LIFE HISTORY, MORPHOMETRIC AND HABITAT USE VARIATION IN ARCTIC CHARR (*Salvelinus alpinus*) POPULATIONS OF SOUTHERN BAFFIN ISLAND, NUNAVUT, CANADA.

BY

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A Thesis submitted to the Faculty of Graduate Studies

of the University of Manitoba

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FACULTY OF GRADUATE STUDIES

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ABSTRACT

Arctic charr (*Salvelinus alpinus*) are known to be phenotypically plastic throughout their range and exist as land-locked, lake-resident and migrant morphotypes. The focus of my study was to compare two morphs of charr (initially classified as small- and large-mature) that co-exist seasonally in three open lake systems of Baffin Island, Nunavut, Canada. Specifically I identified differences between the two morphotypes within each lake studied via morphological comparisons and habitat use (Chapter 2) and life history characters (Chapter 3). Results indicate that maximum otolith Sr level and the range of otolith Sr are statistically significant in lakes LH001 and PG082 between small-maturing and large-maturing groups. No statistical significance was observed for the maximum otolith Sr level and the range of otolith Sr in lake PG015. A component of each charr population within lakes LH001 and PG082 is migratory (large-maturing charr) whereas another component is lake-resident (small-maturing charr). In lake PG015 there is evidence to suggest that small-mature charr are utilising inter-tidal habitats. Four morphological characters were identified as different in lakes LH001 and PG082 between small-maturing and undeveloped groups (immature and small resting individuals): eye diameter, pectoral fin length, pelvic fin length and upper jaw length. Four morphological characters were identified as different in lake PG015: eye diameter, pectoral fin length, pelvic fin length and fork depth. Univariate tests of the morphological characters showed statistically significant differences between the maturity types with the exception of eye diameter in lake PG015 and upper jaw length and pelvic fin in lake LH001. The clear morphological variation observed between small-maturing and undeveloped fish in all three lakes of the study suggests ecological niche specialisation. Within all 3 lakes

studied small-mature charr appear to have body form and structural characteristics that suggest lake-residency whereas large-mature charr have body form and structural characters that suggest anadromy. The lake-resident charr had larger fin lengths which are functionally better for manoeuvring in complex habitats (i.e. darting between rocks). The anadromous charr had short fin lengths which are functionally better for swimming long distances. Life history characters were variable amongst the two morphs further referred to as lake-resident and anadromous morphs. Anadromous charr within all lakes of the study had a mean size at maturity that ranged from 532 mm to 641mm and mean age of maturity that ranged from 10 to 13 years. In comparison, lake-resident charr had a mean size that ranged from 184 mm to 202 mm and a mean age at maturity that ranged from 8 to 9 years. The relationship between body size and fecundity or egg diameter did not differ between the two morphs. The von Bertalanffy growth model indicated that overall growth of both lake-resident and anadromous charr was significantly different in all three lakes studied. Specifically, lake-resident charr initially had growth rates that were double that of anadromous charr. The results of our study parallel what is observed in general salmonid life histories but differ from some current European studies of Arctic charr growth. These studies suggest that juvenile stage lake-resident charr growth is slow and juvenile stage migrant charr growth is fast.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1. GENERAL INTRODUCTION

Arctic charr (*Salvelinus alpinus*) are the northern most freshwater fish to inhabit circumpolar, sub-polar, boreal and temperate climate regions of the Holarctic (Klemetsen et al. 2003; Scott and Crossman 1973). Charr inhabit oligotrophic and ultraoligotrophic alpine lake systems that are species poor. Often charr are the only fish species that exist within these lake systems (Klemetsen et al. 2003; Scott and Crossman 1973). Multiple morphologies of charr have repeatedly been identified in lake systems globally. Morphotypes most often identified in lake systems with rivers accessing the marine environment (open-lake systems) are anadromous and lake-resident or "dwarf" charr (Jonsson and Hindar 1982; Rikardsen et al. 2000; Strand and Heggerget 1994). In lake systems with no river access to the marine environment (closed lake systems) benthivorous charr, planktivorous charr, and picivorous charr are often identified. Specifically Adams and Huntingford (2002), and Adams et al. (1998, 2007) have identified three morphotypes of charr (benthivorous, planktivorous and picivorous) within Loch Rannoch, Scotland. Alekseyev et al. (2002), Samusenok et al. (2006) and Savvaitova's (1995) studies of Russian charr have also identified three analogous morphs. Riget et al.'s (1986, 2004) studies of Lake Tasersuaq, Greenland found similar morphs of charr. Knudsen et al.'s (2007) identified benthivorous and planktivorous morphs of charr in the lake Fjellfrøsvatn, Norway. Icelandic studies of charr have identified 4 morphs (large and small benthivorous, planktivorous and picivorous charr) within Thingvallavatn (Sandlund et al. 1987; Skúlason et al. 1993; Sigursteinsdóttir and Kristjánsson 2005).

Historically, the complexity in charr morphology has sometimes led to the delineation of multiple species or sub-species instead of one for each of the different morphs (Adams and Maitland 2007; DeLacy and Morton 1943; Jonsson and Jonsson 2001; Savvaitova 1995; Scott and Crossman 1973). This problem was termed the "Arctic charr species complex". Presently it is believed that all morphotypes of charr are of the same species although genetic divergence has been found within many charr populations (Adams et al. 2007; Gíslason et al. 1999; Magnusson and Ferguson 1987; Skúlason et al. 1996). Currently discussion of the charr literature focuses on the evolutionary advantage of "semi-speciation" as a way to maximise fitness for individual charr populations (Klemetsen et al. 2003; Parker et al. 2001; Savvaitova 1995). Phenotypic plasticity that is evident in charr populations is thought to have evolved as a method for colonising and adapting in unpredictable and harsh climates (Parker et al. 2001).

Charr populations can either experience inter-breeding amongst various morphs or experience some form of reproductive isolation. Reproductive isolation generally exists between different (land-locked) morphs within some charr stocks. Aass et al. (2004) and Jonsson and Hindar (1982) and Telnes and Sægrov's (2004) studies on Norwegian charr in closed lake systems demonstrate that spawning of the two morphs occurred at different depths. Elliot and Baroudy's (1992, 1995) studies of Windmere Lake (England) charr suggest reproductive isolation for all three morphs with one morph spawning in the spring. Adams et al.'s (1998, 2007) studies on Scottish charr suggest reproductive isolation between at least two morphs of charr. Sandlund et al. (1987) and Gílason et al. (1999) suggest reproductive isolation in Thingvallavatn and Lake Galtabóĺt (Iceland) charr.

Incomplete assortative mating occurs between morphs that exist within open or closed lake systems. Jonsson and Jonsson (1993) and Svedäng (1992) have both documented spawning between different morphs of Norwegian charr. Common garden experiments of Norwegian and Canadian charr have also demonstrated that one morphotype of charr can reproduce offspring like itself as well as offspring of other morphs (Nordeng 1983; Papst 1994). Further it has also been shown that in some charr populations one morph of charr can switch into another morph upon reaching a larger body size (Nordeng 1983; Riget et al. 1986; Savvaitova 1995; Strand and Heggberget 1994).

Multiple morphotypes of charr that co-exist within land-locked lakes and open-water systems tend to be extreme habitat or resource specialists and exist as different eco-types as a result (Jonsson and Jonsson 2001; Klemetsen et al. 2003). Each morph will often inhabit a specialised niche within a lake system and this specialisation has lead to variation in physical and meristic characteristics as well as life-history characters (Adams and Huntingford 2002; Adams et al. 1998; Hindar and Jonsson 1982; Klemetsen et al. 2003; Skúlason et al. 1996). Morphological variation and associated life history variation has been shown to have a combination of both genetic and environmental basis. Adams and Huntingford (2002) and Alexander and Adams (2004) found that head allometry in Loch Rannoch, Scotland was genetic but also had an environmental basis. DeMarch (1995) and Papst's (1994) studies of Fraser River, Labrador (Canada) charr suggest a genetic basis for growth of the morphs expressed. Similarly Skúlason et al. (1996) found a genetic basis for morphs grown in a common environment. Forseth et al. (1995) suggests a genetic basis for age at maturity in charr from Lake Høysjøen, Norway.

Phenotypic expression of niche specialisation has resulted in characteristic differences between morphs that are commonly observed throughout the range of distribution of Arctic charr. For example large and small benthivorous charr tend to have sub-terminal mouths, live at deeper depths and feed on bottom dwelling invertebrates; whereas planktivorous and picivorous charr tend to have terminal mouths, live in the upper part of the water column and feed upon pelagic plankton and fish (respectively) (Adams and Huntingford 2002; Adams et al. 1998; Alekseyev et al. 2002; Jonsson and Jonsson 2001; Sandlund et al. 1987; Skúlason et al. 1996). Age-at-first maturity also tends to vary amongst different morphologies of charr. For example lake-resident charr tend to mature early in life and have a small body size at maturation whereas anadromous charr tend to delay maturation and attain a large body size at maturation (Björklund et al. 2003; Klemetsen et al. 2003; Rikardsen et al. 2000; Tallman et al. 1994).

In an open lake system, the anadromous sub-component of the charr population migrate into the marine environment, feed for approximately 35-50 days at sea and migrate back into freshwater annually to over-winter and/or spawn (Bégout Anras et al. 1999; Dutil 1986; Klemetsen et al. 2003). Charr are generally known to migrate out into the marine environment at a size of 9-13 cm and 1-8 years of age but this can vary greatly among charr populations (Dempson and Green 1985; Klemetsen et al. 2003; Radtke et al. 1998). Further, charr through laboratory experiments have been shown to tolerate estuary type seawater conditions (10-20$^{0}/_{00}$) at a body size of < 12 cm (Dempson 1993; Jonsson and Atonsson 2005). In resting or non-spawning years, charr especially within the Hudson's Bay region and Cambridge Bay regions of Canada have shown low fidelity for purpose of over-wintering (Kristofferson 2002).

Charr tend to exhibit great homing tendencies for spawning in natal lake systems (Klemetsen et al 2003; Kristofferson 2002; Nordeng and Bratland 2006). Charr are iteroparous but often experience resting periods between spawning events (2-4 years but varies due to regional ecosystem productivity) (Dutil 1986; Klemetsen et al. 2003). Spawning in charr generally occurs in the fall ranging anywhere from mid-September to late-November depending on environmental and climatic conditions of the region (Dempson and Green 1985; Klemetsen et al. 2003; Scott and Crossman 1973). In some cases where multiple land-locked morphs of charr co-exist and reproductive isolation is exhibited one morph will spawn at a greater depth and experience a delay in reproduction timing (Elliot and Baroudy 1995; Sandlund et al. 1987; Telnes and Sægrov 2004). In some cases the delay in timing results in a complete seasonal shift for spawning by benthivorous morph from fall to winter or spring time (Elliot and Baroudy 1995; Sandlund et al. 1987; Telnes and Sægrov 2004).

Arctic charr within Canada are most predominantly distributed within Northwest Territories, Nunavut, Nunavik, Labrador and northern Manitoba (Hudson Bay region) (Scott and Crossman 1973). Small relic populations of charr exist in southern Quebec, New Brunswick and Newfoundland (Scott and Crossman 1973). Land-locked studies of charr have demonstrated that up to three morphotypes of charr (benthivorous, planktivorous and picivorous) can exist within lakes of the Hudson Bay region (Parker and Johnson 1991). Two morphs (picivorous and lake-resident) of charr are known to exist within Lake Hazen, Ellesmere Island (Reist et al. 1995).

Anadromous charr within Canada are studied at a higher rate than other morphs since they have economic value and are harvested for subsistence by local Inuit communities. Much has been learned about anadromous charr through the Nauyuk Lake (Canada) study where it was found that spawners sometimes forego migration out to sea in the same year that they spawn (Dutil 1986). Dutil's (1986) study of Nauyuk Lake also advanced our knowledge of anadromous charr energetics and its relation to resting periods between spawning events. Kristofferson's (2002) study of Cambridge Bay region anadromous charr demonstrated spawning stock differentiation between various lake systems in the region and showed that non-spawners strayed in over-wintering years. He also found that long river length resulted in spawning females foregoing seaward migration in years when spawning occurred. Shorter river length resulted in spawning females migrating out to sea to feed in the same year when spawning occurred. Dempson (1993, 1995), Dempson and Green's (1985) and Dempson et al.'s (2002, 2007) studies of anadromous charr have provided information regarding salinity tolerance, genetics, morphometrics, life history and diet of charr within the Labrador coast region. Studies from the early 50's and the 70's on anadromous Arctic charr from Cumberland Sound and Frobisher Bay provide basic information on life history and diet (Grainger 1952; Moore 1975a; Moore 1975b; Moore and Moore 1974). Sprules (1952) reported the existence of both lake-resident and anadromous charr in his studies of various lakes in the Hudson Bay region. Babaluk et al. (2002) found both lake-resident and anadromous charr within Heintzelman Lake on Ellesmere Island.

Few of the Canadian studies highlighted above discuss the lake-resident sub-component of charr populations. Scientists or technical staff involved in many of these studies (1980's to the present) have verified the existence of the lake-resident morphotype within each of their respective studied populations even though it is not reported within the primary literature (A. Kristofferson, pers. comm.). My study has focused on this research gap by examining variation between two morphs of charr that co-exist seasonally within open lake systems of Southern Baffin Island Canada. In chapter two, I identify habitat use and morphological variation of small-maturing charr in comparison to undeveloped charr (juvenile and small bodied resting individuals) of a similar size (morphological analysis) and large-maturing charr (habitat use analysis). Habitat identification (via otolith strontium) is employed to determine differences in habitat use between the small- and large-maturing morphs of charr. I quantify morphological characters observed between each of the forms. Further I relate the significant morphological characters to fish behaviour and habitat use and determine their ecological significance. Within the third chapter of my thesis I examine variation between life history characters of the small- and large-maturing morphs of charr. Specifically I examine growth variation, fecundity, egg diameter and age at maturation between the morphs. I then relate the life history analysis back to the available literature on general life history theory and specifically to published studies on European Arctic charr and other related species.

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CHAPTER 2. Intra-population ecological niche specialisation inferred from morphological variation and otolith strontium of Arctic charr (*Salvelinus alpinus*) found within open lake systems of southern Baffin Island, Nunavut, Canada.

ABSTRACT

Two morphotypes of arctic charr are thought to exist within in three open lake systems of Southern Baffin Island, Nunavut Canada: Qinngu (LH001), Iqalugaarjuit Lake (PG082) and Qasigiat (PG015). The purpose of my study was to verify the existence of these morphotypes and to relate this variation to habitat use. For the purpose of statistical analyses, fish were initially classified on the basis of body size and degree of maturation into three groups: large charr (>400 mm) in reproductive condition (large-mature), small charr (<400 mm) in reproductive condition (small-mature) and small charr (<400 mm) in resting or immature condition (undeveloped) groups. Strontium (Sr) composition of the otolith via electron microprobe analysis was analyzed to determine if habitat use varied between large-maturing and small-maturing groups. Principal factor analysis (PFA) and univariate tests were used to determine differences in morphological characters between small-mature and undeveloped groups. Multivariate analysis of variance (MANOVA) test of max Sr and range of Sr showed differences in habitat use for lakes LH001 and PG082. No differences were observed between morphotypes for max Sr and range of Sr in lake PG015. Three morphological characters were identified by PFA as characters that were different between maturity groups for all lakes studied: eye diameter, pectoral fin length, pelvic fin length. As well, upper jaw length (LH001 and PG082) and fork depth (PG015) were identified in PFA as traits that differed

between morphs. Univariate tests of morphological characters identified by PFA demonstrated maturity group differences with the exception of eye diameter in lake PG015 and upper jaw length and pelvic fin length in lake LH001. No difference was found in the MANOVA test of upper and lower gill raker number between small-maturing and undeveloped fish within all lakes studied. A component of each charr population within lakes LH001 and PG082 is migratory (large-maturing charr) whereas another component is lake-resident (small-maturing charr). In lake PG015 it appears that small- and large-maturing charr may both inhabit tidal habitats during their life time. The clear morphological variation is observed between small-maturing and undeveloped fish in all three lakes of the study suggests ecological niche separation between morphotypes.

INTRODUCTION

Morphology as applied to fisheries research is defined as the study of body shape and form or physical structure of fish (Rohlf 1990). Morphological variation between fish stocks or between groups within a stock has been shown to be a combination of both phenotypic adaptation to a specialised ecological niche and early life-history constraints (Lecomte and Dodson 2004; Robinson and Parsons 2002). Specialised ecological niches are related to the separation or partial separation of groups of individuals within a lake system in terms of habitat and diet (Jonsson and Jonsson 2001; Snorrason et al. 1994). In some cases where anadromous and lake-resident individuals co-exist, separation of habitat is related to migration out of the lake system into the marine environment. This separation within a population may lead to reproductive isolation depending on the long term stability of the environmental conditions and geology of the region (Elliott and Baroudy 1995; Gíslason et al. 1999; Hindar and Jonsson 1982; Telnes and Sægrov 2004).

Arctic charr (*Salvelinus alpinus*) are known to show great morphological variation within and between populations throughout the species' distribution. Arctic charr are known to exist as lake-residents, migratory and land-locked forms (Jonsson and Jonsson 2001; Klemetsen et al. 2003; Savvaitova 1995). Land-locked refers to the lack of accessibility of migration corridors to marine environments due to the geology of the lake basin. Lake-resident refers to individual fish that choose to remain within freshwater systems throughout their lifetime even though they have access to the marine environment.

Up to four different morphs of charr have been known to co-exist within the same land-locked lake system. Each morph has differences in body size and shape that have been adapted to utilise a specialised habitat within the lake system (Jonsson and Jonsson 2001; Klemesten et al. 2003). For example, four different morphs of land-locked charr known to co-exist within some Icelandic lake systems are small and large benthivorous morphs, piscivorous morph, and planktivorous morph (Sandlund et al. 1987; Skúlason et al. 1996). Benthivorous morphs have a sub-terminal mouth whereas planktivorous and piscivorous forms have a terminal mouth (Malmquist 1992; Sandlund et al. 1987). This phenotypic diversity has been repeatedly documented within other European and Russian studies of charr. Studies of land-locked charr in Loch Rannoch and Loch Tay, Scotland have documented morphological variation between benthivorous, planktivorous and picivorous morphs of charr (Adams and Huntingford 2002; Adams et al. 1998; Adams et al. 2003; Adams et al. 2007). Similarly Alekseyev et al. (2002) and Samusenok et al.

(1996) have documented picivorous and planktivorous morphs of charr within high altitude lakes and Transbaikalia lakes of Russia. Variation between lake-resident or "dwarf" charr and anadromous or "normal" charr has been well documented in many European lakes with passage to the sea (Klemetsen et al. 1997; Nordeng 1983; Rikardsen and Elliott 2000).

Within Canadian systems few studies have documented morphological variation in charr. Reist et al. (1995) and Parker and Johnson (1991) have documented land-locked morphological "ecotypes" of charr within the Canadian High Arctic regions. Parker and Johnson (1991) have identified three morphs of charr within each of the lake systems of the respective studies: benthivorous, planktivorous and piscivorous. Reist et al. (1995) have identified two morphs of charr within Lake Hazen, Ellesmere Island: planktivorous and piscivorous morphs. No studies of charr within the Canadian Arctic have examined the morphological variation between lake-resident and anadromous individuals that seasonally co-exist in open lake-systems.

The objective of this study is to examine the morphological variation and identify the habitat use of two morphologies of charr within the Southern Baffin Island region of the Canadian Arctic. I hypothesize that the small-maturing morph of charr is lake-resident and the large-maturing morph of charr is anadromous. Further I expect that the small-maturing morph will have developed physical character traits that suggest lake-residency in comparison to undeveloped fish (immature and small resting fish) of a similar size within each lake system.

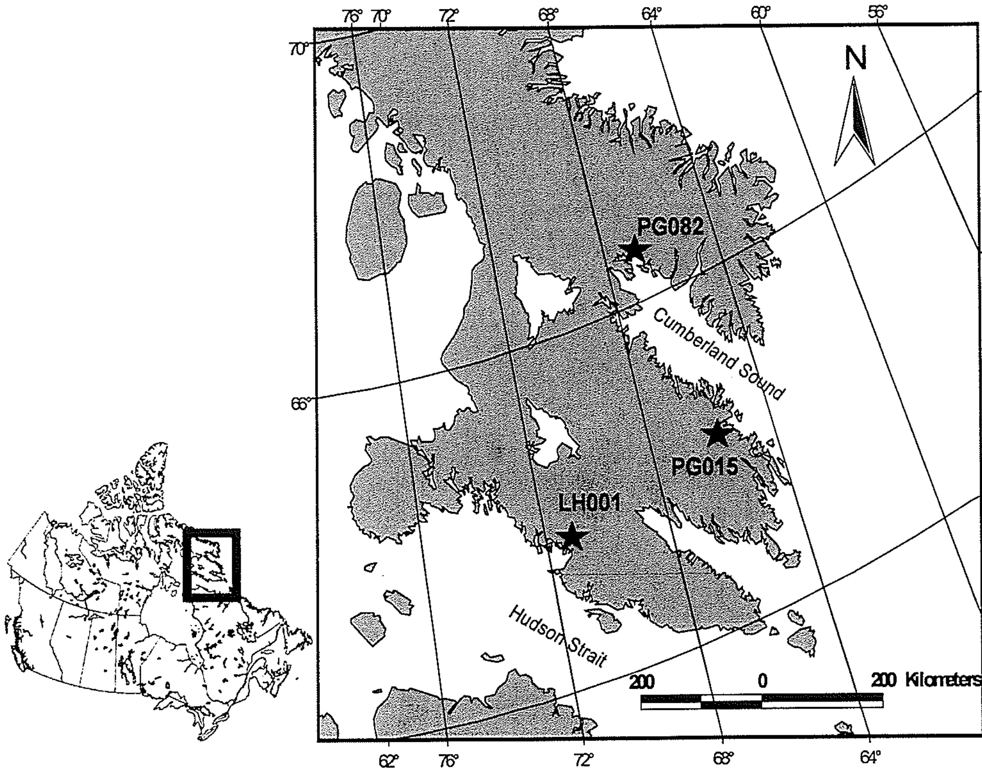
METHODS

Study Area & Field Collection Methods

Three small Arctic lake systems were the focus of Arctic charr data collection in the Southern Baffin Island region: Iqalugaarjuit Lake (PG082), Shark Fiord, Nunavut (66^0 34.364'N, 66^0 42.809'W), Qasigiat (PG015), Ptarmigan Fiord, Nunavut (64^0 37.657'N, 66^0 18.670'W), and Qinngu (LH001), Blandford Bay, Nunavut (63^0 31.418'N, 71^0 17.665'W) (Fig. 1.1). Water body codes listed above were assigned to each lake by Fisheries and Oceans, Canada and will be used as abbreviations in subsequent discussion and analysis. No previous limnological or geological studies have been undertaken in the three lake systems of the study and thus detailed information regarding each lake system is not known. Due to limited resources and time we were not able to collect this information ourselves. The only other fish species observed within all three lakes of the study was the threespine stickleback (*Gasterosteus aculeatus*). The geology of the Southern Baffin region is characterized by that of Precambrian granite and Ordovician sedimentary rocks overlaid by glacial, glaciofluvial and marine sediment deposits (Hamilton et al. 2001; Scott et al. 2002). The general regions of study are known to have large deposits of clastic (i.e. sandstone) and carbonate (i.e. limestone, dolomite, marble) rock formations (Hamilton et al. 2001; St-Onge et al. 2000).

