An Examination of Lacustrine and Estuarine Populations of Mackenzie Broad whitefish (*Coregonus nasus* Pallas): the Role of Migration and Commercial Exploitation on Life History Variation

by

Darryl H. Chudobiak

A Thesis
Submitted to the Faculty of Graduate Studies
in Fulfilment of the Requirements
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University of Manitoba
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Darryl H. Chudobiak

For my parents Harry and Joyce Chudobiak

and my uncle John Chudobiak

These people instilled in me the fundamental desire

to ask questions on the world around us.

THE ROAD NOT TAKEN

Two road diverged in a yellow wood,
And sorry I could not travel both
And be one traveller, long I stood
And looked down one as far as I could
To where it bent in the undergrowth;

Then took the other, as just as fair,
And having perhaps the better claim,
Because it was grassy and wanter wear;
Though as for that the passing there
Had worn them really about the same,

And both that morning equally lay
In leaves no step had trodden black.
Oh, I kept the first for another day!
Yet knowing how way leads on to way,
I doubted if I should ever come back.

I shall be telling this with a sigh
Somewhere ages and ages hence:
Two roads diverged in a wood, and I-
I took the one less travelled by,
And that has made all the difference.

Robert Frost

Abstract

Population structure of the arctic Broad whitefish (*Coregonus nasus* Pallas) was examined during the summer and winter of 1993 in the lower Mackenzie River system, Northwest Territories, Canada. The objectives of this study were to determine 1) if two distinct populations of broad whitefish exist in the Mackenzie River system, premised by preliminary support for such populations, 2) if population differences exist, are they the result of migration differences (i.e. migratory and non-migratory populations) and 3) if differences in exploitation pressure influence the observed population structure.

Using eighteen morphological measurements population phenotypes were compared, while gill raker counts were used to indirectly compare population genotypes. Canonical discriminant analysis was used to examine morphological variance: differences in mean gill raker number were determined with a one-tailed *t*-test. Mackenzie and Travaillant populations were successfully discriminated, with winter samples and female fish having the highest resolution. Observed morphological differences are possible the result of selection, as genetic differences between populations were observed in this study and unpublished research.

The Mackenzie River population is known to conduct lengthy migrations from the coast to the interior (estuarine). However, the Travaillant Lake system may house a closed population of lacustrine broad whitefish that could complete

their life cycle within the same system and eliminate the need for long distance migration. Also, due to its shallowness, the Travaillant River may act as a semi-annual physical barrier between the Travaillant and Mackenzie systems. To test this theory I compared the swimming efficiency of each population. Morphological features adapted to hydrodynamic efficiency were examined: fin areas, body depth, caudal peduncle depth and caudal fin aspect ratio. The migratory Mackenzie population was predicted to have a smaller fin areas, deeper body, shallower caudal peduncle and a higher aspect ratio. Also, life history differences associated with differences in migration behaviour were examined. Mackenzie broad whitefish were predicted to have a higher size at adult age and a higher absolute fecundity than Travaillant fish. All predictions were tested using a one-tailed *t*-test. For both males and females, only caudal fin aspect ratio varied as predicted. As a result, the hypothesis that Mackenzie and Travaillant individuals differ in hydrodynamic efficiency was rejected. All predictions on the variation of life history traits associated with migration were not satisfied; therefore, the hypothesis that Mackenzie and Travaillant broad whitefish differ in life history patterns associated with migration was rejected.

Finally, I examined the effects of exploitation on broad whitefish life history pattern. Mackenzie broad whitefish are harvested on a semi-annual basis commercially and for subsistence. Travaillant fish, however, are assumed to be harvested for subsistence on a semi-annual basis. It is well documented in the coregonids that high exploitation increases individual reproductive effort, but decreases life span; therefore, Mackenzie broad whitefish were predicted to have a higher reproductive effort and a lower life span than Travaillant individuals. Each prediction was tested with a one-tailed *t*-test. Both predictions were satisfied, supporting the exploitation hypothesis. Observed life history differences between populations are not the result of phenotypic plasticity, but have a selective basis.

Acknowledgements

I am indebted to my advisor Dr. Mark V. Abrahams for his enthusiasm, patience and willingness to make my own mistakes and learn from them. To Trevor Thera, Kim Howland, and Marc Lange who provided assistance in the collection of samples. To Dr. Ross F. Tallman, Gabe Andre, Danny Andre and members of the Gwich'In Tribal Council who helped in the organization and execution of my field research. To Tannis Thomas who assisted in the measurement of samples in Winnipeg. To all these individuals I am deeply grateful, for without them this thesis would not be possible.

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General Introduction

The Broad whitefish (*Coregonus nasus* Pallas) are an amphidromous arctic member of the Coregonidae family found throughout northern regions of Asia, Europe and North America (McCart 1986; Reist and Bond 1988). The life cycle of the Mackenzie broad whitefish (a geographical group of the broad whitefish species) encompasses three distinct habitats: the coastal freshwater systems, the Mackenzie delta and the inland rivers. Broad whitefish eggs hatch in late May and the emerging young-of-the-year (y-o-y) are swept downstream by spring floods (Reist and Bond 1988). The y-o-y migrate from the inland rivers to the coastal freshwater systems, moving through the saline waters of the Beaufort Sea. In the coastal systems, y-o-y feed on macrophytes and benthic invertebrates for up to four years (Craig 1989). Juveniles migrate out of the coastal systems to overwinter in the regions (>10 m in water depth) of the Mackenzie delta. Juvenile broad whitefish return to the coastal systems in spring to feed during the short growing season (approximately 115 days). Adults and first time spawners (broad whitefish mature in 6 to 8 years) migrate from the Mackenzie delta and the coastal areas to spawning grounds in the Arctic Red, Mackenzie and Peel rivers (Chang-Kue and Jessop 1992). After spawning, the adults return to the Mackenzie delta, resting in deep pools in winter and feeding in shallow lakes in summer.

In Canadian and Russian populations, lacustrine, riverine and estuarine forms of broad whitefish have been proposed (Berg 1965; Reist and Bond 1988). The estuarine form is well known in the Mackenzie River system, Northwest Territories: the biology and migration behaviour of the estuarine form has received considerable attention in recent years (Chang-Kue and Jessop 1992; Craig 1989; McCart 1986; Reist and Bond 1988). However, there is very little information on the existence of other forms; there are preliminary morphological and genetic evidence of a distinct lacustrine form that resides in Travaillant Lake, N.W.T. (Reist in press) Whether these forms represent distinct populations is not yet established. In other coregonids, the existence both of a migratory estuarine form and a resident lacustrine form has not been suggested or observed. Therefore, what characteristics should be examined in order to identify a resident population of fish? Before population differences can be explained, population structure must be determined.

Throughtout this document, I define a population as a group within a species that is phenotypically and genetically distinct from similar such groups. A popular and inexpensive method of discriminating populations is the use of morphometrics or body form. Morphometrics involves the collection and analysis of various linear measurements used to describe body form (Pimentel 1992). Variation of the linear measurements between samples is compared and summarized with a data reduction technique, such as canonical discriminant analysis or principal component analysis (or PCA). The data is reduced and the major trends of the data are represented in one, two or three planes. If there are significant differences between samples for most of the linear measurements, the sample grand means (centroids) will be separated. In canonical discriminant analysis, these grand means can be tested for significant differences using a multivariate analysis of variance (MANOVA) (Kzranowski 1988). However, the use of morphometrics only allows for a phenotypic discrimination between populations, and provides no information on whether the observed morphological differences have a genetic and therefore selective basis; for example, phenotypic plasticity can occur between populations, or over a season within a population. Genetic differences between populations can be determined indirectly or directly. Indirect comparisons of population gene pools involves the examination of genetically fixed morphological features, such as gill raker number or allozymes (Svärdson 1970; Vuorinen et al. 1993). Direct examination of genomes is accomplished by analysing mitochondrial DNA (mtDNA), DNA sequencing, or DNA-DNA hybridization. Of these techniques, the examination of a genetically fixed morphological feature is the quickest and easiest, but has the least resolution. Nonetheless, the use of gill raker number has been successful in discriminating stocks of Lake whitefish (*Coregonus clupeaformis*) (Vuorinen et al. 1993).

Unfortunately, rarely does the sole use of morphometrics or genetic techniques explain why populations differ. Once population structure is established, analysis of physiology, behaviour and life history can be used to explain why different populations exist.

Migratory and non-migratory populations of fish have been successfully differentiated on the basis of swimming efficiency. Weihs and Webb (1983) proposed that migratory species of fish have specific morphological adaptations for reducing drag during swimming: reduced fin area, deep anterior body, shallow caudal peduncle and a high aspect caudal fin. Using the predictions proposed by Weihs and Webb, migratory and non-migratory stocks of Coho salmon were successfully discriminated (Taylor and McPhail 1985).

In Pacific salmon, population structure is influenced by the life history "decision" to migrate (Hutchings and Morris 1985). In coho salmon (*Oncorhynchus kisutch*), for example, migration distance (and therefore life history pattern) is determined by the geographical distance between marine feeding and freshwater spawning areas (Taylor and McPhail 1985). Roff (1988; 1991) theorized on the response of life history traits to migration behaviour. Roff predicts that migrants have a larger size at age, delayed maturity and a greater absolute fecundity. To date, Snyder and Dingle (1990) have experimentally compared migratory and non-migratory populations with specific reference to Roff's theories, providing support for these theories.

Since many populations of salmonids and coregonids are commercially fished, differences in exploitation pressure will affect variation in life history traits. The effects of exploitation on life history pattern are well documented: exploited individuals have a faster growth, an earlier age at maturity, a higher reproductive effort and a shorter life span than fish of unexploited populations

(Healey 1978; ;1980; Stearns 1992).

The identification of a resident population of broad whitefish requires two steps. First, evidence of a separate population are established. Also, the nature of population differences should be determined. Are differences in populations the result of phenotypic plasticity, or is there a genetic basis for observed differences? Second, in light of possible differences in migration and exploitation, can the observed population differences be explained?

The objectives of this study were to determine 1) if two distinct populations of broad whitefish exist in the Mackenzie River system, premised by preliminary support for such populations, 2) if population differences exist, are they the result of migration differences (i.e. migratory and non-migratory populations) and 3) if differences in exploitation pressure influence the observed population structure.

Chapter I

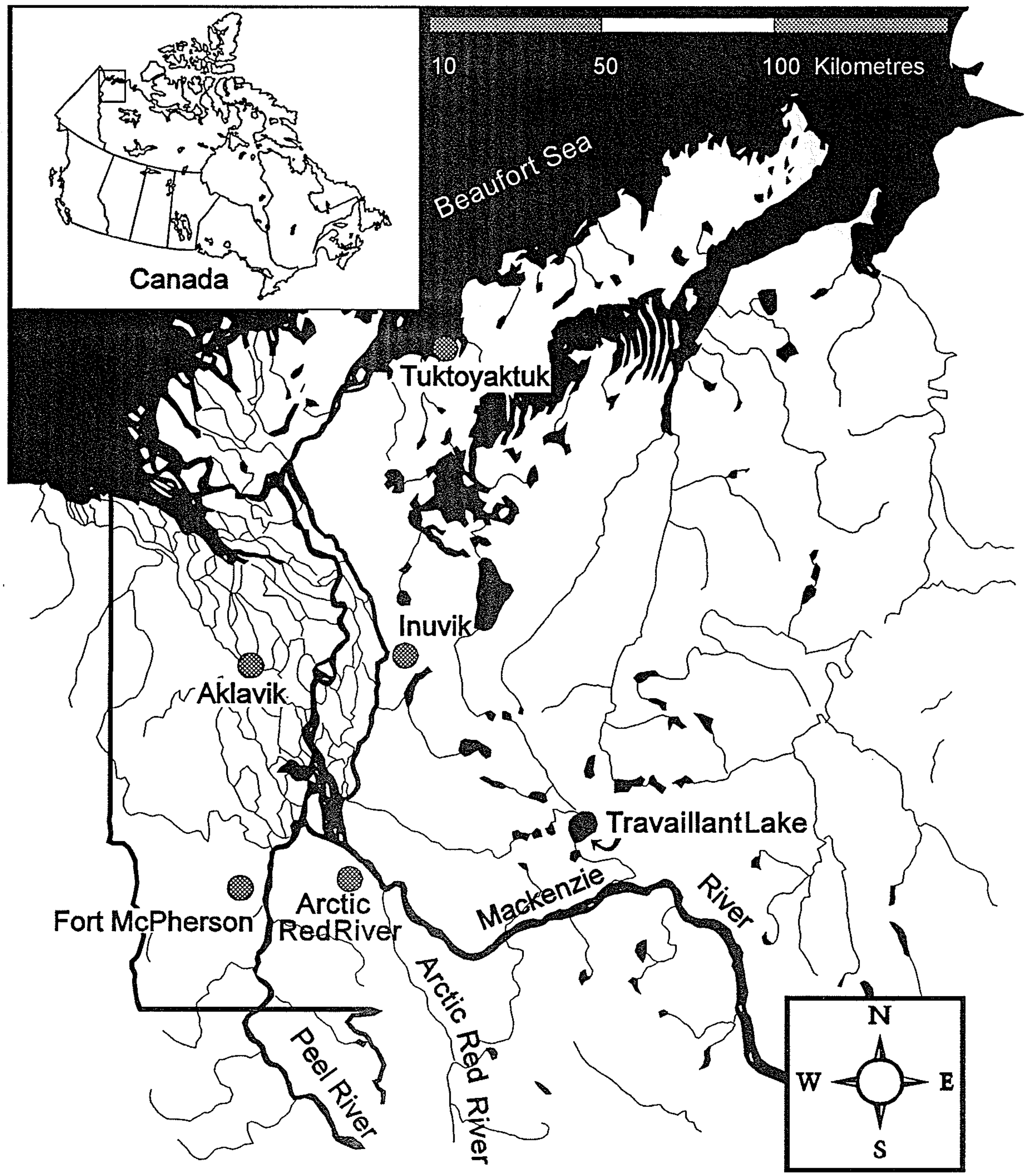
Analysis of Body Form and Gill Raker Number of Mackenzie River basin Broad whitefish (*Coregonus nasus* Pallas): an examination of population structure

Introduction

Multiple stocks are thought to exist in the broad whitefish species, but to date there are few documents supporting this theory. In Russia, Berg (1965) described three phenotypic forms of broad whitefish, each living in separate habitats of the Ob' River. In Canada, Reist and Bond (1988) suggest that at least three forms of broad whitefish exist in Canada. However, firm empirical support of distinct broad whitefish forms has yet to be documented. To address this problem I will first present reasons why I believe that the Canadian broad whitefish population should consist of more than one population. Next, I will discuss how population structure can be determined using phenotypic and genotypic methods.

Figure 1.1 illustrates the lower Mackenzie River system. Throughout its life history, the broad whitefish obtains resources from various habitats. Coastal freshwater systems, which consist of shallow and deep lakes, provide food and overwintering grounds for juveniles (Chang-Kue and Jessop 1992; Craig 1989). Inland rivers, in contrast, are deep and turbulent and are excellent spawning grounds for adults (Craig 1989). There is, however, a problem: coastal and

Figure 1.1. The lower Mackenzie River system. Fishing commmunities of Aklavik, Arctic Red River, Fort McPherson, Inuvik and Tuktoyaktyuk are illustrated. Each of these locations represent broad whitefish populations that are exploited yearly as commercial or subsistence fisheries (Berkes 1989). The Travaillant Lake population, however, is fished for subsistence purposes only and is exploited on a semi-annual basis.



Canada
10
50
100 Kilometres
Beaufort Sea
Tuktoyaktuk
Inuvik
Aklavik
Travaillant Lake
Fort McPherson
Arctic
Red River
Mackenzie
River
Arctic Red River
Peel River
N
W
E
S

inland systems are more than 200 km apart. As a result, broad whitefish undergo seasonal migrations, adapting to the geographical separation of habitats (Chang-Kue and Jessop 1992).

Migration expends energy that might otherwise be used for growth and reproduction (Roff 1991). Populations could forgo seasonal migration if they encountered new habitats suitable for all stages of broad whitefish life history: feeding, overwintering and spawning. In encountering new habitats, populations are exposed to new selective pressures. Within the Mackenzie system, populations enclosed in a single habitat encounter higher levels of inter and intraspecific competition, greater risk of predation and are more susceptible to local catastrophes (Chang-Kue and Jessop 1992; McCart 1986). Under new selective pressures, a founding population may diverge phenotypically from the original population, provided that there is sufficient reproductive isolation between the founding population and the original population. Long-term maintenance of reproductive isolation will result in a new genetic stock.

Within the Mackenzie River system there are few habitats that can accommodate broad whitefish feeding, overwintering and spawning. Travaillant Lake, however, is an inland system containing suitable habitat and resources for all stages of broad whitefish life history. As a new environment, the Travaillant system would invoke selective pressures on a founding population of broad whitefish, as lengthy spawning migrations would no longer be required (Snyder and Dingle 1990). Given sufficient reproductive isolation, the Travaillant broad whitefish population would become phenotypically distinct and eventually, genetically distinct. Also, a Travaillant population of broad whitefish would be small in number relative to the Mackenzie population. As a result, genetic drift may play an important role in the divergence of the Mackenzie and Travaillant populations. I believe that connections between the Travaillant and Mackenzie system are sufficiently rare so as to produce and maintain reproductive isolation between respective stocks; the Travaillant River freezes to the bottom in certain regions during the winter, preventing the movement of spawning Mackenzie broad whitefish into the Travaillant system (Hatfield et al. 1972). Note that based on the known broad whitefish life cycle, Mackenzie broad whitefish are near the Travaillant River only during the spawning run (Chang-Kue and Jessop 1992).

The stock concept was developed to segregate fish populations into discrete and manageable units (Taylor and McPhail 1985). Various methods are employed to divide populations into distinct groups: phenotypic methods (such as life history traits, behaviour, morphology and physiology), direct genetic methods (such as mitochondrial DNA or mtDNA), and indirect genetic methods (such as gillraker counts and allozyme electrophoresis). Traditionally, phenotypic and indirect genetic methods were used to identify fish stocks. In order to discriminate between broad whitefish stocks in this project, I employed the phenotypic method and the indirect genetic method of stock identification. Morphometric and meristic measurements used to discriminate between populations of Lake whitefish (*Coregonus clupeaformis*), were also used in this study (Vuorinen et al. 1993) (Table 1.1). Implementation of a direct genetic method, however, was beyond the budget and time constraints of this thesis.

Phenotypic methods involve the quantitative measurement of phenotypic parameters such as body measurements (morphology), energy allocation (physiology), migration distance (behaviour) and life history traits. In salmonids and coregonids, the analysis of body morphology is the principal phenotypic method of stock discrimination (Lindsey 1981; Taylor and McPhail 1985; Vuorinen et al. 1993). Lindsey (1981) suggests that, given the phenotypic plasticity of coregonid body morphology, environmental variation will always produce phenotypically distinct populations between locations. Population segregation, however, will only be maintained with sufficient reproductive isolation. Once separate genetic stocks are established, it is difficult for populations to re-integrate (Skelton 1993). Note that reproductive isolation does not necessarily result in the segregation of gene pools: reproductive isolation may allow certain phenotypic traits to be expressed over others (Skelton 1993). Genetic conservation, coupled with substantial phenotypic plasticity, has allowed the coregonids to be successful in a variety of habitats (Lindsey 1981). With respect to the broad whitefish of the Mackenzie River system, sufficient geographical segregation will produce a Travaillant population that is phenotypically distinct from the Mackenzie population.

Lindsey (1981) and Svärdson (1970) state that gill raker number is

Table 1.1. Morphological features (and abbreviations) measured on Mackenzie and Travaillant broad whitefish as outlined in Vuorinen et al. (1993). Measurements were taken using a Vernier caliper and were measured to the nearest 0.01 millimetres. Refer to figure 1.5 for an illustration of measurements

Abbreviation	Variable
POL	Pre-Orbital Length
OOL	Orbital Length
PBL	Post-Orbital Length
TTL	Trunk Length
DOL	Dorsal Length
LUL	Lumbar Length
AUL	Anal Length
CPL	Caudal Peduncle Length
IOW	Inter-Orbital Length
HDD	Head Depth
BDD	Body Depth
CPD	Caudal Peduncle Depth
MXL	Maxilla Length
MXW	Maxilla Width
PCL	Pectoral Fin Lenght
PVL	Pelvic Fin Length
ADL	Adipose Fin Length
GIRTH	Body Girth

genetically determined and varies little phenotypically. Gill raker number in coregonids can undergo adaptive radiation (absence of other species in certain feeding niches) or character displacement (presence of species within the same feeding niche) (Lindsey 1981). However, of all morphological and meristic characters examined in the coregonids, gill raker number is the least influenced by environmental modification. Therefore, an examination of population mean gill raker number will provide information on the genetic distinctness of each population.

Using the combination of morphometric measurements and gill raker number, I examined the population structure of broad whitefish in the Mackenzie River system, Northwest Territories, Canada (Fig 1.1). The purpose of this project was to test the hypothesis that at least two populations of broad whitefish exist in the Mackenzie system. Given that coregonids are very plastic in morphology, populations exposed to two distinct environments should result in morphological differences between populations. I predict that Mackenzie and Travaillant broad whitefish are exposed to different environments and, as a result, will express distinct morphologies. Second, I predict that the genetic differences between populations will manifest themselves as differences in mean gill raker number.

Methods and Materials

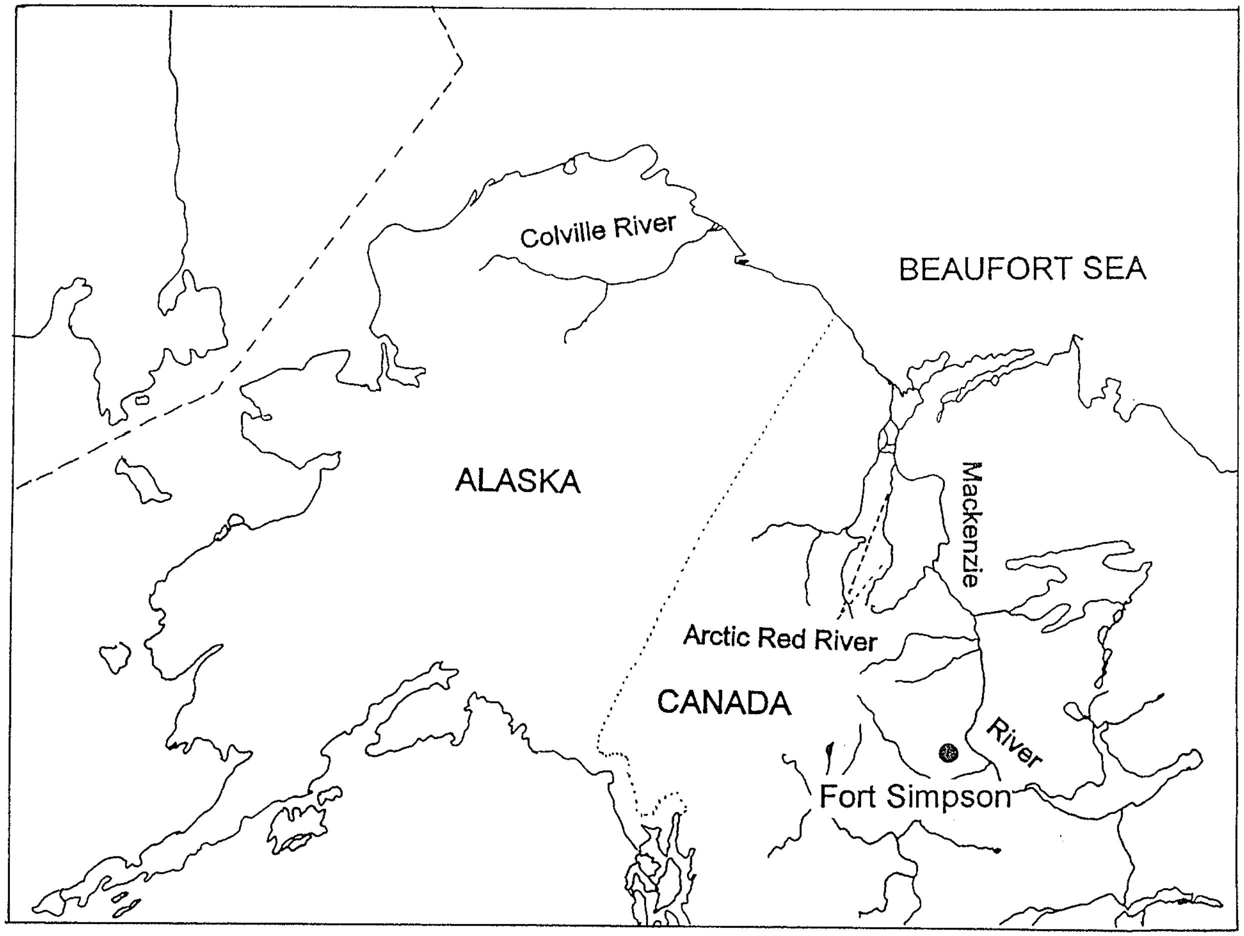
Study Area

The broad whitefish has a semi-circumpolar distribution extending east from the Perry River, Northwest Territories to the Perchora River in Russia. In North America, the broad whitefish exists mainly in the Mackenzie River (N.W.T.) and the Colville River (Alaska) systems (Reist and Bond 1988; Craig 1984) (Fig. 1.2). In the Mackenzie River, broad whitefish are rarely found south of Fort Simpson and occur mostly in the lower reaches of the Mackenzie basin (Stein et al. 1973).

The Mackenzie River system is located in northwestern Canada (Fig. 1.2). The system extends from the 54° N to 69° N latitude (4,200 km) and is the second largest river system in North America (Craig 1989). In the lower Mackenzie river system, arctic conditions occur. Waters systems remain ice covered for at least 250 days of the year (Bond and Erickson 1985); systems are ice free by June and are ice covered again by September. Average temperatures range from 10 to 16° C in summer to -23 to -29° C in winter (Craig 1989). Topographical features consist of glacial till lying over permafrost, formed during the last glacial period (Bodaly et al. 1989). Most lakes and river systems in the Mackenzie delta are shallow (<3 m in water depth) and freeze to the bottom in winter (Chang-Kue and Jessop 1989; Craig 1989). In contrast, freshwater systems along the Tuktoyaktuk Peninsula contain deep lakes, that act as refugia for overwintering fish (Chang-Kue and Jessop 1989).

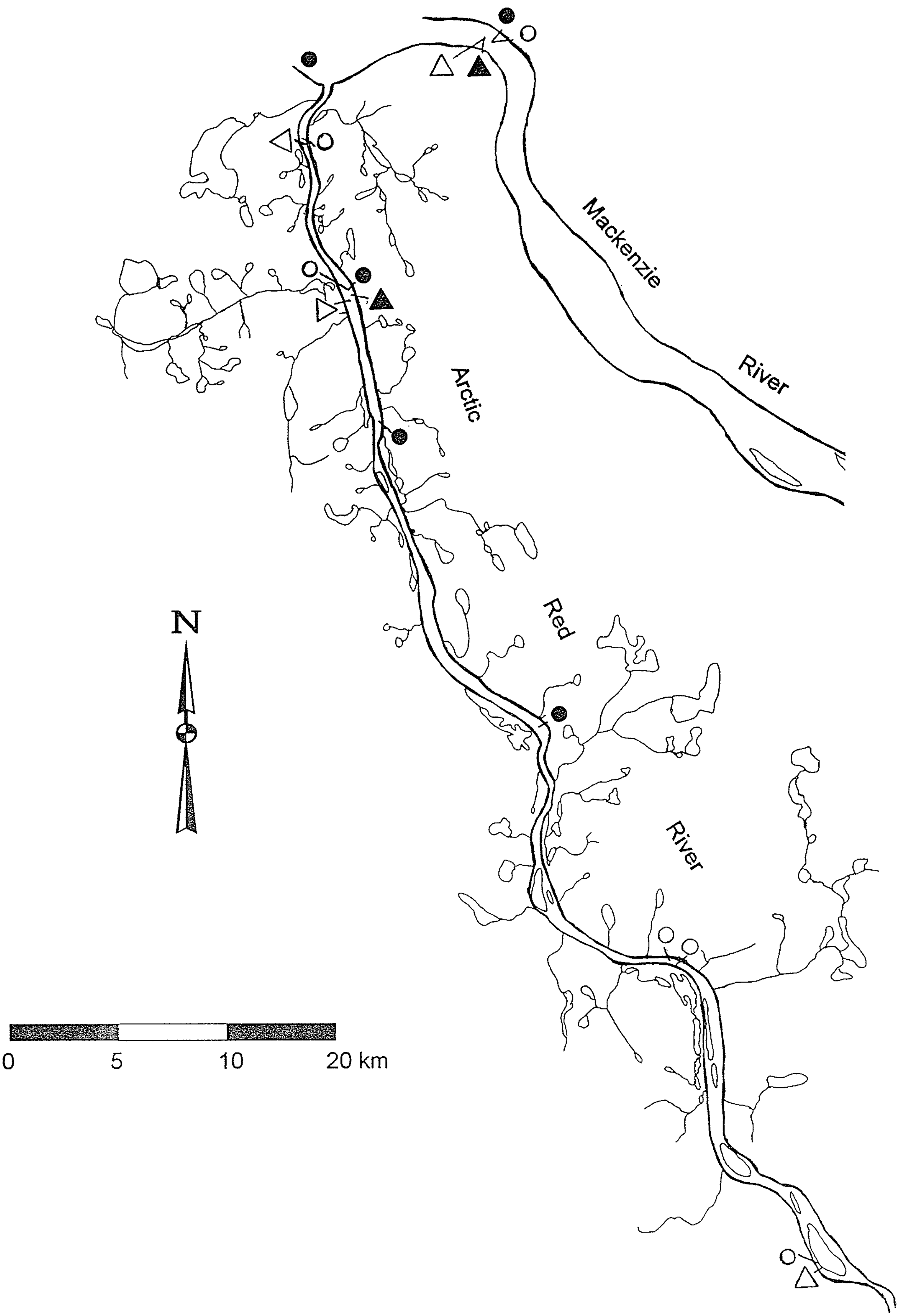
The Arctic Red River is a major tributary of the Mackenzie River (Fig. 1.1 and 1.3). Originating in the Mackenzie Mountains, N.W.T., the Arctic Red River drains into the Mackenzie River at the hamlet of Arctic Red River (67° 28'N,

Figure 1.2. Map of Alaska and Northwestern Canada, showing the Colville River and Mackenzie River drainages. Refer to figure 1.1 for a detailed map of the lower Mackenzie River system.



Colville River
BEAUFORT SEA
ALASKA
Mackenzie
Arctic Red River
CANADA
River
Fort Simpson

Figure 1.3. Map of the Arctic Red River, illustrating winter and summer sampling sites. Monomesh and multimesh gillnets are marked by circles and triangles, respectively: summer and winter samples are indicated by filled and open symbols, respectively. For scale, one centimeter equal 2.5 kilometers.

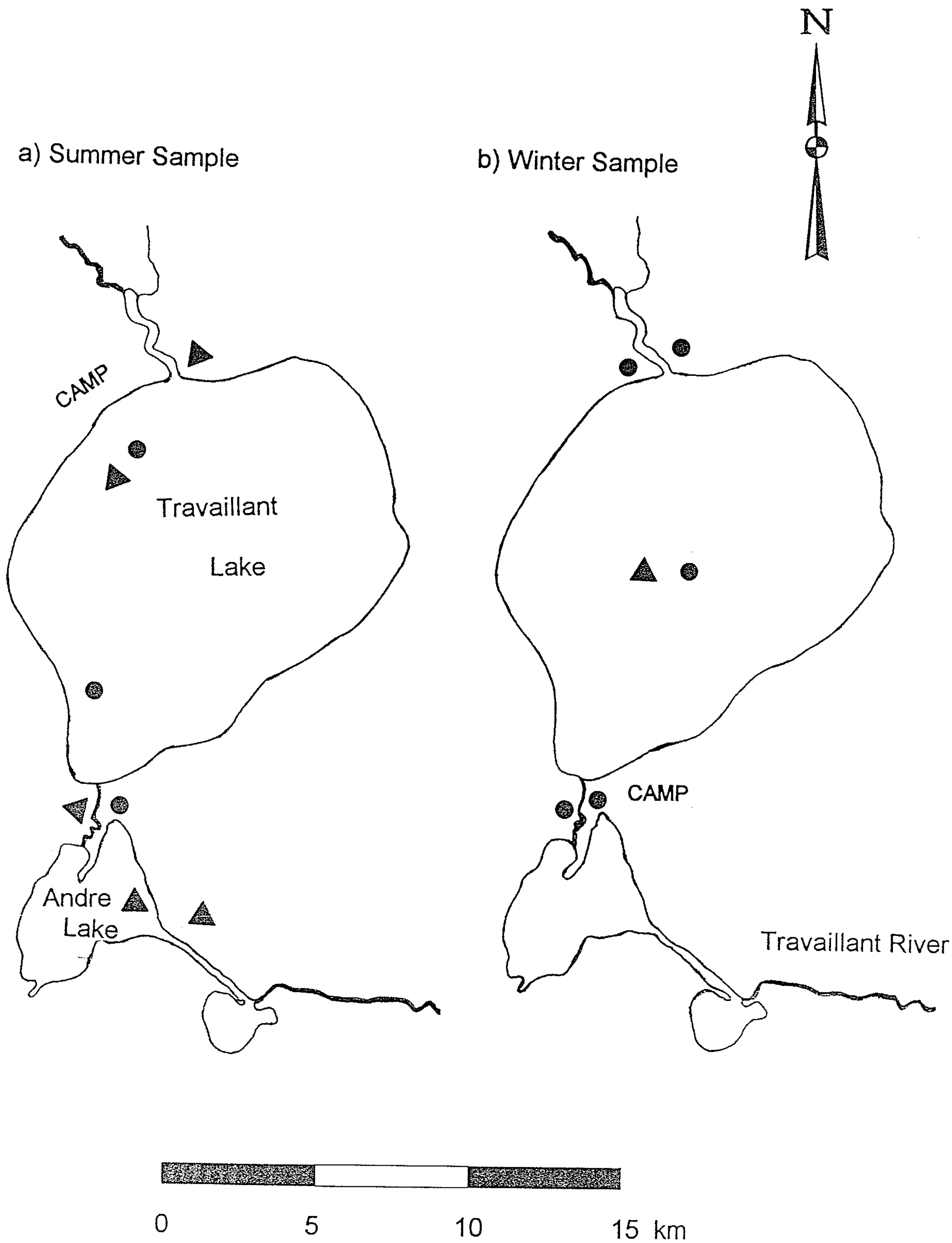

Mackenzie
River
Arctic
Red
River
N
0
5
10
20 km

133° 15'W); this river has a total length of 357 km and a total drainage area of 31, 707 km^2 (Hatfield et al. 1972). Sediment of the Arctic Red River changes from coarse and fine gravel at its origin to mud and silt at its confluence with the Mackenzie River. As a result, turbidity increases from the headwaters to the drainage of the Arctic Red River. Water depth of the Arctic Red River increases from origin to drainage; water depth ranges from a few meters in the mountains, to more than 20 meters at the confluence (Hatfield et al. 1972). Conversely, water velocity decreases from origin to end. Due to stratification of the Arctic Red River in depth, velocity, turbidity and substrate, suitable spawning grounds are found more than 100 kilometers upstream of the confluence.

In contrast, the Travaillant River (67 28'N, 131 30'W) consists entirely of coarse and fine gravel substrate. High water clarity results from a low silt load in the river (Hatfield et al. 1972) (Fig. 1.1 and 1.4). Due to a combination of high water clarity and gravel substrate, the entire Travaillant River system is adequate for whitefish spawning. The Travaillant River originates at the Lost Reindeer Lakes and ends at the Mackenzie River, draining a series of large lakes (Fig. 1.1). Total length of the river is 126 km and total drainage area is 308 km^2 (Hatfield et al. 1972). Depth of the Travaillant River ranges from 0.1 to under 5.0 m (pers. obs.; Hatfield et al. 1972).

Travaillant Lake, approximately 40 km north of the Mackenzie River/Travaillant River confluence, has an area of 115 km^2 (Hesslein et al. 1991) (Fig. 1.4). Travaillant lake contains a littoral zone (2.5 m deep and runs 2 km

Figures 1.4a and b. The Travaillant Lake system, showing Travaillant Travaillant Lake and Andre Lake. Experimental mesh and monomesh gillnets are denoted by a circle and a triangle, respectively. Camp sites of summer and winter sampling periods are indicated.



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

offshore) along the west shore of the lake. The eastern shore contains many gravel shoals and is considerably deeper than the western region of the lake. Water depth exceeds 30 meters in the north and eastern regions (Hesslein et al. 1991). Shallow and deep areas occur in the same lake, making Travaillant Lake an ideal system for feeding and rearing coregonid fish (Craig 1989). The eastern shore contains many gravel shoals and is considerably deeper than the western region. The eastern shoals and the sandy southern region of Travaillant lake are important spawning grounds for lake whitefish and broad whitefish (pers. obs.).

Data Collection

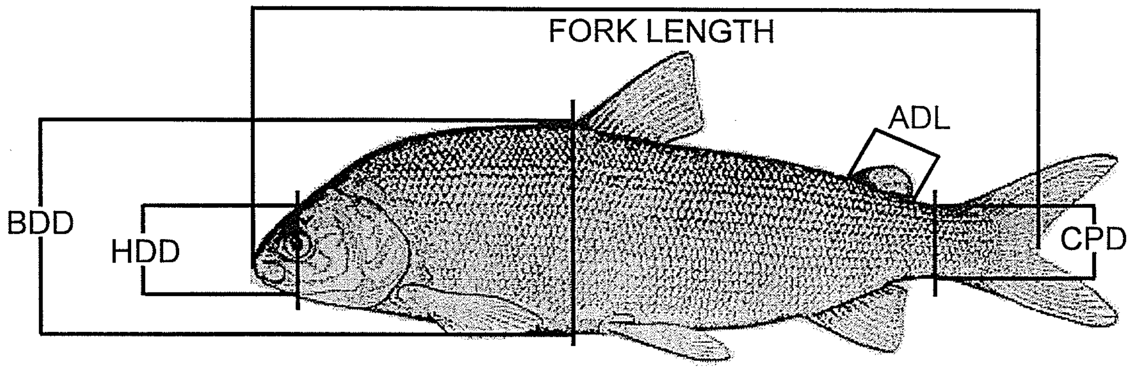
The Mackenzie and Travaillant locations were sampled using 30 m long monomesh nets (13 cm mesh used for larger fish, >500 cm) and 60 m long multifilament nets (3.8 to 11.4 cm mesh with six panels used for juveniles and smaller adults, 100 to 500 cm). At each site, gillnets were set for a permanent period of time (set time varied depending on location and specific sample site) and subsequently checked every afternoon. Gillnets were set in specific areas (non-random) to ensue a high catchability of broad whitefish, such as river eddies and littoral zones of lakes. Each sample site contained either one monomesh net or a combination of one monomesh and one experimental (multimesh) gillnet. In sites with two gillnets, the nets were set parallel to each other and perpendicular to shore. Both nets were staggered relative to each other and were separated by at least 100 m.

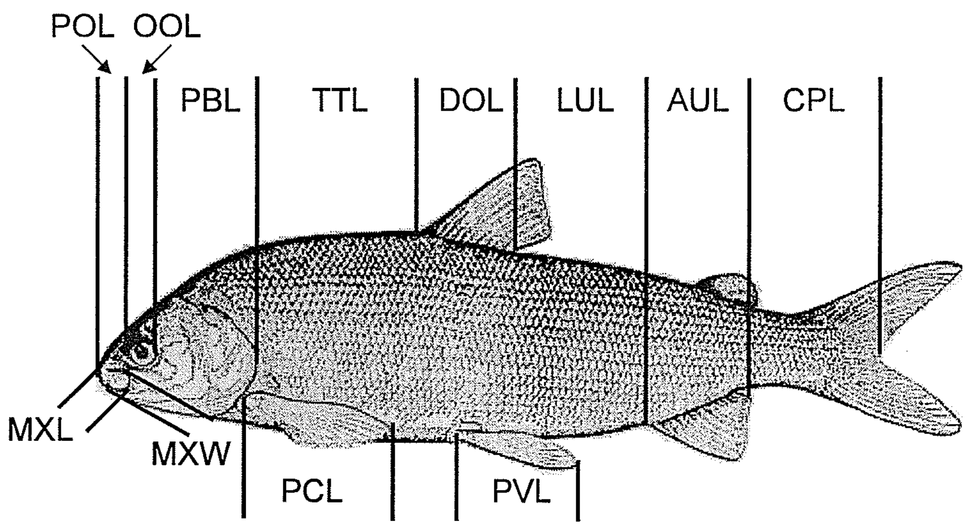
Figure 1.3 illustrates the sampling sites of the Mackenzie and Arctic Red Rivers. Both rivers were sampled continuously from mid July to mid November 1993 as part of a project conducted by the Department of Fisheries and Oceans. Data collection included measurements of fork length (length from snout to fork of tail), total body weight, gonad weight and sex. Also, whole specimens were frozen (summer n=44, winter n=72) for analysis of body morphology and gill raker counts.

