*K25		=K25^2			
26		=C26-H5		=I26^2		=I26*K26		=K26^2			
27		=C27-H5		=I27^2		=I27*K27		=K27^2			
28		=C28-H5		=I28^2		=I28*K28		=K28^2			
29		=C29-H5		=I29^2		=I29*K29		=K29^2			
30		=C30-H5		=I30^2		=I30*K30		=K30^2			
31		=C31-H5		=I31^2		=I31*K31		=K31^2			
32		=C32-H5		=I32^2		=I32*K32		=K32^2			
33		=C33-H5		=I33^2		=I33*K33		=K33^2			
34		=C34-H5		=I34^2		=I34*K34		=K34^2			
35		=C35-H5		=I35^2		=I35*K35		=K35^2			
36		=C36-H5		=I36^2		=I36*K36		=K36^2			
37		=C37-H5		=I37^2		=I37*K37		=K37^2			
38		=C38-H5		=I38^2		=I38*K38		=K38^2			
39		=C39-H5		=I39^2		=I39*K39		=K39^2			
40		=C40-H5		=I40^2		=I40*K40		=K40^2			
41		=C41-H5		=I41^2		=I41*K41		=K41^2			
42		=C42-H5		=I42^2		=I42*K42		=K42^2			
43		=C43-H5		=I43^2		=I43*K43		=K43^2			
44		=C44-H5		=I44^2		=I44*K44		=K44^2			
45		=C45-H5		=I45^2		=I45*K45		=K45^2			
46		=C46-H5		=I46^2		=I46*K46		=K46^2			
47		=C47-H5		=I47^2		=I47*K47		=K47^2			
48		=C48-H5		=I48^2		=I48*K48		=K48^2			
49		=C49-H5		=I49^2		=I49*K49		=K49^2			
50		=C50-H5		=I50^2		=I50*K50		=K50^2			
51		=C51-H5		=I51^2		=I51*K51		=K51^2			
52		=C52-H5		=I52^2		=I52*K52		=K52^2			
53		=C53-H5		=I53^2		=I53*K53		=K53^2			

	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
1	21	22	23	24	25	26	27	28	29	30	31
2	B	C									
3	sum xy	sum y^2	bi	SS	n	DF		total X	total Y	total meanX	
4	=SUM(O4:O53)	=SUM(Q4:Q53)	=+U4/T4	=+V4-U4^2/T4	=+COUNT(C4:C4991)	=+Y4-2		447	38008.16	total mean Y	
5								455	37587.387		
6								460	28220.408		
7								465	25418.518		
8								465	44955		
9								466	44857.377		
10								469	36240.718		
11								470	34361.07		
12								470	40816.11		
13								470	31500		
14								470	31314.705		
15								473	35795.294		
16								475	43078.527		
17								480	65781.4		
18								480	35827.55		
19								480	49932.413		
20								480	46827.745		
21								483	44784		
22								485	49472.09		
23								485	51090.697		
24								488	46953.947		
25								490	41547.17		
26								490	39664.67		
27								490	41747.560		
28								490	66370.469		
29								490	55482.608		
30								495	51540.659		
31								497	35815.384		
32								500	93270.37		
33								500	50491.099		
34								500	45058.895		
35								500	38844.604		
36								501	45308.196		
37								504	61517.880		
38								505	64078.571		
39								510	61418.18		
40								512	54831.645		
41								520	83283.02		
42								520	68767.857		
43								520	37091.93		
44								523	70459.17		
45								525	59749.41		
46								525	44089.285		
47								525	34232.335		
48								526	69995.238		
49								528	80865.088		
50								530	56238.04		
51								530	75864.827		
52								530	61837.113		
53								532	33409.859		

	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AC	AP	AC
1	32	33	34	35	36	37	38	39	40	41	42	43
2												
3	total x	total y	x^2	xy	y^2							
4								Coincidental regression	F-manual			
5								Fcalc	ABS(((X8-X6)/(2*(2-1)))/(X6/Z6))			
6								p	FDIST(AN5,2,Z6)			
7								Coincident counter	23			
8								slope	F			
9								F	((X7-X6)/(2-1))/(X6/Z6)			
10								p	FDIST(AN9,1,Z6)			
11									SQRT(AN9)			
12								slope counter	4			
13												
14								Intercept	F			
15								F	ABS(((X8-X7)/(2-1))/(X7/Z7))			
16								p	FDIST(AN15,1,Z7)			
17									SQRT(AN15)			
18								intercept counter	35			
19												
20												
21							No					
22							N1					
23							Manip					
24							intercept_sig_diff__counter					
25							power					
26												
27												
28												
29							TIME:					
30												
31												
32												
33												
34												
35												
36												
37												
38												
39												
40												
41												
42												
43												
44												
45												
46												
47												
48												
49												
50												
51												
52												
53												