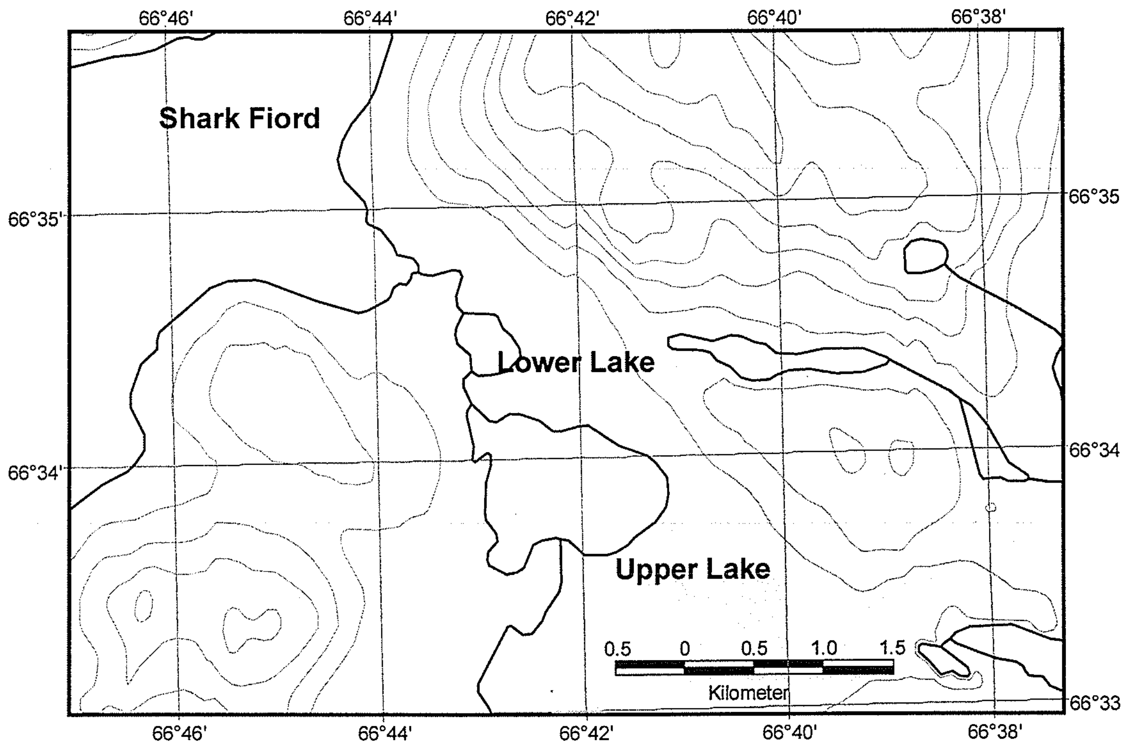
PG082 is a two basin lake with a short river joining the upper and lower lake (0.3 km in length) (Fig. 1.2). The river joining the two lakes is a shallow stream flowing over a boulder field with many outcropping ponds. The upper lake is shallow (1-2 m in depth) whereas the lower lake has deeper (approximately 15-20 m) regions and sloped edge habitat. The surface area and perimeter of the lower lake is 0.15 km^2 and 1.5 km

Fig. 1.1. The map of Canada is shown to highlight the study region of Southern Baffin Island, Nunavut. Within Southern Baffin Island, each study lake is represented by a star: Iqalugaarjuit Lake, Shark Fiord, NU (PG082); Qasigiat, Ptarmigan Fiord, NU (PG015) and Qinngu, Blandford Bay, NU (LH001). Both river systems of Iqalugaarjuit Lake and Qasigiat drain into Cumberland Sound. Qinngu drains into Hudson Strait.



PG082
Cumberland Sound
PG015
LH001
Hudson Strait
N
200
0
200 Kilometers

Fig. 1.2. The map of Iqalugaarjuit Lake, Shark Fiord, NU (PG082) showing the lower and upper lake basins. Fish were only captured for the purpose of this study in the lower basin due to logistical reasons.


66°46'
66°44'
66°42'
66°40'
66°38'
Shark Fiord
66°35'
66°35
Lower Lake
66°34'
66°34
Upper Lake
0.5 0 0.5 1.0 1.5
Kilometer
66°33
66°46'
66°44'
66°42'
66°40'
66°38'

respectively and the surface area and perimeter of the upper lake are 1.11 km^2 and 4.92 km respectively. The river joining the lower lake to the marine environment is approximately 0.64 km in length at low tide with a change of elevation of approximately 2-3 m. Maximum high tide in the region generally ranges from 4.3 m to 6.6 m (in reference to chart datum) in Cumberland Sound (Canadian Hydrologic Service 2008). Chart datum refers to the vertical reference point which is usually measured as mean water level within the region. Specific criteria for deciding upon chart datum are found on the Canadian Hydrologic Service website (2008).

PG015 is a fiord lake that is extremely close to the marine environment (Fig. 1.3). The lake is characterized by its deep regions (> 21 m) and has few shallow ponds attached to the lake system. Further, PG015 has reduced littoral edge habitat and tends to have more fiord like features (lake edges are steep). The surface area and perimeter of the lake is 1.2 km^2 and 4.5 km respectively. PG015 has two rivers flowing out to the marine environment which are approximately 0.11 km and 0.39 km in length at low tide. Similar to PG082, PG015 may experience maximum high tide in the range of 4.3 m to 6.6 m (in reference to chart datum) (Canadian Hydrologic Service 2008). The elevation change of the river to the ocean is approximately 2-3 m.

LH001 is a two basin lake with an expansive shallow region (at maximum 1 m in depth) joining the upper and lower lake that is 0.53 km in length (Fig. 1.4). The upper lake has not been investigated and little is known about its physical characteristics such as depth. The surface area and perimeter of the lower lake is 0.35 km^2 and 3.5 km respectively. The surface area and perimeter of the upper lake is 5.6 km^2 and 20 km

Fig. 1.3. The map of Qasigiat, Ptarmigan Fiord, NU (PG015) showing the lake basin and its close proximity to the marine environment.

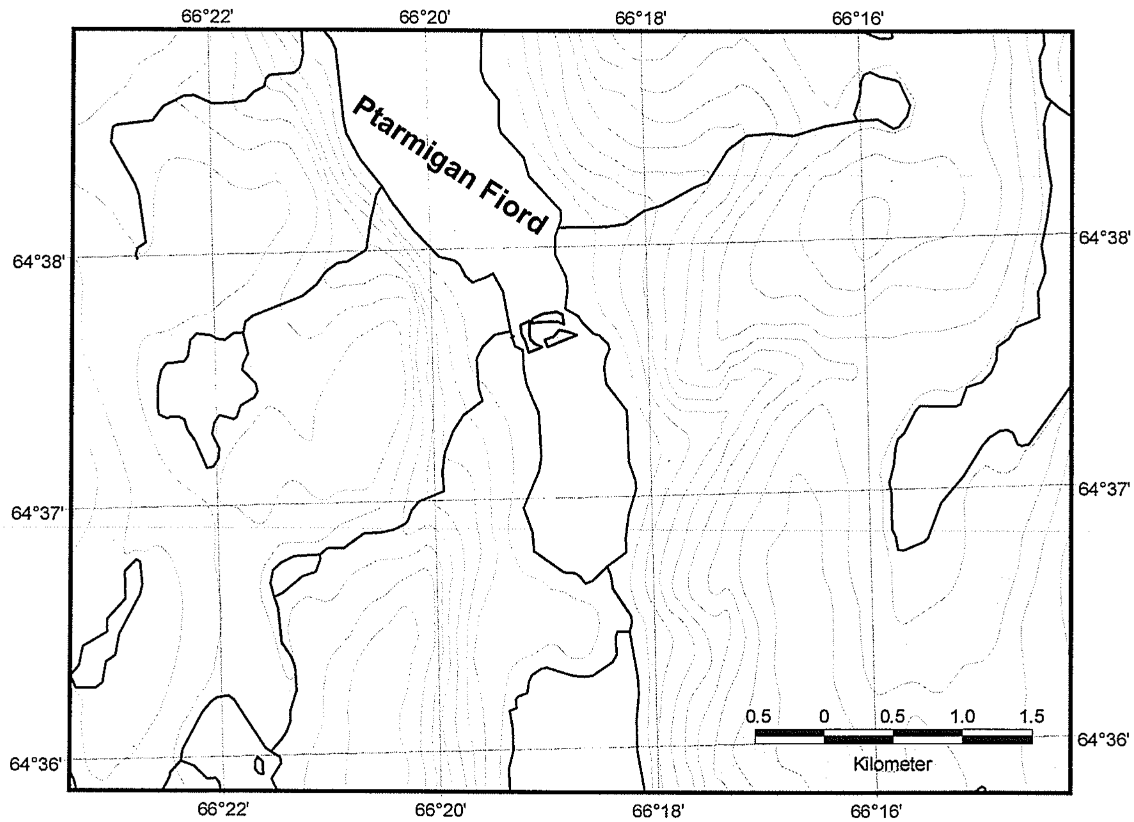
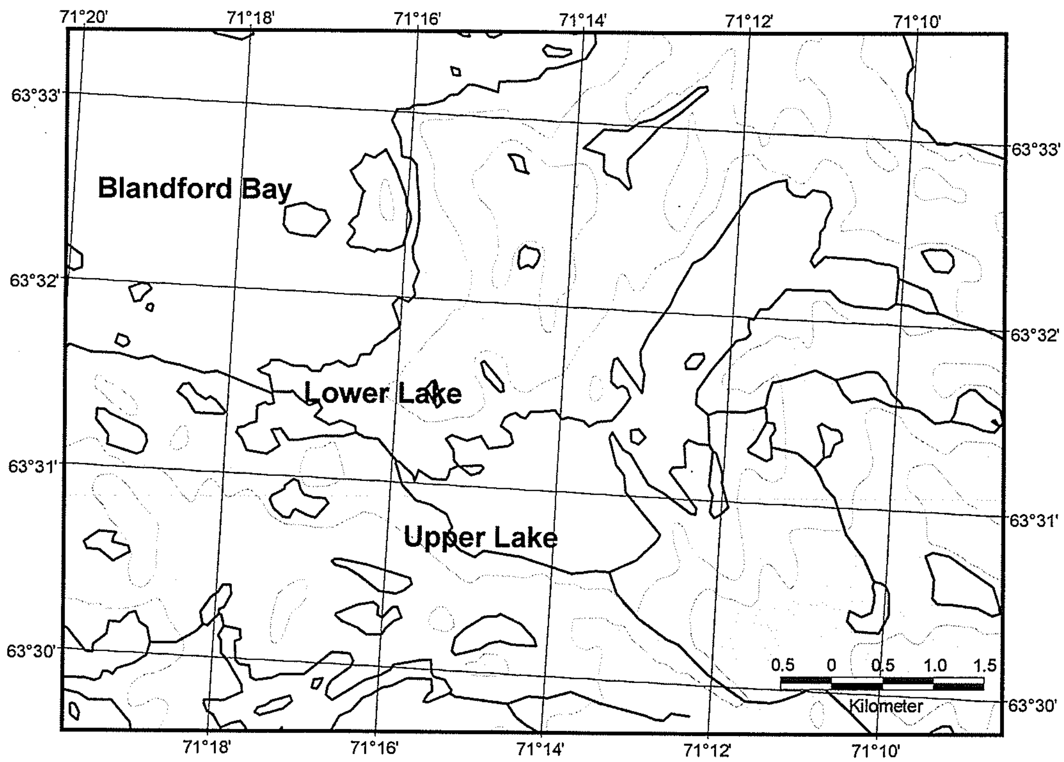

66°22'
66°20'
66°18'
66°16'
Ptarmigan Fiord
64°38'
64°37'
64°36'
0.5 0 0.5 1.0 1.5
Kilometer

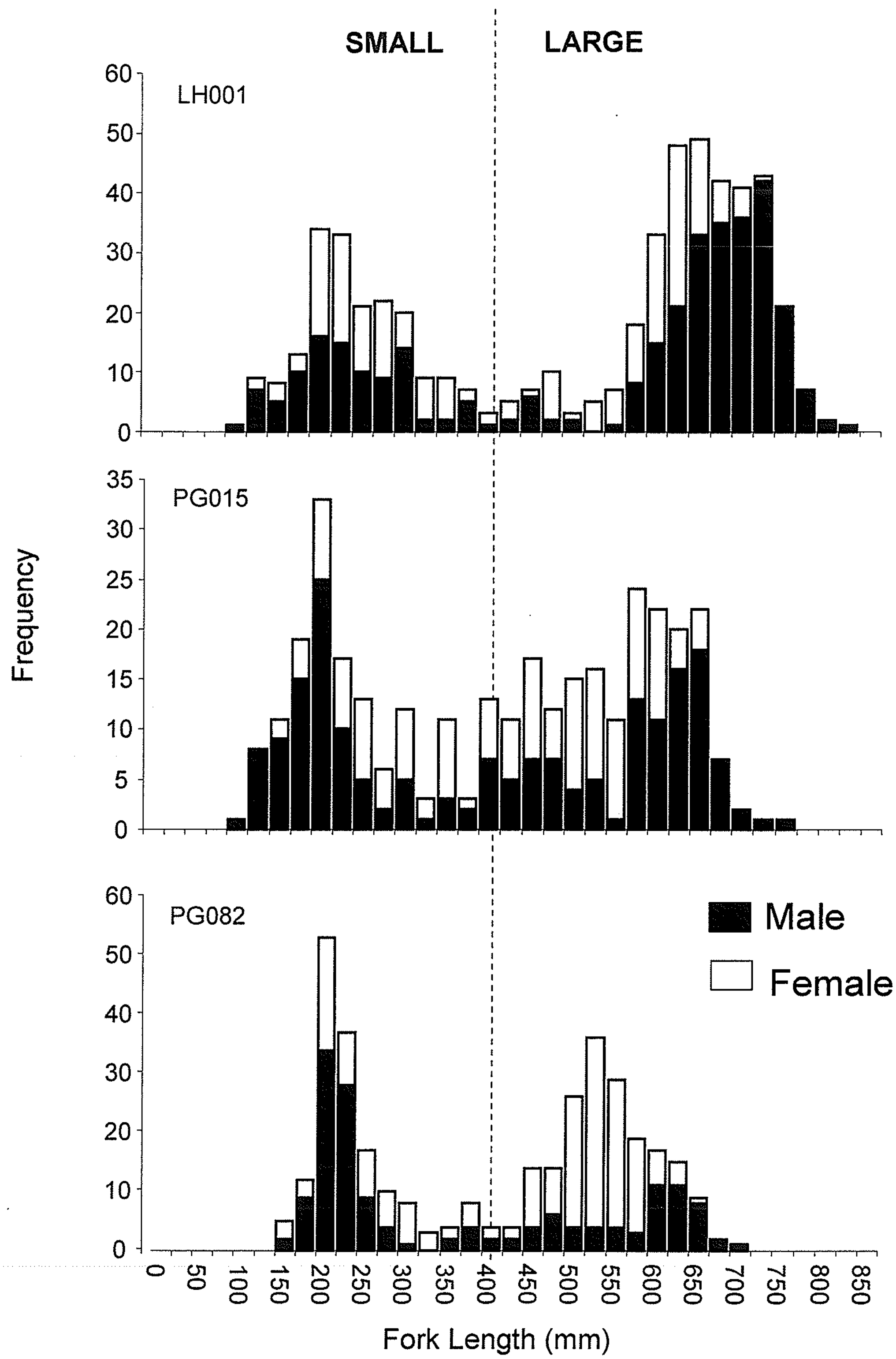
Fig. 1.4. The map of Qinngu, Blandford Bay, NU (LH001) showing the lower and upper lake basins. Fish were only captured for the purpose of this study in the lower basin due to logistical reasons.


71°20'
71°18'
71°16'
71°14'
71°12'
71°10'
63°33'
63°32'
63°31'
63°30'
Blandford Bay
Lower Lake
Upper Lake
0.5 0 0.5 1.0 1.5
Kilometer

respectively. The river system joining the freshwater to the ocean is approximately 0.26 km in length with an elevation change of approximately 17 m. Maximum high tide in the region generally ranges from 8.0 m to 11.5 m (in reference to chart datum) along the Meta Incognita Peninsula (Canadian Hydrologic Service 2008). Many outcropping shallow ponds are found around the perimeter of the lower lake. The lower lake has gradually sloping littoral habitat.

Field collection occurred within the lake systems from late-August to mid-September from 2001 to 2005. During the late summer/fall season, I infer from several years of gillnetting information that the majority of sea-going charr had returned to freshwater after their summer marine feeding season to over-winter and/or spawn. To obtain a representative sample of the individuals within the population, fish were captured with multi-mesh (38 mm-102 mm stretched mesh), 38 mm and 140 mm gillnets. Fish were collected from the lower lakes within PG082 and LH001 for logistic reasons. Fork length (mm), whole weight (g), sex and maturity were recorded for all fish (n = 1221) captured. In addition, sagittal otoliths were removed for age analysis and gonads were collected from spawning females for subsequent life history analysis. A sub-sample of fish (n = 515) was frozen whole and shipped back to the laboratory in Winnipeg, for further morphometric and meristic data collection. All fish were initially sorted into size groups for the basis of future classification: small fish group (< 400 mm) and large fish group (> 400 mm). Primary size group classification was based on the lowest midpoint size group (400 mm) within the bimodal frequency distribution of fork length that was consistent amongst all of the studied lakes (Fig. 1.5). All fish in the small group were included in the sub-sample whereas only random selections of fish from the

Fig. 1. 5. Bimodal size histogram for all fish sampled for each studied lake (LH001, PG015, and PG082) that was used to aid in primary group classification. The dashed line indicates how groups were classified according to size (small fish < 400 mm and large fish > 400 mm). Male and female numbers are represented by stacked bars.



SMALL
LARGE
LH001
PG015
PG082
Male
Female
Frequency
Fork Length (mm)
0
10
20
30
40
50
60
5
15
25
35
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850

large group were included in the sub-sample.

Fish were further classified into three groups for future analyses. These groups were named large-maturing, small-maturing and undeveloped based on field observations that best described each group. Fish were first separated by size as described above and then separated into the three groups based on confirmed maturity stages. During data collection all fish were initially classified into five main degrees of maturity based on their degree of gonadal development: immature (juvenile), mature, resting, running ripe, and spent (Hutchings et al. 1999). Small-mature fish group were <400 mm in size and were in mature or running ripe maturity stages. Large-mature fish group were >400 mm in size and were in mature or running ripe maturity stages. Since it was difficult to distinguish between immature and resting fish that were small (<400 mm) the fish were grouped together as undeveloped. If small (<400 mm) fish were suspected of being resting within the group they were eliminated from all analyses.

Strontium Analysis Techniques

Otoliths from all fish caught in the study were placed in ice cube trays, covered with epoxy resin, and sectioned perpendicular to the otolith sulcus across the nucleus (Baker and Timmons 1991; Chilton and Beamish 1982; Jenke 2002; Wischnioski and Bobko 1998). All otolith sections were read to estimate age. Ten fish that were previously classified as small-maturing and ten fish previously classified as large-maturing were chosen for strontium (Sr) analysis from each lake system (see Appendix 1.3). In lake PG082 otoliths from 6 females and 4 males comprised the large-mature group and otoliths from 1 female and 9 males comprised the small-mature group. In lake

PG015 otoliths from 3 females and 7 males comprised the large-mature groups and otoliths from 1 female and 9 males comprised the small-mature group. In lake LH001 otoliths from 6 females and 4 males comprised the large-mature group and otoliths from 2 females and 7 males comprised the small-mature group. When possible, otoliths that showed the highest degree of clarity in annular rings were selected.

A Lucite disk was attached to label paper, 6 previously sectioned otoliths were positioned within the Lucite disk. The disk was then backfilled with epoxy resin and left to harden for several days. The Lucite disk was initially polished by hand with 30 μm and 9 μm abrasive papers and was then polished again with 5 μm, 3 μm and 0.1 μm alumina paste. Polishing the Lucite disk removed deep surface scratches which can interfere with microprobe analysis. The otoliths were labelled, photographed in the Lucite disk and ultrasonically cleaned to remove all excess particles. The disk surface was carbon coated by technicians at the Electron Microprobe lab in the Department of Geological Sciences, University of Manitoba, and Winnipeg, MB.