The Travaillant population was sampled by setting gillnets on Andre Lake, Travaillant Lake and the Travaillant River, between 30 July 1993 and 8 August 1993 (n=95) and during the spawning season between 25 and 28 October 1993 (n=102) (Fig 1.4a and b). Summer samples were measured for fork length and body weight and then frozen for later analysis. However, winter samples (n=197) could not be measured before freezing, due to sampling conditions and time constraints. Sampling protocol was identical to that of the Mackenzie location.

Frozen samples were prepared for analysis in February 1994. All thawed samples were measured for length, weight, sex, 18 linear morphometric measurements and one meristic count. Linear morphometric measurements and abbreviations are illustrated in figure 1.5. All morphometric measurements were made with Helios calipers; all data were recorded electronically (calipers attached to a storage computer) or manually. Gill raker counts were obtained from the second left gill arch, as recommended by Lindsey (1981) (Fig. 1.5).

Figure 1.5. Morphometric measurements used for the discrimination of broad whitefish samples - refer to table 1.1 for a description of abbreviations. All measurements were made to the nearest 0.1 millimeters. Body girth (not shown) was measured as the girth of the fish in front of and perpendicular to the dorsal fin. Also, structure of the lower gill arch with gill rakers is shown.


FORK LENGTH
ADL
BDD
HDD
CPD


POL
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MXW
PCL
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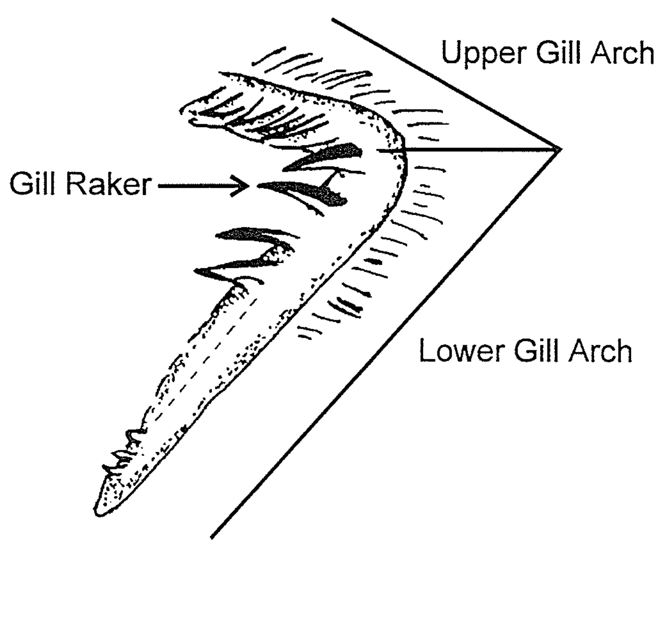
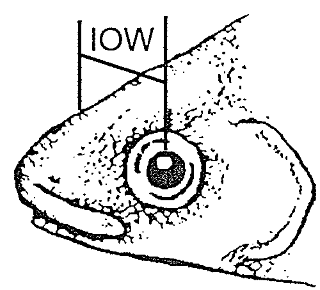

Upper Gill Arch
Gill Raker
Lower Gill Arch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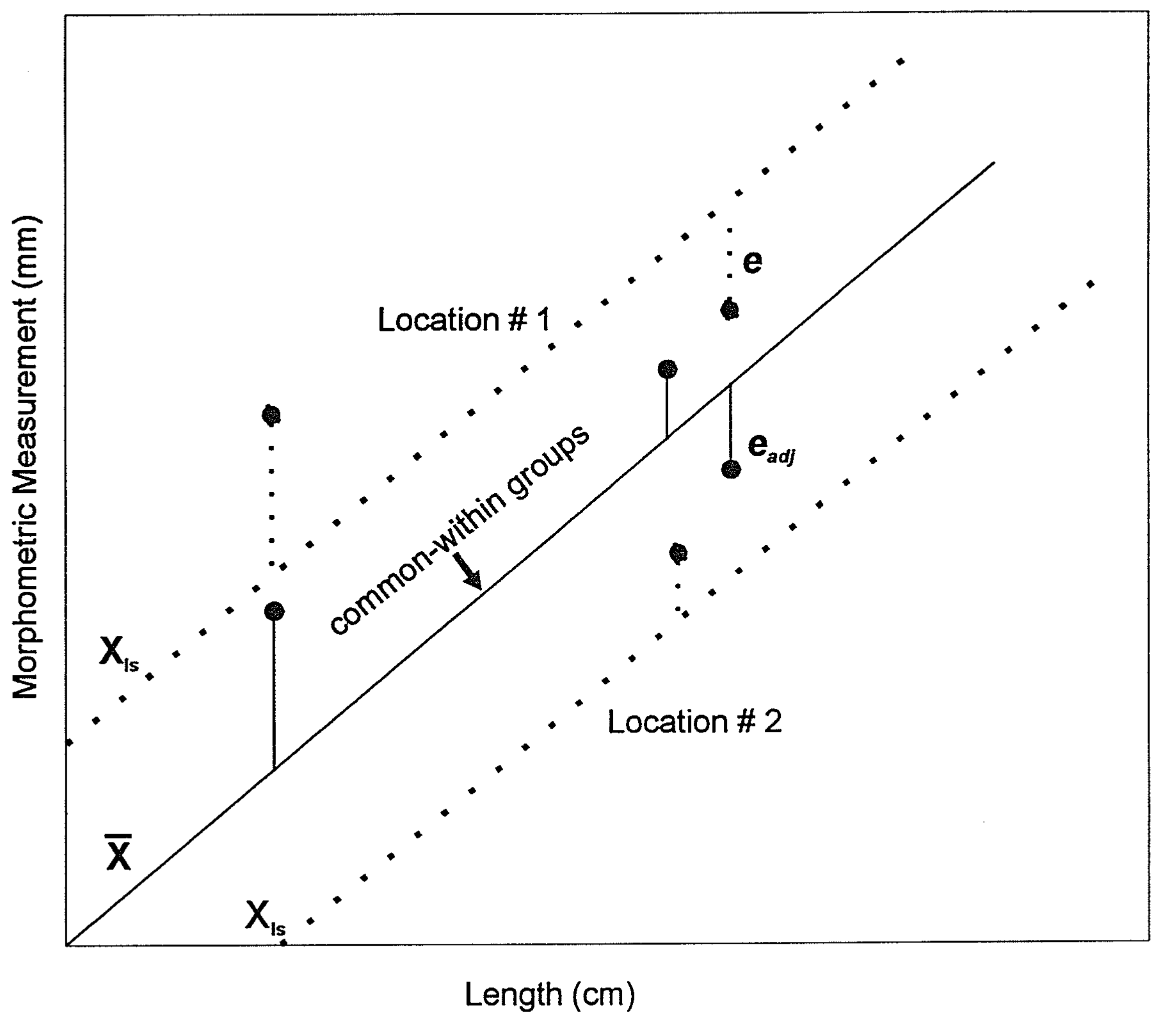
Data Standardization

All morphological variables varied positively with length. To standardize variables for length, I used a univariate method developed by Reist (1986; 1985) (Fig. 1.6). This standardization procedure accomplishes two tasks: 1) residuals from all samples are adjusted to a common slope and 2) an analysis of covariance is performed using length as a covariate - the residuals are used as shape information (Reist 1986; 1985). It is important to note that when multiple data sets are compared in an analysis of covariance (ANCOVA), sample slopes must be parallel (Sokal and Rohlf 1981). Interaction between covariates in ANCOVA was used to test for a common slope. Any variable that interacted significantly ($p<0.05$) with length was omitted from analysis.

Data Analysis

Statistical analyses were conducted separately for each sex, as the variation of broad whitefish body morphology between the sexes is unknown. Canonical discriminant analysis was used to test for differences in body form between samples. Discrimination between mean centroids was conducted using the CANDISC procedure in the SAS for Windows program (Version 6.0) by calculating pairwise distances (D^2) between each mean centroid. Differences between mean centroids were analyzed for statistical significance by calculating the Wilk's approximation of the *F* statistic (SAS 1985) and 95% confidence radii were calculated for each mean centroid (Krzanowski 1988). I concluded that samples were significantly different in body morphology if pairwise distances

Figure 1.6. Standardization procedure of morphometric measurements by length. An analysis of covariance was performed for each measurement, in which each measurement is a dependent variable, locations are the independent variables and length is a covariate. Hatched lines represent regression lines of hypothetical samples "Location #1" and "Location #2". The residuals of each group are adjusted to a common-within groups regression line (solid). This allows for an unbiased comparison of a particular measurement between all locations. The adjusted residuals are assumed to be the remaining variance that is not explained by length. This variance is assumed to contain shape information and error (see Reist 1986; 1985 for details).



Legend

e = unstandardized residual

e_{adj} = standardized residual

X_{ls} = least squared means

$\overline{X}$ = grand mean

$e_{adj} = e - (\overline{X} - X_{ls})$

were significant (*F*-statistic, $p<0.05$) and 95% confidence radii did not overlap (Krzanowski 1988; Pimentel 1992).

Parametric statistics are robust to non-normality, but are sensitive to differences between sample variances (Sokal and Rohlf 1981). Therefore, homoscedaciticity of gill raker sample variances were tested using the PROC TTEST procedure of the SAS for Windows program. Gill raker distributions were compared using a two-tailed *t*-test. Power analysis was performed on results that were not statistically significant.

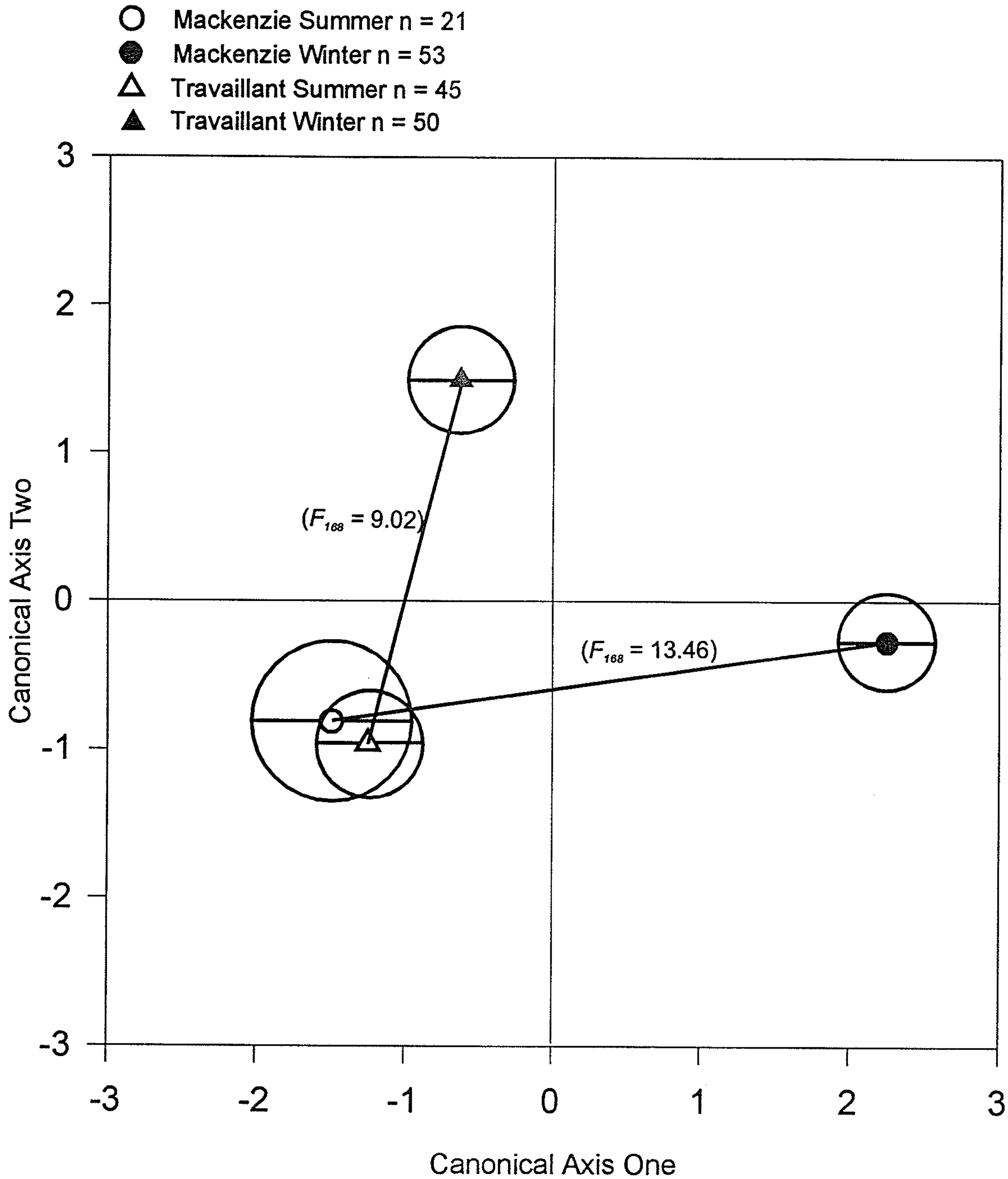
Results

Canonical Analysis of Body Morphology

During the standardization procedure, female post-orbital width, orbital width, anal length, maxilla length, pectoral fin length and pelvic fin length and male pectoral fin length and pelvic fin length did not satisfy the assumption of parallelism for the analysis of covariance; therefore, these variables were removed from further multivariate analysis. For each sex, homogeneity of within covariance matrices was tested using a chi-square test of homoscedasticity. All covariance matrices were not significantly different ($p<0.05$). Therefore, using the parametric form of canonical analysis was justified.

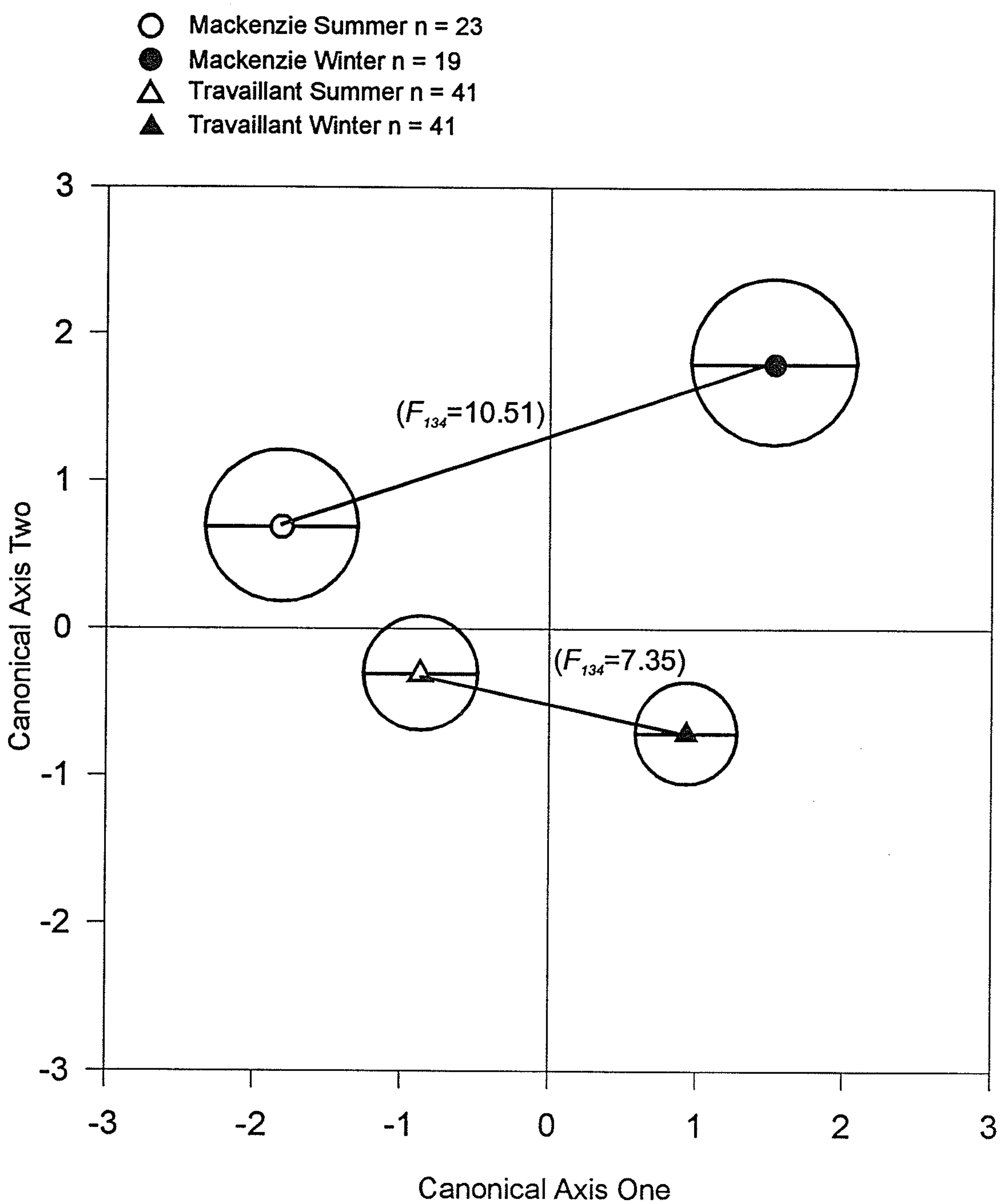
Spawning broad whitefish exhibited substantial variation in body morphology between locations (Fig. 1.7 and 1.8). Canonical discriminant analysis performed on four samples (by sex) concluded that discrimination between locations is greatest during the winter. As is seen in figures 1.7 and

Figure 1.7. Canonical discriminant analysis of 16 morphological characters for summer and winter Mackenzie River and Travaillant Lake males. Mean centroids of the winter samples are significantly different ($F_{16,150}$ =16.70, p<0.001). Means of Mackenzie and Travaillant summer individuals do differ statistically, but overlap in 95% confidence radii; therefore, morphological differences between summer males are not considered biologically significant. Mahalanobis distances (D^2) are given for summer and winter samples. Distance between summer and winter means is greater for the Mackenzie location then for the Travaillant location. Seasonally, Mackenzie males vary along canonical axis one, while Travaillant males vary along canonical axis two.



Mackenzie Summer n = 21
Mackenzie Winter n = 53
Travaillant Summer n = 45
Travaillant Winter n = 50
(F168 = 9.02)
(F168 = 13.46)
Canonical Axis Two
Canonical Axis One
3
2
1
0
-1
-2
-3
-3
-2
-1
0
1
2
3

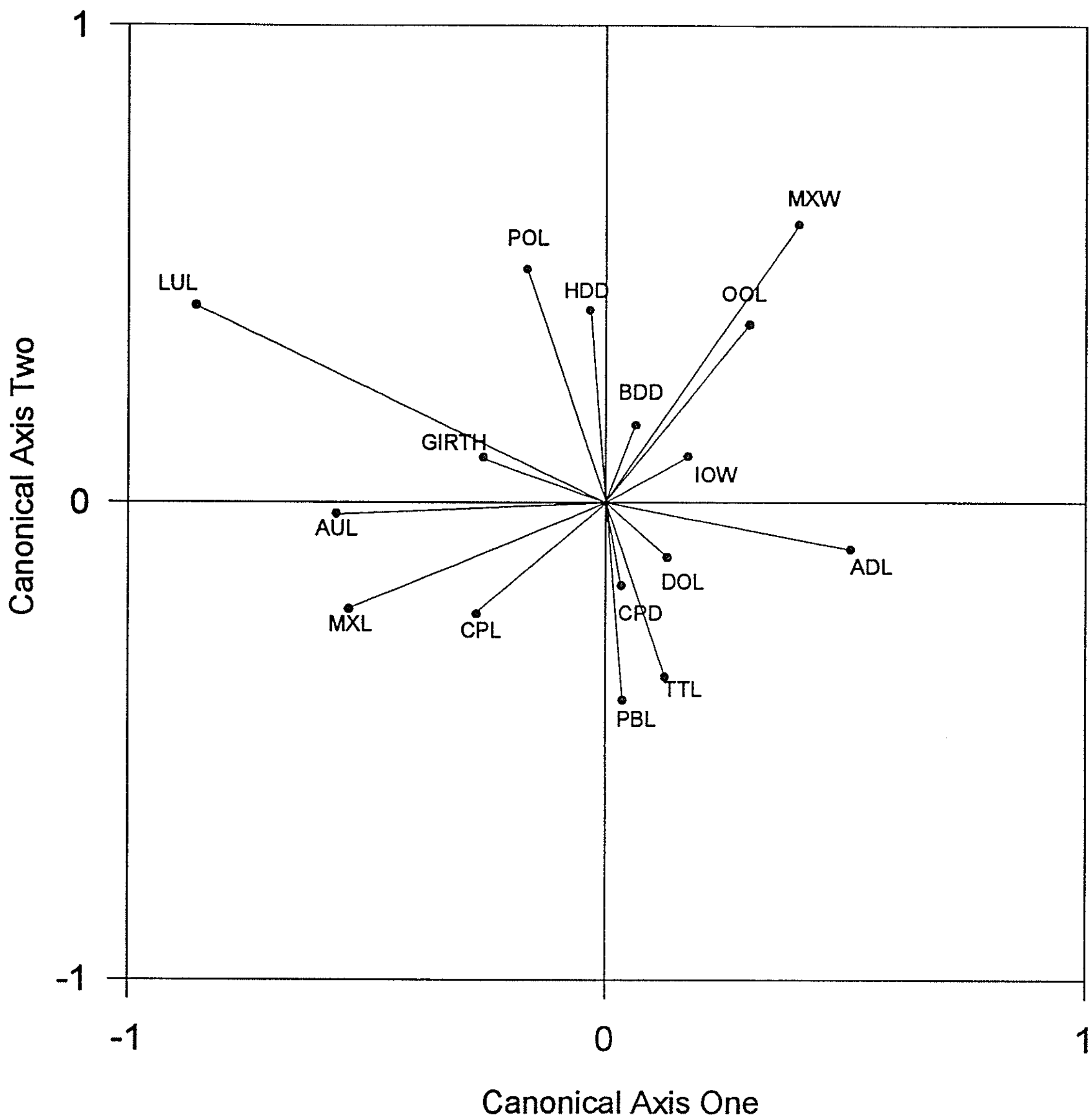
Figure 1.8. Canonical discriminant analysis of 12 morphological characters for summer and winter samples of Mackenzie River and Travaillant Lake females. Mean centroids of Travaillant and Mackenzie winter ($F_{12,120}$ =7.34, p<0.001) and summer ($F_{12,120}$ =3.96, p<0.001) samples were significantly different; the greatest discrimination occurred between winter samples. Within the populations, Mahalanobis distance (D^2) were greatest between Mackenzie summer and winter samples. Over a season, Mackenzie females demonstrate a greater morphological change than do Travaillant females. Differences within the populations varied along canonical axis one, while differences between the populations varied along canonical axis two.


Mackenzie Summer n = 23
Mackenzie Winter n = 19
Travaillant Summer n = 41
Travaillant Winter n = 41
(F_{134}=10.51)
(F_{134}=7.35)
Canonical Axis Two
Canonical Axis One
3
2
1
0
-1
-2
-3

1.8, the greatest pairwise distance between mean centroids occurred during the winter (male:$F_{16,150}$=16.70, p < 0.001 ; female: $F_{12,120}$=10.23 , p < 0.001). In females, mean centroids of summer fish from Travaillant and Mackenzie are significantly different ($F_{12,120}$=3.96, p < 0.001). In the same females, the pairwise distance between winter means doubled the pairwise distance between summer means. Males, however, are indistinguishable in summer, but differ greatly in winter ($F_{16,150}$=16.70, p <0.001).

If Mackenzie and Travaillant individuals were part of the same population their body form should vary from summer to winter in the same direction, along the same canonical axis, and therefore, be influenced by the same variables. This, however, was not observed. In the males, canonical axis one separated the winter populations, while the summer populations remained indistinguishable. Along canonical axis two , Travaillant winter males differed from Travaillant summer males in maxilla width, post-orbital length, orbital length, and head depth (Figs. 1.7 and 1.9). Mackenzie males, however, vary along canonical axis one: changes were observed in lumbar length, maxilla length, adipose length, caudal peduncle length, maxilla width and body girth (Figs. 1.7 and 1.9). Between male populations, differences in body form suggest two points. First, both populations change in body form from summer to winter, but each population is unique in this change. Second, in canonical discriminant analysis, the first axis represents more of the total variation than the second axis, and so on. In broad whitefish males, canonical axis one and two represent

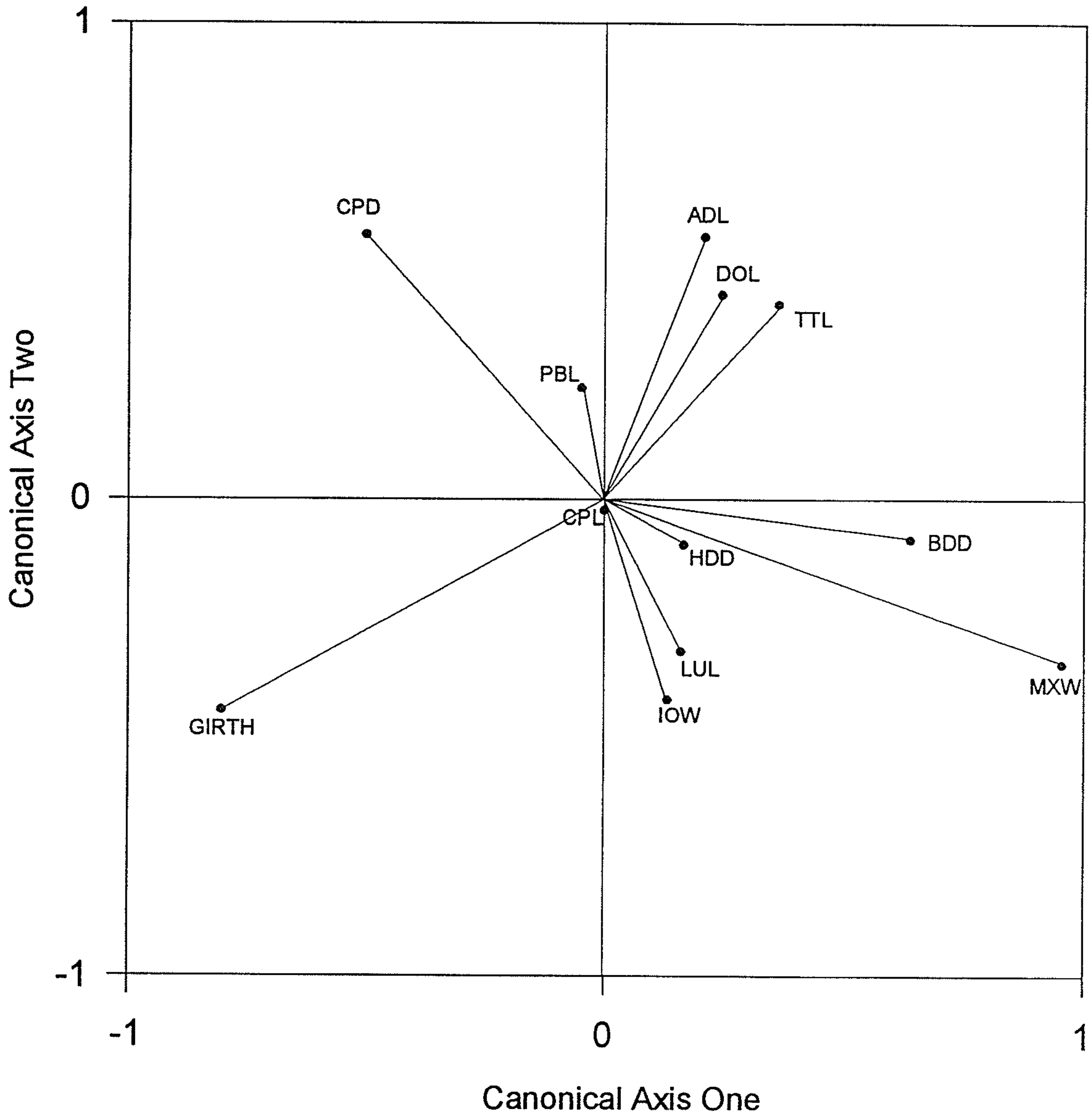
Figure 1.9. Influence of 16 morphological variables on the canonical discrimination of summer and winter samples of Mackenzie River and Travaillant Lake males. The direction of each line, terminating at a variable, indicates the direction and plane that each character varies. For example, values LUL, POL, HDD and GIRTH are highest in the Travaillant winter sample. Also, Mackenzie and Travaillant winter males are mutually effected by MXL. However, both populations differ in LUL, where LUL is highest in the Travaillant winter males. For orientation and direction of population mean centroids, refer to figure 1.7.


1
0
-1
Canonical Axis Two
-1
0
1
Canonical Axis One
MXW
POL
LUL
HDD
OOL
BDD
GIRTH
IOW
AUL
ADL
DOL
CPD
MXL
CPL
TTL
PBL

65.0% and 27.4 % of the total variation, respectively. Both canonical axes were significant ($F_{64,715}$ = 9.907 and $F_{45,544}$ = 5.895, respectively). As a result, the greatest discrimination occurred between Mackenzie winter males and all other males. It appears that males of each population differ in reproductive morphology only (see discussion). While the similarity of summer males is confusing, the differences of winter males suggest that two distinct populations exist.

Similarly, variation of female body morphology strongly suggests the existence of distinct populations. Significant differences were observed between all female samples. Unlike males, intrapopulation changes in female body form varied mainly along canonical axis one (Fig. 1.8). However, as in males broad whitefish, the Mackenzie population exhibited the greatest change in body morphology. Mackenzie females showed the greatest changes in adipose length, dorsal length, trunk length and body girth, while Travaillant females exhibited the greatest changes in caudal peduncle depth, body depth and maxilla width (Fig. 1.10). Population differences, however, varied along canonical axis two (Fig. 1.8). The most pronounced differences occurred in the winter. As in the males samples, canonical axis one explained much more of the overall variation than canonical axis two (59.6 % and 31.1%, respectively). Both canonical axes were significant ($F_{60,541}$ = 6.297 and $F_{42,413}$ =4.437, respectively). As a result, intrapopulation differences in body morphology overtime were greater than interpopulation differences in body form.

Figure 1.10. Influence of 12 morphological variables on the canonical discrimination of summer and winter samples of Mackenzie River and Travaillant Lake females. As in figure nine, the direction of each line indicates the direction and plane of variation for each character. Using the canonical axis as a point of reference, the influence of each variable on discrimination is determined. For example, differences between Mackenzie summer and winter samples are effected the greatest by variables ADL, TTL, DOL and GIRTH. Travaillant summer and winter samples, however, are influenced the most by CPD, BDD and MXW. Refer to figure 1.8 for the placement of population mean centroids.



1
0
-1
-1
0
1
Canonical Axis Two
Canonical Axis One
CPD
ADL
DOL
TTL
PBL
CPL
HDD
BDD
LUL
MXW
IOW
GIRTH

Gill Raker Counts

Gill raker counts showed considerable variation between populations, as well as seasonal variation within the Mackenzie population. Between populations, mean gill raker count was significantly higher in Travaillant spawning (winter) individuals than Mackenzie spawners (Fig. 1.11a and b), but was not significantly different between summer individuals (Fig. 1.12a and b). Statistical power was calculated for the comparison of summer means. Power was low (41% and 1% for males and females, respectively) and the observed similarity of summer gill raker means should be interpreted with caution.

Within each population, I examined seasonal changes in gill raker number. Travaillant summer and winter individuals did not differ significantly in mean gill raker number (Fig. 1.13a and b). Power of each test was low (31% and 18% for male and females, respectively) and again these data should be interpreted with caution. In contrast, Mackenzie winter individuals had a lower mean gill raker count than summer individuals (Fig. 1.14a and b), suggesting that summer and winter Mackenzie individuals are not part of the same gene pool.

Discussion

In the lower Mackenzie basin at least two populations of broad whitefish exist: 1) migratory Mackenzie population and 2) a Travaillant population. As predicted, Travaillant and Mackenzie fish differed in morphological characters. This discrimination, however, is most evident during the winter spawning run.

Figure 1.11a and b. Comparison of gill raker number between Mackenzie River and Travaillant Lake winter samples. Males and females differed significantly in mean gill raker number (t_{99} =4.065, p<0.0001 and t_{68} =3.027, p=0.004, respectively).

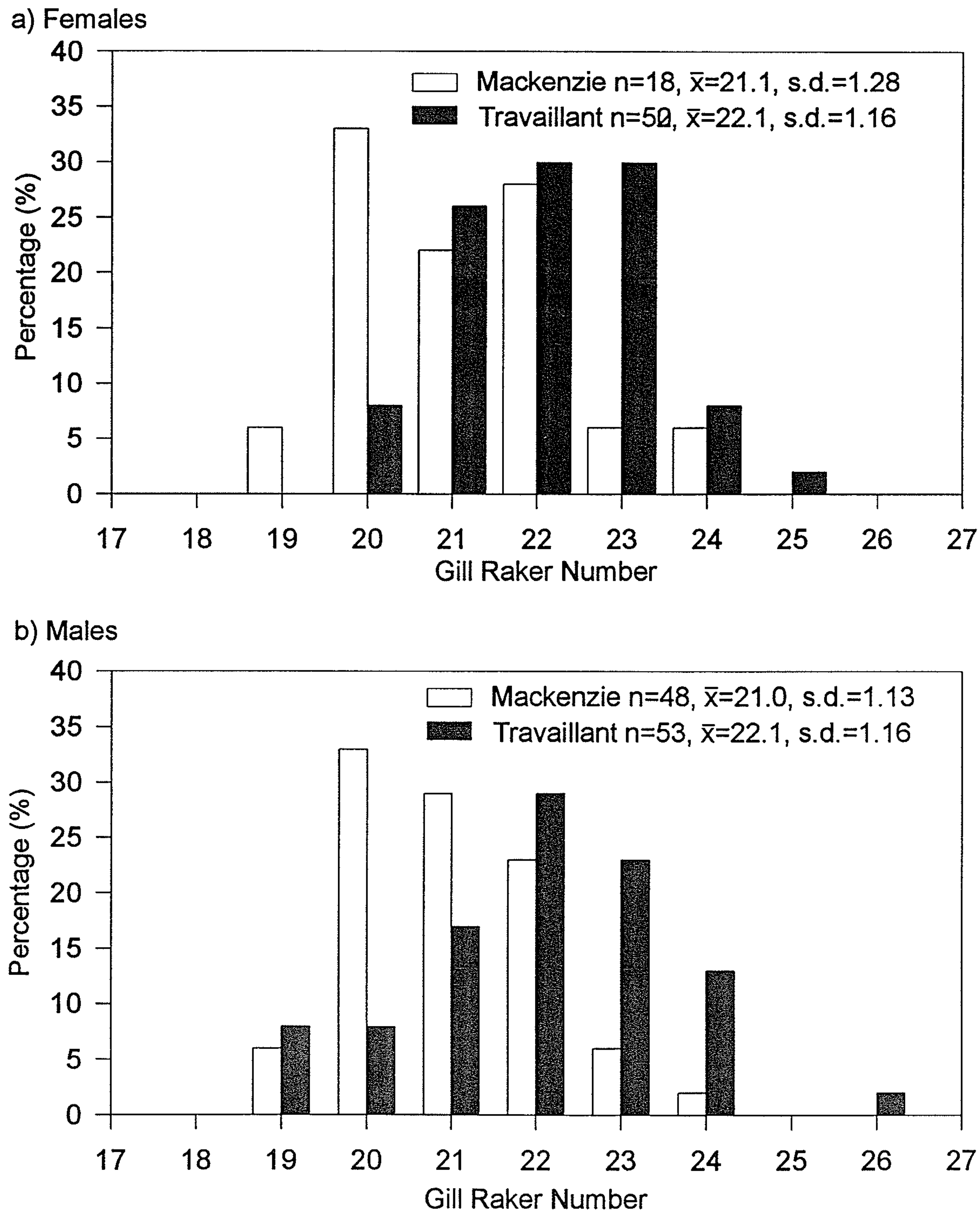
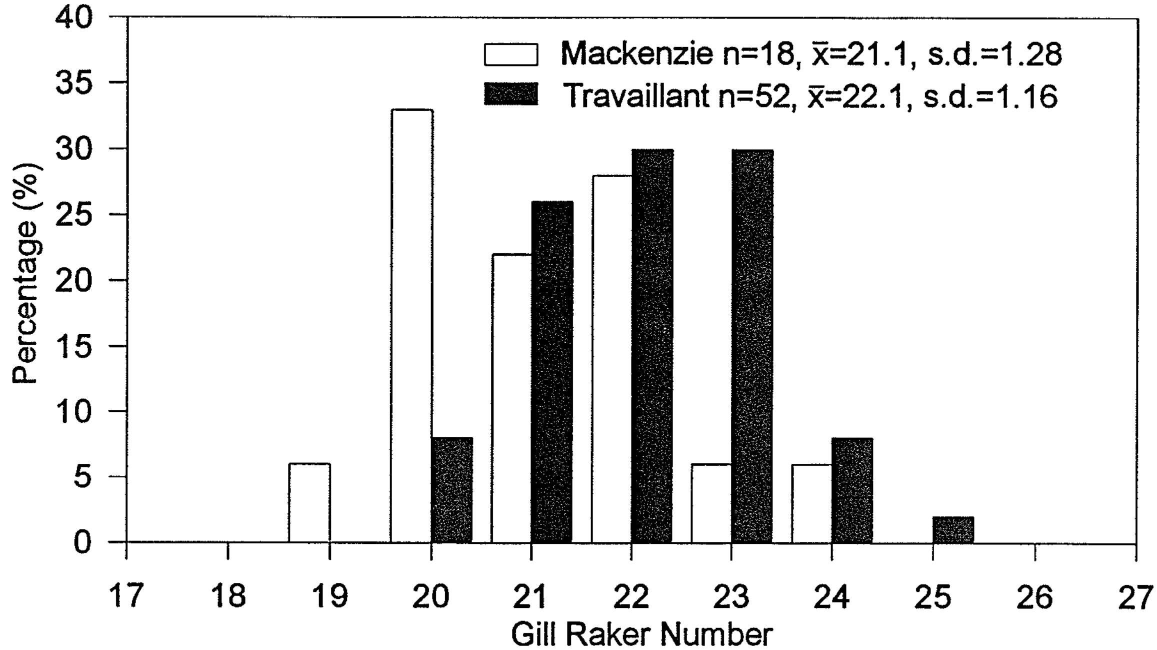

a) Females
Mackenzie n=18, x̄=21.1, s.d.=1.28
Travaillant n=50, x̄=22.1, s.d.=1.16
Percentage (%)
Gill Raker Number
b) Males
Mackenzie n=48, x̄=21.0, s.d.=1.13
Travaillant n=53, x̄=22.1, s.d.=1.16
Percentage (%)
Gill Raker Number

Figure 1.12a and b. Comparison of gill raker number between Mackenzie River and Travaillant Lake summer samples. Males and females did not differ significantly in mean gill raker number (t_{74} =1.801, p=0.076 and t_{64} =0.413, p=0.681, respectively). However, both tests had low statistical power: males=41% and females=1.0%.