	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC	BD
1	44	45	46	47	48	49	50	51	52	53	54	55	56
2	No	N1	Manip	intercept_sig_diff__counter	power	Coincident counter	slope counter	intercept counter	sig diff				

APPENDIX IV. Program for testing experimental design for length-at-age, written in Microsoft Visual Basic® for Applications.

```
Sub growth_template()

    a1 = Time()
    Range("C4:D65536").ClearContents
    Range("G3:g8").ClearContents
    Range("m3:r6500").ClearContents
    Cells(10, 7).ClearContents
    no = 83
    Range("G3") = no
     n1 = 10

     'calcs for Xo

        For sample_size = 1 To 2
        Cells(4, 7) = n1
        manipulation = 0

            For trial_manipulation = 1 To 3
            Range("g5") = manipulation
            sig_count = 0
            Rep = 5

                For trial = 1 To Rep
                Range("C4:D65536").ClearContents

                'calcs for X1
                Range("C4").Select
                ActiveCell.FormulaR1C1 = "=+NORMINV(RAND(),0,22.7908)"
                Selection.Copy
                Range(Cells(5, 3), Cells(3 + n1, 3)).Select
                ActiveSheet.Paste
                Range("D4").Select
                ActiveCell.FormulaR1C1 = _

                "=VLOOKUP(INT(RAND()*82+1),R4C1:R86C2,2,FALSE)+RC[-
                1]+R5C7"
                Selection.Copy
                Range(Cells(5, 4), Cells(3 + n1, 4)).Select
                ActiveSheet.Paste
                Range("C4", "D5000").Copy
                Range("C4").PasteSpecial Paste:=xlValues
                Range("G6").Select
                ActiveCell.FormulaR1C1 = _
                "=+TTEST(R[-2]C[-5]:R[65530]C[-5],R[-2]C[-3]:R[65530]C[-3],2,3)"

                    If Range("g6") < 0.05 Then sig_count = sig_count + 1
```

```
                    Range("g7") = sig_count
                Power = sig_count / Rep * 100
                Range("g8") = Power

                Next trial


            Range("g3:g8").Copy
            If Cells(q + 2, 13) <> "" Then q = q + 1
            Cells(q + 2, 13).PasteSpecial Paste:=xlValues,
            Operation:=xlNone, SkipBlanks:= _
            False, Transpose:=True

            manipulation = manipulation + 5

            ActiveWorkbook.save

            Next trial_manipulation
            n1 = n1 + 10

    Next sample_size

a2 = Time()
Cells(10, 7) = a2 - a1
MsgBox "I'm Done!"

End Sub
```

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2	Growth												No	N1	manipulation	ttest	sig_count	power
3	index	Xo	norminv	X1		No	83											
4	1	504	-7.07808	557.		N1	10											
5	2	515	10.98779	502.		manipulation	0											
6	3	533	14.3220	504.		ttest	=+TTEST(B4:B65536,D4:D65536,2,3)											
7	4	504	9.81652	584.		sig_count	1											
8	5	580	7.46458	482.		power	0.100000001490116											
9	6	539	14.3581	547.														
10	7	523	-1.55147	528.		Time												
11	8	542	-11.9033	518.														
12	9	518	8.81232	538.														
13	10	549	-17.1198	522.														
14	11	482																
15	12	493																
16	13	503																
17	14	565																
18	15	530																
19	16	598																
20	17	440																
21	18	480																
22	19	510																
23	20	470																
24	21	550																
25	22	480																
26	23	490																
27	24	495																
28	25	500																
29	26	520																
30	27	520																
31	28	475																
32	29	509																
33	30	485																
34	31	500																
35	32	540																
36	33	560																
37	34	520																
38	35	480																
39	36	520																
40	37	520																
41	38	575																
42	39	420																
43	40	475																
44	41	500																
45	42	550																
46	43	514																
47	44	440																
48	45	540																
49	46	570																
50	47	540																
51	48	400																
52	49	530																
53	50	427																
54	51	535																
55	52	440																
56	53	530																
57	54	505																
58	55	469																
59	56	485																
60	57	570																