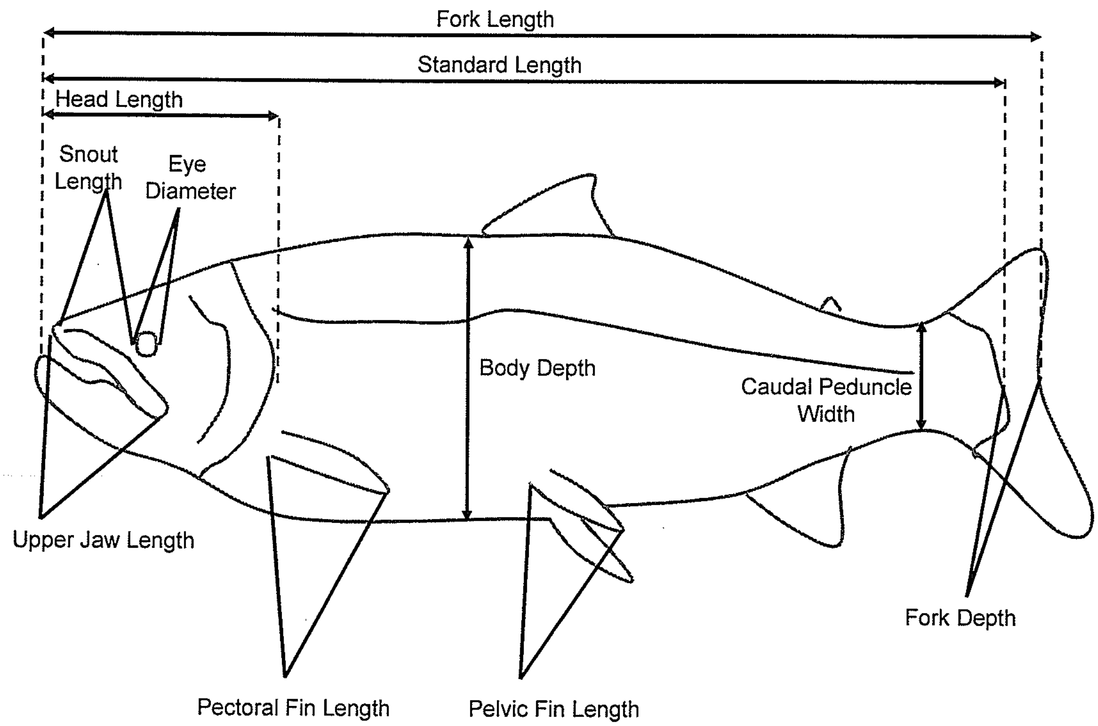
Otoliths were chemically analysed with a CAMECA SX100 electron microprobe. Transect lines were chosen on areas of the otolith where annular ring clarity was highest and spacing of annular rings was farthest apart (Babaluk et al. 2002; Howland et al. 2001). Specifications for the electron microbeam were decided upon based on previous work done by John Babaluk and on commonly used specifications found within the literature (Brown and Severin 1999; Brown et al. 2007; Radtke et al. 1998; Zimmerman and Nielsen 2003). The electron microbeam diameter was 5 μm with an accelerating voltage of 15 kV and a beam current of 20 nA with a dwell time of 25 sec. Centre to centre distance between point measurements along the transect line were chosen to be 7 μm so that no overlap in measuring Sr occurred between points. The elements Sr and calcium (Ca) were measured with thallium acid phthalate (TAP) and penta-erythritol (PET) crystals respectively. Sr and Ca were measured simultaneously at each point along the transect line.

Morphometric & Meristic Laboratory Collection Methods

Morphological characteristics were measured on the sub-sample of frozen whole fish (see Appendix 1.1). In lake LH001 the sub-sample comprised of 31 females and 40 males for the undeveloped group and 2 females and 19 males for the small-mature group. In lake PG015 the sub-sample comprised of 28 females and 45 males for the undeveloped group and 1 female and 20 males for the small-mature group. In lake PG082 the sub-sample comprised of 44 females and 51 males for the undeveloped group and 1 female and 31 males for the small-mature group.

Measurements were made from the left side of each fish to the nearest 0.01 mm with digital callipers (Cadrin 2005; Reist et al. 1995). Fish were frozen for no more than 2 months before data was collected to minimalise shrinkage. If the fish was damaged on the left side, morphological character measurements were then collected from the right side of the fish. Morphological characters measured were: standard length, head depth, head length, eye diameter, snout length, upper jaw length, pelvic fin length, pectoral fin length, body depth, fork depth and caudal peduncle width (Fig. 1.6). Morphological and meristic characters were chosen on the basis of published charr literature. Previously published studies indicated that this suite of morphological and meristic characters were useful in discriminating between phenotypic groups in multi- and univariate analyses

Fig. 1. 6. Morphological characters measured for each individual fish: fork length, standard length, head length, head depth, upper jaw length, snout length, eye diameter, pectoral fin length, pelvic fin length, body depth, caudal peduncle width. Fork depth was calculated by subtracting fork length from standard length.


Fork Length
Standard Length
Head Length
Snout Length
Eye Diameter
Body Depth
Caudal Peduncle Width
Upper Jaw Length
Fork Depth
Pectoral Fin Length
Pelvic Fin Length

(Adams and Huntingford 2002; Alekseyev et al. 2002; Krisofferson 2002; Reist et al. 1995).

Meristic data was collected from the first gill arch from the left side of each fish (see Appendix 1.2) (Waldman 2005). In lake LH001 the sub-sample comprised of 33 females and 39 males for the undeveloped group and 2 females and 19 males for the small-mature group. In lake PG015 the sub-sample comprised of 28 females and 45 males for the undeveloped group and 1 female and 12 males for the small-mature group. In lake PG082 the sub-sample comprised of 45 females and 54 males for the undeveloped group and 1 female and 31 males for the small-mature group. Upper and lower gill raker numbers were counted separately for each sample. The length of the lower lateral arch was also measured with digital callipers to the nearest 0.01 mm.

STATISTICAL ANALYSES

Strontium Analysis

To examine the variation between small- and large-maturing groups, the range of Sr (ppm) was plotted against the maximum Sr (ppm) value for each chemically analysed otolith (Brown et al. 2007; Howland et al. 2001). The maximum and range of Sr in other studies have been shown to be good indicators of separation between migratory and non-migratory groups (Brown et al. 2007; Howland et al. 2001). Since environmental conditions and physical characters of the lakes are variable, each lake was examined separately. The range and maximum Sr values were combined in a multivariate analysis of variance (MANOVA) to test for statistical difference between small- and large-maturing groups with R statistical software (see Appendix 1.4; Quinn and Keough 2006; R Development Core Team 2007).

Morphometric & Meristic Analysis

It is impossible to separate isometric and allometric growth problems in the course of trying to standardise size in morphometric analysis (Jorge et al. 1996; Somers 1989). Size standardising techniques found within the literature are numerous but there is no agreement on a universally correct method to standardise for size (Burnaby 1966; Jorge et al. 1996; Humphries et al. 1981; Parsons et al. 2003; Reist 1984; Rohlf and Bookstein 1987; Sundberg 1989). Most size standardising techniques are statistically problematic and cannot completely remove size from shape analysis (Freckleton 2002; Jensen 2003; Parsons et al. 2003; Rohlf 1990). As a result, morphometric and meristic comparisons were only made between fish of like sizes (the small-maturing and the undeveloped group). Sexes were pooled for all analyses to increase sample numbers for each lake studied.

Principal factor analysis (PFA, Everitt 2007) was performed on morphometric data with the inclusion of lower lateral arch length for each individual lake system. Standard length was also included in the analysis to further attempt to account for the partial influence of size within the shape analysis. R statistical software was used to perform principal factors analysis (PFA) and PFA rotation using the stats library package, specifically the factanal( ) and rotation( ) functions (see Appendix 1.5; Everitt 2007; R Development Core Team 2007). PFA is similar to classical principal components analysis (PCA) but operates on the reduced covariance matrix (Everitt 2007). The PFA does not account for all observed variance as in regular PCA but only that which is shared through common factors. The PFA tries to account for the covariance or correlations between the manifest variables. Manifest variables refer to variables derived from parts of the variance of each observed variable that can be explained by the common factors. PFA was chosen over PCA because it has a specific statistical model associated with its functional use, has a formal hypothesis testing procedure for the number of factors used within the model and uses a maximum likelihood approach to calculate factor scores (Crawley 2007). After initial calculation of the principal factor scores, an orthogonal rotation (varimax) was applied to the factor scores. Rotation allowed for a clearer interpretation of results while maintaining the overall mathematical structure of the resulting analysis (Crawley 2007; Everitt 2007; Manly 2005).

The factor loading highly (> 0.700) on standard length was considered to be size related and not used for subsequent analyses. Variation in body morphology unrelated to size was represented by the subsequent factor. Only two factors were maintained in the PFA since all traits loaded high on either factor score 1 or 2. The addition of more factors was initially examined and did not change the outcome of the analysis. Univariate analyses were performed on characters that loaded high on the morphological factor in the PFA. The linear univariate model was:

$$y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \beta_3 (x_{i1} * x_{i2}) + \varepsilon_i \quad (1)$$

where x_{i1} = fork length, x_{i2} = maturity group $\in \{0,1\}$, x_{i3} = $(x_{i1} * x_{i2})$, y_i = morphological character, and ε_i = normally distributed error (see Appendix 1.6 ; Quinn and Keough

2006). To reduce the likelihood of a type 1 statistical error Bonferroni correction was applied to univariate statistics. The Bonferroni correction factor was 4 in all univariate statistics based on the number of morphological characters that were not related to size in PFA. The Bonferroni corrected level of significance was $p < 0.002$.

Meristic data such as gill raker number are discrete variables and should not be statistically analyzed with other continuous variables such as gill raker length or lower arch length (Waldman 2005). Upper and lower gill raker numbers were combined in a MANOVA test to examine differences between small-maturing and undeveloped fish groups (see Appendix 1.4; Quinn and Keough 2006).

RESULTS

General Observations

The majority of the fish captured during daylight hours were large bodied charr (>400 mm). I was most successful at capturing small-mature charr when gillnets were set over night. Further, small-mature charr were captured within the same locations and within the same gillnets as large bodied charr during the over night sets. This pattern was repeated in all three lake systems of the study over all 4 years of data collection. Gillnetting at the river mouth in the marine environment within all studied lakes resulted in the capture of large-maturing charr in spawning condition that were attempting to move upstream into freshwater.

Strontium

The maximum and the range of Sr concentrations for small-maturing fish were statistically different than that of large-maturing fish in both LH001 and PG082 whereas no statistical difference is observed in PG015 (Table 1.1). The shift between freshwater and saltwater, represented by changes in maximum Sr and range of Sr, in LH001 and PG082 appears to be gradual with no clear and abrupt change between changes in environment (Fig. 1.7). In lake PG015 small- and large- maturing fish seem to overlap in maximum Sr and range in contrast to the other lakes.

Field data indicate that fish of small sizes (25-83 mm) thought to be young of the year (YOY) charr within lake PG015 utilise the inter-tidal region. Small sized charr were captured via dip-net in August of 2008 at low tide within tidal pools near the river system joining the lake to the marine environment. The maximum salinity observed near the river mouth in the inter-tidal region was 26 $^{0}/_{00}$ during high tide.

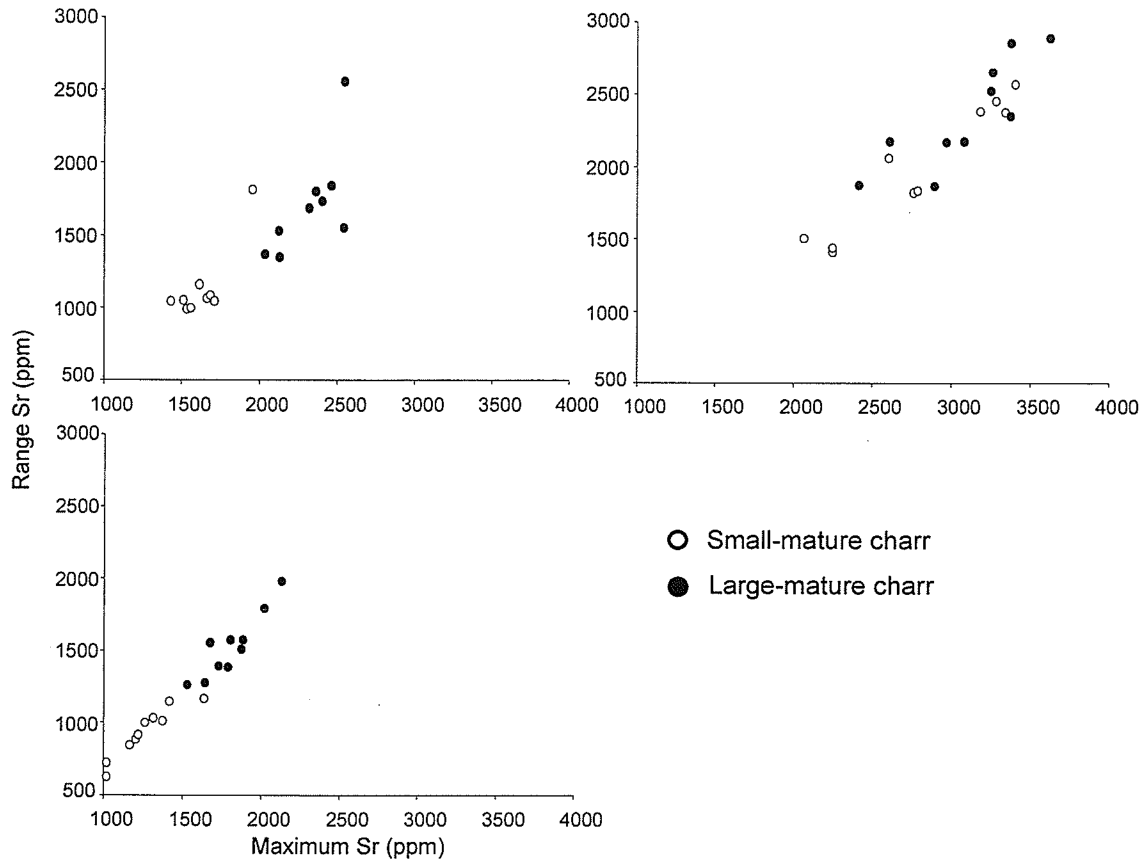
Morphometric & Meristic Analyses

PFA consistently identified three morphological characters that were independent of body size in each lake system studied. Significant covariation was observed between the morphological traits of eye diameter, pectoral fin length, and pelvic fin length in all lakes of the study. Upper jaw length and fork depth were also identified as significant morphological traits within lakes PG082 and LH001 and PG015 respectively (Table 1.2, Table 1.3, and Table 1.4). By examining factor score plots, separation of small-mature and undeveloped fish groups was observed in all lakes studied (Fig. 1.8).

Table 1.1. MANOVA of Sr (range and maximum value) for all 3 lakes within the study: LH001, PG015 and PG082. df_N is representative of degrees of freedom of the numerator and df_D is representative of degrees of freedom of the denominator. The Bonferroni corrected level of significance is $p < 0.015$. A star indicates significance.

Location	df_N	df_D	Pillai Trace	F-value	p-value
LH001	2	16	0.829	38.744	< 0.001 *
PG015	2	17	0.207	2.216	0.140
PG082	2	17	0.719	21.787	< 0.001 *

Fig. 1.7. Maximum Sr (ppm) was plotted against range in Sr (ppm) from otoliths of all three lakes studied: LH001, PG015, and PG082. Small-maturing charr are represented by open circles and large-maturing charr are represented by closed circles.



Range Sr (ppm)
Maximum Sr (ppm)
Small-mature charr
Large-mature charr

Table 1.2. PFA scores for lake LH001. Morphological character traits that loaded high on factor 1 scores (Factor1 > 0.700) are considered to be size related. Morphological characters that loaded high on factor 2 scores (Factor2 > 0.700) were considered to be ecologically significant and are underlined. Uniqueness scores are also shown for all morphological characters. Uniqueness scores or unique variance is the variability in x_i of the PFA that is not shared with other variables (Everitt 2007).

Morphological Character Trait	**Factor1**	**Factor2**	**Uniqueness**
Body Depth	0.869	0.344	0.126
Caudal Peduncle	0.827	0.465	0.100
Eye Diameter	0.434	<u>0.792</u>	0.184
Fork Depth	0.439	0.603	0.443
Head Depth	0.749	0.595	0.084
Head Length	0.711	0.652	0.070
Lower Lateral Arch	0.756	0.482	0.196
Pectoral Fin Length	0.415	<u>0.823</u>	0.151
Pelvic Fin Length	0.377	<u>0.863</u>	0.112
Snout Length	0.698	0.656	0.082
Standard Length	0.890	0.442	0.012
Upper Jaw Length	0.404	<u>0.791</u>	0.210

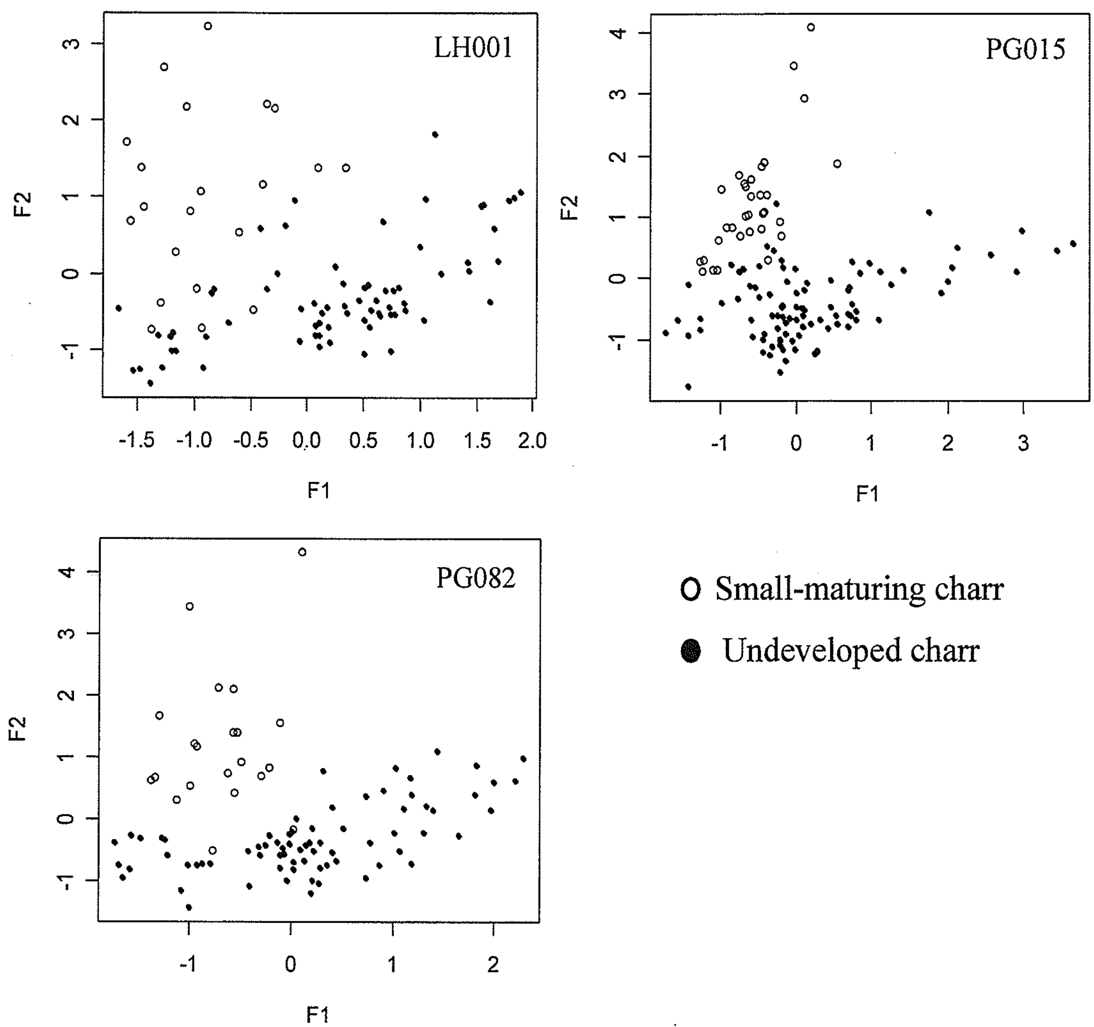
Table 1.3. PFA scores for lake PG015. Morphological character traits that loaded high on factor 1 scores (Factor1 > 0.700) are considered to be size related. Morphological characters that loaded high on factor 2 scores (Factor2 > 0.700) were considered to be ecologically significant and are underlined. Uniqueness scores are also shown for all morphological characters. Uniqueness scores or unique variance is the variability in x_i of the PFA that is not shared with other variables (Everitt 2007).

Morphological Character Trait	Factor1	Factor2	Uniqueness
Body Depth	0.845	0.402	0.125
Caudal Peduncle	0.790	0.499	0.127
Eye Diameter	0.364	<u>0.806</u>	0.218
Fork Depth	0.334	<u>0.702</u>	0.395
Head Depth	0.802	0.509	0.099
Head Length	0.802	0.571	0.032
Pectoral Fin Length	0.456	<u>0.851</u>	0.067
Pelvic Fin Length	0.530	<u>0.802</u>	0.076
Snout Length	0.808	0.533	0.063
Standard Length	0.918	0.349	0.035
Upper Jaw Length	0.729	0.655	0.040

Table 1.4. PFA scores for lake PG082. Morphological character traits that loaded high on factor 1 scores (Factor1 > 0.700) are considered to be size related. Morphological characters that loaded high on factor 2 scores (Factor2 > 0.700) were considered to be ecologically significant and are underlined. Uniqueness scores are also shown for all morphological characters. Uniqueness scores or unique variance is the variability in x_i of the PFA that is not shared with other variables (Everitt 2007).

Morphological Character Trait	**Factor1**	**Factor2**	**Uniqueness**
Body Depth	0.911	0.185	0.136
Caudal Peduncle	0.810	0.298	0.255
Eye Diameter	0.238	<u>0.835</u>	0.246
Fork Depth	0.544	0.437	0.513
Head Depth	0.722	0.538	0.189
Head Length	0.768	0.614	0.034
Lower Lateral Arch	0.830	0.509	0.052
Pectoral Fin Length	0.251	<u>0.933</u>	0.067
Pelvic Fin Length	0.381	<u>0.866</u>	0.104
Snout Length	0.600	0.698	0.152
Standard Length	0.930	0.299	0.046
Upper Jaw Length	0.507	<u>0.821</u>	0.069

Fig. 1.8. PFA plots for all three lakes of the study: LH001, PG015 and PG082. Factor score 1 (F1) is plotted against factor score 2 (F2). Small-maturing fish are represented by open circles and undeveloped fish are represented by closed circles.