a) Females



b) Males

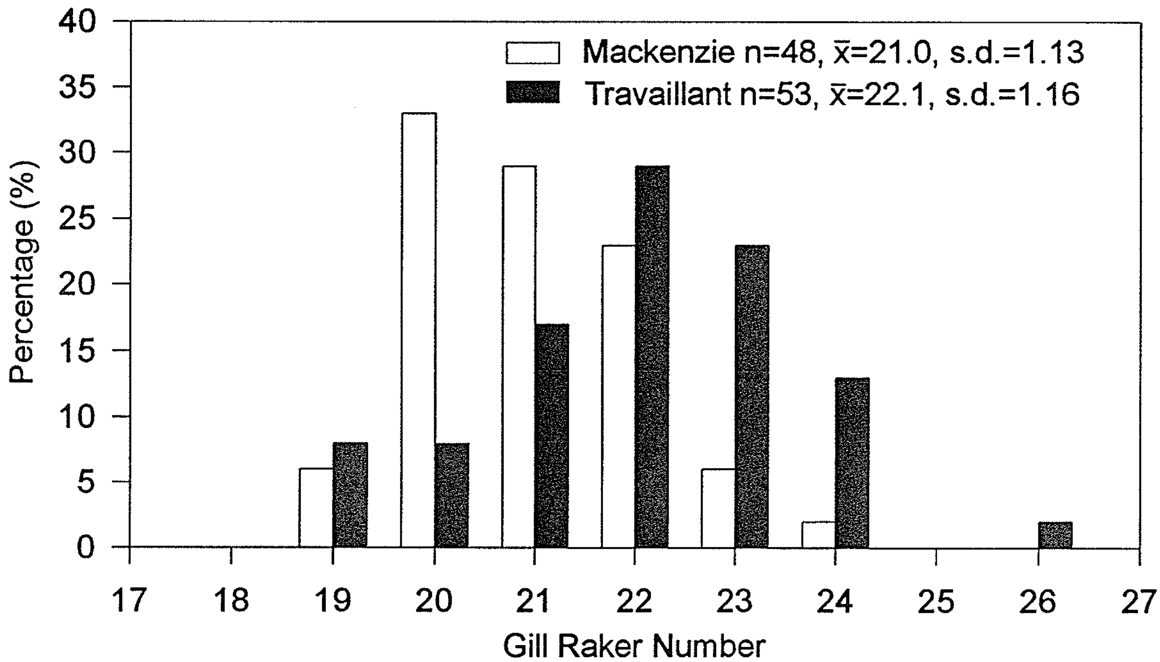
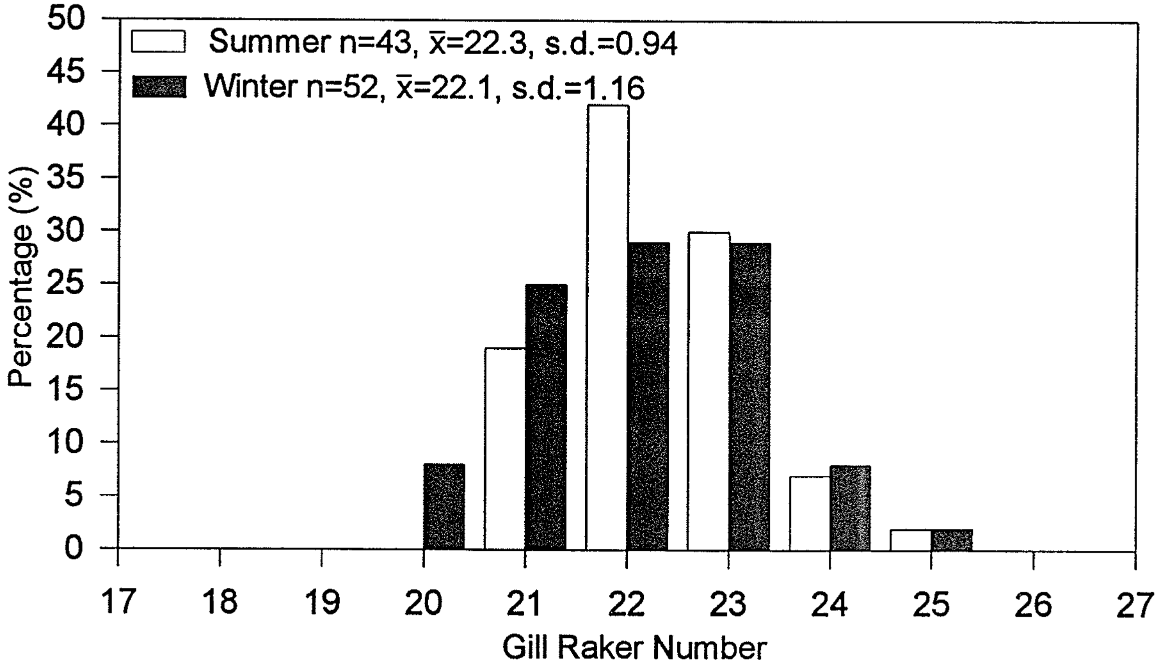


Figure 1.13a and b. Comparison of gill raker number between samples from Travaillant Lake, by season. Males and females did not differ in mean gill raker number (t_{103} =1.470, p=0.146 and t_{93} =1.042, p=0.300, respectively). Both tests had low statistical power: males=31% and females=18%.

a) Females



b) Males

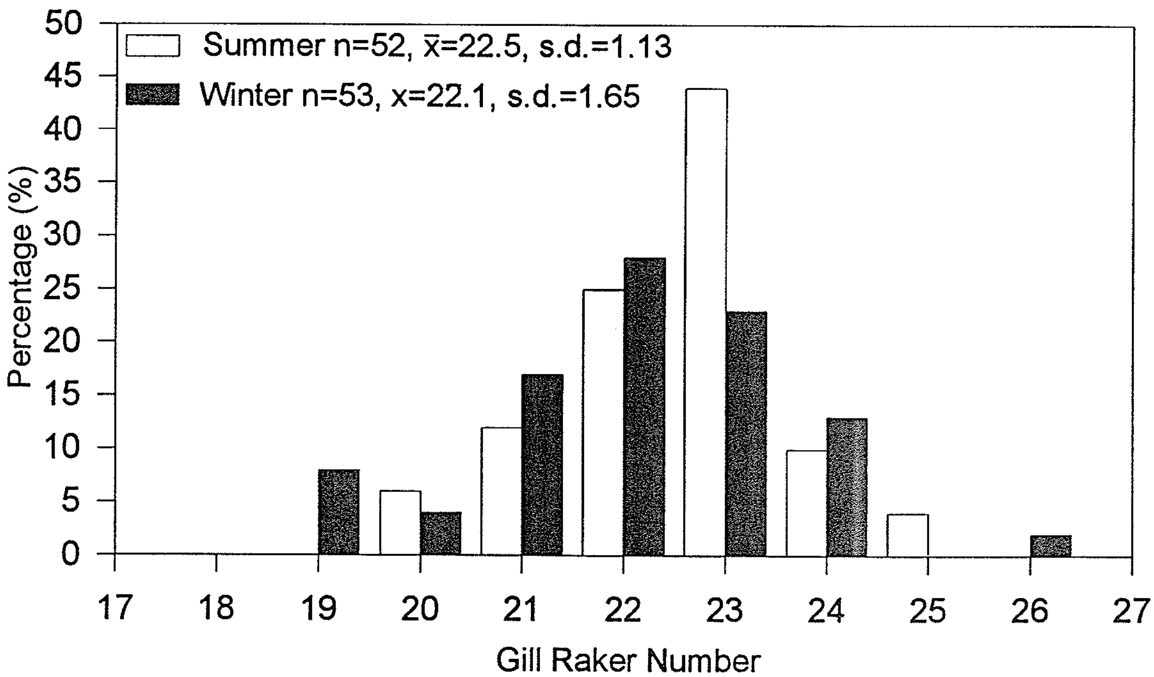
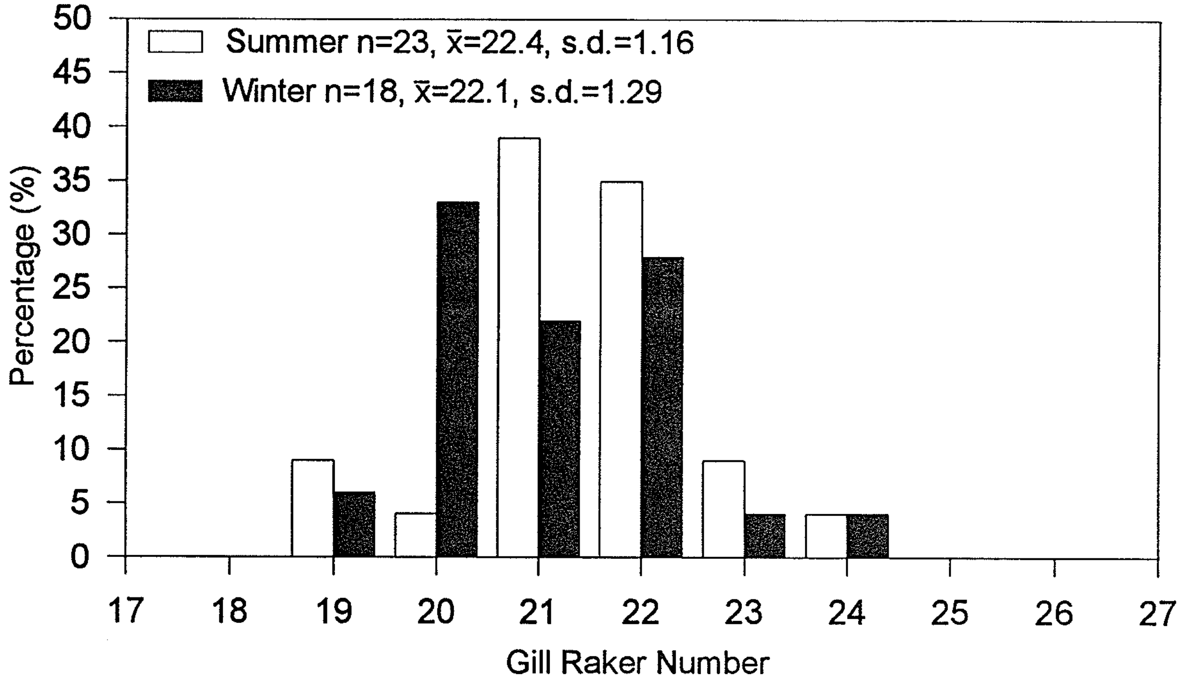
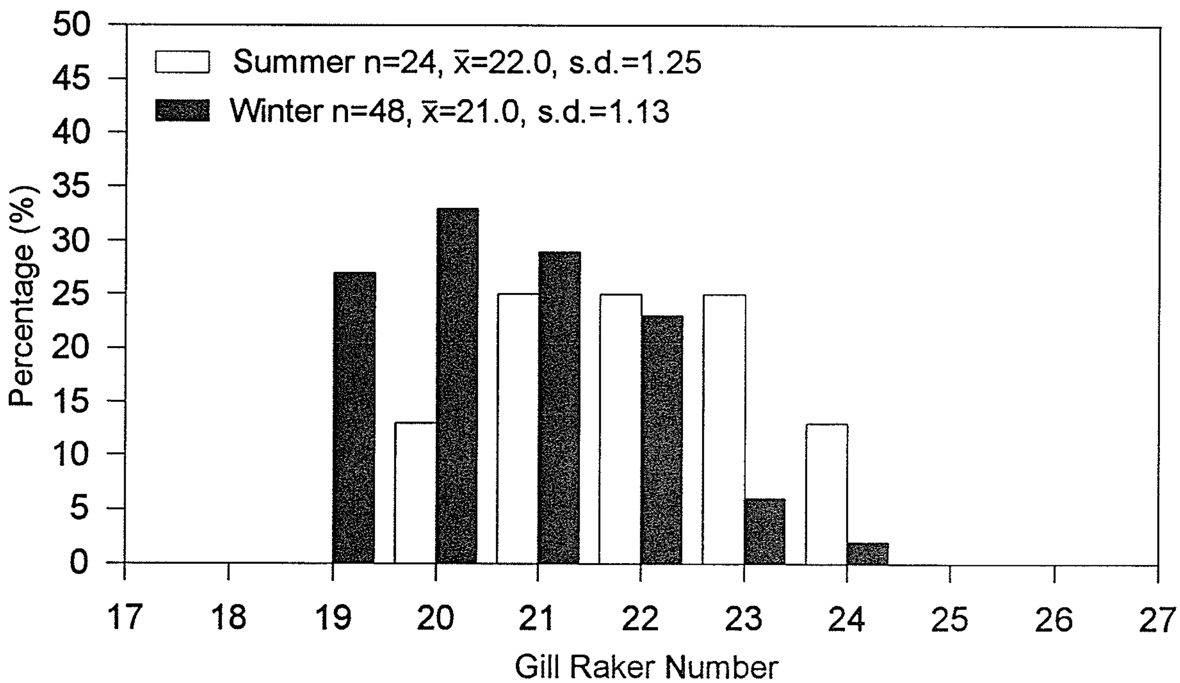


Figure 1.14a and b. Comparison of gill raker number between samples from Mackenzie River, by season. Males and females differed significantly in gill raker number (t_{70}=3.560, p=0.001 and t_{39}=3.466, p=0.001, respectively).

a) Females



b) Males



Discrimination may be maximized in winter for two reasons: 1) spawning condition has a different effect on each population, 2) stock structure is more complicated than originally predicted.

Body Morphology

Seasonal changes in body form from summer to winter in Travaillant fish differed substantially from seasonal changes in Mackenzie individuals (Figs. 1.6 and 1.7). Travaillant winter males differed from all summer males in head characters, such as maxilla width, post-orbital length, orbital length and head depth (Fig. 1.8). Male broad whitefish have a prominent "hump", just posterior to the head (pers. obs). The male hump is likely a secondary sexual characteristic and probably influences some or all head morphological characters (especially head depth). In contrast, Mackenzie winter males differ from summer males the most in body characters, such as lumbar length, adipose length, caudal peduncle length and body girth (Fig. 1.8). Of these characters, only decreasing body girth is readily explained in terms of seasonality. Mackenzie individuals feed voraciously in summer to store fat reserves for growth, migration, reproduction and overwintering (Craig 1989; Lugas'kov and Stepanov 1988). In late summer, adult fish cease feeding to begin their spawning migration up the Mackenzie and Colville River systems. When these adults are captured at or near the end of their spawning migration, their fat reserves are depleted (Dabrowski 1985). In marine fishes, gonad tissue is not compromised and somatic tissue maybe depleted to supply energy required for migration (Roff

1988). Winter Mackenzie males did have less fat than summer fish (pers. obs.) In contrast, Travaillant fish may be able to feed during their spawning run. For this reason, there is little difference in body girth between Travaillant summer and winter males (Fig. 1.9).

Travaillant winter females vary seasonally the most in caudal peduncle depth, body depth and maxilla width (Fig. 1.10). A change in female body depth with season maybe due to the onset of spawning condition. The development of eggs over the season may displace the body cavity in a dorsal/ventral plain. Thick muscles along the body coelom could prevent an increase of the body cavity in a transverse plain. Travaillant females showed no significant change in body girth over a season. Mackenzie winter females, however, have a slimmer body girth than summer females (Fig. 1.10). Again, a decrease in body girth in Mackenzie fish is best explained by a depletion of somatic tissue (which provides energy for migration) since somatic reserves are fixed due to the cessation of feeding (Lugas'kov and Stepanov 1988; Dabrowski 1985).

Gill Raker Number

As predicted, Travaillant and Mackenzie broad whitefish differed in gill raker number, but only in the winter (Fig. 1.11a and b). Differences in mean gill raker counts suggest that Travaillant and Mackenzie populations are separate gene pools; electrophoretic analysis of winter populations by Reist (in press) also demonstrated a genetic difference between Travaillant Lake broad whitefish and those of the lower Mackenzie system.

Due to its genetic determination, gill raker number can be used to examine stock structure (Lindsey 1981; Svärdson 1970). Similarities in gill raker number between all Travaillant individuals indicate that these individuals are part of a common gene pool (Fig. 1.13a and b). In contrast, Travaillant Lake individuals and Mackenzie River winter fish differ in mean gill raker number and are therefore separate genetic populations. However, a comparison of all four samples raises confusion. Mackenzie summer and winter populations differ in mean gill raker number, while Mackenzie summer and Travaillant summer populations are similar in mean gill raker number. Mackenzie and Travaillant summer samples may differ in mean gill raker number, but these sample sizes were insufficient to detect a statistical difference.

Based on stable isotope analysis, Hesslein et al. (1991) proposed that Travaillant Lake lacks a resident population of broad whitefish: broad whitefish captured in Travaillant Lake are actually migrants from the Mackenzie River system. Isoptopes of organic compounds can be used as organism "signatures", identifying an organism to a local habitat. Using isotopes of carbon, nitrogen and sulfur, Hesslein et al. (1991) suggest that broad whitefish captured in Travaillant Lake (winter samples only) did not have sulfur signatures similar to the background carbon of the Travaillant food chain. Carbon and nitrogen isotopes, however, showed no discrepancies. Nonetheless, they suggested that broad whitefish in Travaillant Lake could not have obtained their body sulfur by feeding in Travaillant Lake. In contrast, my research does not confirm the observations of Hesslein et al. (1991): I found Travaillant Lake broad whitefish to be morphologically and genetically (gill raker counts) distinct from Mackenzie River broad whitefish, especially in the winter. Due to the uniqueness of each population, it is doubtful that Mackenzie and Travaillant broad whitefish interbreed and it is therefore doubtful that these populations intermix.

Conclusions and Future Research

Analysis of body form and gill raker number support the hypothesis that at least two stocks of broad whitefish exist in the lower Mackenzie basin. The Travaillant and Mackenzie stocks, however, are most distinct during the winter. Exactly why these stocks differ, or how they became different, is speculative. The Travaillant River is a shallow waterway that probably freezes solid in the regions (Craig 1989; Hatfield et al. 1972). As a result, the Travaillant and Mackenzie systems are geographically separated during the winter, preventing access of the Travaillant system by Mackenzie migrants. It is also doubtful that Mackenzie individuals migrate into the Travaillant system during high water periods such as spring. For most of the year, Mackenzie broad whitefish are concentrated in the Mackenzie delta, Mackenzie estuary and the Tuktoyaktuk freshwater systems, all more than 100 kilometers from the Travaillant system. During high water years the Travaillant system may become accessible for lengthy periods of time. It is probably in these high water years (or periods of years) that the Travaillant system was colonized by Mackenzie broad whitefish.

Future research must examine the movements of the Mackenzie population, in order to determine the exact location of this population in summer and winter. Movements of the Travaillant population must also be monitored; do Travaillant broad whitefish leave the Travaillant system? Are Travaillant and Mackenzie populations separated by behaviour or geography? Such problems are yet to be examined. Nevertheless, conclusions of this project have added to the current knowledge of and will re-shape future research on, the Mackenzie River broad whitefish.

The purpose of the following chapters is to determine why multiple broad whitefish populations exist and why they exhibit profound differences in morphology and genetic structure. In Chapter II, I examine morphological features associated with efficient swimming. In Chapter III, I look at life history trade-offs associated with migration behaviour and exploitation pressure.

Chapter II

Variation in Body Form Between Travaillant and Mackenzie Populations: a Test for Hydrodynamic Efficiency With Respect to Long Distance Migration

Introduction

Migration is the movement between sites whose duration and location are unpredictable (Roff 1992). Northcote (in McKeown 1984) presents four reasons for migration in fish: optimization of feeding, avoidance of unfavorable conditions (environmental or climatic), enhancement of reproductive success and promotion of colonization. In temperate and polar species, however, it is the habitats required for optimal feeding and optimal reproduction that largely influence migration patterns (McKeown 1984). In the lower Mackenzie River system, coastal and delta feeding grounds are often unsuitable for broad whitefish spawning (Craig 1989). As a result, Mackenzie broad whitefish must undertake long spawning migrations to upstream areas of the Arctic Red, Mackenzie and Peel rivers (Craig 1989). In Chapter I, I outlined the life cycle of the Mackenzie broad whitefish, illustrating the spawning migration. Also, I presented evidence of a separate population of broad whitefish that may not undergo the spawning migration from the coast to the interior - - the Travaillant Lake population.

There are several reasons why Travaillant broad whitefish may not undergo long spawning migrations. First, the Travaillant system is a chain of several large and deep lakes, each with an extensive littoral zone and a connection to a number of small streams, including the Travaillant River itself. Due to its size and ecological diversity, the Travaillant system could provide habitats required for a closed population of broad whitefish (Hesslein et al. 1991). Second, Travaillant broad whitefish compete with two species of coregonids (*Coregonus clupeaformis and C. sardinella*) for food, as opposed to four coregonid species in the Mackenzie system Craig 1989; Reist 1987). Finally, Travaillant broad whitefish may be incapable of leaving the Travaillant system and entering the Mackenzie River on a regular basis. Rivers such as the Travaillant River freeze solid in regions during the arctic winter, with river ice thicknesses reaching 2 meters (Craig 1989). I observed regions of the Travaillant River that are less than 2 meters deep in summer. Since water depth drops from spring to fall, shallow regions of the Travaillant River freezes to the bottom and thereby prevent spawning migrants from entering (from the Mackenzie) or leaving the Travaillant system (Craig1989). Travaillant broad whitefish could, however, leave and re-enter the Travaillant system in the spring or high water years.

In this chapter, I examine variation in body morphology between two populations, under the assumption that Mackenzie and Travaillant broad whitefish differ in distances traveled during migration. Webb (1982) and Weihs and Webb (1983) document theories on the relationship between body form and swimming efficiency. According to these authors, fish swimming is segregated into two general hydrodynamic categories: steady swimmers (periodic motion) and burst swimmers (transient motion). Steady swimmers transport themselves with cyclic periodic movements, swimming at a steady speed for long periods of time and long distances. Burst swimmers, however, move with quick and short bursts of speed, allowing for quick acceleration and fast turning. As a result, steady swimmers have morphological features that improve hydrodynamic efficiency (important in migration), while burst swimmers have a body form adapted to prey capture (Webb 1982). Weihs and Webb (1983) demonstrate four key features that improve swimming efficiency. First, migratory species have deeper or larger anterior bodies, providing an anterior center of gravity required for inertial propulsion. An extreme example of this body type are the Thunidae (tunas) which have a large portion of their body mass placed anteriorly (Webb 1982). Second, a shallow caudal peduncle reduces drag created as the caudal region is moved in a horizontal plane. For example, the Lamnidae (the sharks) have a caudal peduncle that is flattened to the point that it slices through the water instead of displacing it (Weihs and Webb 1983). Third, area of the median fins are reduced, allowing for a further decrease in unnecessary drag. Reduced fin area is documented in migratory forms of Coho salmon (*Oncorhynchus kisutch*) (Taylor and McPhail 1985). Finally, a high aspect ratio caudal fin increases the geometric dimensions of the fin and increases the depth of the trailing edge, resulting in more force and less drag produced by the caudal fin. The lunate tails of the Thunidae are an extreme example of hydrodynamically efficient caudal fins (Weihs and Webb 1983). All four features optimize locomotion in long distance migrants.

The morphological adaptations of migratory fish result in the reduction of drag. The cost, however, of drag reduction is the inability for fast acceleration (Weihs and Webb 1983). As a result, there is morphological trade-off between migration efficiency and predator escapement. Individuals that do not undergo lengthy migrations will have a body form that optimizes thrust (Weihs and Webb 1983). Given the assumption that Travaillant broad whitefish are non-migratory, I pose the following hypothesis: Mackenzie broad whitefish are morphologically, more efficient swimmers than Travaillant fish. Using Weihs and Webbs's (1983) predictions on the effects of body morphology on hydrodynamic efficiency, I compared body forms of Mackenzie and Travaillant broad whitefish. Individuals of the Mackenzie population (migratory) are predicted to have greater body depths, smaller median fin areas, shallower caudal peduncles and a higher caudal fin aspect ratio than fish of the Travaillant (non-migratory) population.

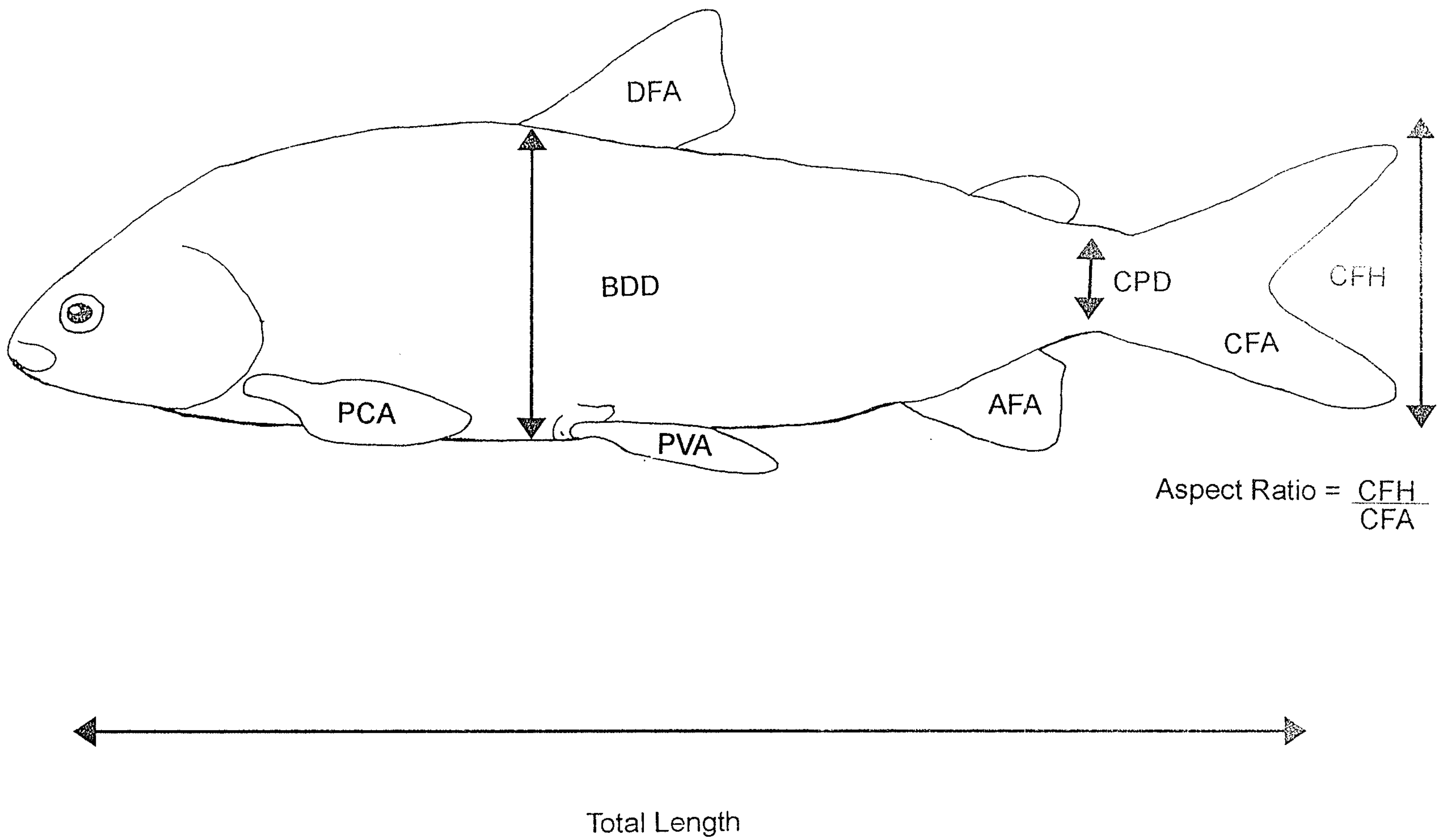
Materials and Methods

The study area and sampling protocol for Mackenzie and Travaillant populations are outlined in Chapter I. Reist (1983) states that maximum stock segregation (and therefore reproductive isolation) occurs during reproduction. Since broad whitefish spawning occurs in late October, only winter samples were used this study. Also, as noted in Chapter I, broad whitefish body morphology changes with time. As a result, analysis of body form is restricted to that time of the year when migration occurs - winter. Figure 2.1 illustrates the measurements used for the analysis of body form. Previously frozen fish were sampled for sex, fork length, fin areas, body depth, caudal peduncle depth and caudal fin aspect ratio. All measurements were conducted at the Department of Fisheries and Oceans laboratories, Winnipeg, Canada.

For analysis of fin area, an image of each fin (removed from the body) was captured with a Nikon video camera. Fin area was then calculated to the nearest 0.01mm^2 using the Biosonics Optical Pattern Recognition System (OPRS Version 1.10) software. Measurements of body and caudal peduncle depth were made to the nearest 0.1 mm with Helios calipers. Caudal fin aspect ratio was calculated as the ratio of fin height to caudal fin area (Fig. 2.1) (Videler 1993).

All measurements were linear and positively correlated with length; fin area increased in a curvilinear fashion with increasing length. Curvilinearity was successfully removed by log (natural) transforming fin area and length data (Sokal and Rohlf 1981). Using Reist's (1985; 1986) common within groups regression method, all data were standardized for length and the residuals were then used for statistical analysis. An exception to the standardization procedure was caudal fin aspect ratio, as this is a relative measure and unaffected by changes in length. Statistical comparisons of measurements were conducted with a one-tailed *t*-test, as specific (directional) predictions were tested: *t*-tests were performed with the PROC TTEST procedure of the SAS for Windows

Figures 1.2. Fin and body morphology important in hydrodynamic efficiency. Measurements are as follows: PCA (pectoral fin area), PVA (pelvic fin area), DFA (dorsal fin area), CFA (caudal fin area), AFA (anal fin area), BDD (body depth), CPD (caudal peduncle depth) and CFH (caudal fin heigth). Aspect ratio is calculated as the ratio of caudal fin height to caudal fin area. All areas were measured to the nearest 0.01 mm^2 and all linear measurements were determined to the nearest 0.1 mm.


DFA
BDD
CPD
CFH
CFA
PCA
PVA
AFA
Aspect Ratio = CFH / CFA
Total Length

(Version 6.0) software. Power of statistical analysis was examined for all tests that failed to reject the null hypothesis.

Results

Preliminary analysis of the data indicated a significant difference in body form between the sexes (Tables 2.1a,b and 2.2). As a result, data were standardized and compared by sex. In females, anal and pectoral fin areas were not significantly different between populations (Tables 2.3 and 2.4). A comparison of pectoral and anal fin area yielded a low power (19% and 57%, respectively) (Table 2.4). Given the current sample size, a statistical difference is not discernable in female pectoral fin area. In contrast, caudal, dorsal and pelvic fins were significantly larger in Mackenzie females (Tables 2.3 and 2.4) - this, however, is opposite to prediction. With the exception of pectoral fin area, comparison of male fin areas resulted in no significant differences between populations, but each test had a low statistical power (Table 2.4). Pectoral fin area was, as predicted, lower in Mackenzie males.

For each sex, body depth did not differ significantly between populations, but again, each test resulted in low power (Tables 2.3 and 2.4). Conversely, caudal peduncle depth was consistently higher in the Mackenzie individuals (Table 2.3). However, a higher caudal peduncle depth in Mackenzie broad whitefish was not predicted.

Comparison of caudal fin aspect ratio between populations did conform to prediction: Mackenzie males and females had higher mean aspect ratios than

Table 2.1a and b. Sex differences in fin area measurements for Mackenzie and Travaillant samples. Means were compared using a two tailed *t*-test. Homoscledacity in variances was tested using the TTEST procedure in the SAS package; t values were adjusted depending on whether variances between samples were equal or not.

a) Mackenzie

Variable	**Sex**	**Mean**	**S.D.**	**N**	**t value**	**p value**
Pectoral	Female	2.1308	0.3687	20	7.8434	< 0.0001
	Male	3.0078	0.5603	55		
Pelvic	Female	2.7777	0.3682	21	6.9950	< 0.0001
	Male	3.5694	0.5910	55		
Anal	Female	2.1935	0.3936	21	5.1033	= 0.001
	Male	2.8359	0.5211	54		
Dorsal	Female	3.1441	0.5332	21	4.3586	< 0.0001
	Male	3.8336	0.6400	52		
Caudal	Female	5.5674	0.6758	19	2.8137	= 0.0054
	Male	6.1292	0.7610	49		

b) Travaillant

Variable	**Sex**	**Mean**	**S.D.**	**N**	**t value**	**p value**
Pectoral	Female	2.2026	0.2609	28	7.8945	< 0.0001
	Male	3.2901	0.6808	28		
Pelvic	Female	2.5433	0.3174	27	9.2558	< 0.0001
	Male	3.6007	0.4923	26		
Anal	Female	1.9826	0.3860	27	6.5839	< 0.0001
	Male	2.7064	0.4142	26		
Dorsal	Female	2.7447	0.3598	25	5.3060	< 0.0001
	Male	3.5825	0.5829	24		
Caudal	Female	5.0869	0.5915	24	3.9374	= 0.0004
	Male	5.8921	0.8318	27		

Table 2.2. Sex differences in body depth, caudal peduncle depth and caudal fin aspect ratio between Mackenzie and Travaillant populations of broad whitefish. Means were compared using a two-tailed *t*-test. Power analysis was conducted on tests thats failed to reject the null hypothesis.

Character	**Mackenzie Population**	**Travaillant Population**
Body Depth	$t = 2.166$, $p = 0.033$ d.f. = 77	$t = 4.462$, $p < 0.0001$ d.f. = 98
Caudal Peduncle Depth	$t = 2.107$, $p = 0.039$ d.f. = 77	$t = 2.732$, $p = 0.008$ d.f. = 98
Aspect Ratio	$t = 0.4191$, $p = 0.677$ d.f. = 68, power = 6%	$t = 1.172$, $p = 0.247$ d.f. = 51, power = 21%

Table 2.3. Comparison of fin areas, body depth, caudal peduncle depth, and aspect ratio (AR) in female and male broad whitefish between Mackenzie and Travaillant populations. Means ($\bar{x}$), standard deviations (s.d.) and sample sizes (n) are given.

Variable/Sex	**Mackenzie Population**	**Travaillant Population**
Pectoral Female	$\bar{x}$=2.131, s.d=0.369, n=20	$\bar{x}$=2.202, s.d.=0.261, n=28
Pectoral Male	$\bar{x}$=3.008, s.d.=0.560, n=55	$\bar{x}$=3.290, s.d.=0.681, n=28
Pelvic Female	$\bar{x}$=2.778, s.d.=0.368, n=21	$\bar{x}$=2.543, s.d.=0.317, n=27
Pelvic Male	$\bar{x}$=3.569, s.d.=0.591, n=55	$\bar{x}$=3.601, s.d.=0.492, n=26
Anal Female	$\bar{x}$=2.194, s.d.=0.394, n=21	$\bar{x}$=1.983, s.d.=0.386, n=27
Anal Male	$\bar{x}$=2.836, s.d.=0.521, n=54	$\bar{x}$=2.706, s.d.=0.414, n=26
Dorsal Female	$\bar{x}$=3.144, s.d.=0.533, n=21	$\bar{x}$=2.845, s.d.=0.360, n=25
Dorsal Male	$\bar{x}$=3.834, s.d.=0.640, n=52	$\bar{x}$=3.583, s.d.=0.583, n=24
Caudal Female	$\bar{x}$=5.568, s.d.=0.676, n=19	$\bar{x}$=5.087, s.d.=0.592, n=25
Caudal Male	$\bar{x}$=6.129, s.d.=0.761, n=49	$\bar{x}$=5.892, s.d.=0.832, n=27
Body Depth Female	$\bar{x}$=128.150, s.d.=10.876 n=22	$\bar{x}$=130.196, s.d.=9.269, n=47
Body Depth Male	$\bar{x}$=123.796, s.d.=6.556, n=56	$\bar{x}$=122.977, s.d.=6.406, n=52
Caudal Peduncle Depth Female	$\bar{x}$=40.473, s.d.=2.496, n=22	$\bar{x}$=38.155, s.d.=2.675, n=47
Caudal Peduncle Depth Male	$\bar{x}$=42.239, s.d.=3.602, n=56	$\bar{x}$=39.566, s.d.=2.570, n=52
AR Female	$\bar{x}$=4.967, s.d.=0.541, n=20	$\bar{x}$=4.400, s.d.=0.607, n=24
AR Male	$\bar{x}$=4.913, s.d.=0.464, n=49	$\bar{x}$=4.220, s.d.=0.498, n=28

Table 2.4. Results of one-tailed *t*-tests perfomed on fin areas, body depth (BDD), caudal peduncle depth (CPD), and aspect ratio (AR). Power analysis was conducted for tests that failed to reject the null hypothesis. Sample sizes required (for each population) to achieve 80% power were determined.

Variable	***t*-value**	**d.f.**	**power**	**Required N**
Pectoral Female	0.789	47	19%	251
Pectoral Male	2.016	82	----	-----
Pelvic Female	2.367	47	----	-----
Pelvic Male	0.235	80	8%	3571
Anal Female	1.862	47	57%	43
Anal Male	1.109	79	31%	155
Dorsal Female	2.262	45	----	-----
Dorsal Male	1.633	75	50%	74
Caudal Female	2.484	33	----	-----
Caudal Male	1.258	75	34%	141
BDD Female	0.808	68	19%	302
BDD Male	0.656	107	16%	775
CPD Female	1.712	68	----	-----
CPD Male	2.207	107	----	-----
AR Female	6.139	75	----	-----
AR Male	3.246	42	----	-----

Travaillant individuals (Table 2.3). Both Mackenzie males and females differed significantly from their Travaillant counterparts (t_{75}=6.139, p<0.0001 and t_{42}=3.246, p=0.002, respectively).

Discussion

The results of this study do not support the hypothesis that Mackenzie and Travaillant broad whitefish differ in morphology associated with swimming efficiency; three of the four predictions were not satisfied. I interpret the lack of variation in body form in two ways. First, samples sizes for the current technique are inadequate to properly test the hypothesis. Second, while other adaptations for migration may be selective, hydrodynamic efficiency may not be selective in broad whitefish.

Of the predictions examined, only caudal fin aspect ratio produced expected results. However, caudal peduncle depth produced results opposite to prediction and the remaining tests had poor statistical power. With low power any differences that may occur can not be detected in a standard *t*-test (Sokal and Rohlf 1981). For the tests in which I found low power, I calculated the sample sizes required to achieve 80% power (one-tailed test, p<0.05) (Table 2.4). For example, to test for a statistical difference in dorsal fin area, a sample size of 74 fish would be required from each population. In contrast, to determine a statistical difference in pelvic fin area, a minimum sample of 3571 fish would be required from each population. However, while the above *t*-tests resulted in low statistical power, there is still a lack of a significant difference in these comparisons. Increasing sample sizes may improve statistical results, but if variances are large, a minute difference between means may not be biologically significant. Therefore, I interpret the results as support for rejecting the hypothesis that Mackenzie and Travaillant populations differ in swimming efficiency.

In addition to inadequate sample sizes, examination of body form may not be the preferred method of determining swimming efficiency (and therefore migratory potential). Three other approaches of calculating swimming efficiency are well documented: analysis of mean power ($\overline{P}$) output (Tang and Wardle 1992), comparisons of prolonged swimming speed or stamina (U_{crit}) (Taylor and Foote 1991; Taylor and McPhail 1986) and determination of red to white muscle ratio (Meyer-Rochow and Ingram 1993). Comparison of red to white muscle ratio is logistically less demanding. In a comparison of migratory and non-migratory Southern smelt (*Retropinna retropinna*) and Threespine stickleback (*Gasterosteus aculeatus*) a higher absolute amount of red muscle tissue was found in the migratory form (Meyer-Rochow and Ingram 1993; Taylor and McPhail 1986).

Hydrodynamic efficiency may not be strongly selective in migratory forms of broad whitefish, or body form may be influenced by other hydrodynamic requirements, or neither. Within the Salmonidae, coregonids are relatively poor swimmers, having a lower swimming stamina than salmon and grayling (Bernatchez and Dodson 1985; Dryden and Stein 1975). Bernatchez and

Dodson believe that whitefish compensate for poor swimming stamina by migrating early and taking advantage of warm water temperatures, thereby minimizing energy expenditure. At colder temperatures, whitefish must expend higher amounts of energy to achieve the same swimming speeds and therefore to travel the same distance. Also, instead of migrating in a steady concerted run as in salmon, whitefish migrate short distances until exhausted (Bernatchez and Dodson 1985).