LH001
PG015
PG082
F1
F2
-1.5 -1.0 -0.5 0.0 0.5 1.0 1.5 2.0
-1 0 1 2 3
-1 0 1 2
-1 0 1 2 3 4
Small-maturing charr
Undeveloped charr

Univariate analyses showed statistical significances between small-mature and undeveloped groups in all morphological characters discussed previously in PFA (eye diameter, pectoral fork length, pelvic fin length, upper jaw length and fork depth). In exception, no statistical significance was observed in the eye diameter in lake PG015 and PG082 and upper jaw length and pelvic fin length in LH001 (Table 1.5, Table 1.6, and Table 1.7). Small-maturing fish tended to have larger eye size, longer pectoral and pelvic fins in comparison to the undeveloped group in all lakes studied. In PG082 and LH001 small-maturing fish also tended to have longer upper jaws whereas in PG015 small-maturing fish tend to have a shallower fork depth than their undeveloped counter-parts.

Meristic analysis of upper and lower gill raker number were compared between small-maturing and undeveloped groups. No statistical difference was observed in upper and lower gill raker number in any of the lakes studied (Table 1.8).

DISCUSSION

A relationship between habitat use and morphological variation was apparent for all lakes studied. Marine and lacustrine habitat use patterns were observed in lakes PG082 and LH001. Small-maturing charr appear to be lake-residents whereas large-maturing charr appear to be anadromous. Within lake PG015 small bodied, small-mature and large-mature fish all appear to utilise the estuarine environment. Although habitat use was atypical in one of the three studied lakes, the same 3 morphological traits were identified in the PFA as group distinguishing characters: eye diameter, pectoral fin and pelvic fin lengths. Additionally, within lakes PG082 and LH001 upper jaw length was identified as a group distinguishing trait whereas fork depth was identified as a group

Table 1.5. Univariate statistical analysis of small-maturing and undeveloped charr groups for LH001. The star symbol is indicative significance of the Bonferroni corrected level of significance at $p < 0.002$. S.E. is representative of standard error.

Morphological Character Trait	Model Coefficients	Estimate	S.E.	t-value	p-value
Eye Length	Intercept	4.373	0.261	16.773	< 0.001 *
	S. Length	0.019	0.001	13.308	< 0.001 *
	Maturity	- 1.674	0.688	- 2.434	0.017
	S. Length:Maturity	0.018	0.004	4.328	< 0.001 *
Pectoral Fin Length	Intercept	6.990	1.217	5.744	< 0.001 *
	S. Length	0.092	0.007	13.984	< 0.001 *
	Maturity	- 5.486	3.097	- 1.771	0.080
	S. Length:Maturity	0.073	0.019	3.836	< 0.001 *
Pelvic Fin Length	Intercept	3.580	0.884	4.050	< 0.001 *
	S. Length	0.084	0.005	17.433	< 0.001 *
	Maturity	1.639	2.331	0.703	0.484
	S. Length:Maturity	0.028	0.014	1.933	0.056
Upper Jaw Length	Intercept	2.648	1.134	2.336	0.022
	S. Length	0.077	0.006	12.410	< 0.001 *
	Maturity	- 0.552	2.990	- 0.185	0.854
	S. Length:Maturity	0.030	0.018	1.656	0.101

Table 1.6. Univariate statistical analysis of small-maturing and undeveloped charr groups for PG015. The star symbol is indicative significance of the Bonferroni corrected level of significance at $p < 0.002$. S.E. is representative of standard error.

Morphological Character Trait	Model Coefficients	Estimate	S.E.	t-value	p-value
Eye Length	Intercept	4.622	0.229	20.189	< 0.001 *
	S. Length	0.016	0.001	12.902	< 0.001 *
	Maturity	0.339	0.765	0.444	0.658
	S. Length:Maturity	0.007	0.005	1.367	0.175
Fork Depth	Intercept	3.750	0.916	4.094	< 0.001 *
	S. Length	0.040	0.005	7.817	< 0.001 *
	Maturity	- 7.247	3.061	- 2.367	0.020
	S. Length:Maturity	0.064	0.019	3.335	0.001 *
Pectoral Fin Length	Intercept	5.899	0.897	6.577	< 0.001 *
	S. Length	0.095	0.005	18.912	< 0.001 *
	Maturity	- 9.096	2.997	- 3.035	0.003 *
	S. Length:Maturity	0.010	0.019	5.299	< 0.001 *
Pelvic Fin Length	Intercept	3.606	0.811	4.448	< 0.001 *
	S. Length	0.083	0.005	18.257	< 0.001 *
	Maturity	- 9.945	2.710	- 3.670	< 0.001 *
	S. Length:Maturity	0.092	0.017	5.425	< 0.001 *

Table 1.7. Univariate statistical analysis of small-maturing and undeveloped charr groups for PG082. The star symbol is indicative significance of the Bonferroni corrected level of significance at $p < 0.002$. S.E. is representative of standard error.

Morphological Character Trait	Model Coefficients	Estimate	S.E.	t-value	p-value
Eye Length	Intercept	5.257	0.248	21.204	< 0.001 *
	S. Length	0.014	0.001	11.713	< 0.001 *
	Maturity	- 1.212	0.974	- 1.245	0.215
	S. Length:Maturity	0.013	0.005	2.405	0.018
Pectoral Fin Length	Intercept	5.069	1.071	4.734	< 0.001 *
	S. Length	0.103	0.005	19.355	< 0.001 *
	Maturity	- 10.551	4.205	- 2.509	0.013
	S. Length:Maturity	0.106	0.024	4.494	< 0.001 *
Pelvic Fin Length	Intercept	3.354	0.759	4.416	< 0.001 *
	S. Length	0.088	0.004	23.406	< 0.001 *
	Maturity	- 5.954	2.982	- 1.996	0.048
	S. Length:Maturity	0.064	0.017	3.846	< 0.001 *
Upper Jaw Length	Intercept	- 0.241	0.609	- 0.395	0.693
	S. Length	0.094	0.003	31.129	< 0.001 *
	Maturity	- 6.627	2.392	- 2.770	0.006
	S. Length:Maturity	0.066	0.013	4.906	< 0.001 *

Table 1.8. MANOVA of upper and lower gill raker numbers for all 3 lakes within the study: LH001, PG015 and PG082. df_N is representative of degrees of freedom of the numerator and df_D is representative of degrees of freedom of the denominator. Bonferroni corrected level of significance is $p < 0.015$. A star indicates significance.

Location	df_N	df_D	Pillai Trace	F-value	p-value
LH001	2	91	0.055	2.635	0.077
PG015	2	83	0.040	1.718	0.186
PG082	2	128	0.012	0.796	0.453

distinguishing trait in lake PG015.

The branchial uptake of Sr from the surrounding environment by fish is generally thought to be the major source of Sr within sagittal otoliths (Bath et al. 2000; Campana 1999; Campana and Thorrold 2001; Farrell and Campana 1996; Thresher 1999). Hence otolith microchemistry can provide a good history of an organism's habitat use. Generally, Sr concentrations are substantially higher in seawater than freshwater (on average 8.0 $mg \cdot l^{-1}$ and 0.1 $mg \cdot l^{-1}$ respectively) (Babaluk et al. 2002). Alternatively Sr in freshwater can become elevated when the underlying geology of the region has marine origins. Carbonate rocks such as limestone, dolomite and marble are formed from marine organisms and are known to have increased levels of Sr due to their ancient marine origins (Hamilton et al. 2001; St-Onge et al. 2000). Regions such as Southern Baffin Island are likely to have naturally elevated levels of Sr within freshwater systems due to the geologic formation of carbonate rocks.

Many authors have used Sr within otoliths as a true representation of freshwater and marine/estuarine habitats over an individual fish's life span (Campana 199; Farrell and Campana 1996; Kennedy et al. 2002). Secor et al. (1995) found that Sr/Ca ratios within striped bass (*Morone saxatilis*) otoliths were positively correlated with Sr in the fish's environment. Lower Sr values within the otolith are thought to be representative of freshwater and high Sr values are thought to be representative of marine waters (Howland et al. 2001; Morris et al. 2003; Radtke 1995; Secor 1992).

Within my study, the minimum levels of otolith Sr were much higher than anticipated for the freshwater otolith regions. Specifically Sr levels were high within the otolith nucleus, within the freshwater portion of the fish's life prior to migration out to sea (if the fish was anadromous) and in otoliths from lake resident individuals (small-maturing group). This was observed in all three lake systems studied. Despite this potentially confounding issue, variation consistent with previous studies was still observed within charr otoliths in lakes PG082 and LH001.

High levels of Sr in the otolith nucleus may indicate a maternal effect. The female fish may have made a migration out to sea to feed in the same year as spawning and thus residual Sr could be found within the offspring's otolith nucleus (Radtke 1995). It has been shown that female charr will feed at sea more frequently in the same year prior to spawning when river systems are relatively short and ease of passage is high (Kristofferson 2002). Within the studied lakes, the gillnet capture of mature charr at the mouth of the river systems for all lakes studied on their migration upstream into freshwater in late summer supports the possibility of residual Sr observed in offspring otoliths from maternal effects.

The patterns in Sr suggest that small-maturing and small bodied charr are likely utilising the inter-tidal habitat in lake PG015. This is in contrast to European studies of charr that suggest a minimal body size is required for tolerance to salinity. Gulseth et al. (2001) and Nilssen and Gulseth (1998) reported a minimal body size of >25 cm for Svalbard (Norway) charr for the successful development of hypo-osomregularity capacities needed to tolerate saline waters. However, other studies have provided evidence of greater tolerance to salinity. Radtke et al.'s (1998) microchemistry study found evidence of early life migration patterns in Labrador charr otoliths. Similarly Dempson (1993) found that small bodied Labrador (Canada) charr were able to tolerate salinities of 10-20$^{0}/_{00}$ and were able to tolerate periodic episodes of higher salinities of approximately 30$^{0}/_{00}$ so long as they had access to freshwater refuge. Additionally Dempson (1993) was able to physically capture small bodied charr in the coastal habitats predominantly near freshwater and saltwater mixing zones. In one case Dempson (1993) was able to capture small bodied charr 5-7 km off the coast. Further Jonsson and Antonsson (2005) captured 1+ and 2+ (1 and 2 year old) charr migrating to a brackish lagoon in Vesturdalsa River, Iceland. They found that Vesturdalsa River 1+ charr could utilise habitats in salinities up to 20$^{0}/_{00}$ for short periods of time. Lack of consistency for minimal body size is notable for charr populations and suggests that the level of salinity tolerance has evolved within each isolated charr population (Dempson 1993; Jøgensen et al. 2007; Jonsson and Antonsson 2005; Nilssen and Gulseth 1998).

Lack of rearing habitat in the form of littoral niches and small out-cropping ponds may have aided the adaptation of inter-tidal habitat use by small-bodied and small-mature charr. Within the study, small bodied charr were captured in the inter-tidal region as well as within the limited littoral regions of the lake. Additionally tidal heights within the regions are high and the river system for PG015 is extremely short, facilitating the ease of movement of charr from freshwater into the tidal zone. Due to the short length and small elevation change in PG015 it is possible that marine water flows into the river system at high tide and tidal water enters the lake. This could provide an opportunity for small bodied charr to acclimate and increase their tolerance to saline waters. Littoral habitat is associated with optimal rearing habitat for young charr as well as optimal habitat for lake-resident morphs of charr (Andersson 2003). The lake ecosystem of PG015 has reduced littoral habitat available in the form of small outcropping ponds and lake edge habitats. This habitat constraint (increasing intra-specific competition) in combination with the ease of passage to the tidal habitat may have encouraged the adaption of the atypical behaviour of small bodied charr and small-maturing charr's use of the tidal habitat early in life.

Common patterns in morphological variation exist between small-maturing and undeveloped fish groups within all lakes studied. Eye diameter, pectoral fin length and pelvic fin lengths were consistently identified to have significant covariation within all lakes studied. These characters have also been identified in other Canadian charr studies as key discrimination variables within multivariate analysis (Krisofferson 2002, Reist et al. 1995). Pectoral fin length and mouth position have been repetitively identified as significant morphological characters in examining locomotor abilities and foraging behaviour within salmonid species (Andersson 2003; Drucker and Lauder 2003; Peres-Neto and Magnan 2004; Robinson and Parsons 2002).

Each phenotype expressed within a population has fitness advantages for existing within a specialised ecological niche (Klemetsen et al. 2003; Robinson and Parson 2002). These fitness advantages relate to behavioural mechanisms and dietary resources that are exploited. Behavioural and dietary exploitation by a fish has functional consequences such as morphometry of fins that effect swimming ability and movement. For example, the adaptation of longer fins (greater surface area) by small-maturing charr within this study suggests a decrease in efficiency at swimming long distances due to drag effects (i.e. migratory abilities) and better adaption for short fast swimming manoeuvres in slow flowing water (Drucker and Lauder 2003; Pakkasmaa et al. 1998; Webb 1984; Webb and Fairchild 2001). Better manoeuvrability would be significant for predator avoidance within low flow habitats. Grünbaum et al. (2007) and Peres-Neto (2004) studies have shown that phenotypic characters relating to swimming demands (predominantly pectoral fin length) are highly plastic especially during developmental stages and are known to respond to environmental constraints such as water velocities. Long pelvic fins are associated with low water velocities whereas short pelvic fins are associated with high water velocities. In lake PG015 a shallow fork depth would further support greater manoeuvrability since the tail fin would have greater surface area and thus a shorter response time and quicker swimming movement (Videler 1993, Webb 1984).

The adaptation of a larger eye diameter suggests that small-maturing charr within the studied lakes live in habitats with decreased water clarity, live at a greater depth within lake habitats, or are nocturnal feeders (Fishelson et al. 2004; Pakkasmaa et al. 1998). Alanärä and Brännäs (1997) found that when intra-specific competition for food resources is high, dualism of diurnal and nocturnal feeding is apparent within Arctic charr and rainbow trout (*Oncorhynchus mykiss*) populations. Nocturnal feeders are known to have larger eye size and better sensitivity to light (Bond 1996; Fishelson et al. 2004; Pankhurst 1989). Baumgartner et al. (1988) suggest eye diameter is related to feeding behaviour within threespine stickleback. In examining netting data, small-maturing charr appear to be more active during the night which may indicate that they are nocturnal feeders. Alanärä and Brännäs (1997) suggest that nocturnal feeding may be a predator avoidance mechanism. This is supported by the small-maturing fish group's cryptic colouration (browns and yellows) which would help to provide camouflage in benthic and low light habitats within the lake system.

Mouth position is suggestive of feeding behaviour within polymorphic phenotypes. A subterminal mouth is indicative of bottom feeding behaviour in the littoral habitat whereas terminal mouth suggests open-water prey capture behaviour in the pelagic lake habitat (Baker et al. 2005; Caldecutt and Adams 1998; Malmquist 1992; Snorrason et al. 1994). Andersson's (2003) and Malmquist (1992) found that diet could induce the expression of different morphological characters relating to feeding behaviour during the early development stage of charr. In separate studies they both determined that zooplankton (pelagic) feeders had terminal mouths and short pectoral fins whereas chironomid (benthic) feeders had subterminal mouths and long pectoral fins. Day and McPhail's (1996) study on threespine stickleback which commonly occur in the same lake systems as Arctic charr showed similar results. Morphological changes were "induced" by differences in prey capture and search behaviour such as the fine manoeuvrability to search substrate for chironomids versus the quick attack response to capture zooplankton in the pelagic habitat.

Within the PFA upper jaw length was a significant morphological character. Univariate analysis showed significant variation between small-mature and undeveloped fish in lakes PG082 and LH001. The elongation of the upper jaw observed in small-mature charr suggests a sub-terminal mouth position whereas undeveloped charr have a terminal mouth position (Savvaitova 1995; Skúlason et al. 1996). However, gill raker number often associated with diet (Alekseyev et al. 2002) showed no separation between small-maturing and undeveloped fish groups. Andersson's (2003) study also suggested that pelagic feeders were efficient at capturing both benthic and pelagic prey whereas benthic feeders were not able to efficiently capture pelagic prey. During the open-water season undeveloped and small-mature charr co-exist within freshwater environments and likely have over-lapping diets. Since pelagic morphs such as the undeveloped group within our study can efficiently feed on both pelagic and benthic prey they may not express full meristic variation.

Patterns found within phenotypic ecotypes or morphs are often representative of specialisation in ecological niche use within teleosts (Baker et al. 2005; Day and McPhail 1996; Robinson and Parsons 2002). Within the charr and threespine stickleback literature benthic morphs tend to be deeper bodied, have long paired fins, and sub-terminal mouths (Andersson 2003; Caldecutt and Adams; Robinson and Parsons 2002). In contrast limnetic morphs tend to have fusiform bodies, short paired fins and terminal mouths (Day and McPhail 1996; Malmquist 1992; Robinson and Parsons 2002). Based on the morphological analyses and the previous discussion it is likely that small-mature charr are a littoral (benthic) ecotype of charr whereas the undeveloped charr are a limnetic (pelagic) ecotype of charr within the studied lakes. Furthermore I infer from the otolith microchemistry analysis that the pelagic ecotype of charr within each lake system is ultimately an anadromous form whereas small-mature charr will remain lake-residents.

Morphological variation exists within all three lake systems studied even though habitat use patterns were different than anticipated (specifically for lake PG015). Pelvic fin length, pectoral fin length and eye diameter were identified as significant ecological traits within the multivariate analysis of the studied lakes. This suggests separate ecological niches for small-maturing and undeveloped charr. Large-maturing charr were shown to be anadromous in all three lakes of the study. Small-maturing charr were shown to be lake-resident in lakes PG082 and LH001. Small-maturing charr as well as small bodied charr in lake PG015 are likely utilising the tidal habitat. The use of tidal habitat by small bodied charr may have evolved due the lack of a necessary body size needed for physiologic changes in dealing with saline water, the ease of passage from freshwater to saltwater and the lack of rearing habitat within the lake itself. No variation in gill raker number was identified between charr of the small-mature and undeveloped groups in any of the lake systems. This suggests an overlap of prey between small-maturing and undeveloped fish groups. Further investigation into the atypical behaviour of charr within lake PG015 is warranted since this is the first documented case of small-maturing and undeveloped charr's use of the tidal habitat in the presence of a migratory large-maturing charr.

Intraspecific competition within a species may lead to resource polymorphism especially in the absence of interspecific competition (Svanbäck and Bolnick 2005). The degree to which resource polymorphism is expressed relates to ecological niche availability within a specific lake system and to environmental factors influencing the lake system (Savvaitova 1995). If stability is observed over extremely long periods of time separation between polymorphs can be found in the form of reproductive isolation as demonstrated in Thingvallavatn (Iceland) and Kalandsvatnet (Norway) charr populations (Sandlund et al. 1987; Skúlason et al. 1996; Telnes and Sægrov 2004). This could lead to parallel sympatric speciation within lakes and the formation of new species over extremely long periods of time (thousands to millions of years) (Johannesson 2001). Under conditions of environmental instability, plasticity in phenotypic expression may still result in resource polymorphs with each phenotypic form participating in incomplete assortative mating (Klemetsen et al. 2003; Nordeng 1983). Thus the occurrence of semi-speciation of charr at various levels within lake systems regionally and globally may be observed (Klemetsen et al. 2003; Parker et al. 2001; Savvaitova 1995; Skúlason et al. 1996). The large degree of phenotypic plasticity and thus the expression of resource polymorphs has allowed charr to inhabit and populate extreme environments globally (Jonsson and Jonnsson 2001; Parker et al. 2001; Skúlason et al. 1996). Within my study I was successful at identifying habitat use and variation of morphology within all studied lakes but further investigation into resource polymorphism mechanisms within each lake is necessary. The degree of genetic separation between benthic and pelagic morphs of charr has yet to be determined within all lakes studied.

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CHAPTER 3. Divergent life history strategies of Arctic charr (*Salvelinus alpinus*) co-existing in lake systems of southern Baffin Island, Nunavut, Canada

ABSTRACT

Life history theory suggests that anadromous fish should experience a delay in maturation in both size and age and have increased fecundity (per spawning event). The focus of this study was to compare two morphs of Arctic charr (*Salvelinus alpinus*) previously identified as anadromous and lake-residents within three lakes of Baffin Island, Nunavut, Canada. Comparisons of my results were made to current life history theory and European studies of Arctic charr. Within all lakes studied, anadromous charr had a mean size at maturity that ranged from 532 mm to 641mm and mean age of maturity that ranged from 10 to 13 years. In comparison, lake-resident charr had a mean size that ranged from 184 mm to 202 mm and a mean age at maturity that ranged from 8 to 9 years. The relationship between size and fecundity or egg diameter did not differ between the two morphs. The von Bertalanffy growth models indicate that lake-resident and anadromous charr overall growth was different in all three lakes of the study. Lake-resident charr initially had growth rates that were double that of anadromous charr. The results of our study parallel what is observed in general life history theory but differ from some current European studies of Arctic charr juvenile growth that suggests resident charr growth is slow and migrant juveniles are fast growing.

INTRODUCTION

Phenotypic plasticity and variation in life history strategy amongst members of the same population exists within most salmonid species. Migration within salmonids has evolved to take advantage of increased food resources within the marine environment (Gross 1987). As a result of smoltification and subsequent feeding at sea, the migrant life style generally follows a similar pattern of rapid growth at sea, larger overall body size at maturity, delay in maturity, longer life span, and increased reproductive investment upon maturation (Hendry et al. 2004; Roff 1988; Stearns 1976). Alternatively, the life history choice of residency within freshwater can also be advantageous. Since smoltification is foregone, residents have opportunities to spawn at a younger age and at a smaller size (Roff 1984; Stearns 1992).

The co-existence of multiple phenotypic morphologies frequently occurs within Arctic charr (*Salvelinus alpinus*) populations. Both reproductive isolation and interbreeding between morphs have both occurred throughout the circumpolar region (Klemetsen et al. 1997; Nordeng 1983; Rikardsen et al. 1997; Svendäng 1992; Telnes and Sægrov 2004). In Icelandic populations of charr, up to four different phenotypic morphs co-exist within one lake system and exhibit reproductive isolation (Klemetsen et al. 2003; Sandlund et al. 1987). Reproductive isolation has also been observed in some Russian, Norwegian, English and Scottish lake systems where multiple morphs of charr co-exist (Adams et al. 1998; Klemetsen et al. 2003; Savvaitova 1995). In cases of reproductive isolation, each morph of charr is purely freshwater and a niche specialist utilising food resources in different regions of the water column within the lake system (Adams et al. 1998; Klemetsen et al. 2003; Sandlund et al. 1987; Savvaitova 1995). In some

some Norwegian and Swedish lakes, interbreeding between forms is generally thought to occur between morphs (Nordeng 1983; Rikardsen and Elliot 2000; Rikardsen et al. 1997; Svendäng 1992). Studies on lake systems such as the Halseva watershed, northern Norway, have demonstrated that lake-residents can change life history tactics and become anadromous later in life (Strand and Heggberget 1994). Studies of other lake systems in the same region such as Lake Storvatn, have revealed lake-residents that are permanently and purely freshwater (Rikardsen and Elliot 2000; Strand and Heggberget 1994).

No studies have been published in the primary literature on the seasonal co-existence of anadromous and lake-resident charr in open lake systems of the Canadian Arctic. Within landlocked populations of charr in Canadian waters it has been demonstrated that up to three phenotypic morphs (picivorous, benthivorous, and planktivorous) exist in a single lake system (Babaluk et al. 1997; Parker and Johnson 1991). The purpose of my study is to compare anadromous and lake-resident morphs of charr that co-exist within three lake systems of Southern Baffin Island, Nunavut, Canada. In a broad perspective I will examine whether the studied charr populations conform to salmonid life history patterns or follow current European studies. Current European studies suggest that slow growing juvenile charr become lake-residents whereas fast growing juveniles transition to the marine environment and become anadromous (Rikardsen and Elliot 2000).

METHODS

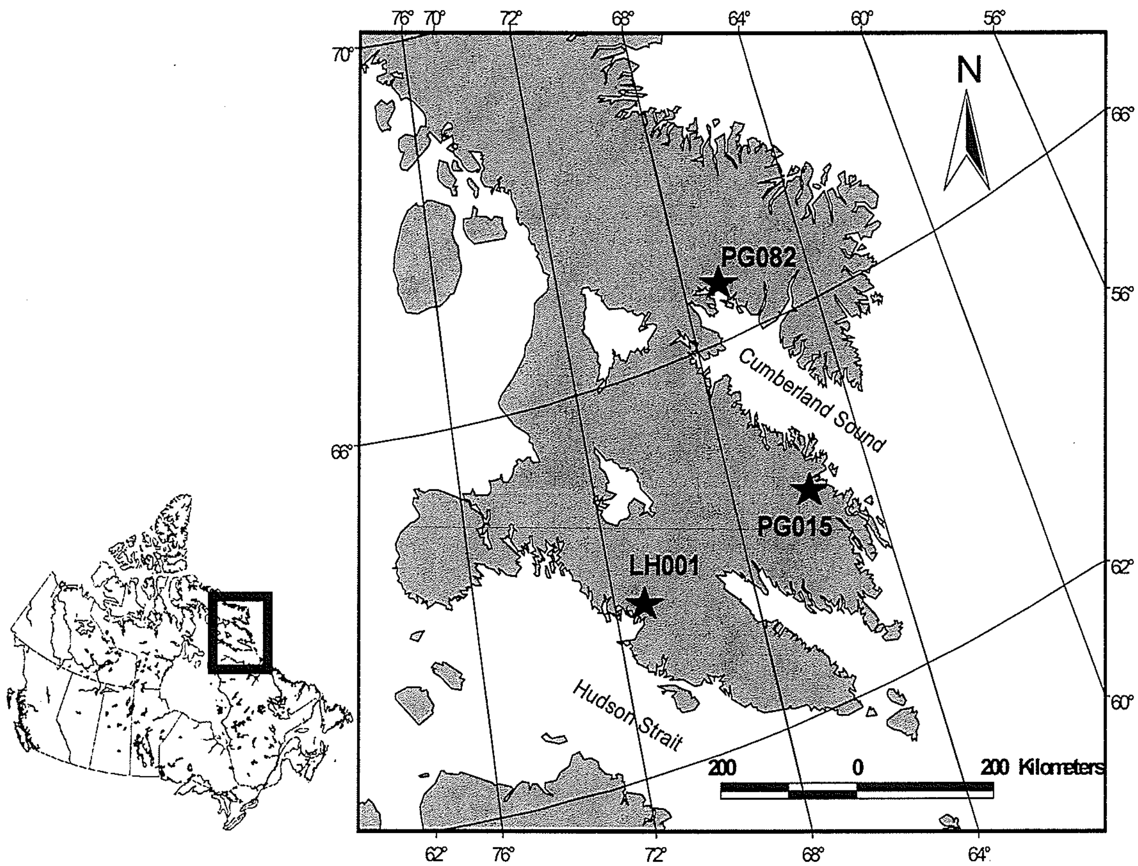
Study Area & Field Collection Methods

Arctic charr were collected from three similar Arctic lake systems in the Southern Baffin Island region: Iqalugaarjuit Lake (PG082), Shark Fiord, Nunavut (66 34.364N, 66 42.809W), Qasigiat (PG015), Ptarmigan Fiord, Nunavut (64 37.657N, 66 18.670W), and Qinngu (LH001), Blandford Bay, Nunavut (63 31.418N, 71 17.665W) (Fig. 2.1). The three lakes are set in mountainous regions and the outlet system to the sea is less than 1 km in length.

Field collection occurred within the lake systems from late-August to mid-September from 2001 to 2005. During the late summer/fall season, the majority of anadromous charr had returned to freshwater after their summer marine feeding season to over-winter and/or spawn. To obtain a representative sample of the individuals within the whole population, fish were captured with multi-mesh (38 mm-102 mm stretched mesh), 38 mm and 140 mm gillnets.

All fish (n = 1221) captured were sampled for fork length (mm), round weight (g), sex, maturity stage, and gonad weight (0.1 g). Degree of maturation was determined by visual inspection of the gonads. Maturity stages were defined as: immature (juvenile), mature, resting, running ripe and spent (see Appendix 2.1; Hutchings et al. 1999). Sagittal otoliths were removed for the purpose of age and size at age analyses. Ovaries of maturing females were preserved for determination of fecundity. Charr that were previously identified as anadromous and lake-resident morphs in Chapter 2 of my thesis were used in subsequent anlalyses. They will be referred to from this point forward as anadromous and lake-resident morphs of charr.

Fig. 2.1. The map of Canada is shown to highlight the study region of Southern Baffin Island, Nunavut. Within Southern Baffin Island, each study lake is represented by a star: Iqalugaarjuit Lake, Shark Fiord, NU (PG082); Qasigiat, Ptarmigan Fiord, NU (PG015) and Qinngu, Blandford Bay, NU (LH001). Both river systems of Iqalugaarjuit Lake and Qasigiat drain into Cumberland Sound. Qinngu drains into Hudson Strait.


PG082
Cumberland Sound
PG015
LH001
Hudson Strait
N
200
0
200 Kilometers
76°
70°
72°
68°
64°
60°
56°
66°
62°

Age Determination & Back-calculation Techniques

The technique of embedding and sectioning sagittal otoliths was used in age analysis of individual fish (Campana 2001; Chilton and Beamish 1982; Jenke 2002). Otoliths were embedded in an epoxy resin and left for approximately 4 days to set. Embedded otoliths were then sectioned across the nucleus perpendicular to the sulcus acusticus with a Buehler Isomet 1000 sectioning saw.

To determine divergence in size at age within each population images of the otolith sections of the mature fish within the population were taken via an Olympus DP12 digital camera attached to a Leica dissecting microscope. The imaging software, Scion Image was initially used to measure the distance from the nucleus to each annulus. Growth rings were measured on a straight line made at a 45° angle from the nucleus to the outer edge on the ventral lobe of the otolith. Preliminary analysis indicated that otolith size to fish size (measured by fork length) relationship was linear thus otolith growth was directly proportional to fish length (see Appendix 2.4; Ricker, 1975). The formula:

(1) $$L_f = \left(\frac{L_a}{L_o}\right)(L_c),$$

where L_f is the back-calculated length for year i, L_c is the fork length at time of capture, L_o is the total length of the otolith transect and L_a is the annular ring length for year i, was used to calculate size at age (Quinn and Deriso 1999). Back-calculated data for mature individuals was overlaid onto the directly observed size at age data for all maturity stages to ensure that it was representative of growth since a biological intercept is not known for these populations of charr (see Appendix 2.3).

Fecundity Determination and Egg Diameter

Fecundity was determined via whole egg counts for all mature (spawning) females within each population (see Appendix 2.2). To measure egg diameter five sub-samples of 2 eggs were chosen at random and measured to the nearest 0.1 mm. A total of 10 eggs were measured for each individual fish. Mean egg size was then determined for each fish. Misshapen eggs which occurred from human error in handling or preserving specimens were eliminated from egg diameter analysis. Eggs were considered misshapen if the outer membrane appeared broken or folded.

STATISTICAL ANALYSES

Age & Size at Maturity

Since it was not possible to reliably distinguish between juveniles of either morph, conventional methods of estimating age and size at maturation were not used in the statistical analyses. Mean age and size of fish previously classified as anadromous or lake-resident was reported as a relative measure of age and size of maturation.

Fecundity and Egg Diameter Analyses

Due to the low sample size of fecund lake-resident charr ($n = 5$), data from the 3 lakes of the study were pooled. A linear regression model was fit to the anadromous morph charr data ($n = 182$) with $\log_e$(total number of eggs) on the y-axis and $\log_e$(fork length) on the x-axis. Both 95% confidence and prediction intervals were fit to the linear regression model. Each datum (x_i, y_i) for lake-resident charr was compared to the linear regression model created for the anadromous fish as a new observation. The limits of the 95% confidence and prediction intervals were calculated for $\hat{y}_i$ at x_i (Neter et al. 1996). I then observed if y_i (observed) fell within the prediction intervals of $\hat{y}_i$ at x_i (see Appendix 2.5).

Egg diameter was also pooled for all lakes of the study and divided into anadromous morph females (n = 92) and lake-resident morph females (n = 5). Since egg development is highly influenced by spawning date, only females caught in the same sampling period for each location between the two morphs were used for the egg diameter analysis. A relationship between fork length and egg diameter was observed for the anadromous morph in preliminary analysis (Anadromous: Adjusted $R^2 = 0.114$, n= 92, p = 0.001) but a not within the lake-resident morph (Lake-resident: Adjusted R^2 = 0.517, n = 5, p = 0.105). As a result of size effects on egg diameter, the same linear regression analysis described above for fecundity was used. The linear model described above was fit to the anadromous charr data with egg diameter on the y-axis and fork length on the x-axis (see Appendix 2.5).

Growth Model

Back-calculated size at age data for fish in mature condition in the year of capture was used to compare growth between lake-resident and anadromous morph life histories. Initially each morph from every lake system studied was fit separately with various growth models commonly used in fisheries such as the von Bertalanffy growth model

(VBGM), logistic model, Gompertz model, and 3rd order polynomial models. The VBGM had the most parsimonious fit of all models, determined by both Akaike's information criterion (AIC) and Bayesian information criterion (BIC) analysis and thus was used for further analysis (Quinn and Deriso 1999). The VBGM model was written as follows:

$$(2) \qquad L_i = L_\infty \{1 - \exp\{-k(i - t_0)\}\},$$

where L_i is the observed fork length, i is the age, k is the growth co-efficient, L_∞ is the mean asymptotic length and t_0 is the hypothetic age at zero length (Jones 2000).

Serial correlation exists in back-calculated size at age data and must be taken into account when fitting models (Jones 2000; Schaalje et al. 2002). R statistical software (R Development Core Team 2006) was used to account for repeated measures with the linear and nonlinear mixed effects model (NLME) library package. Specifically, I used the generalised least squares fit of nonlinear models, gnls() function and the autocorrelation structure of order 1, corAR1() function (see Appendix 2.6; Box et al. 1994; Lindstrom and Bates 1990; Pinheiro and Bates 1996).

Various techniques have been proposed to compare the VBGM between groups since the parameters of the model are auto-correlated and should not be examined individually (Haddon 2001). To determine if each overall model fit was different between anadromous and lake-resident morphs, the analysis of the residual sum of squares (ARSS) test was used:

(3) $$F = \frac{RSS_p - \sum RSS_i}{DF_p - \sum DF_i} \bigg/ \frac{\sum RSS_i}{\sum DF_i}$$

where F = f-statistic, RSS_p is the residual sum of squares for the pooled data, DF_p is the associated degrees of freedom for the pooled data and the new growth model fit, $\sum RSS_i$ is the sum of the residual sum of squares for each data set i and $\sum DF_i$ is the associated degrees of freedom for each data set i and assuming all errors are distributed normally (Chen et al. 1992; Haddon 2001). Differences between sexes were examined for the anadromous fish groups for each lake studied using the same techniques outlined above.

RESULTS

General Observations

Consistency was noted in the degree of gonadal development between both morphs within each individual lake system of the study. Individuals of both morphs in spawning condition were captured in the same nets near regions in the lake that were thought to have available spawning habitat. During late August, I was able to capture charr via gillnets in the tidal environment moving upstream into river systems of all studied lakes.

Age & Size at maturation

In all lakes studied, the magnitude of variation between the two morphs of charr was substantial for mean age and mean size of mature individuals. The anadromous morph have a mean age of 10-13 years and a mean size of 532-641 mm at maturity whereas the lake-resident charr have a mean age of 8-9 years and a mean size of 184-202 mm at the relative measure of maturity (Table 2.1).

Fecundity & Egg Size

The lake-resident charr followed a similar fecundity and egg diameter model as anadromous charr. Lake-resident charr fell within the 95% prediction intervals of the anadromous charr linear regression model (Table 2.2 and Fig. 2.2). The egg diameter of lake-resident charr fell within the 95% prediction intervals of the anadromous charr linear regression model (Table 2.3 and Fig. 2.3).

Growth Models

The overall growth of lake-resident and anadromous charr within the same lake system was significantly different (Table 2.4 and Fig. 2.4). Although statistical comparison of individual parameters was not possible; a general descriptive comparison can be made. Specifically, the asymptotic growth parameter (L_∞) for anadromous charr is approximately three to four times larger than that for lake-resident individuals in all three lakes of the study (Table 2.5). Hypothetical age at zero length (t_0) is similar for both morphs of charr regardless of location. Lake-resident charr initially grow faster than anadromous charr in all three lakes of the study (Table 2.5). The growth co-efficient (k) for lake-resident charr is approximately double that of anadromous individuals in lakes LH001 and PG015. In lake PG082, lake-resident charr have a growth co-efficient similar to other lake-resident fish in the other two lake systems. A higher growth co-efficient is observed for anadromous fish from PG082 when compared to other migrant fish from the

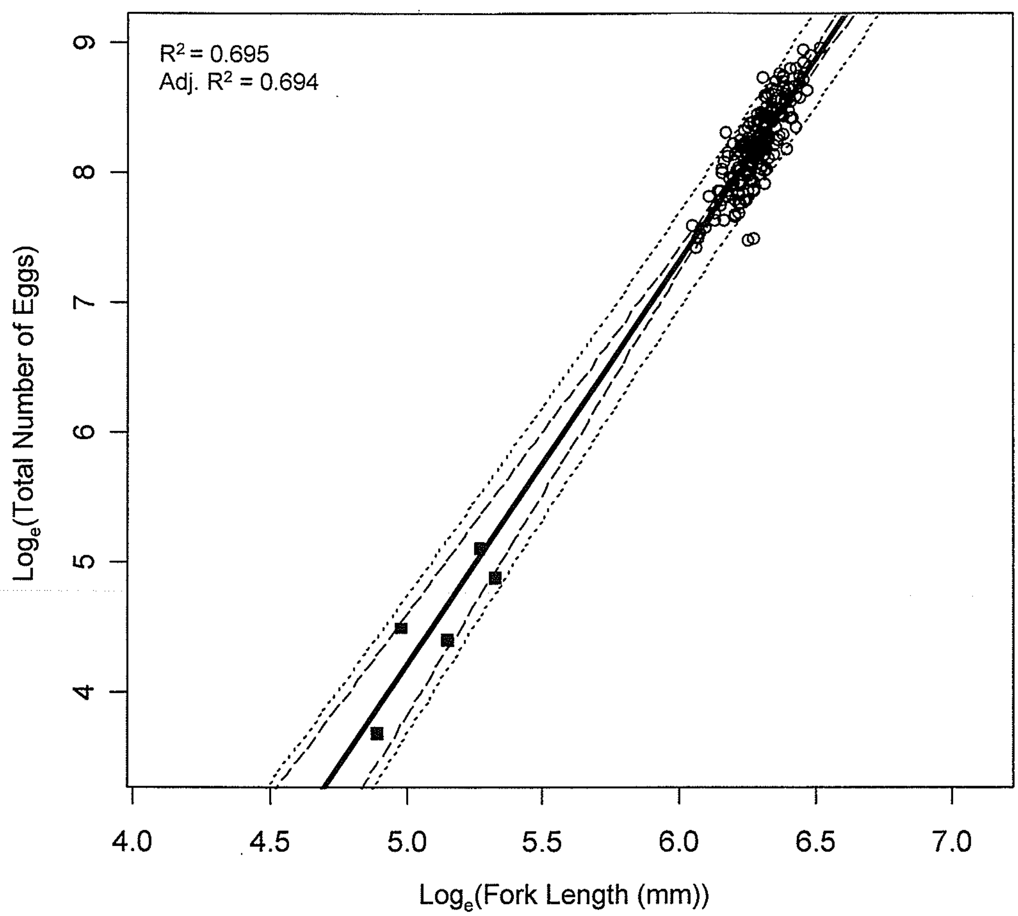
Table 2.1. The table represents mean age (years) and size (mm) of mature fish and the associated standard error (S.E.) for all three lakes in the study. n represents the sample size in the analysis. Ana refers to anadromous charr and Res refers to lake-resident charr.

Location-Type	n	Mean Age (S.E.)	Mean Size (S.E.)
LH001- Ana	324	13.28 (0.14)	641.10 (3.97)
LH001- Res	31	8.71 (0.57)	187.35 (7.09)
PG015- Ana	172	10.15 (0.18)	549.03 (6.15)
PG015- Res	35	7.89 (0.38)	184.42 (5.01)
PG082- Ana	172	10.15 (0.15)	531.99 (4.41)
PG082- Res	38	7.84 (0.31)	202.30 (3.98)

Table 2.2. Fecundity data (total number of eggs) for lake-resident charr was fit to the linear regression model of anadromous charr. A lower (lwr) and upper (upr) 95% confidence (C.I.) and prediction interval (P.I.) was calculated for each predicted value ($\log_e(y_i)$). No significance between actual and predicted value was observed ($t = -0.5742$, $df = 4$, $p = 0.5966$).

Actual Datum **$\log_e(y)$**	**Predicted Value** **$\log_e(y_i)$**	**(lwr, upr P.I.)** **$\log_e(y_i)$**
3.689	3.872	(3.317, 4.427)
4.500	4.143	(3.608, 4.677)
4.407	4.671	(4.173, 5.169)
5.106	5.048	(4.574, 5.521)
4.890	5.219	(4.756, 5.682)

Fig. 2.2. The linear regression model fit for anadromous charr fecundity (open circles) with associated confidence (dashed line) and prediction intervals (dotted line). The x-intercept for the model is -11.3406 (S.E. = 0.9647) and the slope is 3.1109 (S.E. = 0.1535). Lake-resident charr total egg number (squares) was overlaid onto the linear regression model of the large-maturing charr.

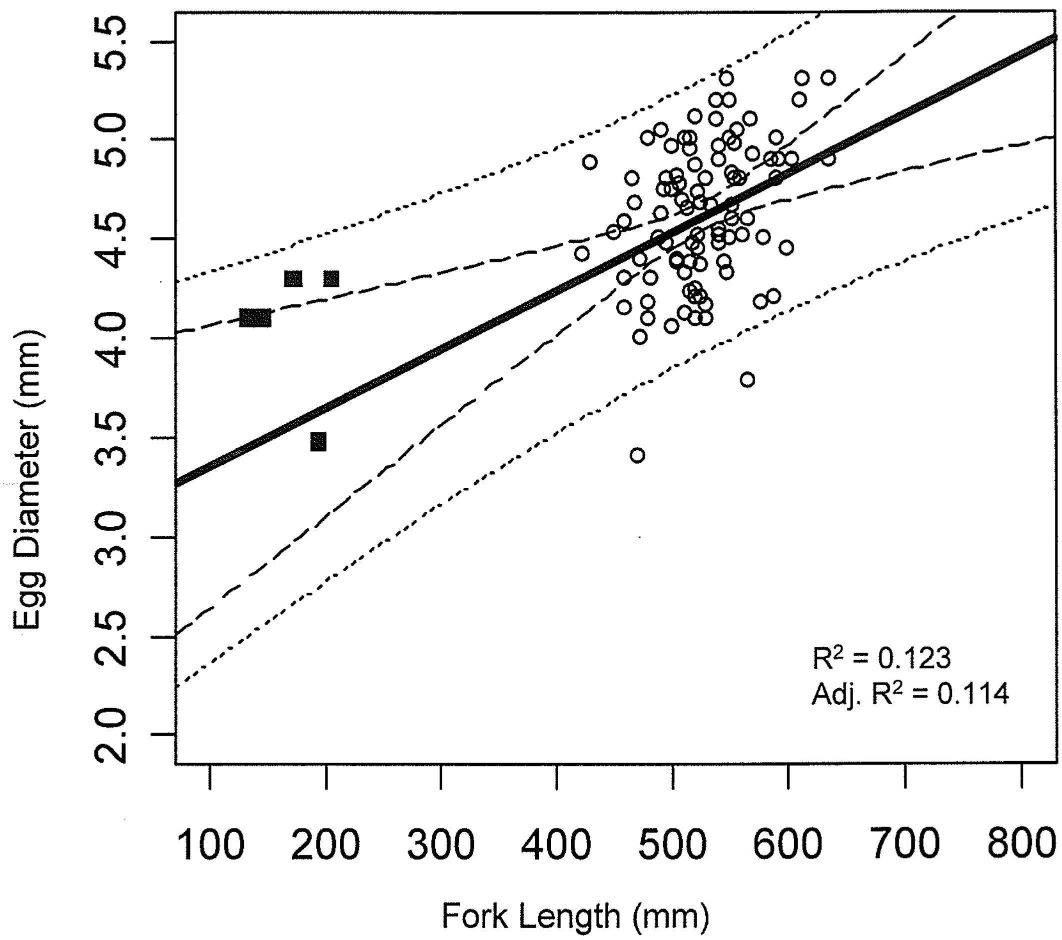


R² = 0.695
Adj. R² = 0.694
Log_e(Total Number of Eggs)
4
5
6
7
8
9
4.0
4.5
5.0
5.5
6.0
6.5
7.0
Log_e(Fork Length (mm))

Table 2.3. Egg diameter (mm) data for lake-resident charr was fit to the linear regression model of anadromous charr. A lower (lwr) and upper (upr) 95% confidence (C.I.) and prediction interval (P.I.) was calculated for each predicted value (y_i).