In a species that tires quickly, the ability to effectively hold in moving water while resting becomes important. Webb (1975) states that the ability of a fin to act as a hydrofoil is proportional to that fin's area; in migrants, the ability to hold in a steam increases with increasing fin areas. In Atlantic salmon (*Salmon salar*), fin area does increase with increasing water velocity (Riddell and Leggett 1981). Therefore, both swimming efficiency and the effective holding have opposite influences on fin morphology. In the broad whitefish, holding a position in a river may be more important than fast and efficient swimming.

Finally, neither optimization of swimming efficiency nor holding ability may be selective in broad whitefish. In this study, male fin area doubled that of female broad whitefish (Tables 2.1a and b). Also, females had significantly smaller caudal peduncle depths (Mackenzie $\bar{x}$=40.473, Travaillant $\bar{x}$=38.155) than males (Mackenzie $\bar{x}$=42.239, Travaillant $\bar{x}$=39.566) (Table 2.2). In contrast, females had significantly larger body depths (Mackenzie $\bar{x}$=128.150, Travaillant $\bar{x}$=130.196) than males (Mackenzie $\bar{x}$=123.796, Travaillant $\bar{x}$=122.977) (Table

2.2). Caudal fin aspect ratio did not differ between the sexes (Table 2.2). Nonetheless, if migration selects for the optimization of body form, males and females are expected to have similar fin areas, body depths, and caudal peduncle depths - sexual variation should not be greater than morphological differences due to differences in migration behaviour.

Conclusions

Using knowledge on the effects of migration behaviour on body design (Weihs and Webb 1983), I compared morphologies of Mackenzie and Travaillant broad whitefish. Results of this study do not support the hypothesis that Mackenzie fish are more hydrodynamically efficient in body design than Travaillant individuals. However, this is not unequivical support for the lack of migration behaviour differences between populations. Comparisons of coregonid and salmonid swimming stamina suggest that migration is not strong selective force in the whitefish (Bernatchez and Dodson 1985). It is important to note that while Weihs and Webb's (1983) theories were produced from comparisons between species, support for these theories at the population level are also well documented (e.g. Taylor and McPhail 1985). Finally, while it is possible that differences in swimming efficiency may exist, larger sample sizes or different techniques are required to properly the hypothesis.

Chapter III

The Effects of Migratory Pattern and Exploitation Pressure on the Expression of Life History Traits in the Mackenzie River Broad Whitefish (*Coregnus nasus* Pallas): Support for Distinct Populations

Introduction

In using the optimality approach, one assumes that there is at least one combination of traits that exceeds all others in fitness (Roff 1992). Optimality theory makes three assumptions on the evolution of life histories: 1) some measure of fitness will be maximized, 2) the set of possible life history trait combinations is limited by trade-offs (negative relationship between traits) and constraints and 3) there will be sufficient genetic variation to allow selection of that combination of traits which maximizes fitness (Roff 1992). In a temporally and spatially variable environment, that combination of life history traits which maximize fitness will vary. Therefore, how will the trade-offs be expressed? Life history trade-offs can be segregated into physiological and evolutionary (micro- and macro-evolutionary) trade-offs (Stearns 1992). Physiological trade-offs simply represent variation in phenotypes generated by environmental variation (no genetic differences between individuals) whereas evolutionary trade-offs represent distinct traits generated by both genetic and environmental variation.

In this chapter I have two objectives. First, I examine variation of inter-population life history pattern to explain phenotypic and genetic differences between the Travaillant and the Mackenzie populations of broad whitefish. Two possible effects are examined: migratory distance and exploitation pressure. Both migration and exploitation elicit specific responses in life history traits, allowing for specific predictions. Second, I combine conclusions of this and preceding chapters to determine whether observed trade-offs and life history patterns are physiological or evolutionary.

Migration is an energetic cost. Life history traits or behaviour that reduce the cost of migration will be advantageous in a migratory species. Roff (1988; 1991) suggests that the relative energetic cost of migration decreases with increasing fish size (length). It is well known that within the same fish species, larger individuals have a greater swimming endurance than smaller individuals (Videler 1993; Weihs and Webb 1983). For example, in the American shad *(Alosa sapidissima)* smaller fish suffer from a higher somatic tissue depletion and higher post-migration mortality than larger fish (Glebe and Leggett 1981). In order to attain a large size at age of maturity, individuals must invest more energy into growth. In general, fish are indeterminate growers. In coregonids, however, the greatest growth in length occurs before sexual maturity (Popov 1975). By delaying sexual maturity a fish has more years to direct energy into growth, resulting in a large size at maturation (Roff 1992). In a migratory fish species, sexual maturity is concomitant with a lengthy spawning migration. Therefore, size at age of maturity becomes paramount, since the increase in size **after** age of maturity is nominal. Large size at sexual maturity is especially important for semelparous migrants, where insufficient body length may result in failed migration and therefore spawning. In non-migratory species (populations), migration has a lesser impact on life history pattern. Obtaining a large size (usually required for migration) no longer ensures a higher fitness. As a result, an earlier age at maturity and a smaller size are selected (Snyder and Dingle 1990; Stearns 1992). Comparative studies of migratory and non-migratory groups have demonstrated a larger size at age, delayed maturity and higher fecundity in migratory species (Hutchings and Morris 1985; Roff 1988; 1992) and migratory populations (Blair et al. 1993; Gresswell et al. 1994; Hutchings and Morris 1985; Roff 1992; Taylor 1990). Also, quantitative genetic studies in Threespine sticklebacks (*Gasterosteus aculeatus*) and Coho salmon (*Oncorhynchus kisutch*) have shown that these life history traits are genetically variable (Snyder and Dingle 1990; Taylor and McPhail 1985).

In the Mackenzie River system, differences in migratory behaviour may explain the existence of multiple stocks of broad whitefish. In Chapter I, I outlined the life cycle of the Mackenzie River broad whitefish, describing the spawning migration from coastal and delta areas to inland spawning grounds. I suggested that since spawning, overwintering and feeding grounds are located within the Travaillant system, Travaillant broad whitefish may not undergo lengthy spawning migrations. If Mackenzie and Travaillant broad whitefish differ in migratory behaviour, then these populations will differ in size and age at maturity and fecundity.

Exploitation (exploitation rate) is the effect of human harvesting on a fish population over and above that of natural mortality (Ricker 1975). Fishing mortality concentrates on a specific portion of the population at a specific time and place, while natural mortality is highly variable in time and space (Nikol'skii 1969). To adapt to this variability, iteroparous fish spread their life time reproductive investment over many small reproductive attempts, evening out the effects of good and bad years (Stearns 1992). Fishing mortality, however, is predictable and directed. In the coregonids, selective fishing removes the larger and older age classes and is conducted during the spawning run in winter. Removal of specific age classes has a selective effect, changing age structure, growth rate and individual and population reproductive effort (Nikol'skii 1969). It is well established that exploitation of fish populations result in earlier maturation, a faster growth rate and few, but large reproductive efforts (McCart 1986; Stearns 1992).

Why does exploitation result in a directed response in life history pattern? Exploitation has an immediate effect on population structure and as a result, an affect on resource competition. As the older and more numerous age groups are removed, mean age of the population decreases. Also, removal of the prominent age classes results in a reduction in resource competition, as the most prominent age classes affect the growth rates of preceding and subsequent age classes (Nikol'skii 1969). Resources are now apportioned among fewer competitors and individual energy intake increases. Each competitor will have a higher growth rate, higher fecundity, an earlier age of maturation and, by virtue of earlier maturity, a shorter life span - this is a plastic response (Nikol'skii 1969; Ricker 1977; Roff 1992). Since fecundity is positively related to both energy intake and fish size (length), fecundity will increase due to both an increase in energy intake and the resultant increase in growth rate (Ricker 1977; Wootton 1990). Consequently, life history patterns vary, due to the immediate effects of selective fishing and the resulting decrease in resource competition. However, while food availability/quality does influence the expression of life history traits, persistence (and therefore selection) of any one strategy depends on the relative fitness of all strategies.

Selection will favour that combination of life history traits with the greatest fitness. In a unexploited iteroparous fish populations, juvenile mortality is high relative to adult mortality (Nikol'skii 1969). Due to a low adult mortality rate and an unpredictable environment, selection will favor investment into many reproductive attempts and therefore a long life span (Stearns 1992). In exploited populations, however, adult age classes are selectively removed (Nikol'skii 1969). Those individuals that spread reproduction over a number of years will not maximize their lifetime reproductive investment; therefore in exploited populations, selection for future reproduction and survival is weak (Stearns 1992). Conversely, individuals increase their chances of survival and producing offspring (and therefore increase fitness) by maximizing reproductive effort prior to recruitment into the fishery. Therefore in exploited populations, selection will favor those individuals that grow fast, mature early and have few, but large reproductive attempts (Stearns 1992). A positive relationship between female fecundity and exploitation pressure has been documented in Lake whitefish (*Coregonus clupeaformis*) (Healey 1978; Salojärvi 1992), Walleye (*Stizostedion vitreum*) (Baccante and Reid 1988) and Northern pike (*Esox lucius*) (Diana 1983). In whitefish, an increase in exploitation pressure results in a higher individual growth rate, due to a decrease in individual age at maturity (Healey 1980; Salojärvi 1992).

As with most arctic fish populations, broad whitefish are slow growers, they mature late in life and they have a long life expectancy (up to 30 years) (Craig 1989). Adult age groups span a number of years, allowing populations to "bet-hedge" against good and bad years (McCart 1986). Both exploited and unexploited populations exist in the lower Mackenzie delta. For the past 100 years subsistence and commercial fisheries have existed on the Mackenzie River, concentrated around the townships of Aklavik, Arctic Red River, Fort McPherson, Inuvik and Tuktoyaktuk (Berkes 1989) (Fig. 1.1). In contrast, broad whitefish in Travaillant Lake maybe fished on a semi-annual basis for subsistence harvest (pers. obs.). I propose the following working assumption: due to the low intensity of subsistence fishing and due to the absence of a commercial fishery, the Travaillant population experiences a lower exploitation rate. In theory, the Travaillant and Mackenzie populations should differ in growth, age at maturity, life span and reproductive effort.

Table 3.1 summarizes all predictions, the relevance of each prediction to a specific hypothesis and the measurement used for each prediction. In this chapter, I pose two hypotheses. First, as I suggested earlier, Travaillant and Mackenzie broad whitefish may differ in the distance travelled during a spawning migration. I pose the hypothesis that individuals of the Travaillant population exhibit a life history pattern that is different from the that of Mackenzie broad whitefish (the migration hypothesis). I predict that Travaillant broad whitefish will have a smaller size at age, earlier age at maturity and a lower overall fecundity than the more migratory Mackenzie individuals (Roff 1988; Snyder and Dingle 1990). Second, due to a difference in exploitation rate, Mackenzie and Travaillant populations will differ in life history pattern (the exploitation hypothesis). For the exploitation hypothesis, I predict that Travaillant broad whitefish will have a slower growth rate, later age at maturity, higher size specific fecundity and longer life span than Mackenzie individuals (Healey 1978; Nikol'skii 1969; Stearns 1992). These hypotheses are not competing; one, both or neither may hold.

Materials and Methods

The study area and the sampling protocol for the Mackenzie and Travaillant populations are outlined in Chapter I. Fish collected from the Mackenzie system were sampled for fork length, total weight, gonad weight, sex, as well as the collection and storage of sagittal otoliths and eggs. Winter sampling in the Mackenzie system occurred between mid September to mid

Table 3.1. Summary of migration and exploitation hypotheses, predictions and measurements of each prediction. Predictions for each hypothesis are compared, where applicable. Note that the migration and the exploitation hypotheses predict opposite results for age at maturity. Both hypotheses predict an increase in fecundity, but the migration hypothesis predicts an increase in absolute fecundity, while the exploitation hypothesis predicts an increase in reproductive effort (size specific fecundity). Here, size specific fecundity refers to the amount of eggs produced by each female of a given size (i.e. standardized).

	Hypothesis		
Prediction	**Migration**	**Exploitation**	**Measure**
Fecundity	increase in absolute fecundity	increase in size specific fecundity	fecundity and GSI
Size at adult age	higher in migratory population	NA	adult length compared over a constant age
Life Span	NA	decreases with increasing exploitation	mean population age
Age at maturity	higher in migratory population	decreases with increasing exploitation	maturity index (Bond and Erickson 1995)

NA - not applicable

November 1993. Total sampling effort in the Travaillant system were ten days in the summer (July 30 to August 8) and two days in the winter (October 25th and 26th). Summer samples were measured for length and weight and then frozen. All winter samples, however, were frozen without length or weight measurements. All frozen fish were sampled for fork length, total weight, gonad weight, sex, sagittal otoliths and eggs. For Travaillant winter samples, fresh lengths and weights were estimated from a linear regression of fresh versus frozen data from the Travaillant summer sample ($y = -25.6976 + 0.9932x$, $R^2=0.9932$ and $y = -15.5660, 0.9774x$, $R^2=0.9864$, respectively). Total sample sizes were 206 from the Mackenzie population (males n=138; females n=68) and 149 from the Travaillant population (males n=81; females n=68).

Ages were determined by counting annuli of prepared sagittal otoliths as described in Bond and Erickson (1985). Preparation involved breaking each otolith at the first annulus, using a No. 9 scalpel. To emphasize the annuli, the open faces of the broken otolith were polished with a jewellery grinder and then burned using an alcohol burner. Annuli were counted starting at the first annulus, moving to the outer edge along the longitudinal axis.

Eggs were separated from ovarian material using Gilson's Solution followed by manual separation. Ovarian material was separated from the eggs by rinsing the ovaries under tap water and then physically removing tissue. Cleaned eggs were placed on trays and air dried for a minimum of two weeks (Healey 1978). For each fish, a subsample of 1000 eggs was counted and weighed to the nearest 0.001 grams. Fecundity was calculated by dividing the total weight by the weight of the subsample, then multiplying by a thousand. Maturities of male and female broad whitefish were determined visually with the aid of a maturity index (Bond and Erickson 1985).

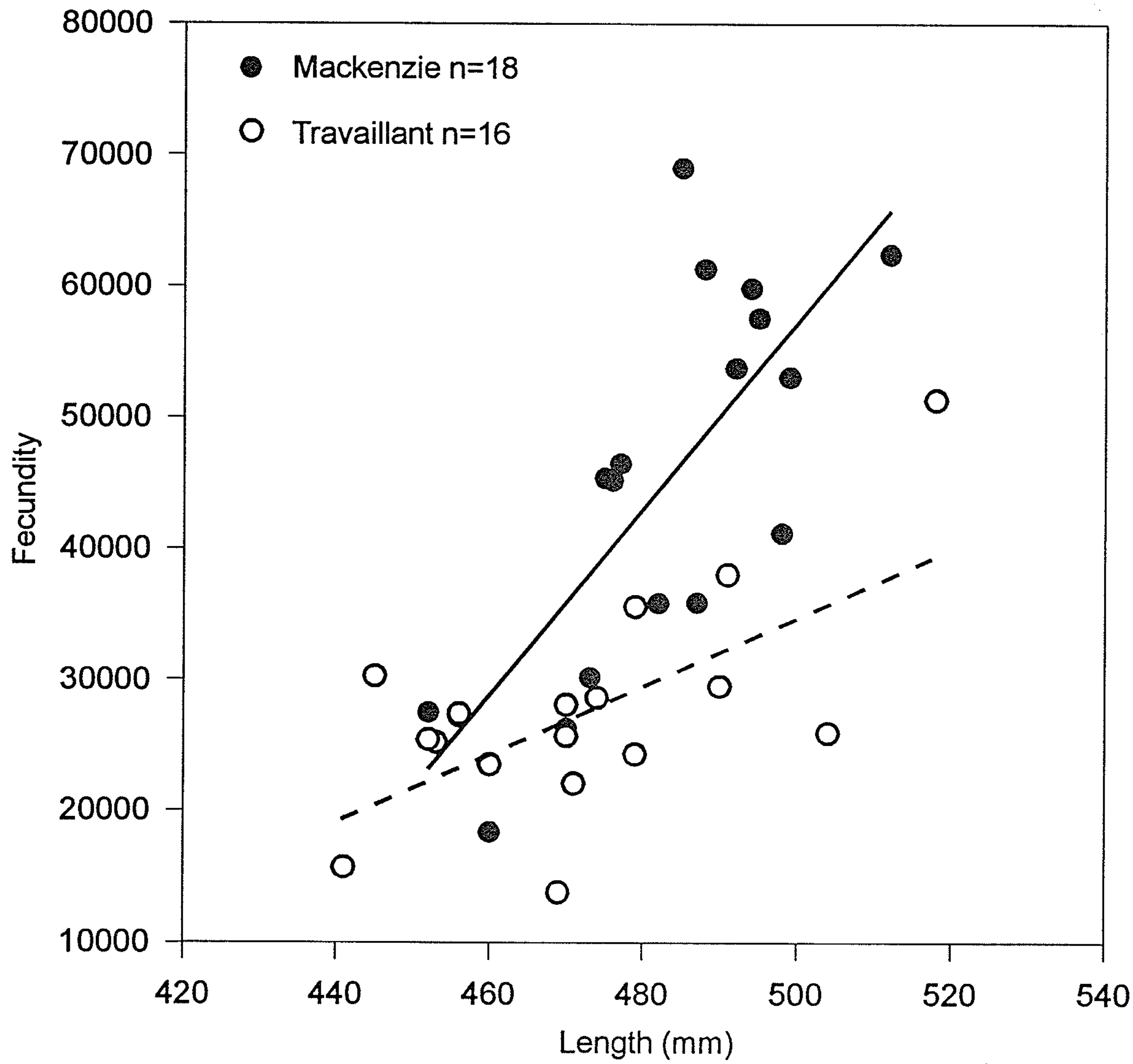
Where a specific prediction was tested, sample means were compared using one-tailed *t*-test. A two-tailed *t*-test was used to determine if sample means were significantly different (i.e. no prediction was implied). In tests where the null hypothesis was not rejected, the power of each test was calculated. Linear regression for fecundity/length and gonad weight/total weight data were performed using the PROC GLM procedure in the SAS for Windows program (Version 6.0). For each regression, a goodness of fit test (R^2) was calculated as part of the PROC GLM procedure. Phenotypic correlations and associated levels of significance of life history traits were analyzed using a PROC CORR procedure (Pearson correlation coefficient).

Results

Relationship of Life History Traits

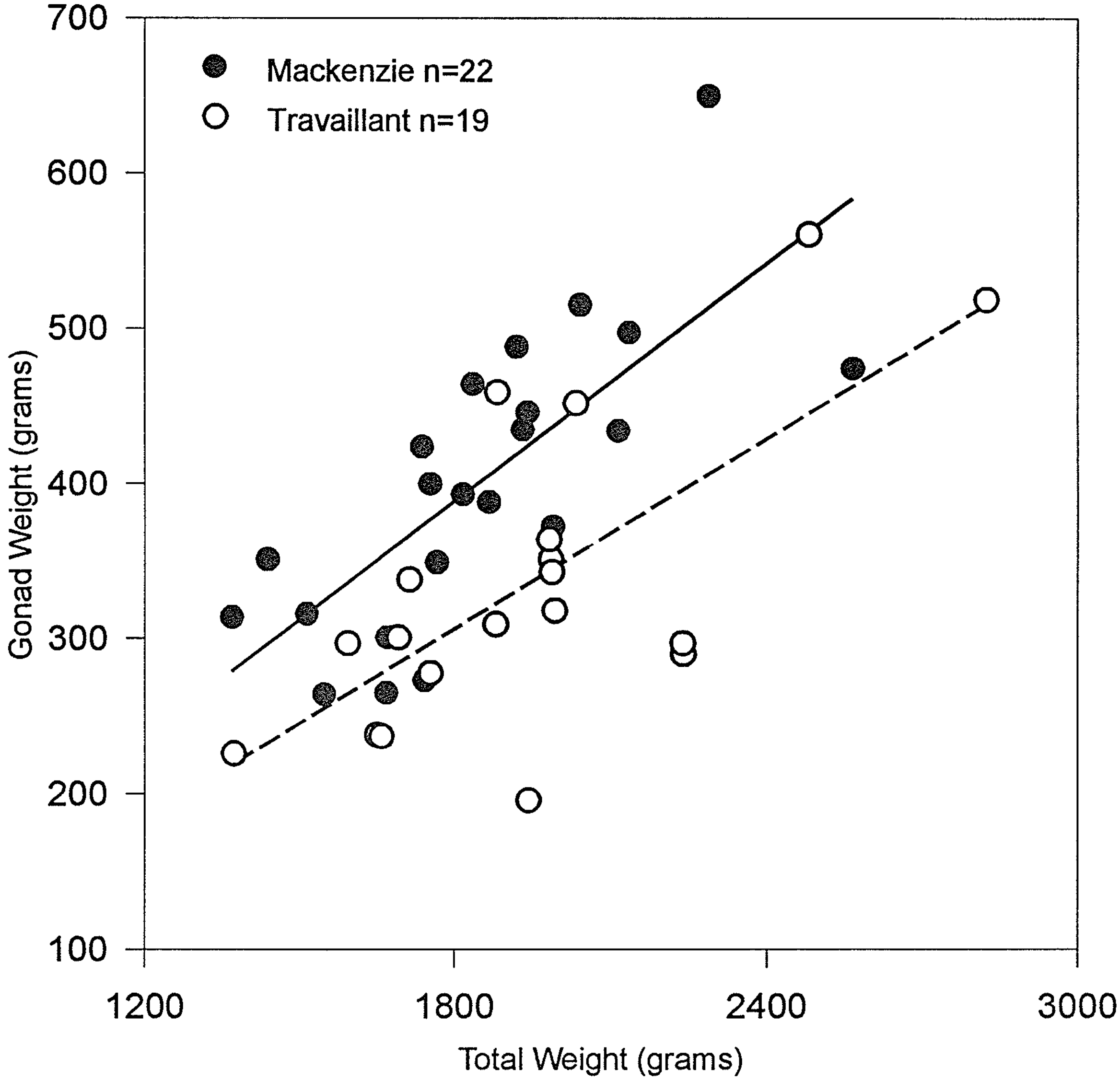
For each sex of each sample, reproductive effort (here interpreted from size specific fecundity and gonadosomatic index or GSI) was positively correlated with size (Figs. 3.1 and 3.2). A positive relationship between reproductive effort and size is consistent with theory (Roff 1988) and experimental observation (Snyder and Dill 1990). Among populations, a trade-off was observed between reproductive effort and mean age in female broad

Figure 3.1. Fecundity of broad whitefish females from Mackenzie (filled circles) and Travaillant (closed circles) populations. Mackenzie females had a significantly higher fecundity (t_{33} = 4.020, p=0.0003) for a given size range. Mean age was $\bar{x}$=11.2 years (s_x=3.56) and $\bar{x}$=15.7 years (s_x=1.23) for Mackenzie and Travaillant females, respectively. R-squared (R^2) values were fair for both populations: Mackenzie=0.5827 and Travaillant=0.4096).



Mackenzie n=18
Travaillant n=16
Fecundity
80000
70000
60000
50000
40000
30000
20000
10000
420
440
460
480
500
520
540
Length (mm)

Figure 3.2. Comparison of gonad and total weight of Mackenzie and Travaillant female broad whitefish. Mackenzie females had significantly larger ovaries than Travaillant females (t_{39} = 2.151, p=0.019) for a common size range. Similarity in total body weight between the populations suggest that Mackenzie females contribute more soma to ovarian tissue, and therefore have a higher reproductive effort than Travaillant females. Differences in ovary weights correspond to differences in size specific fecundity (Fig. 1.3). R-squared (R^2) values were 0.5582 and 0.4827 for the Mackenzie and Travaillant samples, respectively.



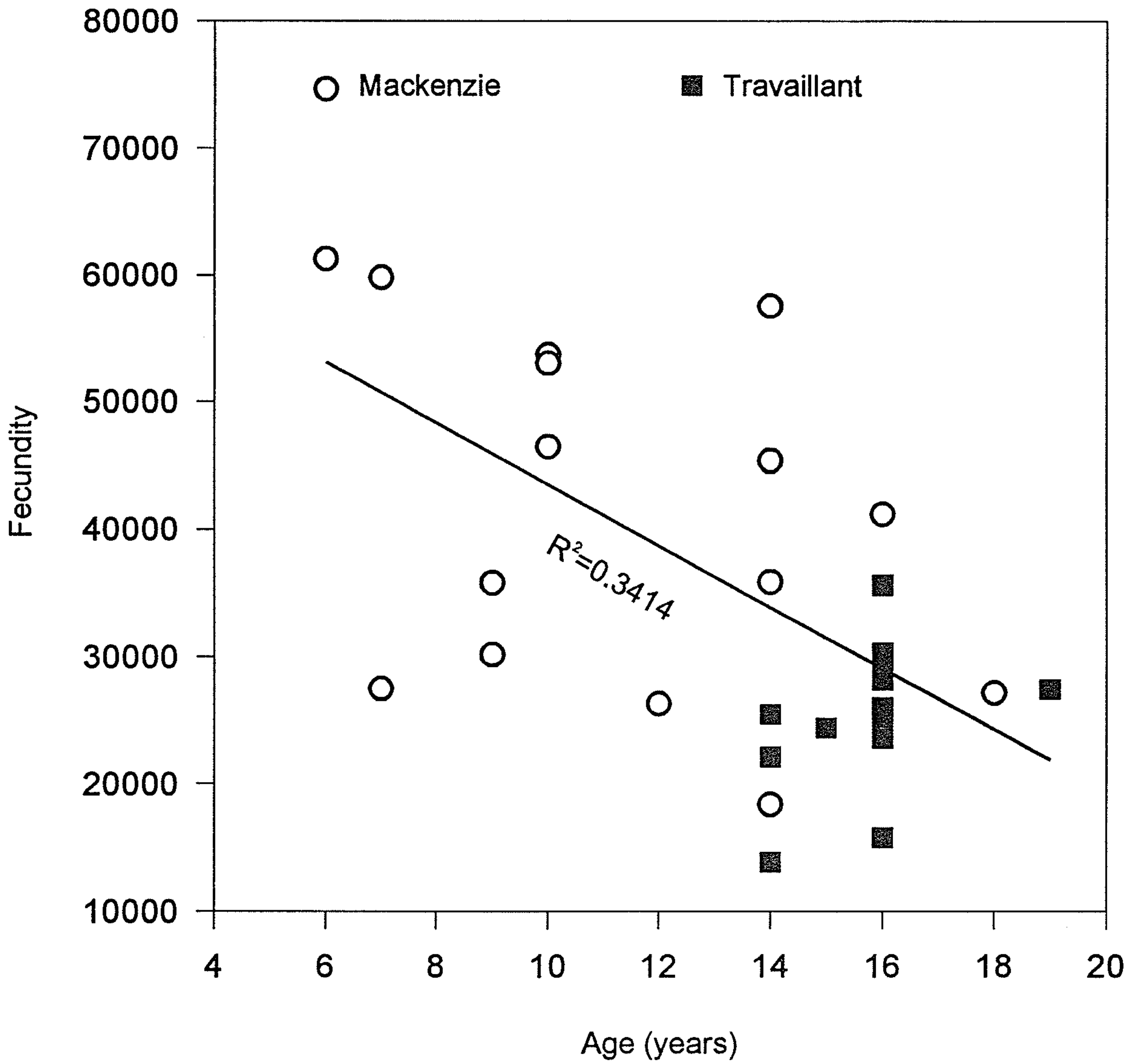
Mackenzie n=22
Travaillant n=19
700
600
500
400
300
200
100
1200
1800
2400
3000
Gonad Weight (grams)
Total Weight (grams)

whitefish; Mackenzie females had a high reproductive effort and a low mean age, while Travaillant females had a low reproductive effort and a high mean age (fecundity: R^2= -0.5739, p=0.0006) (Fig. 3.3). A negative correlation of reproductive effort and age is consistent with theory (Stearns 1992) and observation (Nikol'skii 1969). In male broad whitefish, however, no correlation was observed between reproductive effort and mean age (R^2=0.0770, p=0.3086). Finally, within a population (Mackenzie females), reproductive effort declined with age (fecundity: R^2= -0.4340, p=0.0817). Nikol'skii (1969) also found a decrease in reproductive effort with age in long lived iteroparous fish.

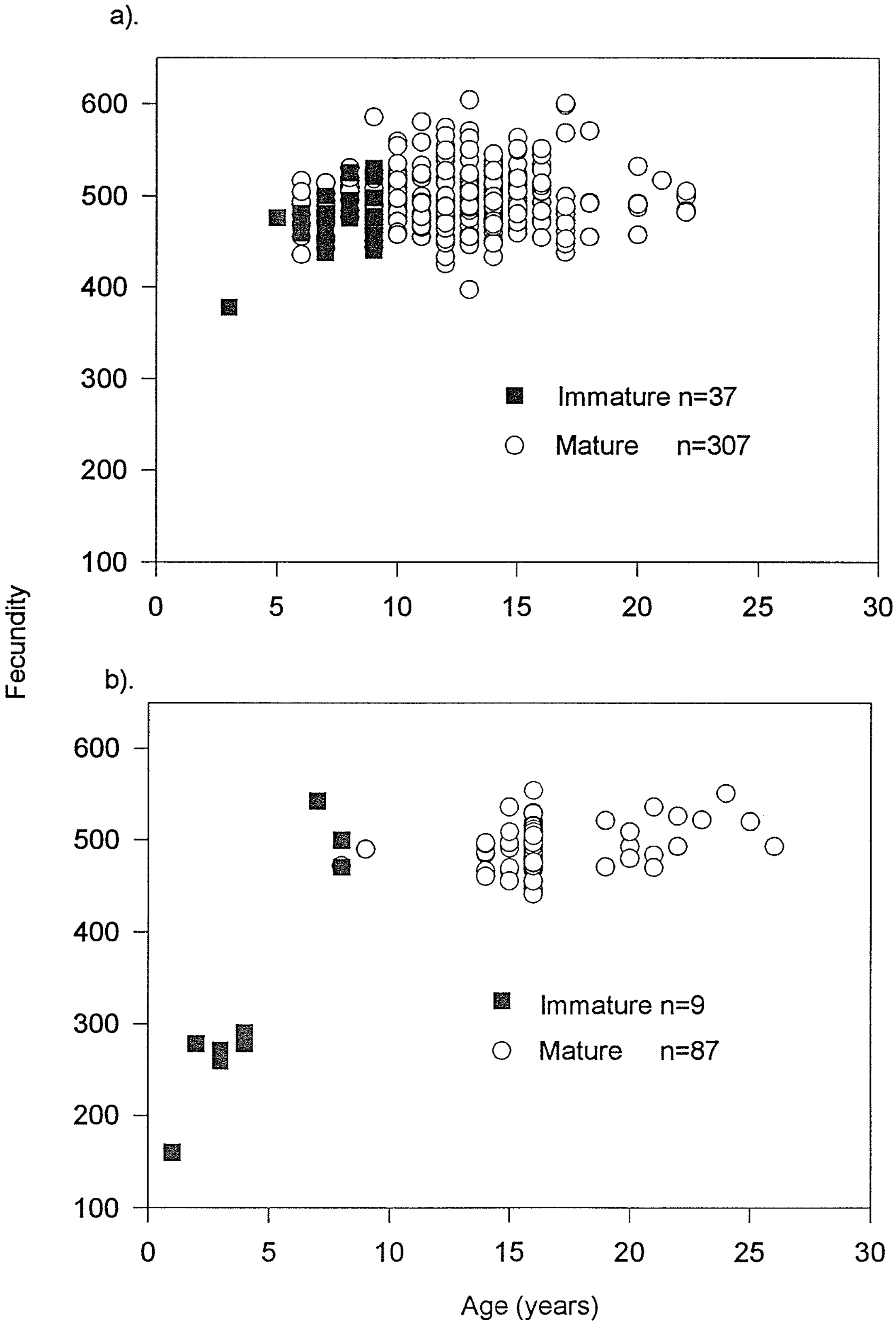
Predictions, the Migratory Hypothesis and the Exploitation Hypothesis

Size at adult age was determined for each population, between the ages of nine and 23. The data set was constrained for two reasons. First, all broad whitefish nine years and older should be adults, as the maximum documented age of maturity is eight years (Chang-Kue and Jessop 1992). Second, the maximum age of individuals of the Mackenzie sample was 23 years, limiting the Travaillant sample. Therefore, by using an age range of nine to 23 years, I compared identical ranges of age. Mackenzie broad whitefish were not significantly larger than Travaillant individuals (female: t_{133}=-1.3393, p=0.0914; males: t_{216}=-0.0631, p=0.4789; all sexes: t_{409}=0.075, p=0.4705) (Fig. 3.4). Similarity of mean adult age was not predicted as part of the migration hypothesis, theory (Roff 1991) or observation (Taylor and McPhail 1985; Snyder and Dingle 1990). However, power of each *t*-test was very low (females=41%,

Figure 3.3. Trade-off between reproduction and mean age (survival). Mackenzie females had a low mean age ($\bar{x}$=11.2 years) and a high mean fecundity ($\bar{x}$=44,261 eggs), while Travaillant females had a high mean age ($\bar{x}$=15.7 years) and a low mean fecundity ($\bar{x}$=27,696 eggs). A decrease of life span with an increase in current reproduction has been theorized (Stearns 1992) and documented (Nikol'skii 1969).


Mackenzie
Travaillant
Fecundity
Age (years)
R^2=0.3414
80000
70000
60000
50000
40000
30000
20000
10000
4
6
8
10
12
14
16
18
20

Figures 3.4a and b. Size at age of immature and mature broad whitefish of the Mackenzie (a.) and Travaillant (b.) populations (both sexes). Mackenzie individuals are not significantly larger than Travaillant individuals (t_{409} = 0.075, p=0.471). Ages at maturity are between six and nine years in the Mackenzie population and between seven and eight years in the Travaillant population. Maturity was determined visually using the index described in Bond and Erickson (1985). Age at maturity values are consistent with literature values (Chang-Kue and Jessop 1992; Popov 1975).

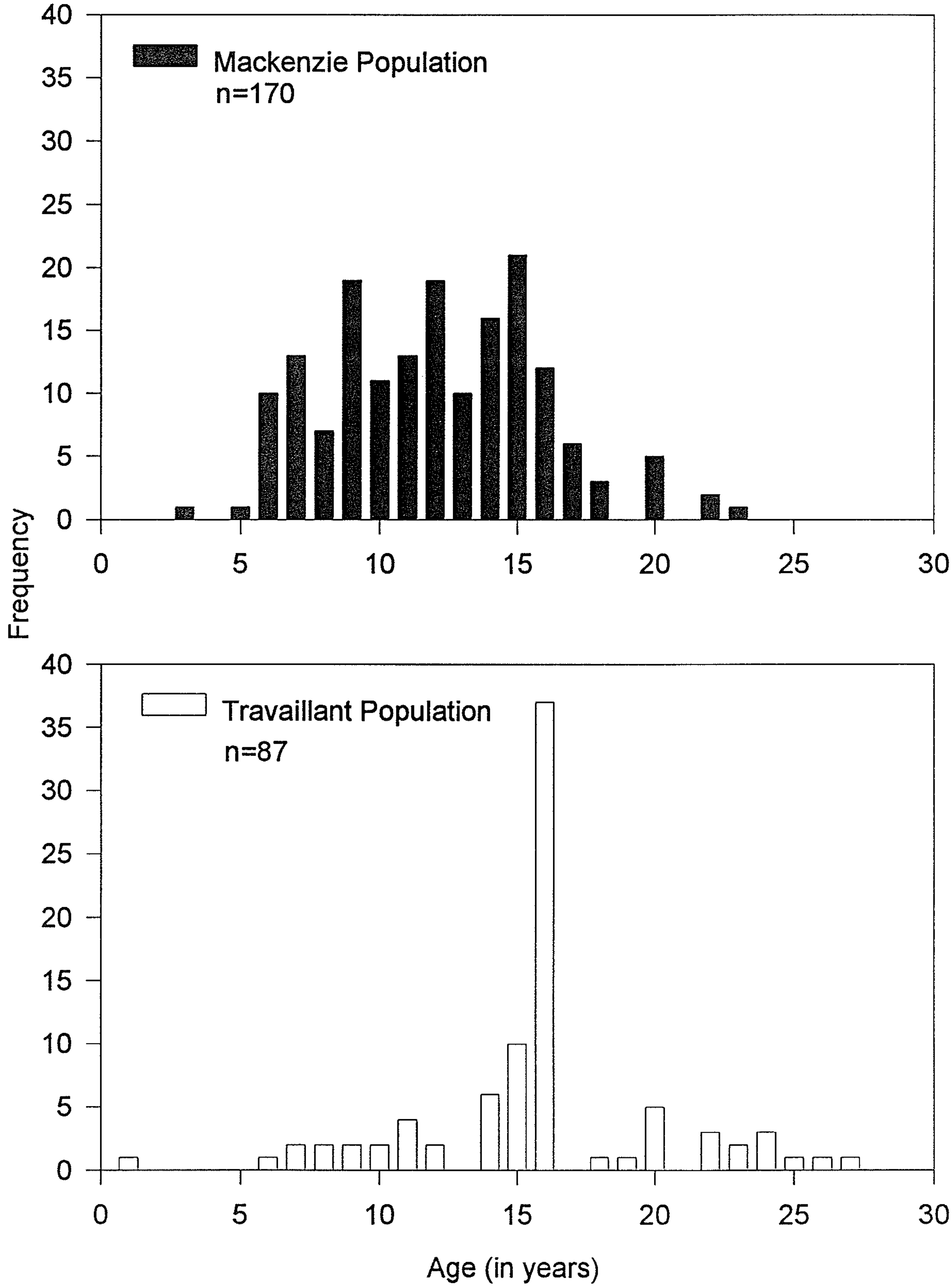

a).
600
500
400
300
200
100
0
5
10
15
20
25
30
Immature n=37
Mature n=307
Fecundity
b).
600
500
400
300
200
100
0
5
10
15
20
25
30
Immature n=9
Mature n=87
Age (years)

males=0.5%, both sexes=0.5%). Consequently, similarity of mean adult size should be interpreted with caution.

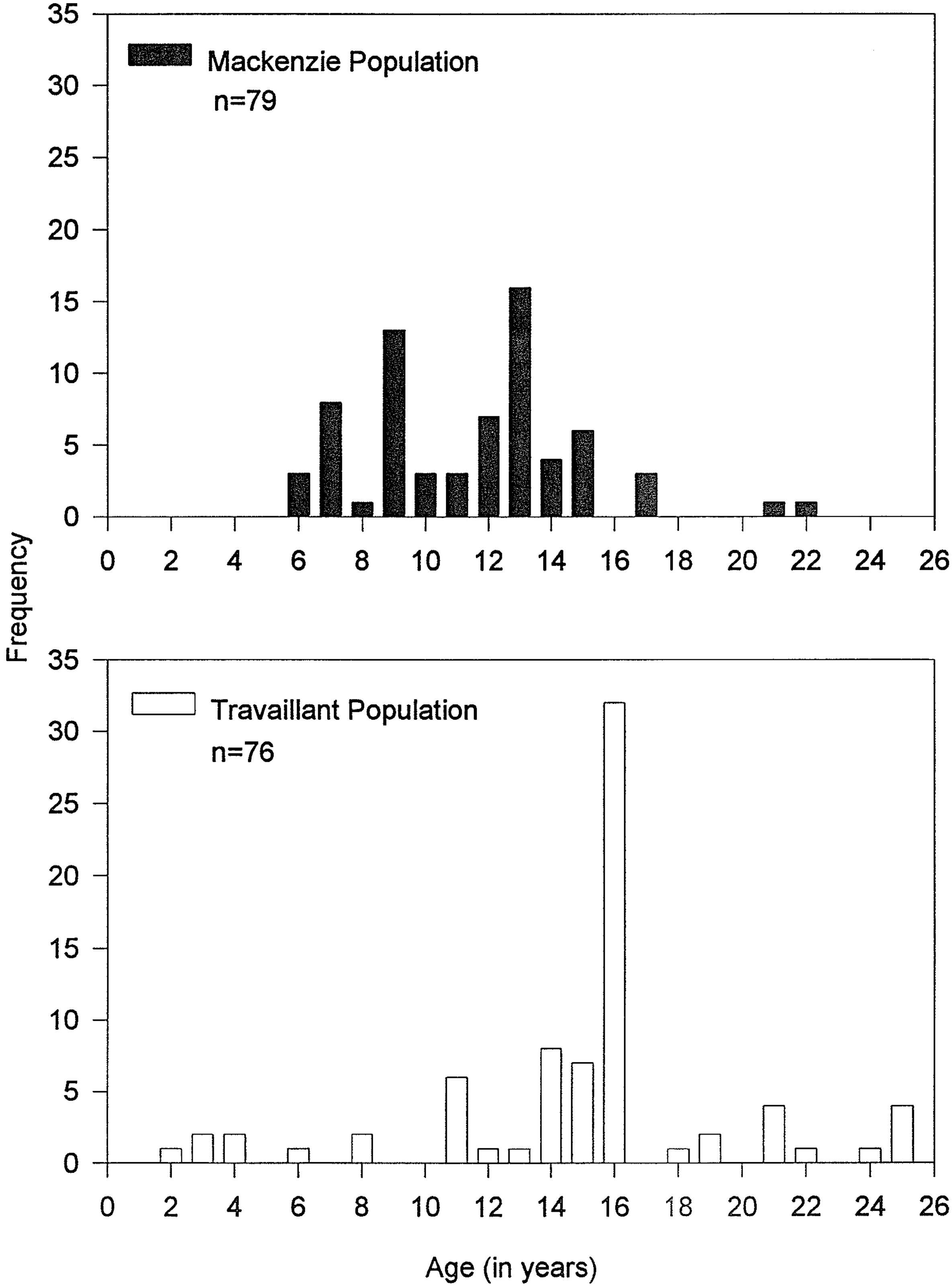
Reproductive effort was examined in females (fecundity and gonad weight) and males (gonad weight). Instead of calculating a gonadosomatic index (GSI), Wootton (1990) suggests that reproductive effort is best determined by regressing ovarian/testes weight on total body weight. For fecundity and gonad weight, size ranges were compared with a two-tailed *t*-test. Mean length was not significantly different between populations (t_{33}=1.2955, p=0.2044). Also, female total weight or size at age (weight) did not differ significantly between samples (t_{39}=0.9849, p=0.3307 and t_{25}=-0.2184, p=0.8351, respectively). Despite similarities in mean size, each test did not demonstrate high power (length=16%, weight=24%): given the variance of length and weight distributions, samples sizes of 167 and 81 (each sample) would be required to acquire a power of 80%, respectively. As predicted, Mackenzie and Travaillant females did differ significantly in fecundity (t_{33}=4.020, p=0.0003). Mean fecundity was 44, 261 eggs in Mackenzie females and 27, 696 eggs in Travaillant females with the greatest divergence in fecundity observed at larger sizes. However, difference in mean fecundity was not as predicted by Roff (1988): differences in fecundity were not due solely to the allometric relationship between size and fecundity. In contrast, the higher relative fecundity in Mackenzie females is consistent with the exploitation hypothesis. Adult size at age did not differ significantly between populations and therefore, a larger mean fecundity in Mackenzie females is not due to a larger size. To confirm the fecundity results, I examined female and male gonad weight. As in fecundity, Mackenzie females had significantly larger gonads (t_{39}=2.1510, p=0.0190) over a consistent size range (Fig. 3.3). Male populations exhibited no significant difference in mean gonad weight, despite differences in total weight. Mackenzie females, however, had a significantly lower mean age than Travaillant females (Fig. 3.1). I wanted to determine if variation in reproductive effort was solely due to differences in mean sample age, since reproductive effort does decline with age in broad whitefish (Fig. 3.3) and whitefish in general (Nikol'skii 1969). To eliminate age bias, I compared an age range represented by both samples (14 to 16 years old). Despite standardization from age, Mackenzie females still had a significantly higher fecundity (t_{19} = 2.8223; p=0.0055).

For each sex, mean sample age was used as a measure of life expectancy. Figures 3.5 and 3.6 illustrate age distributions of each population and sex. Mean ages of Mackenzie males and females ($\overline{x}$=12.1 and $\overline{x}$=11.8, respectively) were significantly younger then the mean ages of Travaillant males and females ($\overline{x}$=15.7 and $\overline{x}$=15.1, respectively). As predicted, Mackenzie broad whitefish were significantly younger than Travaillant individuals. Within each population, males and females did not differ significantly in mean age (Mackenzie t_{247}=-0.4829, p=0.6296 and Travaillant t_{161} =-0.9200, p=0.3589), but power for each test was low (Mackenzie=7% and Travaillant=16%). Male life expectancy, however, should theoretically be shorter than female life

Figures 3.5. Age distribution of male broad whitefish for Mackenzie and Travaillant populations (winter). Differences between age distributions were examined using a one-tailed *t*-test. Age distributions were significantly different ($t_{255} = -6.080$, $p<0.0001$).


Mackenzie Population
n=170
Travaillant Population
n=87
Frequency
Age (in years)
0
5
10
15
20
25
30
35
40

Figures 3.6. Age distribution of female broad whitefish for Mackenzie and Travaillant populations (winter). Differences between age distributions were examined using a one-tailed *t*-test. Age distributions were significantly different (t_{153} = -4.898, p<0.0001).



Mackenzie Population
n=79
Travaillant Population
n=76
Frequency
Age (in years)
0
5
10
15
20
25
30
35
0 2 4 6 8 10 12 14 16 18 20 22 24 26

expectancy. If there is no selective advantage to increase male body size (scramble mating), than males should mature at a size optimal for reproduction. The body size required for optimal reproduction in male fish is usually smaller than the body size required in females (Roff 1991). Early maturation results in a shorter life span (Stearns 1992). Therefore, in theory, males should have a shorter life span than females. Results of mean age of male and female broad whitefish do not support this theory.

Mean age at maturity could not be determined: despite combining the sexes, all immature age groups were not represented and therefore mean age at maturity could not be determined. In figure 3.4, the range of age at maturity is suggested for each population. In addition, growth rates were not calculated (using age and length), due to low sample sizes and poor representation of immature age classes; the highest rate of body growth occurs before the age of maturity and, as a result, pre-maturation growth rate is the most interesting (Nikol'skii 1969; Popov 1975). Alternative methods of calculating growth rate and age at maturity are considered in the discussion.

Discussion

Migration Hypothesis

Examination of size at age and reproductive effort (GSI and fecundity) of male and female broad whitefish did not support the migration hypothesis - contrary to prediction, Mackenzie broad whitefish did not have a larger size at sexual maturity than Travaillant individuals. Mackenzie females did have a larger reproductive investment than Travaillant females, but this increase in investment was not consistent with Roff's (1988) prediction that the larger fecundity of migrants is a function of a larger size. Mackenzie and Travaillant populations do differ in their life history traits, but this difference is not consistent with variation in migratory behaviour.

Life history comparisons of migratory and non-migratory fish have demonstrated a larger size at age of maturity, delayed maturity and a higher fecundity in the migratory group. The relationships of age and size of maturity and migration are intuitively clear - larger fish migrate greater distances. However, the effects of fecundity on migration (or vice versa) are not as clear. It is well known in fish that absolute fecundity is positively correlated with fish length (Wootton 1990). Assuming no energetic limitations, optimum fecundity is determined by fish size; fish size is a mechanical constraint on fish fecundity. However, making the prediction that migratory fish should have greater fecundities is confusing. Migratory fish do not have greater absolute fecundities by virtue of a migratory behaviour, but because they are large in length. If one were to compare migratory and non-migratory groups of fish of similar size, one could predict that the migratory group will have a lower relative fecundity, possibly due to the energetic demands of migration. In this study, the migratory population of broad whitefish had a **higher** size specific fecundity than proposed non-migrants, suggesting that migrants are not energetically taxed or that the energetic cost of migration is insignificant. Again, this is confusing as migration is a known energetic cost. Factors other than migration may be responsible for the observed variation in life reproductive effort.

Exploitation Hypothesis

In general, the results of this study are consistent with the exploitation hypothesis. Namely, Mackenzie females have a higher reproductive effort and a shorter life span than Travaillant individuals.

Many authors suggest that changes in fish population dynamics are mediated through changes in resource competition (Baccante and Reid 1988; Hartmann and Quoss 1993). High adult mortality rates result in a decrease in resource competition between the remaining age groups, resulting in an increase in the abundance of, for example, food. Assuming that juveniles compete for the same resources as adults, an increase in the abundance of food results in higher growth rates of juveniles and therefore higher fecundities. I believe, however, that change in reproductive effort with exploitation is a selective response and not a plastic response as suggested by Baccante and Reid (1988). It is important to differentiate between effects of trade-offs with a selective basis and the effects of variable energy intake on life history traits. An increase in food availability will increase fecundity, growth and survival, regardless of exploitation pressure - this, however, is not selective. In an exploited population, increased survival is of little use to an individual that will have a short life span. In contrast, changes in reproductive effort (this is **not** the same as absolute fecundity) result in changes in growth and survival (Roff 1983;

Stearns 1992). In exploited populations, selection favours those individuals that trade high reproductive effort for a decrease in survival and future growth. I believe the results of Baccante and Reid (1988) and Healey (1978) support a selective response to exploitation; in each study, a higher size specific fecundity (reproductive investment) was observed in the exploited population, while **no** differences were observed in size (weight in grams) at age. Direct measures of reproductive effort, such as measurement of calorific equivalents, are more informative than the indirect methods of measuring fecundity and gonad weight. Using calorific measures, one can determine the exact amount of a fixed energy source that is directed to the soma and the gonads. Diana (1983) examined energetic investment in gonads of Northern pike, comparing exploited and unexploited populations, and observed a higher reproductive effort in the exploited populations.

With respect to life span, are the differences in mean population age the result of selective removal of older individuals (i.e. proportionally more young age groups) or the result of adaptation to a shorter life span? Results of this study support the latter theory. In the exploited Mackenzie population, reproductive effort of females was high, but at the expense of survival (Fig. 3.3). In contrast, males showed no difference in reproductive effort, yet exploited males had a shorter life span (Figs. 3.5 and 3.6). Despite no significant difference in male reproductive effort of northern pike, Diana (1983) did observe an earlier age of maturity in exploitation populations. Therefore in the current study, adaptation to exploitation pressure should not be ruled out in male broad whitefish.

Scientific and Management Considerations

Results of this study are the most consistent with the exploitation hypothesis. This does not exclude, however, the possibility that both hypotheses act simultaneously and synergistically. Both hypothesis have a positive effects on common parameters: both migration and exploitation select for an increase in fecundity (Table 3.1). Also, both hypotheses have common negative effects: exploitation selects for an early maturity at a small size, while migration selects for a delayed maturity at a large size. If exploitation has a greater effect on life history traits than migration, exploitation will mask the expression of a migratory life history pattern in migratory broad whitefish. I observed no significant difference in size at adult age between populations (negative affect), but I did observe significant differences in fecundity (positive affect). What would the life history patterns of each population be if the effects of exploitation were removed? Mackenzie broad whitefish may have a larger size at age than Travaillant individuals, but this difference would be masked by selection for a smaller size at age in the exploited population.

The synergistic effects of the two hypotheses have important implications for fisheries management. Management may ignore the influence of migration on life history pattern, concentrating on the effects of exploitation pressure. Estimates of optimal catch size would only consider natural exploitation and an estimate of fishing mortality (Ricker 1975). However, if exploitation pressure does reduce the optimal size required for migration, stocks of broad whitefish may forgo spawning migrations. Recruitment into the fishery would decline and the stock may crash well before traditional estimates of sustainable catch size.

In order to better understand the effects of migration and exploitation on life history pattern future researchers may consider the following. Both mean age at maturity and growth rate could not be determined in this study. I propose two methods of obtaining maturity and growth data. First, sample sizes of immature individuals could be increased so that all immature age groups are well represented. Second, it is possible to obtain a measurement of growth rate by comparing otolith size to actual fish length and then fitting a growth curve to the data - this indirect measure of growth rate is one facet of a technique called virtual population analysis, or VPA (Salojärvi 1992). Also, since growth rate (length) decreases dramatically with the onset of sexual maturity, comparisons of otolith growth rings can be used as an estimate of the age at sexual maturity. Finally, traditional measures of reproductive effort (fecundity and GSI) should be replaced with a direct measurement of energetic investment into soma and gonads. Using a measurement of energy flow (e.g. kcals), the amount of energy directed to soma and gonads are determined. Also, the transfer of stored energy (soma) to gonadal tissue can be traced. Essentially, the trade-off between somatic and gonadic growth is monitored directly.

Conclusions

Using knowledge on effects of exploitation and migration behaviour on life history pattern, I examined life history parameters between two populations in an attempt to explain observed differences in population phenotype and genotype. Results of this study are more consistent with an exploitation hypothesis than a migratory hypothesis. However, choosing one explanation over an alternative may oversimplify observed results. It is most likely that many factors influence the expression of life history pattern, two of which are examined in this study. Therefore, while the data collected in this study are consistent with the exploitation hypothesis, synergism between exploitation and migration should not be ruled out. With the exception of the current study, only Snyder and Dingle (1990) have pattern, compared of migratory and non-migratory populations and addressed Roff's (1988) theories on migration behaviour and life history.

Are the observed life history patterns the result physiological or evolutionary trade-offs? In Chapter I I established the Mackenzie and Travaillant populations as morphologically and probably genetically distinct. The results of this chapter support the existence of distinct populations: both populations differed in reproductive effort and mean population age. Differences in life history traits should not be observed in a single population, unless these traits are phenotypically plastic. As indicated in Chapter I, however, it is doubtful that these populations intermix, suggesting that the observed life history patterns are selective. As in other studies, the use of quantitative genetics will clarify the selectivity of these life history traits (Snyder and Dingle 1990).

General Conclusion

Examination of body morphology and gill raker number in this study confirm Reist's suggestion that Travaillant Lake contains a population of broad whitefish which is phenotypically and genetically distinct from Mackenzie River broad whitefish. Furthermore, summer and winter samples of Travaillant broad whitefish do not differ significantly in mean gill raker number, while body morphology did change over a season. I conclude that summer and winter samples of Travaillant lake are from the same gene pool and that observed changes in body morphology from summer to winter correspond to changes in morphology associated with the onset of reproduction. Within the Mackenzie population, however, mean gill raker number decreases from summer to winter, suggesting the existence of two or more distinct Mackenzie populations. While it is possible that the Mackenzie population does consists of many stocks, further analysis with better genetic techniques (e.g. mtDNA) are required in order to discriminate between such stocks.

Given that the Travaillant system houses a distinct population of broad whitefish, I made the assumption that, as lacustrine fish, Travaillant broad whitefish would not travel long distances during the spawning migration and would therefore exhibit fewer adaptations to migration than Mackenzie fish - -this assumption was not validated. Mackenzie and Travaillant broad whitefish show no significant differences in either body form or life history traits associated with migration. I considered three possible explanations of these results. First, since coregonids in general are relatively poor swimmers, selection for efficient migration may be weak in all broad whitefish. Second, migration and exploitation have synergistic effects on common life history traits. Therefore, a greater selection in one will suppress expression in the other. Also, environmental effects are not accounted for in this study. Ideally, offspring of both populations should be raised in a controlled environment and the resultant phenotypes compared. Finally, both Mackenzie and Travaillant broad whitefish are capable of migrating long distances. With respect to theories on life history and migration, it is important to note that these theories have only been tested on broad whitefish (this study) and threespine stickbacks (Chapter III) and that the results observed in broad whitefish are not supportive.

Life history differences between Mackenzie and Travaillant broad whitefish are consistent with the exploitation hypothesis. Mackenzie fish have a higher reproductive effort, but a lower life span than Travaillant individuals. Since the populations are concluded as genetically distinct (Chapter I), the observed differenced in life history pattern are selective (evolutionary trade-offs). The selectivity of reproductive effort and life span, are indirect evidence that Travaillant broad whitefish do not regularly utilize the same migration corridors as Mackenzie fish. If Travaillant broad whitefish did migrate to spawning areas in the Mackenzie River, they would be subjected to the same exploitation pressure as the rest of the Mackenzie population. Consequently, Travaillant and Mackenzie fish would have similar life history patterns. I conclude that

Travaillant Lake represents a closed population of broad whitefish that is removed and distinct from broad whitefish in the rest of the Mackenzie River system.

Biological Considerations

The Mackenzie River broad whitefish has traditionally been considered as a single population, using specific habitats at different stages of their life cycle. However, conclusions from this study confirm the existence of at least one additional population. A closer examination of the Mackenzie River system will undoubtedly uncover more such populations and individual stocks within each population. Therefore, from a management perspective, the Mackenzie River broad whitefish should be studied as a multi-stock population rather than as a single stock.

The effects of exploitation on broad whitefish migration must be considered. As demonstrated in this study, migration behaviour and exploitation pressure have synergistic effects on size at age and age of maturity. As a result of annual commercial fishing individual size at adult age of Mackenzie individuals has probably declined. A level of exploitation pressure that drives adult size below the minimum required for migration will result in failure of the spawning migration and reproduction. Therefore, informed decisions on quota sizes will need to consider the effects of fishing intensity on 1) stock sizes and 2) migration behaviour.

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Appendices

Appendix 1. Description of abbreviations used in appendices 2. to 5.

ID or SAMPLE	Identification number of sample
LOC or Location	Location of sampling site
ARR	Arctic Red River
MACK	Mackenzie River
TL	Travaillant Lake
TR	Travaillant River
FRL1	Fork Length (cm) Before Freezing
FRL2	Fork Length (cm) After Freezing
WT1	Weight (g) Before Freezing
WT2	Weight (g) After Freezing
SEX	Sex of Individual
MAT	Maturity of Sample (see Bond and Erickson (1985)
GWT	Gonad Weight (g) - refer to WT1 or WT2 to determine is measured before or after freezing
AGE	Otolith Age (years)
JDAY	Julian Day

Appendix 2. Raw data for 18 morphological measurements. Refer to Table 1.1 and figure 1.5 for descriptions of measurements. All measurements were to the nearest 0.01mm. Mackenzie and Travaillant summer and winter samples are given (MS, MW, TS and TW, respectively).

LOC	ID	POL	OOL	PBL	TTL	DOL	LUL	AUL	CPL	HDD
MW	1996	18.6	13.7	50.9	105.1	55.7	77.9	44.0	47.7	42.2
MW	1961	15.4	12.2	49.8	115.7	52.2	101.3	47.5	46.2	41.5
MW	1652	15.4	13.1	49.5	102.4	73.9	101.4	43.5	39.4	38.7
MW	1659	21.4	11.7	53.7	135.4	51.9	102.3	40.8	47.3	44.4
MW	1651	19.2	14.1	54.3	111.5	56.5	96.3	34.0	43.9	41.5
MW	1621	19.8	13.6	48.6	115.6	63.3	87.7	45.9	47.1	48.1
MW	1636	18.1	15.8	51.9	124.1	64.7	90.8	42.9	44.0	38.5
MW	1637	19.2	13.2	50.3	110.8	60.9	96.2	41.6	49.4	46.0
MW	1639	15.8	7.9	49.9	132.8	60.2	88.7	39.9	43.3	42.4
MW	1635	20.3	11.7	55.0	118.4	71.4	77.6	47.5	45.2	52.8
MW	1630	20.6	13.0	50.1	123.5	61.9	102.5	47.5	55.2	49.0
MW	2002	17.1	14.8	53.9	105.6	56.3	77.8	53.2	52.5	42.5
MW	2005	14.1	13.9	47.0	110.4	54.4	76.2	42.4	38.3	37.0
MW	1657	20.0	11.9	49.9	106.8	76.4	88.6	47.3	43.5	53.3
MW	1627	15.8	13.3	52.4	118.3	54.8	83.6	42.2	40.9	46.8
MW	1840	18.1	12.5	51.8	122.3	63.5	96.5	44.1	47.0	47.5
MW	1841	21.4	14.5	54.1	122.0	65.6	88.8	42.6	41.9	45.8
MW	1623	21.6	12.5	50.1	134.3	57.5	86.3	51.2	45.1	44.7
MW	2007	16.9	12.4	49.5	130.2	54.0	80.6	46.3	44.3	44.9
MW	2011	19.0	14.1	50.2	103.8	66.1	65.5	53.2	36.5	45.9
MW	1822	15.4	11.0	49.1	122.8	57.3	102.3	37.3	44.5	44.5
MW	1620	18.8	12.9	52.9	116.1	67.3	97.5	61.0	45.0	66.7
MW	1962	17.7	12.4	48.5	125.1	67.4	85.7	52.4	41.9	45.7
MW	2013	19.5	14.5	56.9	132.5	78.3	78.2	67.9	48.4	49.0
MW	2014	17.0	13.6	49.3	117.4	58.5	97.2	50.1	42.6	41.7
MW	1999	20.1	15.1	57.3	137.5	78.6	81.7	59.6	50.3	52.0
MW	1998	22.2	15.0	53.2	116.5	65.8	75.8	47.9	44.3	50.3
MW	1656	16.6	14.7	51.6	114.2	68.4	86.0	56.6	32.8	42.4
MW	1642	19.1	13.7	56.1	105.4	73.7	80.1	55.1	38.7	48.7
MW	1660	20.0	13.6	53.5	123.9	70.0	105.0	40.5	39.0	46.9
MW	1661	19.1	14.5	59.9	108.8	74.1	108.1	46.4	45.0	46.5
MW	1641	16.7	14.6	51.2	121.5	69.0	89.1	48.9	35.1	45.3
MW	1648	17.0	12.5	46.8	100.5	55.6	81.2	42.2	39.8	42.5
MW	1663	18.8	15.0	50.0	107.6	59.4	77.3	51.6	42.7	41.8
MW	1645	21.1	19.2	55.5	123.4	65.4	103.2	42.9	47.0	40.5
MW	1643	16.2	12.8	53.9	98.8	63.6	83.4	41.6	37.7	42.8
MW	1662	16.5	17.4	53.9	100.6	67.7	87.0	37.9	35.4	42.0
MW	1646	21.5	18.8	57.0	125.3	70.6	101.2	47.6	45.8	43.4
MW	1644	15.9	14.4	53.3	100.7	82.3	71.7	45.7	38.6	44.4
MW	1654	18.3	13.3	53.7	122.2	70.8	88.4	47.3	44.4	43.5
MW	1658	19.7	12.6	55.3	128.5	67.3	100.7	46.8	44.2	52.2
MW	1622	18.7	14.1	46.7	102.8	59.8	77.3	44.7	37.7	39.9
MW	1615	17.0	13.5	50.7	107.8	67.0	94.8	43.7	47.9	41.2
MW	1640	21.3	12.5	49.2	95.3	60.3	74.6		39.3	42.1
MW	1638	22.5	15.9	58.4	121.4	76.5	94.6	47.4	48.6	49.2
MW	1617	20.4	13.2	56.2	108.2	65.8	75.3	52.2	47.5	49.6

Appendix 2. (continued).

LOC	ID	BDD	CPD	IOW	MXL	MXW	PCL	PVL	ADL	GIRTH
MW	1996	101.1	37.3	27.7	15.3	9.5	91.5	77.8	38.2	52.3
MW	1961	119.3	39.3	26.7	18.5	8.2	79.0	72.5	40.7	
MW	1652	131.1	36.3	24.7	16.8	9.2	73.2	67.2	37.9	65.6
MW	1659	137.5	39.1	27.3	19.2	10.5	78.5	71.5	51.2	71.6
MW	1651	123.6	37.6	28.6	19.7	8.6	80.4	72.5	43.2	56.2
MW	1621	123.4	40.6	29.8	18.5	9.3	80.6	69.3	46.3	57.8
MW	1636	135.5	39.7	28.3	17.3	10.0	71.8	68.3	40.9	63.2
MW	1637	146.4	43.4	29.7	20.7	10.0	82.3	79.9	56.0	62.7
MW	1639	137.5	40.9	27.6	17.1	8.3	81.1	73.6	35.2	66.0
MW	1635	146.0	42.5	30.6	17.1	10.0	82.9	79.8	49.9	67.8
MW	1630	120.6	43.6	30.7	18.4	9.9	86.4	76.1	45.9	62.9
MW	2002	123.2	42.3	28.7	17.9	9.0	82.6	77.3	50.7	61.6
MW	2005	117.9	37.2	20.5	16.1	9.5	73.7	69.7	44.2	54.3
MW	1657	136.0	41.2	28.3	19.6	9.3	84.5	79.0	41.7	54.3
MW	1627	106.2	37.5	27.2	18.3	9.2	73.1	69.8	40.3	54.3
MW	1840	127.8	41.6	30.7	15.7	9.3	91.2	74.4	45.9	
MW	1841	130.8	38.5	30.8	17.6	9.7	92.9	82.6	48.2	59.3
MW	1623	125.6	41.2	27.9	15.0	9.6	80.8	72.2	41.2	61.4
MW	2007	133.5	43.6	28.4	16.7	8.1	86.8	70.7	45.3	
MW	2011	112.6	40.0	26.1	16.7	8.8	76.9	71.3	46.1	47.4
MW	1822	142.1	36.2	25.8	15.1	9.0	77.6	75.5	43.5	63.8
MW	1620	114.1	42.2	29.3	18.6	10.7	82.8	72.4	46.6	56.7
MW	1962	114.9	38.3	28.3	15.9	9.3	78.7	74.5	45.5	60.2
MW	2013	131.2	44.0	35.0	21.3	11.7	90.4	77.7	51.9	70.2
MW	2014	119.3	41.9	30.2	11.4	9.2	87.3	71.4	49.7	68.7
MW	1999	135.2	49.8	33.0	17.9	11.7	88.3	81.1	55.2	70.4
MW	1998	123.1	43.8	29.8	17.6	10.2	89.4	79.0	43.1	63.3
MW	1656	124.2	42.6	25.0	16.3	8.9	78.9	75.4	43.8	64.6
MW	1642	137.7	46.8	26.5	11.8	10.8	84.0	79.5	50.2	50.2
MW	1660	124.5	43.5	30.2	18.3	9.6	78.4	78.1	47.5	66.6
MW	1661	124.5	41.4	28.2	17.1	11.6	82.9	78.0	57.2	67.4
MW	1641	131.5	46.9	30.9	21.3	10.0	89.2	83.5	48.4	68.2
MW	1648	110.2	36.4	25.6	17.8	9.1	69.4	67.8	41.8	52.5
MW	1663	126.9	40.6	26.7	19.0	9.8	84.1	76.7	54.9	57.7
MW	1645	134.4	48.2	32.3	19.2	11.2	76.5	75.1	55.7	68.2
MW	1643	118.1	42.8	27.2	17.0	9.1	83.5	78.1	49.1	60.7
MW	1662	127.9	41.8	28.1	17.5	9.6	84.4	79.3	45.8	59.3
MW	1646	133.9	47.5	27.1	19.0	8.5	93.9	81.7	49.1	72.4
MW	1644	123.4	44.0	29.1	15.6	9.5	90.2	80.3	44.1	56.2
MW	1654	117.6	41.8	28.7	17.7	10.2	79.3	75.6	44.1	60.2
MW	1658	146.4	44.9	31.3	19.5	10.6	91.4	82.4	61.4	72.1
MW	1622	108.4	37.8	25.9	15.9	10.3	74.4	68.2	44.2	58.0
MW	1615	109.3	38.4	29.0	18.1	9.5	84.5	74.4	39.1	57.7
MW	1640	106.9	37.8	27.2	19.4	9.4	73.7	66.7	41.2	57.7
MW	1638	128.9	25.9	31.9	22.5	11.3	94.3	82.8	50.5	67.5
MW	1617	112.2	41.3	28.4	19.1	10.6	88.1	80.2		56.5

Appendix 2. (continued).

LOC	ID	POL	OOL	PBL	TTL	DOL	LUL	AUL	CPL	HDD
MW	1632	22.2	13.1	58.6	110.9	68.6	99.9	42.2	47.3	45.3
MW	2113	18.1	12.2	53.3	113.8	59.7	91.6	50.6	47.8	47.9
MW	1616	22.5	15.3	57.6	127.8	75.6	98.2	49.8	47.6	46.2
MW	1614	22.4	12.8	52.3	102.5	69.2	85.2	51.7	41.6	47.2
MW	1612	21.7	13.4	54.0	117.8	63.5	93.2	49.7	53.0	48.8
MW	1980	16.5	12.6	49.4	132.7	56.7	91.6	46.1	42.9	37.9
MW	1828	22.3	14.2	54.8	116.0	69.8	92.3	49.8	48.4	47.4
MW	2004	19.5	14.6	55.8	117.0	68.2	98.8	52.1	49.9	46.6
MW	2006	19.5	14.1	50.2	106.7	65.6	75.7	47.7	45.2	49.2
MW	1631	19.2	13.5	56.4	122.9	75.5	89.3	52.0	42.7	50.3
MW	1618	19.5	13.4	44.9	121.0	53.5	78.9	39.7	37.8	44.0
MW	1629	20.0	12.8	50.1	120.6	63.4	84.8	46.6	40.5	45.0
MW	1628	23.5	13.5	58.2	120.4	71.8	76.7	66.4	45.2	51.5
MW	1625	20.0	12.7	54.2	121.9	55.3	88.7	48.1	48.6	50.4
MW	1626	19.2	15.3	49.6	108.0	67.0	83.8	54.2	42.4	47.0
MW	1624	22.7	14.3	43.7	111.9	61.9	74.7	48.5	38.9	42.7
MW	2008	20.5	14.6	55.3	109.1	65.5	78.4	45.2	39.0	44.9
MW	2009	18.7	14.3	51.5	116.7	68.3	98.2	49.9	42.7	47.8
MW	2010	17.2	14.2	48.0	112.5	69.4	78.5	47.3	36.2	39.9
MW	1650	19.5	13.5	53.4	105.3	70.8	89.6	47.5	43.6	50.5
MW	1835	17.9	14.5	53.0	114.6	69.8	80.2	46.4	35.7	47.1
MW	1653	17.2	13.3	45.9	107.0	57.8	75.7	44.6	32.4	41.1
MW	1633	17.0	13.7	50.2	114.5	59.9	92.7	42.3	44.9	50.3
MW	1649	24.9	14.7	51.3	103.1	55.7	80.3	46.5	42.6	49.2
MW	1647	21.0	14.1	53.2	135.5	68.7	88.9	49.5	42.3	47.0
MW	1655	20.5	17.8	52.0	129.9	62.4	94.5	50.9	44.5	43.6
MW	1669	24.6	13.3	56.9	136.3	69.3	84.3	58.2	44.2	52.7
TW	674	15.6	12.9	50.6	119.1	55.5	92.3	47.9	45.6	40.4
TW	677	11.6	10.8	32.2	55.7	31.9	48.7	30.1	26.5	26.5
TW	678	11.3	9.0	32.2	60.8	33.1	61.3	24.3	27.4	26.3
TW	679	11.0	9.5	28.2	63.6	30.3	50.7	27.2	23.6	23.5
TW	681	10.7	9.2	27.6	53.3	29.8	53.0	23.9	24.3	22.5
TW	682	11.1	8.5	27.4	59.6	28.7	53.6	25.4	26.6	23.1
TW	586	19.4	11.3	47.2	120.5	52.9	103.4	39.0	44.4	41.4
TW	611	23.0	13.3	51.2	88.9	51.8	90.9	45.0	41.4	46.6
TW	613	26.8	12.8	54.6	123.5	58.7	114.8	47.8	38.2	49.1
TW	622	20.2	10.2	51.3	109.6	54.7	101.3	41.2	41.3	39.1
TW	575	19.4	13.2	53.7	107.4	52.9	99.9	42.8	51.0	46.2
TW	576	21.7	12.9	49.6	103.8	60.7	97.2	45.4	43.4	46.8
TW	579	24.2	14.0	52.9	121.2	65.1	103.5	48.1	49.2	51.6
TW	580	20.2	13.8	53.3	107.7	60.9	93.3	44.0	46.1	46.8
TW	589	22.5	13.4	55.3	109.1	60.9	109.7	46.3	48.0	46.0
TW	590	23.4	12.3	51.4	102.0	60.4	88.0	45.6	51.5	44.5
TW	591	19.0	13.9	53.4	108.1	52.9	100.5	48.6	44.8	51.2
TW	595	26.1	12.9	53.8	120.0	59.6	101.1	48.2	54.4	46.1
TW	597	22.1	13.3	50.3	95.0	68.6	89.4	34.2	46.5	43.5
TW	598	24.1	12.7	54.3	117.1	59.1	111.6	48.7	47.6	42.4
TW	600	17.1	13.0	49.6	92.5	56.7	82.7	47.2	40.5	41.0
TW	603	24.2	12.9	56.5	121.6	62.0	109.8	48.0	55.6	45.9
TW	609	19.5	11.1	47.0	118.5	55.6	108.7	39.3	49.2	38.5

Appendix 2. (continued).

LOC	ID	BDD	CPD	IOW	MXL	MXW	PCL	PVL	ADL	GIRTH
MW	1632	124.9	44.5	29.5	17.5	9.7	84.5	75.2	52.1	65.2
MW	2113	125.0	41.7	29.4	20.5	10.0	84.4	72.8	52.9	59.7
MW	1616	125.5	46.3	31.9	21.2	10.3	89.2	82.1	53.3	60.9
MW	1614	126.2	43.9	29.9	19.3	10.8	95.1	82.9	51.1	60.5
MW	1612	128.9	42.3	32.9	19.4	9.0	80.9	70.4	49.5	63.8
MW	1980	125.8	43.2	27.9	19.9	11.6	78.4	77.3	48.2	56.7
MW	1828	139.7	51.7	28.5	17.9	12.3	94.1	81.3	48.7	73.0
MW	2004	142.7	48.7	29.5	17.8	9.7	84.5	71.5		71.9
MW	2006	123.8	42.7	24.9	16.6	8.2	78.2	75.3	40.5	60.2
MW	1631	134.6	47.6	31.5	18.7	10.0	93.8	84.4	45.3	67.9
MW	1618	109.2	38.4	27.1	15.8	8.0	78.5	70.2	30.2	53.5
MW	1629	118.4	39.5	28.8	17.0	9.5	80.9	72.8	44.2	57.6
MW	1628	133.4	39.6	29.5	19.5	10.3	84.9	78.0	49.3	71.6
MW	1625	132.1	40.6	32.0	17.1	8.6	87.6	67.3	50.3	67.4
MW	1626	122.3	42.5	31.0	17.5	10.1	83.2	76.0	44.4	62.9
MW	1624	115.4	39.5	27.7	17.4	8.8	89.6	76.4	43.3	58.8
MW	2008	129.5	42.6	26.4	17.0	9.3	88.4	77.7	49.8	61.8
MW	2009	130.0	46.1	29.7	16.6	8.7	84.9	78.7	50.4	68.6
MW	2010	120.4	41.8	27.2	15.7	9.2	82.5	69.9	49.6	62.7
MW	1650	132.8	44.1	31.2	18.7	9.2	96.1	85.4	47.3	61.4
MW	1835	127.2	45.4	31.7	17.3	9.0	81.9	75.4	45.9	64.2
MW	1653	104.4	38.1	24.6	18.1	9.1	79.8	69.9	37.7	54.6
MW	1633	130.1	43.4	33.3	19.4	9.1	82.3	69.3	49.5	63.1
MW	1649	121.7	43.1	33.1	21.3	10.9	89.0	77.4	59.8	59.3
MW	1647	136.2	45.0	33.9	23.3	10.7	91.7	83.6	48.3	68.1
MW	1655	123.5	41.7	28.9	17.6	10.1	84.2	73.2	44.3	66.8
MW	1669	143.8	47.2	40.9	20.0	11.8	94.5	83.6	63.7	72.1
TW	674	127.8	40.7	28.4	19.3	8.3	86.2	77.9	43.6	67.3
TW	677	70.3	22.3	16.2	10.9	5.0	47.2	46.1	19.5	33.6
TW	678	67.3	22.4	15.3	12.2	5.6		40.8	23.1	35.9
TW	679	64.2	20.1	15.3	12.0	4.9	45.2	43.5	19.2	33.9
TW	681	59.4	19.1	14.0	11.1	4.8	44.1	42.0	19.0	32.8
TW	682	60.0	18.2	15.2	11.4	5.2	43.7	40.2	19.9	32.5
TW	586	134.9	35.2	26.4	18.2	9.2	78.3	74.2	37.4	62.6
TW	611	136.4	37.1	29.7	21.8	9.6	85.7	78.9	44.4	71.1
TW	613	133.8	39.4	29.4	21.5	10.8	95.4	78.6	44.9	72.3
TW	622	119.2	37.1	24.1	19.5	8.5	88.4	77.2	39.5	66.7
TW	575	130.8	39.1	30.5	19.6	9.2	88.4	76.7	37.5	68.1
TW	576	118.1	37.4	26.2	18.8	10.1	79.4	69.4	41.0	61.6
TW	579	143.3	41.0	31.3	21.6	9.1	90.4	84.9	44.0	74.6
TW	580	147.9	42.1	31.1	19.3	9.3	87.9	81.2	39.4	69.6
TW	589	135.3	41.4	30.1	19.8	10.1	80.8	73.5	37.7	66.4
TW	590	129.8	37.6	28.9	20.4	10.2	90.0	80.5	42.0	66.0
TW	591	135.7	39.7	29.1	21.0	10.0	83.8	71.1	36.0	70.6
TW	595	119.1	36.8	28.1	21.3	9.5	83.3	78.6	48.1	72.8
TW	597	126.8	39.3	27.6	20.4	9.5	84.7	73.7	38.4	65.8
TW	598	149.3	42.2	29.0	21.5	10.6	85.4	80.0	39.9	67.1
TW	600	132.8	38.3	26.5	19.7	9.0	80.5	75.4	39.0	60.8
TW	603	158.5	44.7	32.4	21.7	11.1	94.1	87.9	43.9	79.1
TW	609	127.0	35.7	26.2	19.3	10.3	82.6	71.8	38.4	68.3

Appendix 2. (continued).

LOC	ID	POL	OOL	PBL	TTL	DOL	LUL	AUL	CPL	HDD
TW	618	20.5	13.3	49.5	103.8	53.3	94.2	47.5	45.7	39.0
TW	620	21.7	12.6	52.4	111.2	65.8	98.3	43.1	44.4	42.8
TW	621	22.6	13.7	50.5	102.9	63.0	89.9	50.5	45.7	45.0
TW	647	17.6	11.9	50.2	105.0	59.0	96.0	41.6	43.4	42.2
TW	660	20.7	13.9	50.9	122.3	62.7	91.3	47.8	32.5	45.3
TW	662	18.0	13.0	55.4	110.4	74.1	94.3	40.8	34.9	48.6
TW	669	17.8	13.3	49.0	122.9	48.7	99.3	43.7	35.0	46.0
TW	629	20.9	13.5	52.6	108.4	59.6	96.9	44.0	40.4	42.0
TW	636	22.0	12.7	49.9	97.9	55.5	106.7	39.6	43.6	49.8
TW	646	22.2	13.8	51.8	112.6	57.2	111.3	33.6	40.5	43.4
TW	648	23.9	13.9	51.8	111.6	53.1	101.7	41.5	39.7	47.2
TW	650	24.8	11.8	51.2	117.2	60.7	103.1	44.7	43.1	45.0
TW	617	20.4	12.4	43.7	121.6	53.5	98.7	39.8	40.5	43.1
TW	657	23.8	14.4	49.7	118.0	57.5	87.7	43.4	49.1	51.5
TW	658	19.9	13.0	44.7	113.1	62.0	89.0	48.1	42.3	47.5
TW	663	20.2	12.8	46.5	112.3	62.7	88.7	48.4	42.9	48.3
TW	664	23.2	12.2	56.0	121.3	57.6	89.3	51.0	53.0	45.6
TW	665	22.1	13.8	50.8	111.3	59.6	88.5	35.0	43.1	47.7
TW	666	21.4	13.1	49.6	122.0	53.1	96.9	48.3	46.5	51.5
TW	667	23.7	14.5	49.8	117.6	57.6	93.2	46.7	49.7	53.1
TW	668	22.1	14.7	52.5	107.0	52.4	100.9	43.0	48.9	47.7
TW	671	24.1	13.1	53.8	118.9	59.5	105.2	48.8	47.9	49.7
TW	588	21.3	11.9	51.9	105.5	55.7	91.2	47.2	44.3	42.5
TW	584	20.8	10.1	51.5	103.1	52.7	84.7	47.2	41.1	46.1
TW	587	24.7	12.4	58.5	123.9	62.9	109.3	43.1	38.9	44.7
TW	594	17.2	9.2	48.6	103.9	55.2	81.0	48.1	44.6	42.1
TW	578	19.1	14.0	50.0	91.9	53.6	86.2	46.5	38.3	40.6
TW	606	22.5	14.9	51.2	112.5	57.4	98.3	46.5	45.5	45.9
TW	614	23.8	13.0	53.1	118.9	57.7	95.8	42.2	46.6	38.1
TW	673	27.2	15.1	54.9	118.8	67.6	104.8	53.3	49.2	52.8
TW	675	19.2	15.5	50.0	125.4	70.2	104.6	50.0	46.1	50.7
TW	680	6.7	6.7	16.6	32.9	14.6	28.4	12.9	14.0	14.8
TW	596	26.7	15.1	53.9	99.3	59.9	97.2	45.3	45.7	49.4
TW	607	21.0	13.7	57.6	107.2	56.2	108.2	51.4	47.3	52.0
TW	612	25.0	13.8	53.1	114.7	57.5	104.2	48.9	44.0	47.2
TW	615	22.4	15.2	51.7	107.7	47.4	116.5	35.5	42.4	42.6
TW	616	18.8	14.2	52.2	109.5	55.6	93.2	45.2	36.9	44.0
TW	574	25.0	18.1	54.1	113.4	60.1	106.9	48.5	52.2	48.0
TW	583	20.9	13.4	47.0	92.1	54.2	85.7	41.3	34.0	
TW	592	24.7	13.5	50.9	100.2	62.7	95.0	51.6	44.9	51.2
TW	593	22.2	13.5	51.7	98.8	56.7	89.5	53.3	48.8	49.8
TW	631	22.1	13.8	50.1	99.1	51.0	97.7	53.0	50.0	48.9
TW	640	19.0	14.2	47.3	112.3	53.1	94.5	43.7	41.8	44.2
TW	641	24.0	13.1	52.5	111.0	54.6	103.9	46.8	51.2	47.8
TW	642	19.8	13.4	51.6	108.5	57.9	94.8	49.1	37.1	45.2
TW	643	23.0	13.7	47.2	106.7	58.1	83.4	43.7	32.2	45.8
TW	644	21.2	14.7	52.1	111.4	57.9	100.5	45.0	44.3	46.4
TW	645	21.9	12.0	52.8	111.6	61.5	97.0	57.3	45.7	51.3
TW	651	24.1	13.4	51.8	104.3	53.6	96.3	55.8	47.7	53.4
TW	661	14.2	11.4	48.0	107.7	57.3	86.4	45.5	32.6	47.9

Appendix 2. (continued).