Actual Datum (y)	Predicted Value (y_i)	(lwr, upr P.I.) (y_i)
4.10	3.45	(2.50, 4.40)
4.10	3.49	(2.55, 4.42)
4.30	3.57	(2.66, 4.47)
3.48	3.63	(2.75, 4.51)
3.00	3.66	(2.79, 4.54)

Fig. 2.3. The linear regression model fit for anadromous charr egg diameter (open circles) with associated confidence (dashed line) and prediction intervals (dotted line). The x-intercept for the model is 3.0545 (S.E. = 0.4421) and the slope is 0.0030 (S.E. = 0.0008). Lake-resident charr egg diameter (squares) was overlaid onto the linear regression model of the anadromous charr.



5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
Egg Diameter (mm)
R^2 = 0.123
Adj. R^2 = 0.114
100
200
300
400
500
600
700
800
Fork Length (mm)

Table 2.4. Overall model fit for VBGM for each lake system of the study. df_N is the associated degrees of freedom of the numerator and df_D is the degrees of freedom of the denominator.

Location	F-statistic	(df_N, df_D)	p-value
LH001	394.097	(3, 910)	<0.001
PG015	493.724	(3, 1117)	<0.001
PG082	221.396	(3, 1064)	<0.001

Fig. 2.4. The box-plots of back-calculated size at age data for anadromous and lake-resident charr from lake LH001 were used to fit VBGM. The box-plots for anadromous and lake-resident charr from lake LH001 are representative of growth patterns observed in the other two lakes within the study: PG015 and PG082.

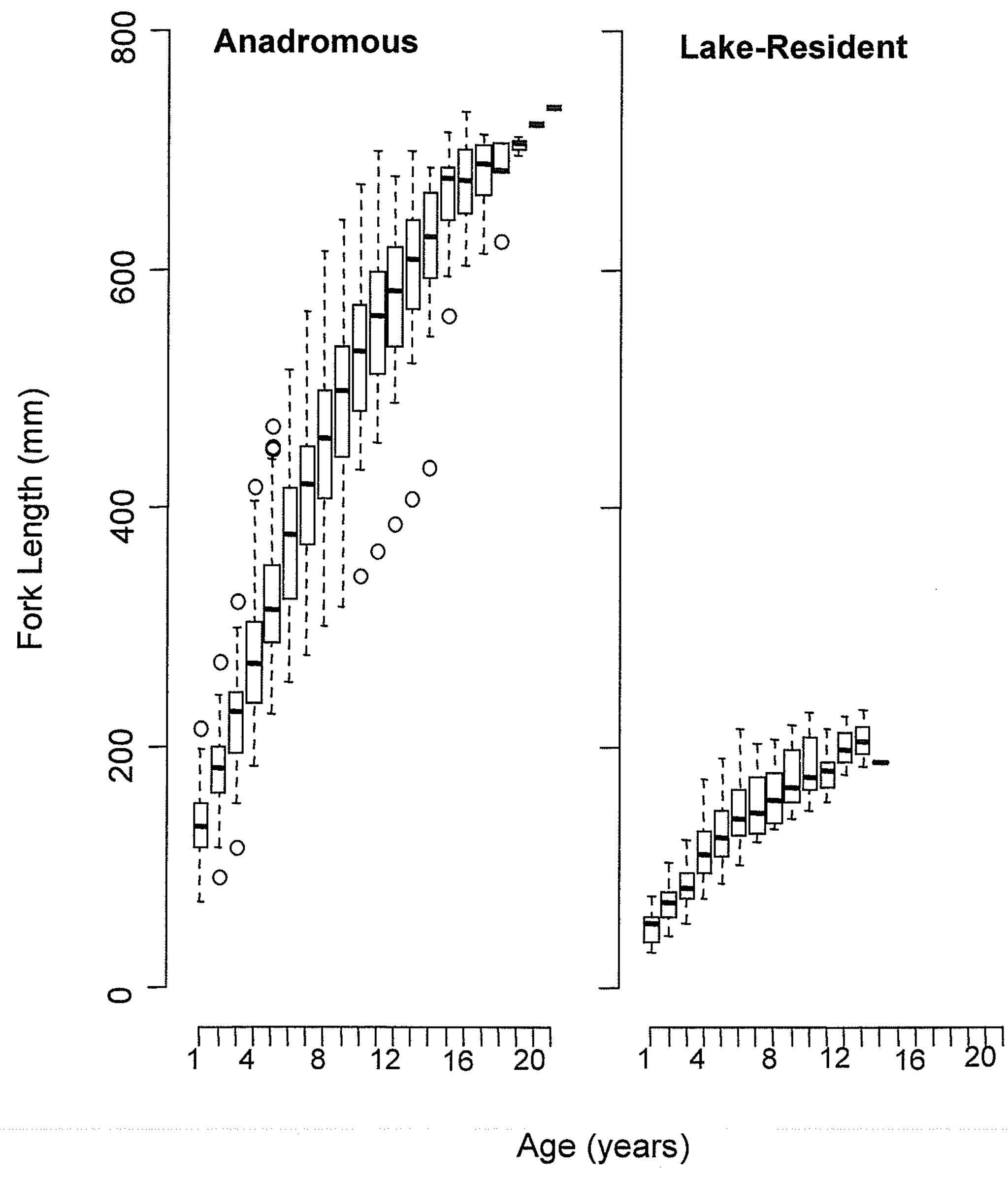

Anadromous
Lake-Resident
Fork Length (mm)
0
200
400
600
800
1
4
8
12
16
20
Age (years)

Table 2.5. VBGM parameters and the associated standard error (S.E.) for anadromous (Ana) and lake-resident (Res) charr for each lake system of the study. Correlations (r) are reported among parameters within each model.

Location-Type	**L_∞ (S.E.)**	**k (S.E.)**	**t_0 (S.E.)**	**$r_{L\infty-k}$**	**$r_{L\infty-t0}$**	**r_{t0-k}**
LH001- Ana	1149.272 (51.161)	0.053 (0.004)	-1.389 (0.142)	-0.975	-0.333	0.347
LH001- Res	293.773 (29.155)	0.094 (0.015)	-1.070 (0.245)	-0.963	-0.431	0.457
PG015- Ana	1468.231 (92.672)	0.038 (0.003)	-1.019 (0.097)	-0.993	-0.337	0.368
PG015- Res	290.024 (23.159)	0.090 (0.012)	-1.058 (0.199)	-0.966	-0.428	0.419
PG082- Ana	905.645 (27.312)	0.076 (0.004)	-0.944 (0.079)	-0.970	-0.362	0.354
PG082- Res	321.399 (24.984)	0.096 (0.013)	-1.549 (0.216)	-0.968	-0.552	0.588

other two lakes of the study but it is lower than the lake-resident individuals from the same lake system.

Growth models were also analysed based on sex for the anadromous portions of each lake system. The ARSS test indicates that male and female growth is different (Table 2.6). Although this is the case, model parameters are similar between males and females from each lake studied (Table 2.7).

DISCUSSION

Energy limitations in the environment should result in variation between tradeoffs of growth, reproduction and mortality within multiple life history forms to achieve optimal fitness (Thorpe 1999). When resource needs are met, fish should mature at the earliest opportunity (Thorpe et al. 1998). Specifically, if resource needs are met within freshwater, individuals would likely mature and follow a resident type life style and when resource needs are not met within freshwater, individuals will likely smolt and follow an anadromous life style (Gross 1987). Within my study, variation of life history choice is observed in all life history parameters examined except fecundity and egg diameter. Further, gillnetting in the marine environment adjacent to the river mouth during late August has captured charr moving upstream into the river system of all lakes studied. Early life growth and juvenile mortality are thought to be indicative of the life history form that an individual will initially adopt (Stearns 1992). Studies on many salmonid species such as Atlantic salmon (*Salmo salar*), brook trout (*Salvelinus fontinalis*) and Arctic charr support classical life history theory (Damsgård et al. 1999; Hendry et al.

Table 2.6. Sex comparison overall model fit for VBGM for each lake system of the study. df_N is the associated degrees of freedom of the numerator and df_D is the degrees of freedom of the denominator.

Location	F-statistic	(df_N, df_D)	p-value
LH001	33.374	(3, 741)	<0.001
PG015	10.251	(3, 948)	<0.001
PG082	21.904	(3, 984)	<0.001

Table 2.7. VBGM parameters and the associated standard error (S.E.) for anadromous male and female charr for each lake system of the study. Correlations (r) are reported among parameters within each model.

Location-Type	**L_∞ (S.E.)**	**k (S.E.)**	**t_0 (S.E.)**	**$r_{L\infty\text{-}k}$**	**$r_{L\infty\text{-}t0}$**	**$r_{t0\text{-}k}$**
LH001- Male	1158.162 (54.894)	0.055 (0.004)	-1.460 (0.158)	-0.973	-0.352	0.386
LH001- Female	1060.025 (92.110)	0.054 (0.007)	-1.201 (0.222)	-0.981	-0.357	0.391
PG015- Male	1562.885 (145.345)	0.036 (0.004)	-1.097 (0.157)	-0.992	-0.317	0.343
PG015- Female	1316.244 (105.252)	0.043 (0.005)	-0.927 (0.112)	-0.993	-0.386	0.427
PG082- Male	1104.915 (80.060)	0.061 (0.007)	-1.177 (0.192)	-0.977	-0.348	0.337
PG082- Female	831.141 (25.682)	0.084 (0.004)	-0.850 (0.079)	-0.967	-0.376	0.385

2004; Morinville and Rasmussen 2003; Thorpe 1999). These studies suggest that fast growth early in life results in early age and small size at maturation and subsequently a freshwater resident life style whereas slow growth early in life results in a delay in age- and large size- at maturation. A parallel trend was observed in all studied lakes. Within all studied lakes, anadromous charr tended to mature at a greater size and older age whereas lake-resident charr tended to initially grow fast to reach an early age and decreased size at maturity. Comparisons of the anadromous group within each lake studied reveal differences between sexes. Although this is the case, model parameters are similar and much overlap in the back-calculated data exists. Sex differences within salmonid populations are a common occurance in the reported literature (Quinn 2005).

According to general life history theory, organisms will mature at the earliest opportunity, and in the case of fish species, maturation takes precedence over smoltification (Stearns 1992). Thorpe et al.'s (1998) studies on Atlantic salmon suggest that environmental opportunity and genetic thresholds are used to determine maturation and smoltification. Fish are able to assess lipid reverses after critical energetically depleting events such as over-wintering and spawning. At these critical times gonadal development can either be initiated or arrested. The decision to smolt or mature occurs well in advance (approximately 12 months) of the actual event. A study on two broad whitefish (*Coregonus nasus*) populations of the Mackenzie Delta watershed further supports Thorpe's suggestion of diversion of energy away from growth prior to age at first sexual maturation. VanGerwen-Toyne (2001) found that broad whitefish of the Peel and Arctic Red River systems slowed growth 1-2 years prior to age at first sexual maturation.

Contrary to classical life history theory, Rikardsen et al.'s (1997, 2000) studies on Arctic charr juvenile growth suggest the opposite effect. These studies indicate that fast growing juveniles smolt and slow growing juveniles become lake-residents. However, Rikardsen et al.'s studies were carried out on juvenile charr in the last 1.5 years prior to maturation or smoltification and do not take into account the entire juvenile growth period. Furthermore, the juvenile stage for migrant and resident individuals may be of varying length in time and this is not accounted for within their studies. It is likely that during their study period, juvenile charr that were going to mature were already diverting energy away from growth and into reproduction whereas individuals that were going to smolt likely continued to invest high levels of energy into growth. By examining Rikardsen and Elliot's (2000) population characteristic data, it is evident that many of the lake-dwelling males and females were already in spawning condition or close to spawning during the study period. Providing age at maturation data for smolting individuals could resolve these issues since first age at maturation is significant in determining which group (smolting fish or resident fish) is delaying maturation. Caution should be used when applying life history theory to studies on juvenile charr growth that do not represent the entire pre-maturation growth period.

In other salmonids, anadromous and lake-resident females may have similar selective advantages in the production of eggs (Stearns 1992). Egg size is generally thought to be positively correlated with offspring fitness and subsequently maternal fitness (Einum et al. 2004). Within my study egg diameter and egg number appear to be continuous between anadromous and lake-resident morph females and a positive relationship exists between fish length and egg size. Although lake-resident morph charr may follow the same reproduction models as anadromous morph charr they still produce smaller eggs on average due to energetic and body size constraints. Increased egg size for anadromous morph charr is a selective advantage as a result of higher amounts of energy available to offspring. Thus, anadromous charr are able to increase their offspring's chances of survival and associated fitness regardless of environmental condition (Einum et al. 2004). Lake-resident offspring, due to smaller egg sizes, have a survival success that is more dependent on environmental condition. They may be at a selective disadvantage when environmental conditions are unfavourable; offspring from small eggs have higher mortality rates in unfavourable environments (Hutchings 1991; Klemetsen et al. 2003). Although this may be the case, recent studies on Atlantic salmon, brown trout, masu salmon (*Oncorhynchus masou*) and white-spotted charr (*Salvelinus leucomaenis*) connect maternal juvenile growth rate to egg size (Jonsson et al. 1996; Lobon-Cervia et al. 1997; Morita et al. 1999). These studies suggest that resident females are able to use their own growth experience to adjust egg size for optimal offspring fitness in the expected environment (Einum et al. 2004). Adaptive phenotypic plastic response to early growth conditions is suggested as reasoning for this occurrence (Einum et al. 2004). Anadromous females within the studied lakes are able to produce greater size and number of eggs but have a have a higher probability of mortality before they are able to reproduce due to a delay in maturity. Lake-resident females within all studied lakes follow a pattern of early maturation accompanied by a reduction in egg numbers and decreased egg size but have an increased probability of survival to maturation since they mature at the earliest opportunity. Lake-resident spawners have shorter generation times and faster rates of gene reassortment due to their ability to produce eggs earlier in life (Thorpe 1999). As a result, balance in fitness between both morphs of charr is observed.

Precociousness in each stock of the study has a sex bias towards males as observed in other studies of salmon species such as Atlantic salmon, brown trout, and Chinook salmon (*Oncorhynchus tshawytscha*) (Jonsson 1985; Jonsson and Jonsson 1993; Hendry et al. 2004, Quinn 2005). Females should have a higher tendency toward anandromy if all members of the stock interbreed and only some members migrate (Hendry et al. 2004). Migration out to sea combined with a delay in maturity would subsequently increase growth potential and energetic reserves before initial reproduction (Stearns 1992; Winemiller and Rose 1992). Increased energy resources and larger body size, allows for the production of increased egg numbers and egg diameter thus maximising fitness. Further, iteroparous females can then migrate back out to sea in the following year(s) after a spawning event and recover energy deficits to reproduce again. Reproductive success in males is not highly correlated with body size but rather is a function of the number of eggs that can be fertilised (Hendry et al. 2004). The data within my study supports the likelihood of sex bias toward a particular life history. Over the four year period of the study only five lake-resident females in spawning condition were caught within all three lake systems whereas 92 precocious males in spawning condition were captured in the same period of time.

The commonality of the existence of multiple phenotypes is observed in many salmonid populations. A balance between life history trade-offs likely exists between multiple phenotypes within a population. Up to four phenotypic morphs (small benthivorous, large benthivorous, picivorous, and planktivorous) of charr exist within landlocked European populations of Arctic charr (Sandlund et al. 1987; Skúlason et al. 1996). Within these populations, habitat specialisation and reproductive isolation are known to occur. Alternatively in some Canadian, Norwegian and Swedish lakes where multiple morphs have been identified, inter-breeding between morphs has been observed (Nordeng 1983; Papst 1994; Svendäng 1992). Further one morph can give rise to other morphs of charr (Nordeng 1983; Papst 1994; Svendäng 1992). Parker et al.'s (2001) model predicted that under unpredictable environmental conditions, bet-hedging of life history choice may maximise individual fitness by incomplete assortative mating especially in species such as charr that exhibit extreme phenotypic plasticity. Indirect evidence for reproduction between forms is observed within my study suggesting that incomplete assortative mating exists between forms. Further, the unequal ratio of males to females and the lack of separation between spawning females of both forms within the fecundity and egg diameter models suggest that individuals belong to the same spawning stock.

Evolutionary stable strategies (ESS) and alternatively disequilibrium theory have both been proposed as evolutionary processes within the development of multiple life histories and morphotypes within a population (Balon 1983; Maynard Smith 1982). ESS are based on game theory to try and attempt to explain how natural selection acts on different behaviours within a population. ESSs suggest a balance or equality in fitness among members of the population regardless of life history strategies or morphotypes based upon frequency dependence. Balon (1983, 1984) relates the mix of observed morphologies to environmental conditions. He suggests that stable states will favour specialisation of traits whereas disturbed states will favour generalist states. He further

(1983, 1984) suggests that disequilibrium exists within populations where members of a population alternate between conditions of stability and instability to achieve the existence of multiple life histories. I am not able to distinguish between the applicability of either ESS or disequilibrium theory using the data collected in my study. Future research directions such as laboratory studies on phenotype-genotype and environmental interaction of charr may provide the resolution to these competing perspectives.

The results of my study are parallel to what is commonly observed in general life history theory for other salmonid species but contradicts what has been reported in some European charr studies. Within my study, anadromous charr matured at 532 to 641 mm in length and 10 to 13 years of age and initially grew slower as juveniles. Lake-resident charr matured at 184 to 202 mm in length and 8 to 9 years of age and initially grew faster as juveniles. Our current study highlights the significance of early life growth rates of juvenile fish in determining life history choice. Further investigation into intra-stock variation and structure of Arctic charr is warranted specifically within Canadian waters.

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CHAPTER 4. SUMMARY AND GENERAL CONCLUSIONS

Phenotypic plasticity is prevalent within Arctic charr populations throughout their distribution (Adams and Maitland 2007; Klemetsen et al. 2003; Sandlund et al. 1987; Savvaitova 1995). Within open lake systems charr are known to co-exist as lake-residents and anadromous morphs (Strand and Heggerget 1994; Rikardsen and Elliot 2000; Rikardsen et al. 2004). Many studies of the inter-relationships between lake-resident and anadromous morphs exist within European regions whereas few studies have focused on these morphs within the Canadian High Arctic regions (Strand and Heggerget 1994; Rikardsen et al.1997; Rikardsen et al. 2004; Svedäng 1992). The purpose of my research was to identify habitat, life history and morphological variation between two forms of charr initially classified as small- and large-maturing found within three open lake systems of southern Baffin Island region. Fish were initially classified as large bodied fish (>400 mm) in spawning condition (large-mature), small bodied fish (<400 mm) in spawning condition (small-mature) and immature and resting small bodied charr (undeveloped) by use of a bimodal fork length histogram and examination of gonadal development for individual fish.

Two patterns of habitat use by small- and large-maturing fish groups were observed within the three lakes studied. Within PG082 and LH001 small-maturing charr were lake-resident whereas large-maturing charr were anadromous. Within PG015 small- and large-maturing charr both appear to utilise the marine habitat. Observational data of small bodied charr within the tidal zone supports the use of the tidal estuarine habitat within PG015. However, small-maturing charr in PG015 have morphological characters that suggest that they are non-migratory. Due to the geography of the lake system and river length small-maturing charr and small bodied charr may facultatively utilise the tidal region. I hypothesize that the lack of good rearing habitat has allowed for the adaptation of small bodied charr to utilise the tidal habitat since entry into brackish waters can occur early in life for charr. Dempson (1993) found similar tolerance of salinity in small bodied charr.

Parallel morphometric variation was observed within all three charr populations of the study. Small-maturing charr tended to have larger eye diameter and longer pectoral and pelvic fin lengths within all three lakes of the study. Within PG082 and LH001 upper jaw length was also significant and tended to be longer than the undeveloped group. In addition PG015 fork depth was significant and tended to be shallower than their undeveloped group counter-parts. Longer pectoral and pelvic fins are associated with short quick swimming movements and are functionally useful for predator avoidance whereas short paired fins are associated with a more streamlined body and increased efficiency in swimming longer distances (Videler 1993, Webb 1984). I infer from both morphological and strontium analyses that small-mature charr are lake-residents and large-mature charr are anadromous. Small-mature charr will be referred to as lake-residents and large-mature charr will be referred to as anadromous from this point forward in the conclusion.

Analogous life-history variation was observed within all three charr populations studied. Lake-resident charr within all three lake systems of the study tended to have an intrinsic rate of growth double that of anadromous charr within the each respective population. Lake-resident charr also had a mean size of maturation that ranged from 184 to 202 mm and a mean age of maturation that ranged from 8 to 9 years of age whereas anadromous charr had a mean size at maturation that ranged from 532 mm to 641 mm and a mean age of maturation that ranged from 10 to 13 years. Lake-resident females in reproductive condition fit similar fecundity number and egg diameter size models. Lake-resident female egg number was likely constrained by body size.

The variation of life history characters summarised above is in agreement with current general life history theory. Alternatively, the intrinsic rate of growth reported within my research deviates from what is currently reported within Rikardsen et al's (1997, 2000) charr studies. He suggests that fast growing individuals in the juvenile stage smolt whereas slow growing individuals in the juvenile stage recruit to lake-residents and mature. In close examination of Rikardsen et al's (1997, 2000) and Rikardsen and Elliot's (2000) charr studies it is apparent that the study was carried out on juvenile charr in the last 1.5 years prior to maturation or smoltification and do not take into account the entire growth period. Furthermore, the juvenile stage for migrant and resident individuals may be of varying length in time and this is not accounted for within their studies. During this period of time lake-resident charr most likely were diverting energy away from growth into maturation. Thorpe et al. (1998) and VanGerwen-Toyne's (2001) studies of Atlantic salmon (*Salmo salar*) and broad whitefish (*Coregonus nasus*) support the diversion of energy away from growth prior to maturation. Caution should be used when applying life history theory to studies on juvenile growth that do not represent the entire growth period.