LOC	ID	BDD	CPD	IOW	MXL	MXW	PCL	PVL	ADL	GIRTH
TW	618	124.1	34.8	27.2	19.5	10.1	85.4	73.4	45.7	65.7
TW	620	140.6	37.9	26.6	17.8	10.3	86.5	78.7	36.1	68.3
TW	621	121.7	34.2	29.3	18.2	10.6	81.2	69.7	32.9	59.9
TW	647	115.9	36.7	25.6	18.1	8.9	84.3	75.1	35.3	57.3
TW	660	129.2	40.1	28.6	18.4	10.7	82.0	68.4	30.2	63.0
TW	662	139.7	40.6	29.3	16.0	10.9	90.2	74.3	35.4	66.9
TW	669	113.8	36.2	28.5	14.8	9.5	81.3	67.0	33.6	62.6
TW	629	124.6	35.0	25.9	17.9	8.7	87.7	78.3	29.3	61.7
TW	636	112.9	33.3	27.4	17.6	9.1	82.8	76.3	37.5	63.6
TW	646	127.5	35.5	25.5	19.0	9.8	87.0	80.0	40.3	67.0
TW	648	108.9	33.7	26.8	19.5	10.1	84.5	76.4	35.4	53.9
TW	650	113.8	32.1	26.0	18.2	8.6	87.6	76.8	40.7	61.3
TW	617	130.3	37.4	25.9	17.9	7.9	81.8	74.2	37.1	64.9
TW	657	129.3	38.3	28.1	18.4	9.9	82.3	74.5	37.9	62.0
TW	658	117.7	41.4	29.5	18.3	8.7	86.6		43.8	60.1
TW	663	125.5	37.6	29.5	18.1	10.1	82.7	75.1	38.0	64.4
TW	664	136.8	38.3	25.4	19.3	11.1	87.4	74.6	41.0	67.3
TW	665	117.3	36.0	30.6	19.2	9.7	88.2	76.4	75.1	59.6
TW	666	121.5	36.6	28.7	17.6	8.3	84.8	69.4	32.4	61.6
TW	667	131.3	37.9	28.8	18.2	9.3	82.4	73.4	36.6	66.8
TW	668	119.2	36.3	30.2	18.4	8.5	83.2	74.9	43.2	60.4
TW	671	132.0	33.5	26.9	20.3	9.7	86.7	72.1	38.8	67.4
TW	588	129.0	38.3	27.0	20.1	9.6	82.8	77.3	41.6	63.2
TW	584	125.8	33.5	27.2	19.4	8.9	86.1	73.3	34.5	64.6
TW	587	127.0	39.9	29.3	19.1	9.9	88.6	78.2	40.8	70.6
TW	594	123.1	33.8	25.2	17.3	8.8	84.3	77.1	35.4	60.3
TW	578	127.0	36.1	27.2	18.8	10.3	80.6	75.7	34.3	59.7
TW	606	128.9	36.9	27.4	18.0	9.9	85.5	75.7	35.4	61.7
TW	614	137.0	39.8	27.5	20.1	9.3	82.1	76.8	38.2	64.1
TW	673	143.0	45.3	32.9	22.1	10.2	97.6	86.8	53.3	74.7
TW	675	155.7	49.9	33.8	22.6	9.3	99.1	85.9	40.6	77.7
TW	680	33.0	10.7	8.7	7.3	3.1	27.0	22.6	8.5	18.4
TW	596	119.5	39.9	29.4	21.8	10.1	91.1	84.9	46.2	61.7
TW	607	135.5	44.7	33.5	21.2	10.0	102.6	94.8	40.0	74.1
TW	612	128.3	39.4	28.4	20.6	10.1	95.7	82.4	50.3	70.0
TW	615	122.0	40.7	28.2	18.7	10.1	96.5	86.2	49.6	67.6
TW	616	120.7	41.9	28.1	18.7	9.4	81.5	84.5	42.9	63.7
TW	574	123.0	41.5	29.1	20.2	10.9	85.9	83.3	41.0	61.7
TW	583	99.7	35.7	25.9	18.6	8.6	79.1	71.0	37.4	55.4
TW	592	123.7	41.5	29.9	18.5	10.9	89.5	81.2	45.8	60.4
TW	593	125.8	37.0	30.5	18.2	9.6	84.7	78.1	39.9	64.2
TW	631	120.3	39.8	29.3	18.7	10.4	90.7	80.0	41.1	60.0
TW	640	110.5	37.1	27.6	18.8	8.8	86.8	81.8	37.1	56.2
TW	641	122.0	40.3	26.4	19.3	10.7	92.1	77.7	45.3	64.7
TW	642	110.5	37.8	28.3	19.2	9.1	89.7	83.7	43.9	57.5
TW	643	112.4	37.4	26.9	18.2	10.1	86.3	75.4	38.9	58.2
TW	644	116.9	34.6	29.4	19.2	10.1	87.9	80.5	35.9	64.5
TW	645	126.6	41.0	31.1	20.4	9.5	82.8	78.1	46.6	66.5
TW	651	120.8	40.7	29.7	21.0	10.4	93.4	81.7	45.6	65.9
TW	661	109.8	37.5	26.6	15.2	8.9	82.2	73.4	35.7	57.7

Appendix 2. (continued).

LOC	ID	POL	OOL	PBL	TTL	DOL	LUL	AUL	CPL	HDD
TW	619	22.5	15.0	53.6	127.9	66.5	103.6	51.7	47.7	52.3
TW	623	21.2	13.3	48.8	102.8	65.9	93.9	41.0	34.7	48.6
TW	624	20.2	16.2	51.0	94.0	64.2	98.3	37.0	40.3	48.5
TW	625	24.5	15.2	53.6	108.1	63.3	98.5	53.9	44.6	53.3
TW	626	22.6	13.0	48.7	109.4	54.0	100.2	45.1	41.7	45.8
TW	628	22.1	15.4	53.9	103.8	57.5	106.8	40.2	39.7	45.4
TW	630	20.5	14.2	51.2	100.0	58.4	94.9	45.3	40.8	47.7
TW	633	24.4	13.6	49.8	107.8	58.5	101.1	47.4	39.0	50.9
TW	634	20.6	14.4	52.1	93.0	64.3	90.3	44.4	37.4	46.1
TW	635	23.7	13.5	49.9	103.5	59.5	103.8	51.9	46.8	46.2
TW	637	23.2	14.9	54.2	110.6	61.2	99.5	42.1	32.0	44.1
TW	638	18.9	14.5	51.5	100.4	59.2	110.4	42.7	45.1	45.1
TW	639	25.7	14.7	50.6	101.9	53.2	90.7	40.0	40.5	45.1
TW	649	24.1	13.4	52.5	99.7	56.8	94.9	42.9	42.3	44.7
TW	652	23.2	13.9	53.4	110.8	53.4	100.6	44.0	38.8	42.4
TW	654	22.4	14.5	51.5	105.3	60.2	103.0	42.2	39.6	50.9
TW	632	24.5	14.0	53.0	111.0	54.3	93.8	47.5	42.0	47.2
TW	659	21.1	13.8	51.9	119.5	59.8	91.6	52.7	48.4	46.5
TW	670	22.7	12.5	54.1	104.2	66.4	99.1	42.9	48.8	45.9
TW	627	21.7	13.3	52.3	116.2	64.3	96.4	50.9	43.0	45.6
TW	672	23.9	14.6	52.2	109.4	63.5	83.5	50.1	41.6	50.6
TW	582	24.8	15.0	50.9	97.0	65.7	99.1	52.7	47.3	55.4
TW	599	25.2	13.8	55.9	97.8	63.4	103.2	54.3	47.6	53.7
TW	572	20.9	12.2	51.9	95.1	58.7	95.2	49.4	49.0	45.2
TW	573	22.6	13.2	50.1	94.3	57.2	95.2	44.4	43.9	47.4
TW	581	19.4	11.4	52.7	92.5	59.9	98.5	33.6	40.8	45.1
TW	585	28.3	13.1	61.6	88.1	66.0	113.1	43.1	42.7	50.9
TW	608	25.9	12.5	58.6	91.0	60.8	102.2	51.3	49.9	52.6
TW	610	25.1	11.9	55.9	89.6	60.5	103.4	40.5	44.9	51.0
TW	602	23.5	14.2	51.3	115.8	49.7	85.4	50.9	40.7	41.3
TW	604	23.6	14.1	53.2	96.3	64.6	77.6	51.2	56.0	51.1
TW	605	21.8	12.4	49.5	118.0	60.0	91.8	51.9	52.5	42.8
TS	266	15.5	11.2	41.7	77.7	44.1	63.4	40.0	40.0	33.9
TS	464	11.5	10.1	55.6	131.6	61.6	117.7	50.4	52.0	48.1
TS	307	11.9	9.3	26.9	59.0	24.8	57.2	20.8	24.2	27.6
TS	374	11.1	9.9	31.7	60.1	31.1	54.1	24.8	28.6	26.5
TS	373	19.1	11.8	47.4	126.8	54.1	103.7	40.8	40.1	43.4
TS	447	11.7	9.1	29.1	54.2	28.6	50.4	22.1	28.6	25.5
TS	448	10.8	9.3	26.3	60.3	32.3	53.0	21.6	29.6	24.8
TS	449	12.9	7.9	28.5	64.7	31.4	61.2	24.4	26.3	26.5
TS	246	23.9	13.8	54.8	125.0	51.8	96.5	41.4	41.4	48.3
TS	247	8.2	8.0	22.9	44.0	22.5	41.6	17.9	21.5	18.0
TS	255	8.2	8.8	26.9	54.5	26.9	51.9	27.3	27.0	23.2
TS	36	14.4	11.0	48.4	118.1	67.2	101.8	45.6	49.1	40.7
TS	37	19.2	11.3	47.1	128.0	65.8	101.9	50.9	50.5	41.8
TS	38	22.7	12.0	59.0	122.1	65.7	103.6	50.6	47.5	43.0
TS	39	15.8	10.3	45.2	98.8	49.7	79.3	43.4	35.0	37.9
TS	40	14.4	10.2	36.8	90.3	41.9	84.9	29.7	40.3	32.8
TS	41	20.3	13.7	45.0	116.3	59.4	99.2	40.5	42.6	40.8
TS	43	17.4	11.8	45.5	103.9	46.5	85.1	40.5	41.8	40.5

Appendix 2. (continued).

LOC	ID	BDD	CPD	IOW	MXL	MXW	PCL	PVL	ADL	GIRTH
TW	619	130.5	43.8	29.8	21.8	9.2	97.1	88.1	47.8	74.4
TW	623	116.7	39.1	30.4	17.2	10.0	86.7	74.8	37.9	63.8
TW	624	112.2	36.4	29.6	18.1	8.9	87.9	73.7	40.8	60.1
TW	625	130.8	40.8	32.0	20.1	9.4	94.1	85.9	41.5	68.2
TW	626	123.3	39.5	27.2	19.5	8.5	93.6	83.1	43.1	64.3
TW	628	118.8	38.3	27.6	20.1	8.9	91.7	80.3		62.6
TW	630	116.5	36.0	26.0	19.2	9.7	86.5	78.5	42.9	62.0
TW	633	117.0	35.1	28.7	18.9	9.7	89.6	79.1	43.0	62.7
TW	634	117.7	38.0	26.5	16.9	8.3	86.5	78.3	40.5	62.9
TW	635	120.3	37.1	28.7	18.6	9.6	89.1	83.9	42.4	65.8
TW	637	116.4	37.7	28.6	20.0	8.2	91.1	83.6	40.5	59.2
TW	638	127.9	41.5	28.0	19.4	9.8	86.8	80.6	47.7	67.4
TW	639	126.7	37.4	29.3	19.7	9.3	83.0	74.1	40.7	66.4
TW	649	114.8	34.5	29.5	18.0	9.1	83.0	81.2	43.3	62.7
TW	652	121.9	36.0	27.0	20.9	8.9	93.3	81.3	41.8	62.1
TW	654	128.1	39.2	27.7	19.4	7.8	82.8	80.2	48.6	65.2
TW	632	114.2	38.0	28.2	19.4	9.7	84.8	77.4	35.5	59.2
TW	659	122.8	39.3	29.6	18.9	10.3	84.8	76.9	46.4	62.3
TW	670	122.9	39.0	29.3	20.0	10.7	91.4	75.2	46.5	62.9
TW	627	122.1	43.0	32.2	20.0	10.5	93.7	77.4	53.1	65.2
TW	672	134.1	46.9	29.3	21.1	9.2	84.8	79.5	44.1	67.5
TW	582	128.9	44.5	32.7	20.6	10.6	86.2	80.8	44.0	69.6
TW	599	136.7	43.5	31.8	21.0	10.5	93.0	86.6	42.1	71.9
TW	572	113.2	34.0	28.7	18.6	9.9	90.9	81.9	52.2	63.2
TW	573	125.5	40.6	27.3	18.7	8.0	84.6	78.5	37.6	60.5
TW	581	117.0	37.5	28.9	19.3	9.6	90.4	77.4	44.4	63.0
TW	585	126.6	39.9	30.1	21.5	10.0	95.9	87.3	41.9	69.6
TW	608	131.8	40.8	29.2	19.1	9.8	98.9	86.7	45.9	69.5
TW	610	129.5	40.4	28.6	20.4	9.6	95.0	84.5	49.1	63.5
TW	602	121.4	36.7	27.0	24.8	8.8	90.1	87.8		60.2
TW	604	134.8	41.8	28.0	21.1	11.0	94.1	79.4	50.1	66.4
TW	605	117.0	35.7	29.5	19.0	9.4	82.7	76.9	43.0	63.0
TS	266	83.5	28.7	19.9	14.5	6.4	63.5	61.6	30.2	43.8
TS	464	140.2	47.0	33.3	23.3	10.9	97.6	89.1	45.1	85.5
TS	307	60.9	18.3	13.3	10.7	5.1	47.1	42.7	20.4	32.5
TS	374	67.8	21.7	15.4	13.0	5.1	51.3	47.9	20.9	36.3
TS	373	120.5	34.8	26.4	19.6	8.6	85.5	75.9	34.6	63.2
TS	447	53.6	19.8	16.3	11.1	5.3	41.6	39.4	22.1	32.1
TS	448	53.0	19.1	14.5	10.4	4.5	44.9	41.8	18.8	30.6
TS	449	62.1	21.9	15.3	11.9	4.7	46.9	44.8	20.9	37.2
TS	246	127.6	36.0	30.0	24.3	8.9	90.2	85.1	27.1	62.0
TS	247	44.2	14.0	10.3	8.1	4.0	33.6	31.5	12.4	22.1
TS	255	57.7	20.0	74.1	11.5	5.0	44.6	41.7	19.9	33.0
TS	36	133.5	40.1	28.5	17.9	6.9	80.9	78.1	30.8	65.7
TS	37	126.8	44.7	30.7	19.5	10.0	97.3	93.5	48.3	66.7
TS	38	137.3	41.5	29.2	19.1	7.5	89.6	88.6	47.5	69.7
TS	39	98.0	32.9	25.2	17.4	7.2	76.4	66.8	34.0	50.8
TS	40	81.8	27.7	21.4	16.2	7.2	72.2	64.3	26.4	42.3
TS	41	125.7	39.8	27.2	18.8	8.4	78.9	79.4	47.0	60.5
TS	43	101.3	34.8	25.7	17.8	7.8	78.8	71.7	39.1	42.3

Appendix 2. (continued).

LOC	ID	POL	OOL	PBL	TTL	DOL	LUL	AUL	CPL	HDD
TS	128	17.5	11.3	43.8	101.4	40.9	84.3	32.4	35.4	32.4
TS	130	16.1	12.3	50.2	116.3	69.9	90.8	54.0	42.0	49.5
TS	131	11.5	9.0	32.3	90.5	39.1	76.4	30.6	34.3	29.7
TS	184	9.4	9.3	27.9	60.6	29.3	50.3	24.9	24.0	23.2
TS	14	10.2	9.2	29.6	61.7	28.6	49.6	28.7	29.5	26.0
TS	15	8.4	8.1	24.3	47.2	26.6	39.3	17.8	22.3	24.2
TS	168	22.3	14.2	58.6	122.5	67.5	95.2	56.8	63.3	53.7
TS	185	10.6	10.6	27.9	62.5	29.2	57.0	23.1	28.7	26.1
TS	468	6.1	7.0	16.6	29.3	15.7	27.3	11.9	15.6	14.9
TS	469	6.2	7.1	17.3	30.8	13.2	29.2	14.3	15.6	17.6
TS	481	6.4	7.1	15.2	30.0	12.7	30.2	10.8	12.7	15.7
TS	35	19.3	14.9	55.5	133.4	59.7	99.7	55.7	51.7	49.3
TS	42	19.2	14.6	51.1	102.0	58.3	103.6	48.9	45.1	49.2
TS	44	19.5	13.0	55.2	145.6	65.5	104.5	64.6	52.9	45.9
TS	129	14.9	12.0	42.4	111.2	54.4	85.3	46.6	47.8	38.1
TS	133	15.3	11.8	57.4	110.9	71.3	76.5	51.8	46.9	53.5
TS	363	17.5	12.2	47.5	107.4	57.6	90.3	43.6	38.8	40.0
TS	365	16.5	13.0	51.5	106.0	53.0	94.0	42.1	63.7	50.3
TS	357	17.1	11.3	59.3	126.4	71.3	105.8	54.0	45.0	51.8
TS	360	17.5	12.4	47.6	114.6	50.5	91.4	47.7	40.6	46.1
TS	361	18.7	11.0	51.1	135.4	57.2	100.0	52.9	53.7	44.5
TS	362	15.3	10.7	52.3	144.5	51.3	108.8	56.6	50.7	44.0
TS	364	19.5	10.5	52.3	127.0	59.4	91.2	49.4	47.9	50.1
TS	366	19.8	12.3	55.6	117.7	62.9	100.5	50.3	45.4	50.2
TS	394	19.4	11.9	56.8	127.6	63.5	96.5	58.3	54.0	51.7
TS	396	18.6	12.7	50.1	133.1	70.1	98.3	53.5	48.2	46.3
TS	147	18.9	12.2	54.5	110.2	58.9	108.3	47.7	46.3	42.9
TS	172	16.8	8.4	43.8	97.8	46.8	90.1	41.2	38.5	36.7
TS	300	18.9	12.9	47.5	103.5	48.5	89.0	42.7	46.3	37.8
TS	178	18.7	14.2	50.3	113.1	55.8	96.4	44.9	41.9	43.8
TS	179	16.2	12.6	50.6	107.9	53.0	85.7	47.2	42.5	39.4
TS	181	22.0	13.2	53.6	122.4	60.0	95.7	49.5	38.4	44.1
TS	428	17.8	13.0	52.8	97.2	56.6	101.8	37.5	41.5	39.9
TS	305	20.6	10.6	56.7	114.1	54.3	111.9	43.5	41.1	45.7
TS	465	23.1	13.7	53.1	117.4	55.5	104.5	47.3	38.4	46.8
TS	443	20.5	11.1	50.2	114.6	57.3	91.0	44.1	53.5	40.1
TS	427	19.5	11.5	52.7	92.1	47.3	93.6	39.6	42.2	38.5
TS	303	19.6	13.2	58.7	110.3	55.1	100.6	46.8	41.8	45.7
TS	301	27.6	13.2	55.7	122.5	60.7	96.1	56.1	40.6	47.6
TS	251	22.7	11.9	49.0	99.7	49.4	88.1	40.8	38.5	42.0
TS	18	21.3	13.3	54.6	106.3	61.2	119.2	40.9	36.9	43.3
TS	16	14.9	12.8	47.7	113.3	53.4	88.6	46.6	45.8	39.8
TS	177	19.5	13.1	50.5	109.8	63.2	93.6	56.8	47.9	42.0
TS	174	20.7	12.7	51.4	114.2	51.6	103.8	44.5	51.6	44.3
TS	173	22.9	13.6	51.4	122.8	61.2	96.6	52.1	47.9	50.5
TS	81	20.8	12.9	54.8	77.7	62.4	76.0	58.3	49.6	54.3
TS	19	17.7	12.5	48.7	94.7	57.1	87.3	46.1	43.5	44.3
TS	302	18.1	13.4	51.9	117.9	55.0	91.3	51.5	49.6	49.3
TS	79	20.5	14.6	53.5	120.7	61.3	96.3	59.3	44.0	41.8
TS	446	18.9	13.3	55.3	109.1	56.1	88.3	57.9	49.8	46.0

Appendix 2. (continued).

LOC	ID	BDD	CPD	IOW	MXL	MXW	PCL	PVL	ADL	GIRTH
TS	128	83.6	33.8	24.0	13.9	7.2	70.1	65.5	34.2	48.1
TS	130	123.7	44.4	31.7	21.1	9.3	92.4	86.2		61.1
TS	131	91.1	28.6	19.6	14.4	6.1	66.6	61.0	34.6	52.0
TS	184	57.0	19.4	14.5	10.8	4.8	43.1	42.2	19.1	33.0
TS	14	63.7	20.6	14.4	11.7	5.0	46.2	45.3	17.1	36.2
TS	15	44.0	16.4	10.5	9.3	4.1	34.0	34.9	16.7	27.5
TS	168	128.9	45.8	32.0	23.5	9.9	91.5	90.0	45.8	58.4
TS	185	57.9	20.0	12.8	11.0	5.6	41.8	40.8	18.0	36.6
TS	468	29.6	9.7	7.9	6.8	2.9	22.0	19.9	10.2	18.7
TS	469	31.1	10.7	7.8	6.7	3.1	21.5	23.1	10.6	19.4
TS	481	28.3	9.3	8.0	6.7	2.9	20.5	20.7	7.5	15.8
TS	35	130.2	42.5	30.7	21.0	8.6	87.1	81.3	36.0	69.5
TS	42	109.3	40.5	26.0	19.3	8.6	82.7	78.0	36.3	62.9
TS	44	132.9	47.5	31.3	22.0	10.7	97.6	84.1	48.9	72.7
TS	129	96.4	35.6	26.4	16.3	8.1	78.7	73.9	31.8	53.7
TS	133	132.4	43.6	30.8	18.1	10.4	90.5	82.1	39.5	72.7
TS	363	106.9	36.1	26.0	18.6	8.4	72.8	71.4	37.9	58.0
TS	365	124.0	40.4	28.3	21.3	8.6	80.6	79.5	48.2	71.2
TS	357	132.6	45.0	30.3	20.8	8.4	85.0	86.4	46.7	74.6
TS	360	107.9	35.4	26.4	18.4	8.4	86.1	75.8	36.4	55.7
TS	361	114.9	40.4	28.9	17.7	9.1	80.7	79.7	41.7	73.1
TS	362	143.4	43.5	30.4	19.9	8.3	85.7	81.6	42.9	76.0
TS	364	131.6	42.0	28.3	20.3	9.8	81.9	79.1	40.4	69.5
TS	366	126.2	43.4	29.4	18.8	8.4	92.2	84.9	34.6	63.2
TS	394	143.0	46.1	29.0	19.8	9.6	82.7	74.7	37.8	75.4
TS	396	133.8	46.1	32.8	20.5	10.0	88.8	84.3	39.3	74.5
TS	147	122.7	35.8	26.9			82.3	72.9	38.5	58.6
TS	172	101.6	32.5	22.9	18.0	7.5	71.0	70.5	34.9	48.7
TS	300	108.1	36.4	24.3	17.6	7.2	77.3	73.0	30.2	66.4
TS	178	111.2	34.8	26.7	18.7	8.7	90.2	80.7	37.9	60.0
TS	179	121.5	34.8	24.8	18.1	8.7	88.5	72.9	38.5	67.3
TS	181	133.6	41.6	27.7	20.6	9.4	87.2	78.2	43.5	68.7
TS	428	118.7	36.0	24.9	20.4	8.5	83.1	76.0	31.8	62.5
TS	305	111.8	35.9	29.0	21.6	9.2	93.3	86.7	47.5	66.4
TS	465	125.1	39.0	28.0	19.6	9.3	93.6	84.3		63.0
TS	443	129.9	39.4	26.4	18.7	8.0	85.9	75.6	38.9	72.6
TS	427	104.7	32.8	24.3	18.3	7.9	82.5	71.4	33.5	61.5
TS	303	121.8	38.8	27.8	20.5	9.1	89.5	83.5		71.3
TS	301	115.9	40.6	28.4	21.1	9.2	96.0	90.0	46.1	63.4
TS	251	109.3	34.3	25.2	19.1	9.0	91.9	78.3	33.4	55.7
TS	18	126.1	38.0	26.6	20.4	8.9	84.2	75.0	36.8	69.9
TS	16	109.9	35.6	26.3	18.8	9.6	84.6	78.1	28.3	66.9
TS	177	109.6	38.4	25.7	19.6	9.6	83.6	82.2	42.0	61.9
TS	174	120.3	40.1	28.9	19.5	9.3	92.8	85.0	44.5	66.1
TS	173	129.3	41.6	28.0	21.2	8.8	89.3	76.8		69.2
TS	81	132.4	41.3	29.5	21.2	7.8	83.6	77.4	49.1	62.3
TS	19	117.2	35.5	29.7	19.8	9.2	79.0	71.4	34.3	70.8
TS	302	119.9	37.6	30.2	18.6	8.2	91.1	83.2	45.5	66.3
TS	79	135.3	41.0	28.4	21.8	10.6	93.9	83.9	47.6	71.5
TS	446	110.8	37.4	29.6	20.8	9.1	91.1	83.0	46.7	56.7

Appendix 2. (continued).

LOC	ID	POL	OOL	PBL	TTL	DOL	LUL	AUL	CPL	HDD
TS	182	21.2	12.1	57.2	102.0	62.0	91.1	54.0	52.3	45.7
TS	306	19.9	12.6	56.6	120.5	68.7	106.2	54.1	54.5	45.8
TS	80	19.3	14.0	51.6	84.8	56.8	89.0	53.1	46.7	49.1
TS	78	20.3	12.2	49.6	82.5	62.4	87.8	53.8	40.4	48.3
TS	430	16.1	12.5	50.7	116.0	52.0	107.9	42.2	47.1	38.2
TS	82	21.8	14.2	49.2	112.1	60.2	104.6	51.3	41.4	50.8
TS	429	23.1	12.1	59.2	131.8	69.1	106.3	60.6	56.6	49.7
TS	175	18.1	12.4	50.4	110.9	53.4	101.4	45.0	45.4	41.2
TS	180	19.7	12.2	51.7	107.1	50.4	98.0	44.7	44.3	41.9
TS	77	19.1	12.5	54.6	152.2	63.0	115.6	49.3	53.2	44.4
TS	33	21.4	12.8	58.6	135.9	63.9	88.3	57.6	50.8	44.8
TS	392	19.2	13.8	52.3	112.8	55.6	92.9	52.1	44.9	42.4
TS	262	20.8	15.6	55.3	145.5	59.3	104.4	53.1	52.8	46.0
TS	309	21.9	13.4	53.5	101.4	53.4	106.0	46.5	54.3	52.0
TS	17	21.5	12.1	54.8	122.8	60.6	104.5	50.2	51.8	47.7
TS	403	15.6	12.9	49.1	123.2	61.1	87.6	52.1	47.1	40.5
TS	263	21.5	14.7	61.7	119.1	65.9	98.3	47.1	51.5	52.0
TS	218	21.1	14.7	53.2	112.8	55.4	89.7	49.3	57.1	46.4
TS	326	21.1	14.5	60.3	134.2	67.1	107.8	52.5	62.0	49.8
TS	132	23.2	13.4	58.2	134.4	68.5	109.3	53.9	58.3	49.7
TS	437	20.7	11.2	50.7	82.2	49.9	93.8	43.3	42.2	42.8
TS	329	20.0	11.8	52.2	130.7	66.2	115.6	49.1	44.7	46.4
TS	324	20.1	11.6	56.2	102.0	58.8	92.6	47.8	47.4	44.0
TS	402	16.1	11.1	47.5	125.5	61.0	92.5	53.8	51.5	43.5
TS	308	21.8	16.2	55.9	101.9	65.0	94.7	45.2	50.8	48.8
TS	355	9.3	14.3	53.3	129.0	65.8	104.3	45.2	57.1	43.1
TS	323	23.5	12.6	57.7	118.3	66.7	117.8	39.1	44.4	48.2
TS	217	20.5	11.2	55.7	104.6	65.9	101.5	48.5	48.5	47.2
TS	327	17.9	11.6	57.0	111.9	61.4	84.6	58.7	44.6	46.6
TS	325	20.3	11.1	64.6	127.7	68.0	115.9	48.7	56.2	50.2
TS	328	23.5	14.5	55.9	129.2	65.0	116.4	46.8	41.5	56.4
TS	219	18.8	12.7	46.7	122.8	54.4	96.2	42.4	47.6	43.0
TS	299	15.0	10.1	49.8	117.3	54.6	109.1	47.1	44.2	42.3
MS	729	20.1	11.6	52.6	106.8	66.5	74.8	53.0	50.0	44.9
MS	766	17.9	12.2	48.5	112.9	47.6	93.5	54.7	48.0	39.2
MS	771	16.6	12.0	53.0	127.0	64.8	100.8	60.6	54.0	44.4
MS	555	14.9	10.8	56.8	135.1	65.3	104.7	52.8	59.9	42.8
MS	781	17.5	12.4	48.0	124.6	50.0	81.2	47.9	46.5	42.2
MS	777	19.9	12.5	51.6	116.3	56.2	84.7	54.8	50.0	45.7
MS	554	21.0	13.1	58.8	106.3	69.3	118.2	58.1	65.8	51.0
MS	817	19.0	12.2	50.4	120.2	62.3	81.3	61.2	39.7	41.5
MS	549	21.1	13.0	62.4	159.5	77.3	127.3	61.5	64.7	53.6
MS	780	16.4	11.8	46.6	106.4	57.1	73.7	60.8	52.6	46.5
MS	772	23.8	15.5	54.2	128.0	61.2	94.8	57.6	50.7	49.6
MS	471	13.6	13.6	48.4	91.8	54.7	97.6	41.6	40.6	43.0
MS	608	19.7	13.5	52.6	111.9	57.1	93.5	48.9	46.0	44.0
MS	806	20.1	12.4	54.8	103.1	59.2	94.2	55.0	49.2	45.3
MS	467	16.6	14.0	50.4	131.9	56.8	98.3	52.3	53.0	40.9
MS	411	24.3	13.8	53.3	118.8	70.6	92.3	58.9	51.3	49.9
MS	779	21.7	11.1	49.4	107.9	55.9	101.7	40.2	49.5	41.7

Appendix 2. (continued).

LOC	ID	BDD	CPD	IOW	MXL	MXW	PCL	PVL	ADL	GIRTH
TS	182	128.2	37.7	29.3	21.3	11.6	90.6	84.1		69.0
TS	306	141.6	46.5	31.0	21.3	9.2	92.4	86.3	43.4	71.8
TS	80	113.3	34.1	28.9	20.5	10.9	92.1	84.7	45.4	61.0
TS	78	111.2	36.9	27.1	18.9	8.9	85.5	76.2	39.1	62.3
TS	430	123.1	35.8	26.9	17.9	8.8	84.3	71.4	33.7	63.9
TS	82	116.3	38.5	29.6	19.1	10.7	92.5	83.8		66.7
TS	429	136.0	47.4	32.3	21.0	10.1	90.5	83.6	40.4	77.9
TS	175	130.8	36.5	28.2	19.5	9.5	84.0	73.2	46.8	69.7
TS	180	115.7	38.8	26.0	18.7	10.9	83.9	75.8	38.3	62.4
TS	77	138.4	44.8	28.3	20.5	8.9	85.7	76.9	37.3	81.5
TS	33	142.0	44.8	30.7	20.6	11.2	86.3	76.0	39.2	77.3
TS	392	124.8	36.8	27.0	20.2	10.1	85.2	76.8	35.5	68.5
TS	262	147.9	42.7	30.0	19.7	9.8	90.2	82.2	33.8	80.1
TS	309	122.4	37.1	27.3	19.7	10.4	93.8	84.3	46.2	70.2
TS	17	144.5	41.4	28.0	19.1	9.9	88.7	79.5	42.2	73.8
TS	403	117.4	39.9	27.9	18.3	9.1	83.5	79.3	37.9	66.8
TS	263	138.2	42.2	30.4	22.4	9.8	94.0	86.6	43.4	81.3
TS	218	123.7	41.9	28.0	20.2	7.4	87.5	80.3	38.2	52.6
TS	326	136.1	45.5	34.3	21.9	9.9	98.4	93.3	47.1	71.8
TS	132	127.8	46.9	32.0	22.6	10.6	95.1	92.9	48.4	56.6
TS	437	112.9	32.6	25.8	19.4	9.2	76.2	68.5	31.3	60.9
TS	329	121.0	38.8	32.8	22.1	9.5	96.9	90.5	48.8	68.2
TS	324	115.3	40.6	27.8	20.5	8.1	80.2	75.9	41.5	65.3
TS	402	113.8	38.0	26.2	19.8	8.1	79.2	78.5	45.3	73.5
TS	308	126.3	36.8	29.6	21.6	10.3	90.3	83.8	43.7	66.8
TS	355	148.1	44.6	28.7	18.1	7.6	87.4	83.0	40.2	70.9
TS	323	138.5	42.7	28.5	21.2	8.1	97.6	92.0	47.6	71.2
TS	217	129.3	43.8	30.0	20.3	8.0	90.1	86.3	46.2	68.6
TS	327	117.7	39.5	29.5	22.2	9.9	92.5	86.2	40.9	56.5
TS	325	123.5	46.4	32.5	21.4	8.9	97.0	93.7	45.1	75.3
TS	328	126.5	40.8	34.6	20.5	9.0	95.7	88.4	40.2	66.7
TS	219	114.3	38.9	28.0	18.5	8.2	81.5	75.6		62.8
TS	299	116.3	38.7	26.1	20.5	7.7	83.4	80.8	38.3	65.4
MS	729	126.4	42.6	24.9	19.2	8.7	85.5	80.3		69.0
MS	766	116.5	38.9	28.0	18.6	8.0	86.1	79.7	46.7	59.2
MS	771	142.2	41.3	25.9	19.0	8.5	81.5	76.2	46.0	73.4
MS	555	141.3	43.0	29.4	20.6	9.1	77.0	74.8	53.4	82.5
MS	781	125.5	34.8	23.9	18.3	7.2	76.3	72.2	33.1	63.4
MS	777	121.5	36.8	27.7	19.0	5.8	83.0	80.4	36.9	62.5
MS	554	133.9	38.4	31.6	22.4	9.6	90.7	82.8	45.0	75.3
MS	817	128.3	42.2	28.4	18.5	7.7	86.8	78.2	45.6	69.4
MS	549	166.1	50.5	30.9	22.1	10.2	99.6	94.5	60.2	91.5
MS	780	130.7	41.2	26.5	19.1	8.2	77.3	73.3	37.5	68.3
MS	772	128.3	40.0	26.1	20.2	9.2	86.7	52.2	46.7	70.0
MS	471	111.0	36.5	24.3	19.6	6.3	86.1	74.7	34.8	67.1
MS	608	123.2	38.3	28.4	18.6	8.4	80.0	75.3	45.3	68.0
MS	806	116.0	41.5	28.8	21.2	9.5	93.6	81.0	47.5	53.5
MS	467	127.2	39.2	27.7	20.3	9.9	86.3	80.4	36.5	69.3
MS	411	125.9	37.4	27.7	20.5	8.2	86.0	81.9	39.3	75.5
MS	779	123.3	39.3	26.8	19.7	9.2	89.3	77.5	51.7	68.4

Appendix 2. (continued).

LOC	ID	POL	OOL	PBL	TTL	DOL	LUL	AUL	CPL	HDD
MS	647	16.9	11.2	55.1	131.3	51.5	107.2	47.6	38.4	39.5
MS	140	22.9	11.0	58.5	92.5	65.3	92.2	61.2	49.5	51.3
MS	818	20.5	11.3	54.4	110.0	71.5	98.9	56.5	45.8	44.2
MS	809	17.2	13.7	49.6	137.2	55.3	90.8	52.6	45.8	44.5
MS	831	21.8	14.7	49.8	121.5	54.4	101.6	48.6	42.8	52.2
MS	483	16.7	11.4	52.5	117.1	66.8	94.5	51.1	46.3	42.9
MS	775	18.4	11.5	49.7	121.8	61.1	90.8	48.7	48.8	41.3
MS	692	16.2	13.5	56.5	121.4	62.9	115.3	46.9	42.2	42.2
MS	409	19.2	10.9	48.7	127.3	57.1	93.7	45.9	43.4	45.4
MS	832	19.5	11.6	53.7	111.0	69.4	97.2	55.6	45.7	50.0
MS	132	21.5	12.1	64.5	171.9	76.5	115.2	55.9	63.1	53.7
MS	470	12.8	13.1	53.3	133.8	63.9	91.2	53.1	47.7	40.8
MS	828	20.6	13.1	56.7	123.3	61.5	121.9	47.5	45.6	44.5
MS	776	25.9	14.2	58.1	114.1	64.3	107.3	48.1	43.4	46.1
MS	808	18.1	9.5	51.5	131.1	73.8	109.5	51.3	35.5	44.6
MS	511	25.1	12.1	63.6	121.7	76.5	104.7	55.6	51.3	52.8
MS	548	19.8	13.1	63.8	150.4	65.1	120.5	58.8	60.0	57.7
MS	774	21.5	13.6	53.1	105.2	52.8	111.4	37.4	36.2	47.3
MS	829	21.0	14.6	51.0	96.6	65.7	95.2	37.2	41.3	47.3
MS	617	18.4	13.1	57.0	108.1	65.5	94.7	58.4	47.7	43.6
MS	615	24.4	12.2	51.2	108.5	66.8	97.2	52.2	45.1	45.8
MS	819	19.6	13.7	58.9	114.7	71.8	107.8	53.7	50.3	45.4
MS	778	16.7	12.4	51.3	118.2	56.5	87.4	50.8	50.0	40.3
MS	119	17.1	9.1	49.5	93.6	62.1	85.5	46.9	36.4	47.8
MS	408	18.6	8.9	43.5	110.5	53.0	87.0	43.3	41.1	34.6
MS	807	23.3	11.7	52.1	107.3	63.6	105.8	46.1	48.0	44.2
MS	616	15.4	9.8	54.0	125.7	62.4	96.9	51.3	51.9	43.8
MS	408	22.6	11.9	56.7	120.5	63.7	94.2	52.2	51.6	44.3
MS	541	19.2	12.0	52.4	132.6	62.2	104.7	42.9	50.6	41.6
MS	773	17.5	10.5	55.8	118.3	64.5	106.9	54.7	56.6	42.0

Appendix 2. (continued).