My current analysis of habitat use, life history and morphological variation has provided a strong foundation for further studies of open-lake systems within the Canadian High Arctic. It also highlights many further questions. Is reproductive isolation or incomplete assortative mating occurring within each of the populations? What is the genetic relationship between small- and large-maturing morphs? Indirect evidence from our life history data suggests incomplete assortative mating is likely occurring but verification is necessary. European and Icelandic studies of charr have shown genetic divergence between morphs within a population but this area has not been well studied on Canadian charr. What are the migratory patterns of charr (juveniles, lake-resident and anadromous) within the marine environment and lake system especially within PG015? Radio and acoustic telemetry studies could be used to investigate habitat use exhibited by different life history stages and morphs within each population. At what time do fish "make the decision" to become lake-resident or migrant? At what point in a juvenile charr's life is energy converted away from growth into reproduction? In large part our research lacked detailed information on early life stages of charr. Future studies should examine juvenile growth patterns from the point of hatch to maturation. Determining when energy is diverted from growth and into reproduction occurs will aid in reconciling the discrepancies between European and Canadian studies of charr.

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APPENDIX 1.1

Morphological data used for PFA and univariate analysis in **Chapter 2**. LOC represents location and CLAS represents classification (UD = undeveloped, SM = small-maturing). Morphological characters measured were head length (Head Len), head depth (Head Dep), eye diameter (Eye Len), snout length (Snout Len), upper jaw length (Up Jaw Len), pectoral fin length (Pec Fin Len), pelvic fin length (Pelv Fin Length), body depth (Body Dep), caudal peduncle (Caud Ped), lower arch length, fork depth (Fork Dep) and standard length (Stand Len). Sexes identified are male (M), female (F) and unknown (U). Blank spaces refer to missing data due to damaged fish samples for morphological analysis. These samples were completely excluded for multivariate analysis (PFA). For PG015 morphological character lower arch length was excluded from analysis to increase sample size (less fish had to be eliminated from analysis).

LOC	Sample #	SEX	MAT	Head Len (mm)	Head Dep (mm)	Eye Len (mm)	Snout Len (mm)	Up Jaw Len (mm)	Pec Fin Len (mm)	Pelv Fin Len (mm)	Body Dep (mm)	Caud Ped (mm)	Low Arch Len (mm)	Fork Dep (mm)	Stand Len (mm)
PG082	CS02477	M	UD	69.24	29.57	10.01	19.52	32.48	44.30	37.84	55.34	21.62	27.06	28.00	314
PG082	CS01271	F	UD	67.25	37.97	9.78	18.10	34.11	41.77	35.56	71.43	23.46		27.90	326
PG082	CS02413	M	UD	67.18	38.45	10.06	17.95	33.13	39.16	34.59	69.25	21.45	26.52	20.00	336
PG082	CS04602	M	SM	35.15	16.34	8.38	11.16	16.79	25.03	18.86	23.98	10.62	12.35	10.00	144
PG082	CS04627	M	SM	32.95	19.13	7.73	9.60	16.60	24.73	20.21	25.80	11.43	12.11	11.00	144
PG082	CS02456	M	SM	33.00	20.63	7.86	8.13	16.73	27.18	21.61	29.61	12.82	12.81	12.00	145
PG082	CS04610	M	SM	34.92	17.64	8.13	9.71	17.02	25.22	18.97	27.96	10.25	12.70	14.00	148
PG082	CS02455	M	SM	34.97	18.00	8.37	9.15	16.01	26.43	19.80	31.72	10.78	12.38	12.00	152
PG082	CS01248	M	SM	38.64	21.12	8.11	10.38	20.02	28.71	20.53	31.22	13.01	15.45	16.94	154
PG082	CS02469	M	SM	34.11	18.78	8.73	10.66	18.46	27.07	23.17	27.90	11.43	14.58	13.00	162
PG082	CS01199	M	SM	37.87	21.86	8.67	10.61	19.89	29.34	22.85	35.19	13.56	13.74	12.41	162
PG082	CS04606	M	SM	40.44	21.93	9.07	10.86	20.73	32.55	24.55	29.00	10.56	15.81	12.00	168
PG082	CS01249	M	SM	39.19	23.65	8.54	9.47	19.90	28.76	22.60	32.33	13.18	15.75	18.23	162
PG082	CS01250	F	SM	39.20	21.83	8.46	9.86	18.72	27.34	21.07	34.29	14.52	14.56	12.69	173
PG082	CS02403	M	SM	41.91	22.86	7.97	11.88	22.71	32.21	24.07	34.36	11.09	16.73	13.00	171
PG082	CS04612	M	SM	38.50	18.88	8.58	10.25	18.22	29.32	23.69	24.75	11.08	14.41	15.00	172
PG082	CS04589	M	SM	40.71	21.27	8.66	12.61	20.69	30.93	21.90	30.93	11.71	15.19	11.00	177
PG082	CS04630	M	SM	39.77	21.24	8.67	11.71	20.35	30.96	23.23	33.87	12.23	14.97	13.00	175
PG082	CS04588	M	SM	40.88	19.66	9.04	11.84	21.30	29.58	19.73	32.32	12.55	15.89	14.00	175
PG082	CS04639	M	SM	42.95	23.08	9.39	11.55	22.20	33.06	25.61	30.62	12.28	16.74	16.00	173
PG082	CS04587	M	SM	41.14	21.40	9.25	11.33	22.26	29.15	24.20	31.47	13.53	16.26	11.00	182
PG082	CS04625	M	SM	43.85	24.21	8.26	13.03	22.63	29.83	26.86	30.86	12.18	17.09	14.00	179
PG082	CS01196	M	SM	41.23	24.71	9.55	9.28	22.45	33.00	25.57	33.47	14.01	16.57	19.84	174
PG082	CS04584	M	SM	42.55	22.41	9.37	11.88	22.55	32.47	23.85	31.58	11.51	16.04	15.00	179
PG082	CS01246	M	SM	41.54	24.20	8.97	9.91	20.04	29.02	23.44	31.75	16.05	16.15	11.11	184

LOC	Sample #	SEX	MAT	Head Len (mm)	Head Dep (mm)	Eye Len (mm)	Snout Len (mm)	Up Jaw Len (mm)	Pec Fin Len (mm)	Pelv Fin Len (mm)	Body Dep (mm)	Caud Ped (mm)	Low Arch Len (mm)	Fork Dep (mm)	Stand Len (mm)
LH001	MIP05050	U	UD	20.83	10.93	5.81	5.07	9.62	16.35	10.96	16.87	6.15	7.59	5.00	90
LH001	MIP04351	M	UD	22.38	10.18	5.69	5.35	9.25	16.53	10.95	13.06	5.14	6.89	6.00	89
LH001	MIP05020	M	UD	22.69	11.93	6.55	5.15	10.08	13.61	10.42	15.66	5.97	8.48	9.00	88
LH001	MIP04355	M	UD	23.67	10.56	6.00	5.72	9.48	17.82	11.77	17.48	6.57	6.77	9.00	100
LH001	MIP05019	M	UD	24.57	10.69	6.40	6.72	9.89	17.84	11.99	18.55	6.77	16.68	11.00	102
LH001	MIP04347	U	UD	24.02	11.52	6.27	6.08	16.93	12.74	18.08	11.11	6.66	7.29	7.00	103
LH001	MIP04350	M	UD	23.38	11.35	6.20	5.76	10.54		12.38	18.38	6.40	7.61	7.00	104
LH001	MIP04343	F	UD	24.56	11.13	6.65	6.10	11.98	18.97	13.70	19.78	7.79	8.27	9.00	105
LH001	MIP04354	F	UD	25.96	11.95	6.28	5.97	11.02	18.49	12.75	17.83	6.87	9.38	8.00	108
LH001	MIP04338	M	UD	26.45	12.76	6.26	6.47	10.43		12.09	18.33	7.19	8.18	9.00	108
LH001	MIP04353	M	UD	26.18	12.52	6.82	6.39	10.88	18.71	13.29	17.29	7.35	9.28	8.00	109
LH001	MIP04349	F	UD	25.25	11.57	6.40	6.32	10.88	17.58	12.02	23.55	6.84	9.96	8.00	112
LH001	MIP04342	M	UD	25.90	11.73	6.67	6.95	11.58	19.76	13.39	16.87	7.98	8.79	8.00	112
LH001	MIP04337	U	UD	27.03	11.08	6.96	7.50	12.59	19.13	14.20	24.04	7.67	11.72	11.00	122
LH001	MIP04359	M	UD	30.11	14.64	6.98	7.68	12.58	20.98	14.86	23.79	8.06	11.34	10.00	133
LH001	MIP04339	M	UD	30.80	13.58	7.17	7.69	13.44	23.03	17.48	21.25	8.58	11.66	8.00	137
LH001	MIP05122	M	UD	30.68	15.30	7.64	7.79	13.96	21.07	17.26	23.57	8.74	12.67	12.00	136
LH001	MIP05060	M	UD	32.60	18.05	7.26	7.96	11.67	18.03	16.47	34.36	8.32	11.60	10.00	151
LH001	MIP05121	M	UD	34.66	15.24	8.56	8.74	14.30	21.47	17.53	22.67	10.09	12.60	10.00	158
LH001	MIP05052	F	UD	32.80	15.70	7.73	8.09	12.11	18.66	16.31	31.71	9.47	11.82	11.00	161
LH001	MIP05059	M	UD	35.20	17.76	7.72	9.38	12.94	18.71	14.55	32.70	9.18	11.77	9.00	162
LH001	MIP05021	M	UD	34.09	15.64	7.09	7.23	14.62	20.19	16.26	32.71	10.28		11.00	168
LH001	MIP05029	M	UD	33.76	15.00	7.47	9.26	15.19	20.40	15.32	32.17	9.86	13.00	10.00	162
LH001	MIP05119	F	UD	34.73	15.88	7.14	7.39	13.90	19.43	16.51	31.33	13.30	13.17	14.00	155
LH001	MIP04357	M	UD	34.59	16.00	7.45	9.82	15.06	22.47	15.71	33.62	9.72	14.48	7.00	164

LOC	Sample #	SEX	MAT	Head Len (mm)	Head Dep (mm)	Eye Len (mm)	Snout Len (mm)	Up Jaw Len (mm)	Pec Fin Len (mm)	Pelv Fin Len (mm)	Body Dep (mm)	Caud Ped (mm)	Low Arch Len (mm)	Fork Dep (mm)	Stand Len (mm)
LH001	MIP04363	F	UD	35.03	16.55	7.00	9.83	14.79	20.38	16.20	29.87	10.47	11.27	10.00	162
LH001	MIP05112	F	UD	36.56	16.73	7.63	9.35	16.63	24.67	18.38	29.42	9.98	13.56	12.00	163
LH001	MIP05056	F	UD	37.01	18.35	7.74	9.87	15.45	23.48	16.50	37.06	10.38	15.03	7.00	167
LH001	MIP05068	M	UD	35.56	17.53	7.34	8.87	14.70	17.90	16.15	29.58	10.35	12.61	8.00	175
LH001	MIP05047	F	UD	35.92	16.14	7.73	9.01	15.00	22.32	18.84	32.38	10.65	13.84	11.00	169
LH001	MIP04362	F	UD	39.02	18.16	7.73	11.15	18.73	26.44	20.70	31.86	10.33	14.80	17.00	165
LH001	MIP05045	F	UD	34.32	16.01	7.26	8.21	17.87	19.61	17.66	30.65	10.42	14.68	10.00	169
LH001	MIP05117	M	UD	34.77	16.44	6.95	9.31	16.95	22.85	17.81	34.67	10.70	11.52	12.00	169
LH001	MIP05113	M	UD	36.08	18.33	7.51	9.18	17.01	23.19	17.07	32.51	11.07	13.55	12.00	178
LH001	MIP05066	M	UD	36.99	16.62	6.27	9.35	15.44	22.46	16.94	39.25	12.33		10.00	179
LH001	MIP05116	F	UD	36.52	17.76	7.98	10.29	16.33	25.54	19.25	35.36	12.11	17.71	12.00	181
LH001	MIP05061	M	UD	36.94	18.86	7.68	8.62	15.10	21.00	18.09	30.11	10.86	15.90	10.00	184
LH001	MIP05067	M	UD	37.83	15.77	7.26	10.32	15.57	22.03	18.49	30.84	12.35	15.51	9.00	182
LH001	MIP05110	F	UD	38.15	19.87	7.99	9.43	15.47	24.13	16.96	36.75	11.27	16.02	11.00	187
LH001	MIP05058	M	UD	38.25	18.25	8.79	10.07	17.35	23.74	20.48	27.69	13.31	15.75	11.00	186
LH001	MIP04361	M	UD	36.93	17.23	7.04	9.78	15.26	25.13	19.85	34.16	10.15	9.54	12.00	184
LH001	MIP04356	M	UD	38.32	18.80	7.93	11.01	16.93	24.64	16.95	39.02	12.48	15.33	10.00	187
LH001	MIP05039	F	UD	35.32	17.54	7.57	8.79	15.20	20.06	16.53	35.52	12.14	14.10	12.00	183
LH001	MIP05043	F	UD	39.91	17.44	7.23	10.87	16.58	22.78	18.15	34.42	11.55	14.43	11.00	189
LH001	MIP05064	M	UD	36.93	16.70	7.56	9.49	15.96	23.91	20.03	39.60	12.00	16.77	12.00	186
LH001	MIP05115	M	UD	38.85	19.15	7.57	10.76	17.62	24.66	19.77	33.43	10.69	15.68	10.00	192
LH001	MIP05123	M	UD	37.30	17.58	7.66	9.24	16.83	23.47	19.80	36.36	12.09	15.17	14.00	185
LH001	MIP05038	F	UD	41.22	18.76	7.51	10.19	17.02	20.39	18.42	36.39	10.91	15.86	21.00	194
LH001	MIP05037	F	UD	42.51	20.58	9.33	11.07	18.66	28.50	21.61	30.19	11.89	14.65	16.00	187
LH001	MIP05120	F	UD	37.57	19.65	7.68	11.52	16.56	23.36	19.61	33.67	11.96		9.00	194

LOC	Sample #	SEX	MAT	Head Len (mm)	Head Dep (mm)	Eye Len (mm)	Snout Len (mm)	Up Jaw Len (mm)	Pec Fin Len (mm)	Pelv Fin Len (mm)	Body Dep (mm)	Caud Ped (mm)	Low Arch Len (mm)	Fork Dep (mm)	Stand Len (mm)
LH001	MIP04371	F	UD	39.16	18.86	8.26	10.66	18.24	22.63	20.70	31.71	11.78	12.14	9.00	197
LH001	MIP05055	F	UD	40.42	18.87	7.64	10.63	18,52	24.90	19.70	34.11	12.28	16.15	11.00	198
LH001	MIP05118	M	UD	38.59	17.87	7.58	8.84	16.98	25.27	19.94	40.17	11.05	16.08	11.00	197
LH001	MIP05036	F	UD	40.73	17.61	8.30	10.35	17.70	24.00	19.57	34.79	11.55	16.60	10.00	205
LH001	MIP05114	M	UD	37.71	19.33	7.68	10.02	15.31	25.29	20.15	41.35	12.35	15.24	13.00	199
LH001	MIP05046	F	UD	39.52	22.22	8.06	9.79	18.31	25.82	19.87	43.99	12.24	16.56	13.00	199
LH001	MIP05062	F	UD	41.49	19.60	7.89	10.19	18.03	25.67	19.70	36.71	12.52	15.85	11.00	200
LH001	MIP05150	F	UD	23.75	21.64	9.35	10.94	16.71	24.04	20.38	45.75	11.67	14.94	11.00	207
LH001	MIP05109	M	UD	41.47	18.96	7.77	8.68	16.63	24.37	17.69	32.41	11.25	16.60	11.00	195
LH001	MIP05033	M	UD	44.60	23.20	8.58	13.88	17.88	29.47	21.02	41.18	13.43	16.16	18.00	207
LH001	MIP05035	F	UD	46.13	20.12	9.47	11.88	19.41	25.62	22.10	38.98	13.52	16.91	17.00	222
LH001	MIP05042	F	UD	46.71	22.00	9.22	11.32	21.36	26.73	21.52	48.26	14.79	18.94	11.00	229
LH001	MIP05111	F	UD	43.10	20.29	9.07	11.19	19.12	26.10	21.48	41.80	14.06	18.94	14.00	221
LH001	MIP05034	F	UD	48.43	23.97	9.04	11.72	20.87	27.67	20.50	46.67	12.50	18.59	14.00	232
LH001	MIP05032	F	UD	43.32	21.24	7.77	11.04	19.67	26.16	22.48	47.29	13.84	18.40	13.00	232
LH001	MIP05023	F	UD	49.85	21.73	9.15	13.33	21.95	31.70	25.38	47.10	15.27	18.83	15.00	231
LH001	MIP05026	F	UD	48.41	21.63	9.49	11.79	20.48	28.91	22.43	46.69	15.79	17.94	18.00	246
LH001	MIP05040	M	UD	50.91	23.14	9.88	14.44	21.31	31.05	25.59	52.09	15.22	20.24	17.00	250
LH001	MIP05041	M	UD	49.67	23.32	8.66	14.16	22.55	32.42	24.11	39.94	13.71	19.73	14.00	257
LH001	MIP05027	F	UD	50.74	22.20	9.54	13.79	23.28	33.06	26.17	52.15	16.33	19.28	17.00	253
LH001	MIP04370	M	UD	54.55	24.50	10.16	15.78	25.46	35.26	28.50	44.72	13.37	20.60	15.00	257
LH001	MIP04369	M	UD	51.72	23.00	8.21	15.03	23.73	31.60	26.23	53.95	15.74		12.00	261
LH001	MIP05024	F	UD	55.00	21.98	9.68	15.97	23.72	33.53	28.06	51.31	16.78	21.69	12.00	270
LH001	MIP05025	M	UD	51.82	24.67	8.27	14.75	23.19	33.04	28.29	52.33	17.11	22.34	18.00	259
LH001	MIP04368	M	UD	53.30	24.38	9.70	15.32	24.23	30.24	27.61	50.78	15.89	18.78	18.00	267

LOC	Sample #	SEX	MAT	Head Len (mm)	Head Dep (mm)	Eye Len (mm)	Snout Len (mm)	Up Jaw Len (mm)	Pec Fin Len (mm)	Pelv Fin Len (mm)	Body Dep (mm)	Caud Ped (mm)	Low Arch Len (mm)	Fork Dep (mm)	Stand Len (mm)
LH001	MIP05065	M	SM	25.28	12.26	5.66	6.37	9.87	19.12	16.30	19.72	7.31	9.02	9.00	103
LH001	MIP05106	M	SM	27.20	12.20	7.32	6.17	11.90	20.72	16.66	24.75	8.14	10.86	11.00	113
LH001	MIP04341	F	SM	30.01	13.38	6.26	7.77	12.02	20.10	14.89	24.23	7.29	10.28	6.00	121
LH001	MIP04346	M	SM	30.76	14.45	7.68	7.79	17.67	18.27	24.44	14.66	8.04	12.80	8.00	128
LH001	MIP05044	F	SM	30.04	14.33	7.86	6.86	12.81	23.04	17.51	26.13	8.32	11.50	9.00	131
LH001	MIP05048	M	SM	30.34	14.67	7.98	7.58	13.74	23.65	20.66	23.82	8.67	11.41	11.00	134
LH001	MIP05049	M	SM	35.41	15.44	8.37	8.64	17.10	26.58	19.32	26.59	8.07	13.15	12.00	129
LH001	MIP05057	M	SM	34.27	15.48	7.97	9.29	34.17	28.26	23.14	29.51	10.14	12.90	11.00	142
LH001	MIP05108	M	SM	31.50	15.80	7.18	7.97	13.68	22.17	16.31	25.32	9.51	13.08	10.00	144
LH001	MIP04345	M	SM	36.07	16.29	8.53	9.16	23.78	17.78	27.35	15.93	8.58	13.92	10.00	146
LH001	MIP05030	M	SM	38.20	17.75	8.54	9.69	17.68	28.18	22.42	28.40	9.01	14.54	14.00	156
LH001	MIP05031	M	SM	37.52	17.65	7.82	10.03	15.92	28.17	20.10	30.90	11.12	13.72	11.00	155
LH001	MIP04340	F	SM	36.32	15.68	9.28	9.46	16.12	24.37	20.75	20.37	8.29	12.30	12.00	152
LH001	MIP05107	M	SM	42.63	20.29	8.93	12.86	21.45	32.86	26.04	31.37	10.30	15.47	19.00	169
LH001	MIP05051	M	SM	39.93	19.58	8.59	10.27	18.65	30.69	24.66	33.96	12.40	14.96	16.00	178
LH001	MIP05028	M	SM	42.77	20.16	9.60	11.20	23.38	37.97	30.00	33.42	12.63	11.02	16.00	174
LH001	MIP05053	M	SM	50.54	23.74	11.61	12.32	26.50	40.06	29.51	39.00	12.03	18.86	15.00	197
LH001	MIP05105	M	SM	47.75	22.75	9.73	13.42	24.14	33.04	27.78	36.84	12.74	17.65	16.00	198
LH001	MIP04366	M	SM	46.28	21.04	10.76	12.69	22.16	34.29	28.31	36.90	13.89	15.81	11.00	203
LH001	MIP05022	M	SM	45.36	22.05	9.66	11.29	21.34	33.01	25.15	35.35	11.88	17.55	12.00	206
LH001	MIP04365	F	SM	46.90	22.51	9.64	12.68	21.94	30.73	25.30	38.75	14.46	14.73	17.00	212
LH001	MIP04352	F	UD	34.89	15.63	7.98	8.43	14.26	22.54	16.97	29.48	9.44	11.61	11.00	151
LH001	MIP04344	M	UD	37.07	16.44	7.43	9.60	16.28	21.54	15.68	29.11	11.35	10.56	12.00	160
LH001	MIP04358	F	UD	41.31	19.50	9.27	10.14	17.53	30.77	22.98	32.88	12.64	16.42	13.00	170
LH001	MIP05069	M	UD	42.35	17.83	8.75	11.62	18.96	27.06	18.66	23.51	10.52	16.08	11.00	179