LOC	ID	BDD	CPD	IOW	MXL	MXW	PCL	PVL	ADL	GIRTH
MS	647	125.7	39.6	26.8	21.5	9.7	90.5	80.1	38.8	72.0
MS	140	142.2	44.4	29.7	20.0	8.1	93.9	84.5	46.7	82.1
MS	818	129.0	44.6	26.8	19.0	7.8	88.5	85.3		68.3
MS	809	132.7	42.8	26.6	19.2	8.2	80.7	78.8	43.2	74.8
MS	831	122.7	43.0	29.3	19.5	7.8	89.6	82.6	40.6	68.4
MS	483	126.7	37.7	24.6	18.4	8.3	76.4	76.4	43.8	69.8
MS	775	116.1	39.8	26.5	19.4	7.7	78.8	76.2	41.4	67.4
MS	692	132.9	44.3	31.4	20.6	8.9	92.9	86.1	46.2	66.2
MS	409	142.3	44.1	27.9	19.9	8.5	85.4	78.0	45.7	76.9
MS	832	143.2	45.0	31.5	17.7	8.8	84.9	85.7	54.3	69.9
MS	132	144.2	45.8	32.7	22.1	10.1	100.3	99.1	55.0	85.9
MS	470	127.6	40.8	23.3	18.9	9.6	78.2	77.0	39.2	76.6
MS	828	131.4	42.2	30.7	19.9	9.5	94.8	90.6	41.9	70.7
MS	776	129.3	43.8	27.5	21.0	9.4	86.7	85.4	48.2	71.9
MS	808	160.5	51.5	31.1	21.1	9.0	89.5	89.0	42.2	80.8
MS	511	152.7	52.1	36.5	20.9	9.4	102.7	96.7	60.7	81.9
MS	548	162.5	48.8	35.9	22.8	10.4	100.4	90.3	45.3	77.8
MS	774	135.0	40.1	27.5	18.4	7.6	79.0	76.8	41.2	75.2
MS	829	119.5	40.1	27.2	19.4	8.4	88.8	83.2	37.8	57.7
MS	617	124.3	40.5	28.0	19.1	8.7	81.6	76.8	43.3	70.1
MS	615	121.2	42.7	27.1	19.3	7.4	86.8	80.3	39.5	72.3
MS	819	119.3	43.3	29.1	21.8	9.3	88.6	87.2	45.2	61.9
MS	778	130.8	39.8	27.5	18.6	7.6	74.4	72.8	37.7	70.8
MS	119	116.1	39.6	24.8	19.9	8.6	85.7	77.7	38.1	62.3
MS	408	106.5	34.3	22.2	17.1	7.6	75.0	73.6	36.8	66.4
MS	807	115.8	38.2	28.1	18.4	7.6	88.5	80.0	44.9	61.6
MS	616	145.1	43.6	30.6	20.8	7.9	93.7	84.8		78.5
MS	408	147.6	45.1	27.5	20.1	8.4	84.7	77.9	47.2	72.5
MS	541	128.4	40.8	28.1	21.1	7.7	89.6	75.5	43.5	66.0
MS	773	140.4	40.2	27.6	19.7	8.5	83.7	74.7	49.3	79.0

Appendix 3. Raw biological data for the Mackenzie and Travaillant locations. Refer to appendix 1. for a description of column headings.

JDAY	LOC	ID	FRL1	FRL2	WT1	WT2	SEX	MAT	GWT	AGE
194	ARR	64	475	.	1570	.	F	4	.	
194	ARR	67	600	.	3210	.	.	.	.	.
195	ARR	80	617	.	2843	.	F	5	98	16
195	ARR	81	618	.	3331	.	F	5	106	11
199	ARR	119	469	.	1588	.	M	7	23.3	9
200	ARR	132	615	.	3498	.	F	2	189.3	17
200	ARR	134	485	.	1572	.	.	.	.	.
200	ARR	140	545	.	2817	.	M	7	49.6	14
208	ARR	375	539	.	2412	.	F	2	162	24
208	ARR	376	527	.	2473	.	M	7	30	12
208	ARR	377	466	.	1507	.	F	2	120	9
208	ARR	380	476	.	1313	.	M	10	8	17
208	ARR	407	757	.	4778	.	F	2?	265	2
208	ARR	408	460	.	1616	.	M	7	20.8	14
208	ARR	409	500	.	2296	.	F	2	152.3	8
208	ARR	410	530	.	2300	.	.	.	.	.
208	ARR	411	537	.	2254	.	F	2	124.7	17
208	ARR	412	480	.	.	.	F	2	117	13
209	ARR	467	500	.	1957	.	M	7	32.2	17
209	ARR	468	525	.	2624	.	.	.	.	.
210	ARR	471	725	.	2540	.	F	2	90.3	12
211	ARR	483	519	.	2146	.	F	2	188.9	15
211	ARR	511	590	.	3505	.	M	7	88	13
211	ARR	521	508	.	2272	.	F	2	248	.
211	ARR	522	500	.	1784	.	M	7	17	14
211	ARR	523	532	.	2936	.	F	2	234	10
211	ARR	524	490	.	1800	.	M	10	26	12
211	ARR	525	584	.	3449	.	F	2	292	11
211	ARR	526	460	.	1616	.	F	2	88	10
212	ARR	541	537	.	2180	.	F	2	88.5	11
213	ARR	548	600	.	3609	.	F	2	368.8	23
213	ARR	549	606	.	4396	.	F	2	484.2	14
214	ARR	554	584	.	2635	.	M	7	29	21
214	ARR	555	551	.	2806	.	F	2	199.5	13
215	ARR	564	570	.	2377	.	.	.	.	.
216	ARR	588	.	.	.	.	.	.	.	.
216	ARR	606	.	.	.	.	.	.	.	.

Appendix 3. (continued).

JDAY	LOC	ID	FRL1	FRL2	WT1	WT2	SEX	MAT	GWT	AGE
216	ARR	607	500	.	2158	.	.	.	.	.
216	ARR	608	482	.	1837	.	F	2	143.8	15
217	ARR	615	517	.	2138	.	M	7	24.7	8
217	ARR	616	535	.	2668	.	M	7	47	7
217	ARR	617	509	.	2124	.	M	7	23	15
217	ARR	624	.	.	.	.	.	.	.	.
218	ARR	647	517	.	2098	.	F	2	135.5	15
218	ARR	654	.	.	.	.	.	.	.	.
218	ARR	661	481	.	2135	.	F	2	191	13
218	ARR	662	500	.	1915	.	F	5	119	10
218	ARR	663	473	.	1962	.	F	2	201	14
218	ARR	668	475	.	1522	.	.	.	.	.
220	ARR	675	.	.	.	.	.	.	.	.
221	ARR	692	545	.	2200	.	F	2	136.2	9
222	ARR	729	498	.	1919	.	M	7	15.3	8
222	ARR	734	495	.	2283	.	F	2	236	7
222	ARR	735	515	.	2063	.	F	2	182	13
222	ARR	736	505	.	2143	.	F	5	202	9
222	ARR	737	514	.	2689	.	F	2	252	9
222	ARR	738	446	.	1341	.	M	10	13	.
228	ARR	764	474	.	1550	.	.	.	.	.
234	ARR	765	507	.	1790	.	.	.	.	.
227	ARR	766	472	.	1478	.	M	7	17.8	6
227	ARR	771	520	.	2372	.	F	2	316.6	8
227	ARR	772	542	.	2161	.	M	7	33.8	15
227	ARR	773	547	.	2778	.	F	2	368.3	14
227	ARR	774	499	.	2238	.	M	7	43.6	13
227	ARR	775	507	.	1871	.	M	7	35.9	15
227	ARR	776	550	.	2425	.	M	7	32.6	11
227	ARR	777	497	.	1804	.	F	2	197.6	9
227	ARR	778	495	.	2095	.	F	2	247.9	14
227	ARR	779	594	.	1845	.	M	7	32.3	13
227	ARR	780	485	.	1945	.	F	2	220.6	9
227	ARR	781	473	.	1700	.	F	2	156.5	17
231	ARR	793	617	.	3500	.	.	.	.	.
231	ARR	794	539	.	2544	.	.	.	.	.
231	ARR	795	485	.	1948	.	F	2	285	7
231	ARR	796	496	.	1962	.	F	2	221	7

Appendix 3. (continued).

JDAY	LOC	ID	FRL1	FRL2	WT1	WT2	SEX	MAT	GWT	AGE
231	ARR	797	515	.	2047	.	F	2	198	11
231	ARR	798	467	.	1530	.	M	7	20	15
231	ARR	799	492	.	1640	.	F	2	165	14
232	ARR	806	497	.	1462	.	F	5	23.8	19
232	ARR	807	515	.	1750	.	M	7	28.8	13
232	ARR	808	557	.	3400	.	M	7	44.1	14
232	ARR	809	521	.	2462	.	F	2	418.8	9
232	ARR	815	467	.	1814	.	F	2	198	15
233	ARR	817	487	.	1967	.	M	7	32.7	7
233	ARR	818	521	.	2123	.	M	7	38.8	9
233	ARR	819	545	.	1857	.	F	5	22.1	14
233	ARR	823	531	.	2221	.	F	2	220	12
233	ARR	824	490	.	1943	.	M	6	43	7
233	ARR	825	500	.	2024	.	F	2	249	9
234	ARR	828	555	.	2478	.	F	2	238.5	20
234	ARR	829	473	.	1452	.	M	7	18.5	10
234	ARR	830	493	.	2076	.	.	.	.	.
234	ARR	831	509	.	1968	.	M	7	24.5	9
234	ARR	832	519	.	2284	.	M	7	29.5	11
234	ARR	833	480	.	1738	.	F	2	181	7
234	ARR	834	542	.	2104	.	M	7	27	17
234	ARR	835	459	.	1515	.	M	7	19	5
234	ARR	836	587	.	1520	.	F	2	173	17
234	ARR	837	484	.	1621	.	M	6	14	7
238	ARR	847	547	.	2401	.	M	7	45	17
243	ARR	861	505	.	1925	.	M	7	22	15
243	ARR	864	525	.	2397	.	M	10	28	8
243	ARR	865	486	.	1570	.	F	2	124	17
245	ARR	868	460	.	1563	.	F	2	237	13
245	ARR	870	520	.	2328	.	F	2	473	15
245	ARR	871	495	.	1965	.	M	10	21	14
248	ARR	882	492	.	1615	.	M	10	22	20
248	ARR	883	505	.	2277	.	F	2	421	14
260	ARR	897	438	.	1200	.	.	.	.	.
260	ARR	903	467	.	1840	.	.	.	.	.
261	ARR	906	490	.	1640	.	.	.	.	.
262	ARR	912	469	.	1625	.	.	.	.	.
263	ARR	936	492	.	2019	.	F	3	394	10

Appendix 3. (continued).

JDAY	LOC	ID	FRL1	FRL2	WT1	WT2	SEX	MAT	GWT	AGE
264	ARR	948	500	.	1761	.	M	8	13	11
264	ARR	949	498	.	1702	.	M	7	17	15
264	ARR	950	525	.	2239	.	M	7	30	15
265	ARR	966	491	.	2074	.	F	2	432	.
265	ARR	971	486	.	1808	.	M	8	35	14
266	ARR	978	.	.	.	.	.	.	.	.
266	ARR	979	512	.	2425	.	F	3	481	14
267	ARR	986	495	.	1940	.	M	8	21	15
267	ARR	987	475	.	1631	.	F	3	335	14
269	ARR	1015	517	.	2050	.	M	8	54	6
278	ARR	1046	524	.	2071	.	M	8	24	11
280	ARR	1110	529	.	2114	.	M	8	18	16
281	ARR	1145	452	.	1325	.	F	3	193	7
282	ARR	1178	468	.	1670	.	F	3	301	13
284	ARR	1223	475	.	1814	.	M	8	20	9
285	ARR	1286	575	.	3146	.	M	8	65	12
287	ARR	1331	581	.	2922	.	M	8	66	11
289	ARR	1422	465	.	1737	.	F	3	424	9
289	ARR	1423	523	.	2012	.	M	8	30	14
290	ARR	1455	495	.	1718	.	M	7	20	8
291	ARR	1460	460	.	1322	.	M	8	14	10
292	ARR	1499	500	.	1784	.	M	8	32	14
292	ARR	1500	466	.	1508	.	M	8	25	11
292	ARR	1504	477	.	1753	.	F	3	400	10
292	ARR	1528								9
289	ARR	1529	505	.	2064	.	M	8	.	6
293	ARR	1530	287	.	278	.	F	3	50	.
293	ARR	1533								15
293	ARR	1534	488	.	1731	.	M	8	11	15
294	ARR	1537	455	.	1438	.	F	3	351	13
293	ARR	1539	508	.	1700	.	.	.	.	.
293	ARR	1540	480	.	1500	.	.	.	.	.
293	ARR	1541	488	.	1700	.	.	.	.	.
293	ARR	1542	512	.	1700	.	.	.	.	.
293	ARR	1543	450	.	1300	.	.	.	.	.
293	ARR	1544	510	.	2000	.	.	.	.	.
295	ARR	1560	488	.	1500	.	.	.	.	.
296	ARR	1567	.	.	.	.	.	.	.	.

Appendix 3. (continued).

JDAY	LOC	ID	FRL1	FRL2	WT1	WT2	SEX	MAT	GWT	AGE
298	ARR	1576	468	.	1433	.	M	8	.	.
298	ARR	1577	467	.	1683	.	M	8	.	.
298	ARR	1578	476	.	1705	.	M	8	.	.
298	ARR	1579	520	.	2190	.	M	8	.	.
298	ARR	1580	518	.	2107	.	M	8	.	.
298	ARR	1581	512	.	2094	.	M	8	.	.
298	ARR	1582	500	.	2080	.	M	8	.	.
298	ARR	1583	.	.	.	.	F	3	.	.
298	ARR	1584	.	.	.	.	F	3	.	.
298	ARR	1585	.	.	.	.	M	8	.	.
298	ARR	1586	.	.	.	.	M	8	.	.
298	ARR	1587	.	.	.	.	M	8	.	.
298	ARR	1588	.	.	.	.	M	8	.	.
298	ARR	1589	.	.	.	.	M	8	.	.
298	ARR	1590	.	.	.	.	M	8	.	.
298	ARR	1591	.	.	.	.	M	8	.	.
298	ARR	1592	.	.	.	.	M	8	.	.
298	ARR	1593	.	.	.	.	M	8	.	.
298	ARR	1594	.	.	.	.	M	8	.	.
298	ARR	1595	.	.	.	.	M	8	.	.
298	ARR	1596	.	.	.	.	M	8	.	.
298	ARR	1597	.	.	.	.	M	8	.	.
298	ARR	1607	474	.	1508	.	M	8	.	11
299	ARR	1612	515	517	2124	2108	M	8	33	10
299	ARR	1613	495	493	1849	1835	M	8	23	12
299	ARR	1614	505	484	1823	1743	M	9	22	13
299	ARR	1615	484	476	1655	1605	M	9	20	16
299	ARR	1616	555	544	2357	2241	M	8/9	31	10
299	ARR	1617	505	491	1616	1560	M	9	18	16
299	ARR	1618	449	.	1342	.	M	8	.	12
299	ARR	1619	.	443	.	1512	M	8	20	7
299	ARR	1620	.	515	.	1610	F	4	82	10
299	ARR	1621	.	456	.	1514	F	3	316	18
299	ARR	1622	.	441	.	1336	M	9	11	9
299	ARR	1623	473	.	1697	.	.	.	.	9
299	ARR	1624	456	.	1466	.	.	.	.	11
299	ARR	1625	489	.	1960	.	.	.	.	17
299	ARR	1626	475	.	1745	.	.	.	.	16

Appendix 3. (continued).

JDAY	LOC	ID	FRL1	FRL2	WT1	WT2	SEX	MAT	GWT	AGE
299	ARR	1627	462	.	1336	.	.	.	.	17
299	ARR	1628	530	.	2226	.	.	.	.	12
299	ARR	1629	476	.	1560	.	.	.	.	6
299	ARR	1630	534	.	1885	1850	F	4	38	11
299	ARR	1631	525	.	2218	.	.	.	.	9
299	ARR	1632	521	506	2042	1926	M	8/9	22	9
299	ARR	1633	476	464	.	1727	M	9	21	8
299	ARR	1634	605	593	.	3254	M	8	34	13
299	ARR	1635	495	494	2176	2136	F	3	497	7
299	ARR	1636	496	487	1971	1866	F	3	388	14
299	ARR	1637	495	482	2098	1931	F	3	435	9
299	ARR	1638	552	534	2475	2362	M	9	21	15
299	ARR	1639	491	488	2083	2042	F	3	515	6
299	ARR	1640	545	434	1363	1310	M	8	20	16
299	ARR	1641	503	486	2095	2043	M	8	34	7
299	ARR	1642	500	486	2241	2216	M	9	18	7
299	ARR	1643	458	457	1576	1514	M	7/9	15	10
299	ARR	1644	474	464	1746	1665	M	9	12	6
299	ARR	1645	515	514	2370	2324	M	8	59	7
299	ARR	1646	544	532	2492	2374	M	8	35	12
299	ARR	1647	525	520	2242	2220	M	8	32	11
299	ARR	1648	447	435	1388	1348	M	9	15	7
299	ARR	1649	490	484	1718	1690	M	9	15	14
299	ARR	1649?		508		2289	F	3	650	14
299	ARR	1650	506	497	1731	1895	M	9	17	16
299	ARR	1651	481	470	1800	1567	F	3/4	501?	12
299	ARR	1652	472	.	1615	.	.	.	.	14
299	ARR	1653	443	438	1295	1261	M	9	10	9
299	ARR	1654?	495?	493	1664?	1654	M	9	23	12
299	ARR	1654?	495?	460	1664?	1548	F	4	264	12
299	ARR	1655	505	509	1947	1910	M	9	24	15
299	ARR	1656	481	474	1745	1714	M	9	19	6
299	ARR	1657	490	.	1983	.	.	.	.	9
299	ARR	1658	518	515	2476	2443	M	8/9	31	10
299	ARR	1659	508	.	2329	.	.	.	.	14
299	ARR	1660	507	499	1967	1917	M	8	24	16
299	ARR	1661	505	491	1845	1791	M	8	26	14
299	ARR	1662	478	470	1751	1701	M	8/9	19	9

Appendix 3. (continued).

JDAY	LOC	ID	FRL1	FRL2	WT1	WT2	SEX	MAT	GWT	AGE
299	ARR	1663	460	455	1602	1545	M	9	15	10
299	ARR	1668	515	.	837	.	.	.	.	.
299	ARR	1669	528	526	2381	2368	M	9	20	12
299	ARR	1670	558	.	2398	.	M	.	.	
299	ARR	1671	488	.	1626	.	M	.	.	.
299	ARR	1672	490	.	1666	.	M	.	.	.
299	ARR	1673	501	.	1881	.	M	.	.	.
299	ARR	1674	474	.	1921	.	F	.	.	. .
299	ARR	1675	545	.	2413	.	M	.	.	.
299	ARR	1676	505	.	2004	.	M	.	.	.
299	ARR	1677	505	.	1938	.	M	.	.	.
299	ARR	1678	560	.	2453	.	F	.	.	.
299	ARR	1679	456	.	1352	.	M	.	.	.
299	ARR	1680	493	.	1862	.	M	.	.	.
299	ARR	1681	490	.	1961	.	M	.	.	.
299	ARR	1682	520	.	2094	.	F	.	.	.
299	ARR	1683	460	.	1847	.	F	.	.	.
299	ARR	1684	478	.	1774	.	F	.	.	.
299	ARR	1685	473	.	1647	.	F	.	.	.
299	ARR	1686	512	.	2105	.	F	.	.	.
302	ARR	1692	481	.	1724	.	M	8	12	14
302	ARR	1693	500	.	1849	.	F	3	.	9
302	ARR	1694	500	.	1808	.	M	8	15	13
302	ARR	1695	472	.	1759	.	M	8	14.7	16
302	ARR	1696	473	.	2043	.	F	3	.	7
302	ARR	1697	483	.	1938	.	F	3	.	7
302	ARR	1698	485	.	2032	.	M	8	16.6	7
302	ARR	1699	495	.	2014	.	M	8	18	9
302	ARR	1700	507	.	2124	.	M	8	33	15
302	ARR	1701	473	.	1649	.	F	3	.	9
302	ARR	1702	490	.	1804	.	M	8	23	7
302	ARR	1703	492	.	1847	.	M	9	20	9
302	ARR	1704	465	.	1756	.	F	3	.	15
302	ARR	1705	465	.	1616	.	M	9	12	12
302	ARR	1706	495	.	2329	.	M	9	27	14
302	ARR	1707	493	.	1549	.	M	9	16.5	20
302	ARR	1708	460	.	1521	.	M	9	14	15
302	ARR	1709	469	.	1611	.	M	9	13.4	6

Appendix 3. (continued).

JDAY	LOC	ID	FRL1	FRL2	WT1	WT2	SEX	MAT	GWT	AGE
302	ARR	1710	490	.	1916	.	M	8	14	.
302	ARR	1711	506	.	2059	.	M	8	17	22
302	ARR	1712	530	.	2497	.	M	9	27	9
302	ARR	1713	467	.	1596	.	M	9	19	7
302	ARR	1714	478	.	1647	.	M	9	16	12
302	ARR	1715	451	.	1135	.	F	4	.	13
302	ARR	1716	493	.	1744	.	M	9	20	18
302	ARR	1717	436	.	1292	.	M	8	18	6
302	ARR	1718	481	.	1814	.	M	8	26	9
302	ARR	1719	571	.	2462	.	M	8	30	18
302	ARR	1720	512	.	1762	.	M	9	9	16
302	ARR	1721	535	.	2676	.	M	8	41	15
302	ARR	1722	492	.	1620	.	M	8	23	9
302	ARR	1723	482	.	1890	.	M	8	15	14
302	ARR	1724	489	.	1934	.	M	8	22	15
302	ARR	1725	483	.	1803	.	M	9	15	10
302	ARR	1726	488	.	2077	.	M	9	25	12
302	ARR	1727	494	.	1844	.	M	9	18	11
302	ARR	1728	452	.	1515	.	M	8	10	14
302	ARR	1729	494	.	1876	.	M	8	.	6
302	ARR	1730	472	.	1619	.	M	8	16	15
302	ARR	1731	481	.	1668	.	M	8	33	17
302	ARR	1732	571	.	2799	.	F	3	.	13
302	ARR	1733	550	.	2750	.	M	8	36	15
302	ARR	1734	491	.	2020	.	M	8	17	15
302	ARR	1735	468	.	1649	.	M	9	22	7
302	ARR	1736	476	.	1601	.	M	9	22	5
302	ARR	1737	462	.	1399	.	M	8	13	.
302	ARR	1738	456	.	1566	.	M	8	21	13
302	ARR	1739	496	.	1895	.	M	8	23	8
302	ARR	1740	472	.	1625	.	M	9	10	15
302	ARR	1741	476	.	1830	.	M	9	24	9
302	ARR	1742	513	.	1944	.	M	8	27	14
302	ARR	1743	490	.	2043	.	M	9	24	8
302	ARR	1744	472	.	1540	.	F	4	.	7
302	ARR	1745	474	.	1561	.	M	9	20	14
302	ARR	1746	464	.	1642	.	M	8	28	15
302	ARR	1747	510	.	2098	.	M	8	24	8

Appendix 3. (continued).

JDAY	LOC	ID	FRL1	FRL2	WT1	WT2	SEX	MAT	GWT	AGE
302	ARR	1748	484	.	1692	.	M	8	11	9
302	ARR	1749	483	.	1800	.	M	9	27	22
302	ARR	1750	508	.	1759	.	F	3	.	13
302	ARR	1751	451	.	1566	.	M	8	14	9
302	ARR	1752	499	.	1900	.	F	4	.	
302	ARR	1753	452	.	1675	.	M	8	25	.
302	ARR	1754	455	.	1363	.	M	9	16	16
302	ARR	1755	601	.	3902	.	M	9	45	17
302	ARR	1756	547	.	3149	.	M	8	45	12
302	ARR	1757	477	.	1519	.	M	8	11	11
302	ARR	1758	560	.	2931	.	M	8	30	10
302	ARR	1759	480	.	1705	.	M	8	.	6
302	ARR	1760	515	.	2435	.	M	8	30	14
302	ARR	1761	563	.	3024	.	M	8	52	13
302	ARR	1762	478	.	1383	.	F	3	.	14
302	ARR	1763	500	.	1750	.	.	.	23	22
302	ARR	1764	476	.	1626	.	M	9	25	8
302	ARR	1765	475	.	1776	.	M	8	24	9
302	ARR	1766	480	.	1800	.	F	3	.	13
302	ARR	1767	498	.	2097	.	M	9	22	10
302	ARR	1768	450	.	1307	.	F	3	.	13
302	ARR	1769	494	.	1950	.	M	8	23	16
302	ARR	1770	505	.	2121	.	M	8	21	8
302	ARR	1771	556	.	2885	.	M	8	43	.
302	ARR	1772	527	.	2763	.	M	9	33	.
302	ARR	1773	494	.	2132	.	M	8	53	18
302	ARR	1774	476	.	1779	.	M	9	22	7
302	ARR	1775	539	.	2791	.	F	3	.	12
302	ARR	1776	500	.	2050	.	M	8	23	17
302	ARR	1777	519	.	2124	.	F	3	.	13
302	ARR	1778	474	.	1610	.	F	4	.	9
302	ARR	1779	516	.	2133	.	F	3	.	14
305	ARR	1791	517	.	2411	.	F	3	.	8
305	ARR	1792	457	.	1350	.	F	3	.	13
305	ARR	1793	533	.	2028	.	M	8	34	20
305	ARR	1794	426	.	1104	.	F	3	.	12
305	ARR	1795	491	.	1984	.	M	8	34	9
305	ARR	1797	476	.	1646	.	M	8	22	13

Appendix 3. (continued).

JDAY	LOC	ID	FRL1	FRL2	WT1	WT2	SEX	MAT	GWT	AGE
305	ARR	1798	472	.	1231	.	M	9	14	15
305	ARR	1799	458	.	1417	.	M	8	21	20
305	ARR	1800	398	.	997	.	F	3	.	13
305	ARR	1813	500	.	1825	.	F	3	.	12
305	ARR	1814	486	.	1608	.	M	8	15	15
305	ARR	1815	456	.	1527	.	M	8	17	7
305	ARR	1816	512	.	1541	.	F	4	.	15
305	ARR	1817	482	.	1642	.	M	8	20	11
305	ARR	1818	496	.	1806	.	F	3	.	11
305	ARR	1819	504	.	1990	.	F	3	.	9
305	ARR	1820	474	.	1333	.	F	3	.	17
305	ARR	1821	474	.	1677	.	F	3	.	9
299	ARR	1822	.	476	.	1835	F	3	464	14
299	ARR	1828	.	531	.	2453	M	8	50	8
299	ARR	1835	.	.	.	.	.	.	.	9
299	ARR	1840	.	476	.	1807	M	9	24	12
299	ARR	1841	.	.	.	.	.	.	.	15
307	ARR	1842	645	.	.	.	.	.	.	.
307	ARR	1843	516	.	1866	.	F	3	.	13
307	ARR	1844	536	.	2814	.	M	9	.	10
307	ARR	1845	477	.	1794	.	F	3	.	12
307	ARR	1846	485	.	499	.	F	4	.	22
307	ARR	1847	499	.	1966	.	F	3	.	13
307	ARR	1865	487	.	1825	.	F	3	.	14
307	ARR	1866	518	.	1908	.	F	5	39.1	21
307	ARR	1867	460	.	1363	.	F	4	.	7
307	ARR	1868	501	.	1704	.	F	4	.	14
310	ARR	1869	559	.	3122	.	M	8	61	11
310	ARR	1870	513	.	1982	.	F	4	.	15
310	ARR	1871	485	.	1740	.	M	8	10	13
310	ARR	1872	469	.	1447	.	F	4	.	9
310	ARR	1873	464	.	1457	.	M	9	7	.
310	ARR	1874	500	.	1972	.	F	3	.	13
310	ARR	1875	487	.	1739	.	F	3	.	15
310	ARR	1876	438	.	1050	.	F	4	.	7
310	ARR	1877	448	.	955	.	F	4	.	17
310	ARR	1878	434	.	1281	.	F	3	.	12
313	ARR	1901	471	.	1523	.	M	8	19	17

Appendix 3. (continued).

JDAY	LOC	ID	FRL1	FRL2	WT1	WT2	SEX	MAT	GWT	AGE
313	ARR	1907	512	.	1918	.	F	4	49	14
313	ARR	1908	496	.	1717	.	M	8	19	12
313	ARR	1909	378	.	745	.	M	6	1	3
313	ARR	1913	491	.	1839	.	M	8	28	12
313	ARR	1914	468	.	1595	.	M	8	26	11
313	ARR	1917	459	.	1424	.	M	9	8	6
313	ARR	1918	480	.	1758	.	M	8	15	9
313	ARR	1919	491	.	1989	.	F	3	372	14
313	ARR	1920	540	.	2104	.	M	8	23	13
313	ARR	1921	449	.	1209	.	M	8	23	14
313	ARR	1922	575	.	1065	.	.	.	.	.
313	ARR	1923	468	.	1742	.	F	3	273	6
313	ARR	1924	488	.	1702	.	M	8	17	13
313	ARR	1925	484	.	1816	.	M	8	19	7
313	ARR	1926	481	.	1855	.	M	8	24	7
313	ARR	1927	475	.	1520	.	M	8	15	12
313	ARR	1928	434	.	1566	.	F	4	31	14
313	ARR	1929	520	.	1582	.	F	4	37	11
313	ARR	1930	521	.	1724	.	F	4	51	12
313	ARR	1932	555	.	2845	.	M	8	32	12
313	ARR	1933	528	.	2019	.	M	8	32	9
313	ARR	1934	525	.	2072	.	M	9	10	13
313	ARR	1935	508	.	1947	.	M	9	8	15
313	ARR	1936	564	.	2658	.	F	4	91	15
313	ARR	1937	507	.	1952	.	M	9	14	15
313	ARR	1938	491	.	1614	.	M	8	27	15
313	ARR	1939	444	.	1223	.	F	3	112	9
313	ARR	1940	481	.	1820	.	M	9	14	7
316	ARR	1941	461	.	1449	.	F	4	19	9
316	ARR	1942	599	.	3246	.	M	8	50	17
316	ARR	1943	523	.	2565	.	F	3	474	15
316	ARR	1944	486	.	1931	.	F	3	.	10
316	ARR	1945	584	.	3011	.	M	9	21	.
316	ARR	1946	461	.	1404	.	F	4	115	14
316	ARR	1952	566	.	2827	.	M	8	32	12
316	ARR	1961	496	.	1827	.	.	.	.	9
316	ARR	1962	497	.	1693	.	.	.	.	14
316	ARR	1963	515	.	2098	.	M	9	.	16

Appendix 3. (continued).

JDAY	LOC	ID	FRL1	FRL2	WT1	WT2	SEX	MAT	GWT	AGE
316	ARR	1967	470	.	1660	.	M	9	10	14
316	ARR	1968	469	.	1570	.	M	8	9	9
316	ARR	1969	488	.	1626	.	M	8	9	20
316	ARR	1970	493	.	2043	.	M	9	13	11
316	ARR	1971	501	.	2076	.	M	9	11	12
316	ARR	1972	586	.	1853	.	M	8	25	9
316	ARR	1973	533	.	2186	.	M	9	14	14
316	ARR	1974	494	.	1388	.	F	4	44	13
316	ARR	1975	485	.	1613	.	M	9	13	15
316	ARR	1976	442	.	1216	.	M	9	9	.
316	ARR	1977	478	.	1429	.	F	4	28	13
316	ARR	1978	483	.	1769	.	M	9	11	12
316	ARR	1979	464	.	1619	.	F	4	88	6
319	ARR	1980	.	496	.	1665	M	8	24	.
319	ARR	1981	550	.	2375	.	M	9	.	12
319	ARR	1982	473	.	1778	.	M	9	.	10
319	ARR	1983	477	.	1480	.	F	5	.	7
319	ARR	1996	.	457	.	1235	F	4	22	12
319	ARR	1998	.	489	.	1784	M	9	24	15
319	ARR	1999	.	546	.	2419	M	9	29	14
319	ARR	1991	508	.	2115	.	F	3	434	13
314	ARR	2000	.	461	.	1666	M	9	15	10
314	ARR	2001	.	506	.	2145	M	9	13	15
314	ARR	2002	.	475	.	1663	F	2	40	7
314	ARR	2003	.	.	.	.	.	.	.	.
314	ARR	2004	.	528	.	2527	M	9	33	14
314	ARR	2005	.	447	.	1548	F	3/4	385	13
314	ARR	2006	.	452	.	1595	M	9	24	7
314	ARR	2007	.	477	.	1971	F	3/4	359	8
314	ARR	2008	.	471	.	1690	M	9	19	12
314	ARR	2009	.	498	.	1988	M	9	17	9
314	ARR	2010	.	457	.	1508	M	9	9	9
314	ARR	2011	.	448	.	1219	F	4	22	7
314	ARR	2012	.	487	.	1768	M	8	14	15
319	ARR	2013	.	520	.	2288	M	9	11	15
319	ARR	2014	.	481	.	1843	M	9	20	15
188	MACK	9	480	.	1415	.	.	.	.	.
188	MACK	10	518	.	1563	.	.	.	.	.

Appendix 3. (continued).

JDAY	LOC	ID	FRL1	FRL2	WT1	WT2	SEX	MAT	GWT	AGE
188	MACK	11	537	.	2445	.	.	.	.	.
188	MACK	12	592	.	3349	.	.	.	.	.
188	MACK	13	490	.	2143	.	.	.	.	.
189	MACK	20	420	.	1114	.	.	.	.	.
190	MACK	23	543	.	3003	.	.	.	.	.
190	MACK	24	583	.	3030	.	.	.	.	.
190	MACK	25	597	.	3070	.	.	.	.	.
190	MACK	26	570	.	2415	.	.	.	.	.
190	MACK	27	558	.	2645	.	.	.	.	.
190	MACK	28	516	.	2172	.	.	.	.	.
190	MACK	29	441	.	1406	.	.	.	.	.
190	MACK	38	464	.	1452	.	.	.	.	.
190	MACK	39	530	.	2330	.	.	.	.	.
193	MACK	48	469	.	1325	.	.	.	.	.
193	MACK	49	482	.	1730	.	.	.	.	.
193	MACK	50	467	.	1664	.	.	.	.	.
194	MACK	70	632	.	3583	.	.	.	.	.
194	MACK	71	485	.	1892	.	.	.	.	.
194	MACK	72	557	.	3550	.	.	.	.	.
194	MACK	73	.	.	.	.	.	.	.	.
195	MACK	87	109	.	1946	.	.	.	.	.
195	MACK	88	530	.	2390	.	.	.	.	.
195	MACK	89	566	.	2799	.	.	.	.	.
195	MACK	90	562	.	3013	.	.	.	.	.
196	MACK	95	577	.	3712	.	.	.	.	.
196	MACK	96	487	.	1786	.	.	.	.	.
196	MACK	97	522	.	2262	.	.	.	.	.
196	MACK	98	563	.	2201	.	.	.	.	.
196	MACK	99	.	.	.	.	.	.	.	.
197	MACK	101	542	.	2780	.	.	.	.	.
197	MACK	102	539	.	2573	.	.	.	.	.
199	MACK	112	514	.	2055	.	M	10	25	.
199	MACK	113	516	.	1846	.	M	10	13	.
199	MACK	114	580	.	2429	.	.	.	.	.
199	MACK	115	520	.	2287	.	.	.	.	.
199	MACK	116	549	.	2445	.	.	.	.	.
201	MACK	180	510	.	3036	.	.	.	.	.
201	MACK	181	522	.	2218	.	.	.	.	.

Appendix 3. (continued).

JDAY	LOC	ID	FRL1	FRL2	WT1	WT2	SEX	MAT	GWT	AGE
201	MACK	182	535	.	2539	.	.	.	.	.
201	MACK	183	550	.	2856	.	.	.	.	.
201	MACK	184	537	.	2765	.	F	2	231	.
202	MACK	185	500	.	2111	.	.	.	.	.
202	MACK	186	533	.	1926	.	.	.	.	.
202	MACK	187	532	.	2838	.	.	.	.	.
202	MACK	188	563	.	2974	.	.	.	.	.
202	MACK	189	482	.	1842	.	.	.	.	.
202	MACK	190	591	.	3395	.	.	.	.	.
202	MACK	191	467	.	1627	.	.	.	.	.
202	MACK	192	447	.	1486	.	.	.	.	.
202	MACK	193	520	.	2023	.	.	.	.	.
202	MACK	208	516	.	2309	.	.	.	.	.
202	MACK	209	538	.	2597	.	.	.	.	.
202	MACK	210	465	.	1671	.	.	.	.	.
202	MACK	211	532	.	2560	.	.	.	.	.
202	MACK	212	579	.	3227	.	.	.	.	.
202	MACK	213	503	.	2284	.	.	.	.	.
202	MACK	214	531	.	2551	.	.	.	.	.
202	MACK	215	521	.	2476	.	.	.	.	.
202	MACK	216	500	.	1887	.	.	.	.	.
203	MACK	256	553	.	2715	.	.	.	.	.
203	MACK	257	442	.	1455	.	.	.	.	.
203	MACK	258	470	.	1506	.	.	.	.	.
203	MACK	259	518	.	1837	.	.	.	.	.
203	MACK	260	552	.	2484	.	.	.	.	.
203	MACK	261	497	.	1906	.	.	.	.	.
203	MACK	262	518	.	1971	.	.	.	.	.
205	MACK	282	520	.	2385	.	.	.	.	.
205	MACK	283	487	.	1880	.	.	.	.	.
205	MACK	284	513	.	2329	.	.	.	.	.
205	MACK	285	565	.	2728	.	.	.	.	.
205	MACK	286	534	.	2304	.	.	.	.	.
205	MACK	287	555	.	2472	.	.	.	.	.
205	MACK	288	535	.	2447	.	.	.	.	.
205	MACK	289	465	.	1412	.	M	10	15	.
205	MACK	290	500	.	2012	.	F	2	153	.
205	MACK	291	565	.	2896	.	F	2	215	.

Appendix 3. (continued).

JDAY	LOC	ID	FRL1	FRL2	WT1	WT2	SEX	MAT	GWT	AGE
205	MACK	292	530	.	2384	.	F	2	211	.
205	MACK	293	511	.	1980	.	M	7	33	.
205	MACK	294	508	.	2061	.	F	2	126	.
205	MACK	295	530	.	2029	.	M	10	9	.
205	MACK	296	525	.	2006	.	M	7	26	.
205	MACK	328	488	.	2174	.	F	2?	124	.
205	MACK	329	505	.	2326	.	M	7	23	.
205	MACK	330	487	.	1875	.	F	2?	108	.
205	MACK	331	527	.	2621	.	F	2	245	.
205	MACK	332	515	.	2237	.	M	10	15	.
205	MACK	333	512	.	2102	.	M	10	42	.
205	MACK	334	496	.	1662	.	M	7	19	.
205	MACK	335	498	.	2027	.	F	2	254	.
207	MACK	361	532	.	2567	.	F	2	161	.
207	MACK	362	480	.	1802	.	M	7	19	.
207	MACK	363	490	.	1949	.	M	10	10	.
207	MACK	364	519	.	2505	.	F	2	174	.
207	MACK	365	543	.	2654	.	M	10	37	.
207	MACK	366	475	.	1660	.	F	2	120	.
208	MACK	424	553	.	2961	.	F	2	281	.
208	MACK	425	462	.	1805	.	M	10	22	.
208	MACK	432	541	.	2456	.	F	2	156	.
208	MACK	433	490	.	2115	.	F	2	181	.
208	MACK	434	509	.	1976	.	M	10	35	.
208	MACK	435	495	.	1972	.	M	10	16	.
208	MACK	436	557	.	2907	.	M	10	41	.
208	MACK	437	530	.	1893	.	M	10	14	.
208	MACK	438	545	.	2604	.	F	2	292	.
288	MACK	997	495	.	1758	.	M	8	18	.
277	MACK	1041	560	.	2501	.	F	3	486	.
278	MACK	1045	483	.	1520	.	M	8	20	.
279	MACK	1051	501	.	1566	.	M	8	21	.
279	MACK	1066	530	.	2090	.	M	8	18	.
279	MACK	1067	560	.	2337	.	F	3	339	.
279	MACK	1068	499	.	2099	.	F	3	435	.
279	MACK	1069	503	.	1933	.	M	7	26	.
280	MACK	1074	558	.	2435	.	M	8	29	.
280	MACK	1089	489	.	1649	.	M	7	23	.

Appendix 3. (continued).

JDAY	LOC	ID	FRL1	FRL2	WT1	WT2	SEX	MAT	GWT	AGE
281	MACK	1120	497	.	1539	.	M	7	20	12
281	MACK	1121	521	.	2317	.	M	7	26	12
281	MACK	1122	539	.	2863	.	F	2	711	14
282	MACK	1173	479	.	1882	.	M	7	12	12
282	MACK	1174	535	.	1981	.	M	7	23	16
282	MACK	1175	500	.	1987	.	M	8	20	11
282	MACK	1176	470	.	1865	.	M	8	16	6
283	MACK	1200	424	.	1357	.	F	3	.	.
283	MACK	1201	500	.	1824	.	M	7	.	12
283	MACK	1202	508	.	2252	.	M	7	.	14
283	MACK	1203	545	.	2092	.	M	7	.	16
283	MACK	1204	500	.	1659	.	M	8	.	17
284	MACK	1239	495	.	2110	.	F	3	507	10
284	MACK	1252	490	.	1615	.	M	7	19	9
284	MACK	1253	485	.	1605	.	M	8	12	10
284	MACK	1254	467	.	1403	.	M	8	16	14
284	MACK	1255	513	.	2115	.	M	8	20	10
284	MACK	1256	490	.	1904	.	M	8	17	13
285	MACK	1278	509	.	1974	.	M	8	22	10
285	MACK	1279	497	.	2181	.	F	3	424	8
285	MACK	1280	476	.	1718	.	M	8	19	12
285	MACK	1281	477	.	1839	.	M	8	17	8
285	MACK	1282	510	.	1803	.	M	8	15	10
285	MACK	1283	499	.	1919	.	M	8	19	14
285	MACK	1284	544	.	2157	.	M	8	28	12
286	MACK	1300	557	.	2562	.	M	8	22	.
286	MACK	1301	500	.	1885	.	M	8	20	.
286	MACK	1302	532	.	2095	.	M	8	19	.
286	MACK	1303	485	.	1911	.	M	8	22	.
286	MACK	1304	508	.	1802	.	M	8	11	.
286	MACK	1309	457	.	1369	.	F	3	314	.
288	MACK	1316	490	.	1634	.	M	8	19	.
288	MACK	1317	525	.	1989	.	M	8	35	.
288	MACK	1318	489	.	1654	.	M	8	27	.
287	MACK	1319	520	.	2246	.	M	8	20	10
287	MACK	1320	494	.	2153	.	F	3	391	9
287	MACK	1321	477	.	1541	.	M	8	15	9
287	MACK	1322	551	.	2664	.	M	8	41	13

Appendix 3. (continued).

JDAY	LOC	ID	FRL1	FRL2	WT1	WT2	SEX	MAT	GWT	AGE
287	MACK	1323	506	.	1323	.	M	8	14	9
287	MACK	1324	457	.	1476	.	M	8	17	12
287	MACK	1325	510	.	1841	.	M	8	20	13
287	MACK	1326	500	.	1943	.	M	8	22	14
287	MACK	1339	489	.	1526	.	M	8	20	17
288	MACK	1419	495	.	1758	.	M	8	18	15
290	MACK	1428	509	.	1973	.	M	8	.	9
290	MACK	1429	485	.	1919	.	M	8	.	8
290	MACK	1430	486	.	1633	.	M	8	.	14
290	MACK	1431	488	.	1571	.	M	8	.	9
290	MACK	1432	527	.	2333	.	M	8	.	10
290	MACK	1433	523	.	2050	.	M	8	.	10
290	MACK	1434	477	.	1791	.	M	8	.	12
290	MACK	1435	515	.	1975	.	M	8	.	12
290	MACK	1436	470	.	1681	.	M	8	.	7
290	MACK	1437	535	.	2640	.	M	8	.	14
290	MACK	1444	480	.	1774	.	M	7	.	7
290	MACK	1445	489	.	1718	.	M	8	.	14
290	MACK	1446	454	.	1478	.	M	8	.	17
290	MACK	1447	514	.	1826	.	M	8	.	15
290	MACK	1448	478	.	1706	.	M	8	.	7
292	MACK	1510	552	.	2128	.	M	8	34	16
292	MACK	1511	500	.	1929	.	M	8	14	11
292	MACK	1512	569	.	2299	.	M	8	41	17
292	MACK	1513	519	.	1981	.	M	8	24	9
292	MACK	1514	485	.	2006	.	M	8	28	7
292	MACK	1515	468	.	1454	.	M	8	17	6
292	MACK	1516	505	.	1821	.	M	8	20	10
292	MACK	1517	478	.	1621	.	M	8	19	11
292	MACK	1518	520	.	2246	.	M	8	19	8
292	MACK	1519	456	.	1571	.	M	8	12	6
292	MACK	1520	489	.	1978	.	M	9	25	12
292	MACK	1521	505	.	2121	.	M	8	21	15
292	MACK	1522	439	.	2049	.	F	3	436	17
292	MACK	1523	453	.	1418	.	M	8	16	12
295	MACK	1550	550	.	.	.	.	.	.	.
295	MACK	1551	510	.	.	.	.	.	.	.
295	MACK	1552	513	.	.	.	.	.	.	.

Appendix 3. (continued).

JDAY	LOC	ID	FRL1	FRL2	WT1	WT2	SEX	MAT	GWT	AGE
295	MACK	1553	528	.	.	.	.	.	.	.
295	MACK	1554	489	.	.	.	.	.	.	.
295	MACK	1555	510	.	.	.	.	.	.	.
295	MACK	1556	489	.	.	.	.	.	.	.
295	MACK	1557	620	.	.	.	.	.	.	.
211	TL	11	445	.	1189	.	.	.	.	.
211	TL	12	493	.	1559	.	.	.	.	.
211	TL	14	278	265	284	277	F	1	0.8	.
211	TL	15	219	212	126	124	M	6	0.1	.
211	TL	16	477	455	1630	1584	F	2	108.5	16
211	TL	17	512	514	2545	2500	F	2	219.7	14
211	TL	18	496	492	2137	2087	F	2	175.8	16
212	TL	19	450	439	1647	1606	F	2	139.7	25
212	TL	33	526	520	2738	2715	F	2	149.2	24
212	TR	34	578	.	3000	.	M	7	33	14
212	TR	35	547	534	2272	2188	F	5	25.9	.
212	TR	36	502	496	2102	2051	F	2	203.5	.
212	TR	37	528	524	2037	1994	M	7	30	.
212	TR	38	538	515	2206	2159	M	7	19.3	.
212	TR	39	415	415	893	871	F	1	0.2	
212	TR	40	388	384	635	614	F	1	1.9	.
212	TR	41	468	468	1755	1702	M	7	10	.
212	TR	42	499	475	1589	1552	F	5	11.2	.
212	TR	43	429	431	928	899	F	1	3.8	.
212	TR	44	556	548	2299	2467	M	7	15.7	.
213	TR	50	400	.	834	.	.	.	.	.
213	TL	77	561	535	2855	2769	F	2	230.1	14
213	TL	78	475	440	1556	1492	M	7	14.3	15
213	TL	79	513	490	2156	2104	M	7	29.1	16
213	TL	80	482	453	1467	1463	M	10	3.5	.
213	TL	81	488	452	1714	1651	M	10	3.5	11
213	TL	82	499	478	1867	1832	M	7	14.5	16
213	TR	114	458	.	1394	.	.	.	.	.
213	TR	128	405	387	792	754	F	1	2.4	.
213	TR	129	441	432	1003	964	M	6	0.8	.
213	TR	130	512	502	1825	1750	M	10	3.2	.
213	TR	131	365	356	696	669	M	6	0.2	.
213	TR	132	572	563	1984	1897	M	10	3	15

Appendix 3. (continued).

JDAY	LOC	ID	FRL1	FRL2	WT1	WT2	SEX	MAT	GWT	AGE
213	TR	133	509	480	2133	2070	M	7	19.5	.
213	TL	147	508	497	1647	1582	F	5	19.2	21
213	TL	168	534	530	1918	1838	M	10	3.4	.
214	TL	172	434	425	991	947	M	6	0.5	11
214	TL	173	502	500	2177	2120	M	7	10.4	11
214	TL	174	500	492	1880	1811	M	7	14.8	22
214	TL	175	478	460	2046	1530	F	2	162.1	16
214	TL	177	492	480	1680	1627	M	7	16.4	15
214	TL	178	481	475	1549	1485	M	7	16.6	16
214	TL	179	462	455	1643	1602	F	2	115.7	16
214	TL	180	469	460	1572	1530	M	7	17.9	16
214	TL	181	504	499	2052	2009	F	2	163.6	25
214	TL	182	511	490	2098	2063	M	7	23.7	24
214	TL	183	512	.	2140	.	.	.	.	.
214	TL	184	266	261	243	235	M	6	0.1	.
214	TL	185	270	262	250	241	F	1	0.4	.
214	TR	217	515	498	2102	1981	M	10	3.4	7
214	TR	218	495	478	1539	1412	F	5	12.2	11
214	TR	219	500	487	1619	1545	F	5	19.3	11
214	TL	246	508	491	1739	1704	M	7	36.8	.
214	TL	247	210	203	109	102	M	6	0.1	.
215	TL	251	453	437	1343	1266	M	7	10.1	15
215	TL	255	263	255	236	231	.	.	.	.
215	TR	262	558	537	3150	3050	F	2	249.7	25
215	TR	263	531	514	2584	2467	F	2	160	15
215	TR	266	378	364	637	598	.	.	.	.
215	TL	289	524	515	1697	1606	M	10	2.1	10
215	TL	292	468	.	1267	.	.	.	.	.
216	TR	299	511	488	1720	1672	M	7	20.8	14
216	TL	300	470	446	1478	1414	F	1	6.3	8
216	TL	301	520	516	1978	1838	M	7	13.5	27
216	TL	302	505	494	2007	1855	M	7	22.6	16
216	TL	303	520	495	2140	1978	M	7	24.6	20
216	TL	305	507	500	1876	1803	M	7	31.5	23
216	TL	306	537	532	2520	2469	M	10	1.4	6
216	TL	307	268	255	258	234	.	.	.	.
216	TL	308	500	486	1985	1906	F	2	123.2	22
216	TL	309	509	480	1965	1885	M	7	26.2	16

Appendix 3. (continued).

JDAY	LOC	ID	FRL1	FRL2	WT1	WT2	SEX	MAT	GWT	AGE
216	TR	323	549	529	2484	2406	M	7	30.7	12
216	TR	324	502	489	1677	1586	F	5	19.8	11
216	TR	325	576	567	2530	2421	M	7	26.9	10
216	TR	326	573	560	2620	2495	M	7	23	18
216	TR	327	524	494	1565	1482	M	10	2.2	.
216	TR	328	552	540	2217	2078	M	7	9.3	19
216	TR	329	550	533	2103	2020	M	7	24.3	20
216	TR	351	544	.	3000	.	.	.	.	.
216	TL	355	530	516	2335	2810	F	2	192.9	11
216	TL	356	490	.	1912	.	.	.	.	.
216	TL	357	347	528	2462	2323	M	7	27.2	15
216	TL	358	511	.	1981	.	.	.	.	.
216	TL	359	517	.	1972	.	.	.	.	.
216	TL	360	464	463	1207	1161	F	5	7	11
216	TL	361	514	508	1984	1875	M	7	20.8	15
216	TL	362	533	519	2724	2584	F	2	148.1	13
216	TL	363	477	450	1394	1323	F	5	20.6	11
216	TL	364	510	485	2210	2113	M	7	25.5	9
216	TL	365	323?	478	1929	1795	M	7	17.3	14
216	TL	366	533	510	1731	1848	M	7	33.1	11
217	TR	372	490	.	1289	.	.	.	.	.
217	TL	373	491	488	1727	1655	F	2	127.4	.
217	TL	374	287	276	326	312	F	1	1.1	.
217	TL	385	535	.	2055	.	.	.	.	.
217	TL	392	494	480	1923	1869	F	2	129.4	25
217	TL	393	549	.	2867	.	.	.	.	.
217	TL	394	542	511	2622	2534	F	2	217.1	12
217	TL	395	541	.	2442	.	.	.	.	.
217	TL	396	531	512	2188	2053	F	2	115.2	14
217	TR	402	515	502	1854	1784	M	7	24.3	14
218	TR	403	492	475	1797	1723	M	7	19.8	12
218	TL	427	465	433	1372	1347	F	2	111.4	16
218	TL	428	488	464	1545	1504	F	5	77.1	18
218	TL	429	579	553	2720	2656	M	7	24.5	14
218	TL	430	489	465	1737	1699	F	2	112	15
218	TR	437	454	430	1382	1339	F	2	83.6	16
218	TR	438	517	.	.	.	.	.	.	.
218	TR	439	479	.	.	.	.	.	.	.

Appendix 3. (continued).

JDAY	LOC	ID	FRL1	FRL2	WT1	WT2	SEX	MAT	GWT	AGE
218	TR	440	546	.	.	.	.	.	.	.
218	TR	441	548	.	.	.	.	.	.	.
219	TR	442	465	.	.	.	.	.	.	.
219	TL	443	500	471	2007	1973	F	5	21.7	6
219	TL	446	523	478	1551	1501	M	7	8.8	24
219	TL	447	268	255	229	226	M	6	0.1	.
219	TL	448	264	262	234	229	F	1	0.1	.
219	TL	449	286	282	310	304	F	2	0.4	.
219	TL	460	530	.	.	.	.	.	.	.
219	TL	461	478	.	.	.	.	.	.	.
219	TL	462	538	.	.	.	.	.	.	.
219	TL	463	@540	.	.	.	.	.	.	.
220	TL	464	574	540	2824	3025	F	2	62	.
220	TL	465	494	490	1865	1807	M	7	27.3	16
220	TL	466	271	.	237	.	.	.	.	.
220	TL	467	250	.	164	.	.	.	.	.
220	TL	468	147	140	39	39	.	.	.	.
220	TL	481	145	140	35	33	.	.	.	.
220	TL	469	154	146	45	43	.	.	.	.
298	TR	572	485	470	1640	1588	M	8	15	16
298	TR	573	472	457	1751	1696	M	8	21	8
298	TR	574	515	500	1956	1897	M	8	16.1	16
298	TR	575	494	478	1828	1770	F	4	59	15
298	TR	576	484	468	1556	1506	F	4	80	16
298	TR	577	.	.	1610	1561	F	4	111	20
298	TR	578	448	434	1401	1354	F	4	58.1	16
298	TR	579	521	504	2554	2481	F	3	560	19
298	TR	580	485	469	2002	1942	F	3	196	14
298	TR	581	470	455	1651	1599	M	8	23.4	16
298	TR	582	500	485	2029	1968	M	8	16.7	.
298	TR	583	442	427	1161	1120	M	8	8.8	16
298	TR	584	468	453	1682	1629	F	4	167.3	15
298	TR	585	526	510	2116	2053	M	8	20.9	22
298	TR	586	495	479	1941	1882	F	3	459	16
298	TR	587	530	513	2092	2030	F	4	49.8	16
298	TR	588	478	462	1615	1563	F	4	98.4	16
298	TR	589	519	502	2029	1968	F	4	112	16
298	TR	590	488	472	1735	1681	F	4	149	16

Appendix 3. (continued).

JDAY	LOC	ID	FRL1	FRL2	WT1	WT2	SEX	MAT	GWT	AGE
298	TR	591	486	470	2055	1993	F	3	318	16
298	TR	592	500	485	1862	1805	M	8	15.5	16
298	TR	593	488	473	1772	1717	M	9	15.3	16
298	TR	594	461	446	1492	1443	F	4	106.3	14
298	TR	595	529	512	2200	2135	F	4	222	16
298	TR	596	493	478	1757	1702	M	8	26.6	26
298	TR	597	467	452	1704	1650	F	3	238	14
298	TR	598	521	504	2308	2241	F	3	290	16
298	TR	599	515	500	2282	2215	M	8	26.1	16
298	TR	600	456	441	1723	1669	F	4	17.1	16
298	TR	601	.	.	2065	2003	M	9	25.2	20
298	TR	602	491	476	1550	1500	M	8	34.5	15
298	TR	603	536	518	2904	2823	F	3	518	15
298	TR	604	490	475	2036	1975	M	8	27.1	16
298	TR	605	502	487	1691	1638	M	9	16.9	16
298	TR	606	487	471	1810	1754	F	3	277.7	14
298	TR	607	522	507	2358	2290	M	8	24.2	23
298	TR	608	520	505	2257	2191	M	8	43.4	25
298	TR	609	486	470	1768	1713	F	3	338	16
298	TR	610	480	465	1998	1938	M	9	31.9	20
298	TR	611	471	456	1959	1900	F	4	138	16
298	TR	612	509	494	2056	1994	M	9	19.4	16
298	TR	613	536	518	2307	2240	F	3	297	21
298	TR	614	489	473	2096	2034	F	3	451.6	16
298	TR	615	493	478	1926	1867	M	9	21.8	16
298	TR	616	493	478	1737	1683	M	8	18.1	20
298	TR	617	490	474	1946	1887	F	4	362	.
298	TR	618	470	455	1677	1624	F	4	191	15
298	TR	619	551	535	2451	2381	M	8	97.8	24
298	TR	620	490	474	2046	1985	F	3	351	16
298	TR	621	484	468	1512	1463	F	4	58	21
298	TR	622	475	460	1713	1659	F	3	237	16
298	TR	623	475	460	1572	1521	M	8	21	16
298	TR	624	480	465	1561	1511	M	8	23.8	16
298	TR	625	516	501	2113	2050	M	8	32.3	16

Appendix 3. (continued).

JDAY	LOC	ID	FRL1	FRL2	WT1	WT2	SEX	MAT	GWT	AGE
298	TR	626	497	482	1769	1714	M	9	25.9	14
298	TR	627	515	500	1926	1867	M	8	21	16
298	TR	628	497	482	1709	1655	M	8	24.7	15
298	TR	629	496	480	1676	1623	F	4	64	16
298	TR	630	480	465	1643	1591	M	8	24.1	16
298	TR	631	488	473	1654	1602	M	8	18.9	16
298	TR	632	480	465	1483	1434	M	8	17.8	16
298	TR	633	497	482	1730	1676	M	8	29.7	16
298	TR	634	470	455	1556	1506	M	9	23	8
298	TR	635	509	494	1855	1798	M	8	35.4	15
298	TR	636	484	468	1471	1423	F	4	59	16
298	TR	637	497	482	1702	1648	M	9	18.1	16
298	TR	638	505	490	2024	1963	M	8	23.4	16
298	TR	639	472	457	1785	1730	M	9	22.1	16
298	TR	640	475	460	1447	1399	M	9	9.9	16
298	TR	641	512	497	1932	1873	M	8	20	16
298	TR	642	469	454	1510	1461	M	8	14.1	16
298	TR	643	456	441	1485	1436	M	8	14.2	16
298	TR	644	476	461	1768	1713	M	9	23.8	16
298	TR	645	509	494	1984	1924	M	8	20.3	20
298	TR	646	507	490	1864	1807	F	4	112	16
298	TR	647	469	454	1416	1369	F	4	42.9	16
298	TR	648	495	479	1420	1373	F	3	226	15
298	TR	649	484	469	1637	1585	M	8	13.2	.
298	TR	650	512	495	1681	1628	F	4	10.4	.
298	TR	651	493	478	1866	1809	M	8	16.9	22
298	TR	652	495	480	1747	1692	M	8	22.1	.
299	TR	654	491	476	1846	1789	M	10	2.6	.
299	TR	655	.	.	.	.	.	.	.	.
299	TR	656	.	.	.	.	.	.	.	.
299	TR	657	484	468	1720	1666	F	4	177.6	16
299	TR	658	472	457	1577	1526	F	5	10.7	
299	TR	659	505	490	1758	1703	M	10	1.6	16

Appendix 3. (continued).

JDAY	LOC	ID	FRL1	FRL2	WT1	WT2	SEX	MAT	GWT	AGE
299	TR	660	470	455	1826	1770	F	4	286.6	21
299	TR	661	456	442	1359	1313	M	10	1.2	15
299	TR	662	490	474	2141	2078	F	4	347.4	16
299	TR	663	471	456	1747	1692	F	3	300.8	19
299	TR	664	507	490	2048	1987	F	3	342.8	16
299	TR	665	460	445	1646	1594	F	3	297.1	.
299	TR	666	481	465	1717	1663	F	4	235	16
299	TR	667	496	480	1938	1879	F	3	309.4	14
299	TR	668	484	468	1571	1520	F	4	53.3	16
299	TR	669	468	453	1518	1469	F	4	243.4	16
299	TR	670	495	480	1810	1754	M	8	16.3	16
299	TR	671	508	491	2043	1982	F	3	363.7	.
299	TR	672	490	475	1920	1862	M	10	2.6	9
299	TL	673	554	538	2727	2650	M	8	41	16
299	TL	674	499	483	1943	1884	F	5	10.3	8
299	TL	675	542	526	2814	2735	M	10	5.7	7
299	TL	676	.	.	246	225	F	1	0.6	3
299	TL	677	278	270	313	291	F	1	0.6	2
299	TL	678	290	281	340	317	F	1	1.2	4
299	TL	679	278	270	295	273	F	1	0.7	4
299	TL	680	160	149	64.	47	M	1	0.1	1
299	TL	681	259	251	246	225	F	1	0.5	3
299	TL	682	271	263	263	242	F	1	0.6	3

Appendix 4. Raw data for fin area (cm^2), caudal fin height (cm), caudal fin width (cm) and caudal fin aspect ratio (cm). Refer to figure 2.1 for an illustration of measurements.

Sample	Sex	LOC	Length	Pectoral	Pelvic	Anal	Dorsal	Caudal	CPD	CDW	AR
1652	F	ARR	46.0	1.764	2.119	1.974	2.339	4.217	11.28	2.43	4.64
1659	F	ARR	50.8	2.454	2.891	1.941	3.103	6.227	13.40	3.14	4.27
1651	F	ARR	47.0	1.996	2.675	1.917	2.782	5.015	12.46	2.80	4.45
2007	F	ARR	47.7	2.267	2.724	2.052	3.590	5.920	16.81	2.85	5.90
1639	F	ARR	48.8	1.718	2.852	2.490	3.228	5.672	14.93	2.47	6.04
2011	F	ARR	44.8	1.700	2.856	1.981	3.185	5.144	13.90	2.40	5.79
2002	F	ARR	47.5	2.046	3.004	2.029	3.071	5.857	14.28	2.83	5.05
2005	F	ARR	44.7	1.577	2.334	1.749	2.419	4.578	11.66	2.77	4.21
1630	F	ARR	42.9	2.334	2.693	2.063	2.869	5.307	12.66	2.85	4.44
1637	F	ARR	48.2	2.434	3.232	3.018	4.065	6.061	14.72	2.74	5.37
1961	F	ARR	47.9	2.366	2.863	2.102	3.660	5.001	13.96	2.84	4.92
1840	F	ARR	49.8	2.864	3.273	3.266	4.078	6.614	16.09	3.08	5.22
1841	F	ARR	48.4	2.582	3.369	2.355	3.577	6.427	16.28	3.03	5.37
1627	F	ARR	46.3	2.264	2.431	1.956	2.554	5.070	13.62	2.67	5.10
1822	F	ARR	47.6	2.441	2.605	1.835	2.762	5.282	13.72	2.72	5.04
1657	F	ARR	48.6	1.601	3.216	2.505	2.753	5.898	13.57	3.13	4.34
1620	F	ARR	51.5	2.128	2.457	2.196	2.967	.	.	.	.
1621	F	ARR	45.6	1.606	2.251	1.708	2.755	.	12.68	2.85	4.45
1623	F	ARR	47.6	2.150	2.514	2.354	3.516	5.694	14.15	2.80	5.05
1996	F	ARR	45.7	2.323	2.601	2.074	2.728	5.144	13.30	2.70	4.93
1635	F	ARR	49.4	.	3.372	2.499	4.025	6.654	13.70	2.88	4.76
1662	M	ARR	47.0	2.791	3.619	2.901	4.110	6.387	15.04	2.77	5.43

Appendix 4. (continued).

Sample	Sex	LOC	Length	Pectoral	Pelvic	Anal	Dorsal	Caudal	CPD	CDW	AR
1645	M	ARR	51.4	2.725	4.132	3.235	3.687	6.270	15.42	3.15	4.90
1663	M	ARR	45.5	2.664	3.220	.	3.840	6.111	14.30	2.98	4.80
1648	M	ARR	43.5	2.237	2.428	2.280	2.447	.	.	.	.
1661	M	ARR	49.1	3.087	3.198	2.760	3.720	6.115	15.04	2.94	5.12
1656	M	ARR	47.4	2.357	3.676	3.014	.	5.669	14.57	3.18	4.58
1641	M	ARR	48.6	3.505	4.380	2.899	4.657	6.752	14.51	3.49	4.16
1642	M	ARR	48.6	3.040	4.366	3.709	4.524	7.273	16.38	3.14	5.22
1660	M	ARR	49.9	3.167	3.604	2.645	2.595	5.909	14.78	2.95	5.01
1644	M	ARR	46.4	2.429	3.055	1.982	3.684	5.971	14.41	3.00	4.80
1643	M	ARR	45.7	2.772	3.218	2.536	3.802	5.173	11.28	.	.
1646	M	ARR	53.2	4.082	4.370	3.498	4.488	6.071	14.45	2.91	4.97
2010	M	ARR	45.7	2.557	3.229	2.800	3.751	5.732	13.58	2.64	5.14
2006	M	ARR	45.2	2.687	3.751	3.070	3.719	.	15.66	2.83	5.53
2004	M	ARR	52.8	2.763	3.411	2.471	4.139	6.267	14.63	2.92	5.01
1828	M	ARR	53.1	3.507	4.732	2.675	.	6.690	17.08	3.35	5.10
2000	M	ARR	46.1	1.926	3.206	2.602	3.808	5.186	8.48	2.68	3.16
2001	M	ARR	50.6	3.036	2.987	2.349	2.985	4.997	14.65	2.63	5.57
1612	M	ARR	51.7	3.290	3.634	2.465	3.992	6.356	15.53	3.05	5.09
1980	M	ARR	49.6	2.571	2.877	2.425	3.904	6.005	13.50	3.15	4.29
2009	M	ARR	49.8	3.810	3.939	2.732	4.127	6.429	14.50	3.25	4.46
1613	M	ARR	49.3	3.502	3.304	2.775	3.639	.	.	.	.
1634	M	ARR	59.3	4.303	4.800	3.706	5.535	7.908	17.80	3.68	4.84
1619	M	ARR	44.3	2.476	2.976	1.753	3.039	5.036	12.20	2.30	5.30

Appendix 4. (continued).

Sample	Sex	LOC	Length	Pectoral	Pelvic	Anal	Dorsal	Caudal	CPD	CDW	AR
1998	M	ARR	48.9	3.204	3.742	2.860	3.385	7.471	15.92	3.12	5.10
1962	M	ARR	49.0	3.217	3.579	2.816	3.609	6.031	15.55	2.59	6.00
2013	M	ARR	52.0	3.709	3.690	3.574	4.379	7.748	16.78	3.18	5.28
1626	M	ARR	47.6	2.954	3.378	2.912	3.576	6.275	14.91	3.19	4.67
1999	M	ARR	54.6	4.533	4.102	3.671	5.370	7.072	17.05	3.20	5.33
1618	M	ARR	44.7	2.326	2.831	2.440	3.368	4.908	13.95	2.64	5.28
1669	M	ARR	52.6	3.717	4.738	3.678	4.354	7.073	17.40	3.30	5.27
2014	M	ARR	48.1	3.039	3.457	2.665	3.314	.	.	.	.
1633	M	ARR	46.4	2.222	3.439	2.469	3.796	.	.	.	.
*1615	M	ARR	.	3.057	3.492	1.818	3.554	5.933	14.85	3.06	4.85
1625	M	ARR	48.5	2.950	3.741	2.599	3.352	5.582	14.24	2.88	4.94
1614	M	ARR	48.4	3.080	3.322	3.479	.	5.887	14.98	3.23	4.64
1631	M	ARR	52.3	3.302	4.253	3.644	4.819	7.480	16.44	3.35	4.91
1617	M	ARR	49.1	2.794	3.750	3.674	4.068	6.392	15.38	2.99	5.14
1632	M	ARR	50.6	3.351	3.120	2.562	3.635	5.960	14.44	2.82	5.12
1629	M	ARR	46.9	2.381	3.321	3.089	3.402	5.524	14.22	2.75	5.17
1654	M	ARR	49.3	2.558	2.995	2.933	4.071	5.591	14.80	3.33	4.44
1624	M	ARR	45.6	2.533	2.854	2.363	3.149	5.129	12.71	2.71	4.69
1622	M	ARR	44.1	2.481	2.633	2.178	3.143	.	.	.	.
1628	M	ARR	52.6	2.811	4.045	3.161	4.154	6.388	15.54	2.99	5.20
A-1850	M	ARR	48.7	2.301	2.391	1.781	2.606	5.484	12.86	3.15	4.08
1638	M	ARR	53.4	3.479	4.005	3.012	4.135	6.516	15.08	3.27	4.61
1640	M	ARR	43.4	2.538	2.744	2.082	2.895	5.432	14.65	2.74	5.35

Appendix 4. (continued).

Sample	Sex	LOC	Length	Pectoral	Pelvic	Anal	Dorsal	Caudal	CPD	CDW	AR
1616	M	ARR	54.4	3.873	4.213	3.167	4.508	6.885	15.24	3.49	4.37
1649	M	ARR	48.4	2.975	3.489	2.624	3.919	6.375	15.10	3.30	4.58
1658	M	ARR	51.5	3.317	4.548	3.389	4.695	6.590	15.63	3.09	5.06
*1615	M	ARR	.	1.966	2.813	2.422	3.177	5.549	15.33	2.70	5.68
1647	M	ARR	52.0	3.095	4.526	3.368	3.952	6.796	16.26	3.59	4.53
1653	M	ARR	43.8	2.303	3.072	2.556	3.141	4.720	12.29	2.60	4.73
1655	M	ARR	50.9	3.473	3.717	2.891	3.968	5.693	13.73	2.55	5.38
1835	M	ARR	47.6	2.881	3.183	2.256	3.637	5.570	13.80	3.10	4.45
1650	M	ARR	49.7	3.750	3.681	3.735	4.544	6.339	15.23	3.05	4.99
2008	M	ARR	47.1	2.999	3.644	2.230	4.210	5.114	13.56	2.75	4.93
646	F	TRAV	49.0	2.042	2.740	1.809	2.837	.	.	.	.
*588	F	TRAV	.	2.169	2.735	2.340	3.233	5.326	12.32	2.96	4.16
665	F	TRAV	44.5	2.154	2.364	1.877	2.601	4.698	13.13	2.30	5.71
657	F	TRAV	46.8	2.082	2.764	2.148	2.907	4.952	11.83	2.85	4.15
671	F	TRAV	49.1	2.370	2.295	2.097	3.012	5.523	12.10	3.29	3.68
667	F	TRAV	48.0	2.260	2.663	1.787	2.650	4.931	12.75	3.19	4.00
658	F	TRAV	45.7	1.918	.	1.875	.	5.330	11.98	2.81	4.26
668	F	TRAV	46.8	2.157	2.632	1.413	2.773	4.592	12.85	2.98	4.31
614	F	TRAV	47.3	2.106	2.244	1.741	2.499	4.936	13.21	2.80	4.72
578	F	TRAV	43.4	2.136	2.365	2.088	.	4.860	11.35	2.96	3.83
606	F	TRAV	47.1	2.218	2.952	1.978	3.215	5.079	11.96	2.64	4.53
587	F	TRAV	51.3	2.513	2.680	2.845	3.584	6.700	16.26	2.83	5.75
594	F	TRAV	44.6	1.759	2.550	2.031	3.181	4.807	11.25	3.15	3.57

Appendix 4. (continued).

Sample	Sex	LOC	Length	Pectoral	Pelvic	Anal	Dorsal	Caudal	CPD	CDW	AR
584	F	TRAV	45.3	2.253	2.523	1.888	2.595	4.526	10.10	2.84	3.56
394	F	TRAV	51.1	2.000	2.209	2.319	2.672	5.296	11.38	2.80	4.06
611	F	TRAV	45.6	2.396	2.675	1.775	2.710	.	.	.	.
598	F	TRAV	50.4	2.330	2.629	2.410	2.739	5.665	12.78	3.26	3.92
580	F	TRAV	46.9	2.732	2.968	2.299	3.246	5.674	13.93	3.13	4.45
603	F	TRAV	51.8	2.870	3.406	3.109	3.754	6.154	13.07	3.19	4.10
*147	F	TRAV	.	2.250	3.302	1.848	2.742	5.860	11.98	3.34	3.59
621	F	TRAV	46.8	2.035	2.274	1.378	2.187	4.232	12.10	2.30	5.26
*147	F	TRAV	.	2.190	.	1.642	2.091	.	.	.	.
576	F	TRAV	46.8	1.727	1.881	1.584	2.598	4.260	11.88	2.50	4.75
591	F	TRAV	47.0	2.248	2.493	1.763	2.761	4.462	11.87	2.75	4.32
669	F	TRAV	45.3	2.015	2.383	1.425	2.435	.	.	.	.
620	F	TRAV	47.4	2.349	2.606	2.126	3.047	5.262	12.89	2.83	4.55
636	F	TRAV	46.8	1.780	2.645	2.071	2.598	5.104	11.50	3.05	3.77
618	F	TRAV	45.5	2.193	2.751	2.118	2.711	5.334	13.20	3.13	4.22
590	F	TRAV	47.2	2.501	2.718	2.069	3.017	.	.	.	.
*588	F	TRAV	.	2.035	2.292	1.995	2.987	5.205	.	.	.
666	F	TRAV	46.5	2.129	2.230	1.752	2.473	4.816	12.68	2.43	5.22
663	F	TRAV	45.6	2.249	1.928	.	.	5.595	13.94	3.14	4.44
664	F	TRAV	49.0	2.144	2.310	2.075	2.988	4.594	13.00	2.88	4.51
605	M	TRAV	48.7	3.038	3.370	2.529	3.328	5.627	13.25	3.07	4.32
630	M	TRAV	46.5	2.544	3.472	2.191	.	5.005	12.27	3.01	4.08
172	M	TRAV	42.5	1.498	1.776	1.173	1.637	.	.	.	.

Appendix 4. (continued).

Sample	Sex	LOC	Length	Pectoral	Pelvic	Anal	Dorsal	Caudal	CPD	CDW	AR
632	M	TRAV	46.5	3.058	3.156	.	2.892	4.745	11.24	2.76	4.07
599	M	TRAV	50.0	4.153	4.214	2.909	3.526	6.147	14.84	3.29	4.51
672	M	TRAV	47.5	2.257	2.935	2.644	3.962	6.024	13.71	2.98	4.60
670	M	TRAV	48.0	3.343	3.588	2.602	3.935	6.006	13.85	3.29	4.21
582	M	TRAV	48.5	2.815	3.644	2.793	.	6.395	14.03	3.05	4.60
627	M	TRAV	50.0	4.002	3.591	2.649	.	5.404	13.40	3.20	4.19
659	M	TRAV	49.0	2.255	2.453	2.145	3.053	5.234	12.78	2.78	4.60
602	M	TRAV	47.6	2.979	.	.	.	5.583	14.60	3.22	4.53
604	M	TRAV	47.5	3.648	4.291	2.397	4.015	6.947	14.08	3.37	4.18
572	M	TRAV	47.0	3.239	3.492	2.159	3.324	5.742	13.00	3.11	4.18
610	M	TRAV	46.5	3.224	3.878	2.786	3.148	6.912	15.00	3.54	4.24
601	M	TRAV	.	3.517	3.781	2.097	.	5.903	13.65	3.35	4.07
581	M	TRAV	45.5	3.171	3.805	2.903	3.965	5.682	13.75	2.75	5.00
573	M	TRAV	45.7	3.214	3.224	2.364	3.333	4.929	15.30	2.87	5.33
608	M	TRAV	50.5	3.630	4.202	3.429	4.281	7.261	15.55	3.40	4.57
585	M	TRAV	51.0	4.150	3.834	3.268	4.347	7.592	15.01	3.78	3.97
593	M	TRAV	47.3	3.133	3.377	2.503	3.474	4.997	10.96	3.39	3.23
631	M	TRAV	47.3	4.369	3.483	3.106	3.327	5.424	12.72	3.67	3.47
619	M	TRAV	53.5	4.591	3.553	3.189	4.554	7.006	13.27	3.40	3.90
612	M	TRAV	49.4	3.830	3.669	2.935	3.415	6.431	14.17	3.46	4.10
642	M	TRAV	45.4	3.097	3.724	2.437	3.221	5.278	14.00	3.03	4.62
365	M	TRAV	51.0	2.236	3.130	1.970	2.276	5.053	9.46	3.41	2.77
364	M	TRAV	48.5	2.378	2.279	2.020	2.677	4.348	8.82	2.94	3.00

Appendix 4. (continued).

Sample	Sex	LOC	Length	Pectoral	Pelvic	Anal	Dorsal	Caudal	CPD	CDW	AR
625	M	TRAV	50.1	3.265	3.922	3.060	4.285	6.487	15.03	3.62	4.15
661	M	TRAV	44.2	1.608	.	1.902	3.188	4.535	11.95	2.82	4.24
592	M	TRAV	48.5	3.573	3.556	3.020	3.931	5.727	12.87	3.55	3.63
607	M	TRAV	50.7	4.066	4.570	3.319	4.235	6.883	16.41	3.55	4.62
616	M	TRAV	47.8	3.204	4.078	2.993	3.243	5.083	10.55	3.59	2.94
583	M	TRAV	42.7	2.668	2.538	2.134	1.999	.	.	.	.

Appendix 5. Raw fecundity data for Mackenzie and Travaillant female broad whitefish. Length (cm) and age (years) of each fish is also given.

Location	Sample	Fecundity	Length	Age
MACK	1822	45229	476	14
MACK	1840	41188	498	16
MACK	1637	35870	482	9
MACK	1639	61321	488	6
MACK	1636	35920	487	14
MACK	1621	27159	456	18
MACK	1635	59860	494	7
MACK	1651	26293	470	12
MACK	1652	18375	460	14
MACK	1623	30204	473	9
MACK	795	69007	485	7
MACK	1145	27492	452	7
MACK	979	62436	512	.
MACK	987	45416	475	14
MACK	1239	57600	495	14
MACK	936	53752	492	10
MACK	1068	53063	499	10
MACK	1504	46505	477	10
TRAV	671	38048	491	.
TRAV	586	35613	479	16
TRAV	665	30311	445	16
TRAV	609	28110	470	16
TRAV	591	25712	470	16
TRAV	603	51333	518	15
TRAV	598	25954	504	16
TRAV	580	13823	469	14
TRAV	669	25232	453	16
TRAV	622	23535	460	16
TRAV	648	24340	479	15
TRAV	606	22079	471	14
TRAV	620	28649	474	16
TRAV	597	25449	452	14
TRAV	664	29519	490	16
TRAV	663	27405	456	19