LOC	Sample #	SEX	MAT	Head Len (mm)	Head Dep (mm)	Eye Len (mm)	Snout Len (mm)	Up Jaw Len (mm)	Pec Fin Len (mm)	Pelv Fin Len (mm)	Body Dep (mm)	Caud Ped (mm)	Low Arch Len (mm)	Fork Dep (mm)	Stand Len (mm)
PG082	CS01241	M	UD	45.38	26.39	8.56	10.85	21.84	28.14	23.68	44.84	17.14	18.38	12.72	217
PG082	CS02442	F	UD	43.00	23.71	8.00	10.46	17.71	24.42	19.81	43.01	14.92	17.26	17.00	214
PG082	CS02475	F	UD	46.12	19.50	8.30	11.76	19.76	28.32	22.75	33.61	13.78	18.71	17.00	217
PG082	CS02473	F	UD	45.44	24.94	8.65	12.23	20.56	25.54	20.54	44.88	15.58		19.00	220
PG082	CS01300	M	UD	45.26	28.24	8.80	12.46	22.13	25.76	20.81	47.33	16.37	17.97	15.42	221
PG082	CS04582	M	UD	45.06	25.12	8.56	13.06	20.38	28.28	22.40	44.96	14.46	19.19	13.00	223
PG082	CS01202	F	UD	48.96	26.55	8.89	10.97	20.57	28.65	23.24	44.43	18.16	19.30	15.84	231
PG082	CS01273	F	UD	48.75	29.85	7.81	11.74	21.52	26.31	24.08	53.00	17.99	20.23	20.70	234
PG082	CS02402	F	UD	38.58	17.78	8.91	11.69	21.24	28.98	24.41	48.90	14.91	17.92	18.00	237
PG082	CS01278	F	UD	50.13	30.66	11.61	11.76	22.97	31.30	23.77	47.34	16.35		20.20	236
PG082	CS02476	M	UD	51.41	26.77	8.01	14.30	20.74	28.96	23.24	53.36	16.70	20.31	10.00	246
PG082	CS01289	F	UD	51.29	30.95	7.72	10.95	18.60	28.83	23.37	51.64	17.05		22.13	238
PG082	CS02407	F	UD	50.68	24.05	8.62	13.39	23.61	30.87	22.97	56.12	18.52	21.19	15.00	255
PG082	CS01274	F	UD	53.54	31.43	9.23	12.63	21.25	32.00	25.50	52.94	17.76	23.43	23.50	247
PG082	CS02447	M	UD	54.81	28.37	9.32	14.77	24.77	33.68	25.36	53.69	15.35	22.05	15.00	246
PG082	CS02450	F	UD	39.70	18.88	7.87	10.36	16.82	26.52	21.64	41.58	13.97	14.74	13.00	187
PG082	CS01275	F	UD	54.76	31.15	9.27	11.42	23.27	32.21	27.08	63.35	23.17	22.72	21.00	262
PG082	CS01277	F	UD	51.34	30.55	8.90	13.53	25.89	31.13	25.91	53.92	20.74		19.50	270
PG082	CS02411	F	UD	56.44	28.15	8.45	14.27	23.92	30.77	26.27	60.30	21.26	21.32	18.00	289
PG082	CS01290	F	UD	55.26	33.36	9.83	15.17	25.46	34.65	28.10	65.11	19.88	25.59	19.90	291
PG082	CS02410	M	UD	59.37	29.40	9.43	15.22	27.29	32.31	26.25	66.14	22.18	25.27	20.00	300
PG082	CS02412	F	UD	60.83	33.95	9.77	17.34	29.78	27.55	28.04	67.13	16.11	26.38	34.00	300
PG082	CS02429	M	UD	64.48	29.40	9.40	17.17	30.60	41.36	32.88	53.39	20.40	22.97	22.00	308
PG082	CS02478	F	UD	62.21	33.90	9.91	18.61	28.58	40.14	33.06	68.86	22.44	26.25	20.00	314
PG082	CS01285	M	UD	61.73	36.19	10.95	16.36	31.65	41.25	33.07	72.21	24.61		26.70	317

LOC	Sample #	SEX	MAT	Head Len (mm)	Head Dep (mm)	Eye Len (mm)	Snout Len (mm)	Up Jaw Len (mm)	Pec Fin Len (mm)	Pelv Fin Len (mm)	Body Dep (mm)	Caud Ped (mm)	Low Arch Len (mm)	Fork Dep (mm)	Stand Len (mm)
PG082	CS01200	F	UD	35.97	21.99	7.16	8.56	16.21	19.56	18.36	36.64	12.63	13.71	11.67	184
PG082	CS01205	F	UD	40.40	23.18	7.97	9.93	16.36	22.77	17.56	33.10	13.14	15.17	10.44	185
PG082	CS04594	M	UD	40.02	22.66	8.61	10.19	18.25	29.42	22.00	29.82	11.58	15.14	11.00	186
PG082	CS04617	F	UD	39.84	21.42	7.48	10.25	17.83	22.87	19.53	35.87	11.17	13.20	10.00	189
PG082	CS04622	M	UD	38.46	20.05	8.01	9.66	16.56	26.90	19.94	36.62	12.45	15.01	10.00	189
PG082	CS04607	F	UD	40.71	18.75	8.64	10.78	16.88	29.40	21.35	27.27	10.59	16.91	15.00	184
PG082	CS04585	M	UD	40.68	20.65	9.07	9.98	18.65	26.32	22.16	29.99	11.88	15.32	10.00	190
PG082	CS02449	M	UD	39.89	23.94	7.89	10.71	16.43	21.63	20.03	40.77	15.15	15.35	17.00	186
PG082	CS02451	M	UD	38.73	20.31	7.07	10.03	17.66	26.64	22.78	43.53	14.76	14.71	12.00	185
PG082	CS04598	M	UD	41.74	19.27	7.96	10.99	17.91	26.36	20.77	34.93	12.86	15.10	11.00	194
PG082	CS02441	M	UD	39.45	21.09	8.17	9.66	16.84	20.38	18.36	38.30	11.06	16.28	18.00	180
PG082	CS04618	F	UD	38.99	16.47	8.29	9.74	16.23	27.24	20.75	30.36	10.99	15.70	14.00	192
PG082	CS01197	M	UD	43.22	25.35	9.81	11.04	20.97	30.64	26.08	34.03	14.45	16.13	16.41	191
PG082	CS02406	F	UD	41.83	24.45	8.20	9.98	17.43	22.87	20.36	39.20	13.55	15.84	11.00	187
PG082	CS02457	F	UD	40.33	20.22	8.02	10.57	20.15	27.57	20.10	35.28	12.01	15.08	13.00	194
PG082	CS04611	M	UD	40.94	19.88	8.03	10.97	17.16	23.64	19.02	39.52	12.04	15.19	12.00	201
PG082	CS01198	M	UD	40.91	23.43	7.77	9.53	18.81	24.28	18.79	45.13	15.17	16.11	12.28	201
PG082	CS02471	M	UD	42.98	20.88	8.16	12.12	19.74	26.87	18.32	36.79	12.09	17.07	14.00	199
PG082	CS02408	F	UD	40.35	22.76	7.31	10.68	16.22	23.57	19.77	40.20	13.18	15.51	13.00	202
PG082	CS02470	F	UD	43.36	19.91	7.76	10.51	18.12	23.68	20.39	41.13	14.19	16.41	21.00	202
PG082	CS02404	M	UD	42.91	20.81	7.49	11.39	17.10	24.84	21.70	38.88	12.71	17.19	14.00	205
PG082	CS01201	M	UD	42.41	24.41	8.30	9.71	17.79	27.09	22.05	40.99	15.20	17.11	11.63	207
PG082	CS02474	F	UD	42.60	19.84	7.86	11.90	18.01	27.00	21.97	40.26	14.75	17.85	17.00	206
PG082	CS02472	F	UD	41.99	21.61	7.04	11.30	17.81	23.38	20.17	31.11	12.33	16.64	15.00	207
PG082	CS04580	M	UD	39.81	23.32	7.28	11.13	18.85	24.09	18.93	35.80	12.20	16.72	14.00	210

LOC	Sample #	SEX	MAT	Head Len (mm)	Head Dep (mm)	Eye Len (mm)	Snout Len (mm)	Up Jaw Len (mm)	Pec Fin Len (mm)	Pelv Fin Len (mm)	Body Dep (mm)	Caud Ped (mm)	Low Arch Len (mm)	Fork Dep (mm)	Stand Len (mm)
PG082	CS04634	M	UD	36.24	20.21	8.44	9.76	16.61	24.52	18.36	24.72	11.82	14.29	11.00	169
PG082	CS01203	F	UD	35.32	21.24	7.56	8.93	16.26	20.86	16.29	32.98	12.38	13.36	12.74	168
PG082	CS04614	M	UD	38.17	20.03	8.17	9.87	18.05	25.39	21.20	25.40	10.46	16.09	13.00	169
PG082	CS02461	F	UD	36.90	18.62	8.07	9.07	15.43	23.55	20.10	36.78	12.30	14.78	19.00	168
PG082	CS04592	F	UD	36.81	18.92	8.78	10.09	17.31	25.16	20.82	27.41	10.86	12.18	16.00	167
PG082	CS01303	F	UD	35.36	21.18	6.87	8.81	15.13	22.18	17.48	34.31	12.62		13.34	171
PG082	CS02459	M	UD	30.45	18.55	7.53	9.31	15.51	19.95	18.25	36.38	11.84	13.54	11.00	172
PG082	CS04590	F	UD	36.41	16.79	7.59	9.48	15.02	22.77	18.64	27.97	9.36	14.26	11.00	174
PG082	CS04624	M	UD	36.72	18.23	7.43	9.36	17.24	22.66	18.05	32.71	12.58	15.37	8.00	177
PG082	CS04581	F	UD	35.44	18.42	7.91	9.58	16.95	22.07	17.13	33.96	11.41	13.81	9.00	177
PG082	CS02468	M	UD	37.06	17.15	7.60	9.56	15.85	20.77	16.64	31.97	12.38	14.08	21.00	174
PG082	CS04609	F	UD	35.33	18.02	7.23	9.34	14.98	20.80	17.37	33.27	10.72	13.77	13.00	175
PG082	CS01298	F	UD	34.98	20.62	7.55	8.58	15.51	23.67	20.09	37.62	14.25		14.70	174
PG082	CS02460	M	UD	36.97	20.50	7.68	8.72	15.14	23.43	19.20	34.70	10.96	14.58	10.00	176
PG082	CS02465	F	UD	36.07	18.48	7.00	9.13	14.96	19.57	17.77	31.49	12.84	14.65	13.00	181
PG082	CS04608	F	UD	36.77	19.65	8.18	9.47	16.97	24.54	18.66	29.67	9.78	14.24	12.00	178
PG082	CS02466	M	UD	37.39	18.46	7.17	9.56	16.54	21.81	17.70	34.31	10.31	15.64	12.00	174
PG082	CS01206	F	UD	38.48	21.32	9.02	9.01	15.91	22.70	17.37	34.03	12.48	15.31	12.02	179
PG082	CS02453	M	UD	37.95	18.50	7.71	10.50	15.23	24.69	17.70	31.86	12.97	14.41	15.00	170
PG082	CS02464	M	UD	37.23	18.46	7.68	10.30	17.27	23.41	19.50	36.20	13.24	15.55	14.00	179
PG082	CS04616	M	UD	39.95	20.60	8.65	10.49	18.96	24.58	21.32	29.74	11.15	16.32	14.00	178
PG082	CS01297	M	UD	35.29	20.57	7.50	8.58	15.97	23.61	18.41	29.21	12.88	14.43	15.66	177
PG082	CS02463	M	UD	38.16	20.08	7.67	9.76	15.56	22.47	19.29	37.62	11.82	15.20	12.00	180
PG082	CS04633	M	UD	38.02	20.27	7.55	9.68	16.19	24.48	19.55	32.56	13.23	14.79	12.00	182
PG082	CS04586	M	UD	38.56	21.05	8.20	9.81	16.88	23.97	17.91	32.69	14.05	14.86	11.00	184

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PG082	CS04615	F	UD	30.17	16.44	7.30	8.49	13.97	18.30	16.27	21.71	7.87	11.12	10.00	131
PG082	CS04604	M	UD	29.53	16.63	7.81	8.34	13.62	21.62	15.87	21.69	9.33	11.78	10.00	139
PG082	CS04593	M	UD	32.06	17.65	8.78	7.00	15.40	23.06	19.08	22.05	9.56	10.94	10.00	145
PG082	CS04601	M	UD	34.55	17.96	7.80	9.68	14.50	22.15	17.88	22.83	9.46	11.60	10.00	151
PG082	CS01243	F	UD	31.79	18.51	7.04	7.73	14.20	19.11	16.87	30.47	12.00	13.01	8.45	155
PG082	CS01244	M	UD	33.81	20.85	6.69	9.04	14.63	19.20	17.17	31.40	11.37	14.53	6.05	157
PG082	CS01245	F	UD	32.23	18.85	7.11	6.68	12.89	19.71	14.11	32.13	12.34	13.30	7.92	158
PG082	CS01242	F	UD	32.68	19.39	7.31	7.13	13.53	21.22	18.78	31.88	12.09	12.76	3.99	163
PG082	CS02462	M	UD	32.67	18.79	7.45	7.04	14.87	18.92	15.20	29.85	9.85	13.05	10.00	161
PG082	CS04619	M	UD	33.16	16.63	6.67	8.02	13.38	21.58	18.24	28.81	10.34	12.42	12.00	159
PG082	CS01194	F	UD	34.42	19.10	7.78	7.94	14.85	20.07	18.34	36.16	14.13	13.34	11.47	160
PG082	CS02454	M	UD	34.28	18.12	7.73	8.67	14.69	24.28	19.47	29.19	11.99	12.73	15.00	156
PG082	CS01304	F	UD	33.91	20.01	6.93	8.92	15.42	17.38	15.54	34.05	12.98		12.02	160
PG082	CS02467	F	UD	33.86	19.16	7.60	9.04	14.74	19.98	17.76	34.08	11.95	13.29	8.00	166
PG082	CS04621	M	UD	35.61	19.33	7.28	9.30	14.70	16.17	14.72	22.51	8.94	13.77	9.00	164
PG082	CS02405	M	UD	33.72	19.41	7.51	9.22	16.07	20.59	18.93	35.44	12.09	13.92	11.00	165
PG082	CS01301	F	UD	33.51	21.13	7.44	8.19	15.15	20.30	16.32	35.39	12.31	15.04	9.92	165
PG082	CS04599	M	UD	33.47	18.12	7.28	8.46	13.01	21.38	19.12	29.70	10.09	13.76	11.00	164
PG082	CS02452	M	UD	33.00	16.77	6.45	8.05	16.57	22.58	19.55	33.54	11.07	12.02	13.00	163
PG082	CS04603	M	UD	36.38	19.36	9.06	9.52	17.45	24.77	19.26	25.51	10.79	13.82	10.00	166
PG082	CS04623	M	UD	36.47	18.37	8.47	10.13	16.74	25.21	17.73	30.54	11.59	13.39	11.00	165
PG082	CS02458	F	UD	36.48	17.45	7.62	9.57	16.22	24.05	18.78	27.48	10.96	14.37	14.00	165
PG082	CS04635	F	UD	37.73	21.06	8.58	10.44	17.07	25.38	19.67	27.02	10.02	13.53	11.00	166
PG082	CS01204	F	UD	32.05	18.81	7.39	8.23	15.20	19.83	17.10	32.82	11.88	12.50	9.52	168
PG082	CS04637	M	UD	36.25	19.03	8.00	9.05	16.37	27.46	20.08	24.23	12.26	14.96	13.00	166

LOC	Sample #	SEX	MAT	Head Len (mm)	Head Dep (mm)	Eye Len (mm)	Snout Len (mm)	Up Jaw Len (mm)	Pec Fin Len (mm)	Pelv Fin Len (mm)	Body Dep (mm)	Caud Ped (mm)	Low Arch Len (mm)	Fork Dep (mm)	Stand Len (mm)
PG015	CS04525	M	SM	42.44	22.99	8.90	9.36	19.15	32.01	21.73	37.20	11.88	17.78	12.00	183
PG015	CS04527	F	SM	37.53	18.79	8.19	8.79	18.58	33.51	25.61	38.09	12.85		17.00	181
PG015	CS031290	M	SM	41.06	19.97	9.72	10.73	19.03	29.66	24.12	37.54	11.08		20.00	171
PG015	CS031281	M	SM	43.49	21.65	9.88	11.19	21.07	38.14	28.81	33.85	11.40		17.00	183
PG015	CS031280	M	SM	53.64	27.18	10.63	14.86	26.03	42.08	36.00	47.75	20.04		21.00	219
PG015	CS04451	M	UD	35.10	18.62	8.52	7.64	14.63	25.09	19.02	33.36	9.43	13.35	9.00	146
PG015	CS04529	M	UD	31.36	16.58	7.99	6.94	13.04	24.84	18.56	30.45	8.16	12.86	10.00	147
PG015	CS04530	M	UD	32.43	15.43	7.65	8.98	14.29	19.72	15.68	30.91	9.85	12.62	11.00	157
PG015	CS04493	M	UD	36.59	15.62	8.47	8.20	15.73	28.03	20.98	32.58	10.00	14.35	13.00	168
PG015	CS04531	M	UD	34.05	17.64	6.99	8.46	12.69	20.16	15.01	33.28	10.86	13.04	11.00	165
PG015	CS04453	M	UD	36.00	18.56	8.31	8.01	14.68	21.36	16.85	38.39	11.25	14.82	9.00	172
PG015	CS04456	M	UD	35.90	19.51	8.09	7.85	15.75	21.91	18.12	34.19	10.15	13.00	12.00	173
PG015	CS031289	M	UD	37.27	18.25	9.18	9.29	16.82	25.77	18.35	31.28	11.84	12.58	5.00	170
PG015	CS04469	F	UD	35.91	16.94	8.98	9.49	15.78	27.19	18.92	31.20	10.75	16.28	10.00	169
PG015	CS04528	M	UD	44.18	19.84	9.32	10.95	18.82	28.50	21.24	41.21	12.06	18.01	11.00	204
PG015	CS031344	F	UD	42.45	24.17	8.69	12.07	18.79	23.67	20.79	39.16	12.43	16.75	12.00	204
PG015	CS031348	F	UD	40.89	22.07	8.57	11.40	17.23	24.73	21.03	43.28	13.30	16.27	13.00	211
PG015	CS031345	F	UD	38.12	15.99	8.38	10.04	19.53	27.31	25.67	43.08	14.32	15.80	14.00	216
PG015	CS031352	F	UD	49.39	26.57	9.20	11.86	21.97	30.07	25.66	49.98	15.66	18.85	21.00	256
PG082	CS01302	U	UD	30.35	21.34	7.27	7.46	14.72	20.81	17.42	34.29	12.13		16.93	152
PG082	CS02448	U	UD	35.17	17.65	7.45	9.31	15.29	24.45	18.72	41.33	14.32	14.01	14.00	161
PG082	CS04591	M	UD	26.05	14.09	6.46	6.69	10.50	14.26	12.51	19.77	6.53	9.55	9.00	114
PG082	CS04620	F	UD	26.29	14.05	7.29	7.33	12.30	18.89	16.75	19.55	7.99	9.60	8.00	124
PG082	CS04600	F	UD	28.26	13.81	7.18	7.53	12.36	20.43	15.05	23.21	8.50	11.02	8.00	126
PG082	CS04583	M	UD	27.99	15.05	7.41	7.38	13.80	20.91	15.53	22.51	8.18	10.98	11.00	124

LOC	Sample #	SEX	MAT	Head Len (mm)	Head Dep (mm)	Eye Len (mm)	Snout Len (mm)	Up Jaw Len (mm)	Pec Fin Len (mm)	Pelv Fin Len (mm)	Body Dep (mm)	Caud Ped (mm)	Low Arch Len (mm)	Fork Dep (mm)	Stand Len (mm)
PG015	CS031353	M	UD	46.96	25.62	8.58	12.98	21.98	31.90	26.55	47.18	15.03	19.86	14.00	242
PG015	CS031369	F	UD	47.24	23.57	9.06	13.60	20.69	27.87	21.88	54.94	14.72	19.48	16.00	243
PG015	CS031366	M	UD	48.93	27.51	8.59	14.16	21.09	32.34	26.44	59.07	15.38	19.94	14.00	243
PG015	CS031288	M	UD	53.22	28.83	9.79	12.89	24.24	29.15	21.99	51.26	18.61	21.08	15.00	245
PG015	CS031275	F	UD	50.19	26.79	9.50	12.58	21.23	31.77	25.24	45.96	14.41		15.00	264
PG015	CS031368	F	UD	49.00	26.72	7.93	12.34	21.72	32.71	26.11	56.30	14.69	21.75	14.00	261
PG015	CS031378	M	UD	55.08	26.45	8.48	14.11	23.83	31.63	28.66	51.96	18.02	20.37	16.00	265
PG015	CS04532	M	SM	29.76	14.82	8.00	6.85	13.70	22.74	16.28	21.92	8.56	11.28	10.00	120
PG015	CS031303	M	SM	29.97	14.48	8.13	6.80	13.55	21.67	15.13	27.04	8.84		11.00	124
PG015	CS04458	M	SM	30.90	14.61	8.52	6.41	13.31	23.60	16.01	23.10	9.09	11.62	10.00	126
PG015	CS04464	M	SM	27.54	15.41	7.05	6.04	12.55	18.30	15.25	26.58	8.70	11.38	8.00	129
PG015	CS031284	M	SM	30.93	16.43	8.02	7.56	14.30	23.12	18.20	33.62	9.65		6.00	125
PG015	CS031285	M	SM	33.20	16.30	8.40	9.44	13.26	28.64	22.66	35.78	8.64	14.37	11.00	156
PG015	CS031292	M	SM	35.06	17.20	8.51	8.45	15.55	28.58	19.92	32.15	9.87		17.00	135
PG015	CS031305	M	SM	35.77	15.77	9.17	8.68	16.55	24.68	19.14	27.94	9.58		14.00	145
PG015	CS031329	M	SM	33.53	15.58	8.06	9.37	14.18	23.99	18.57	26.09	10.18		11.00	154
PG015	CS04450	M	SM	34.04	19.28	7.68	8.69	14.40	23.32	16.52	43.57	10.67	12.46	10.00	155
PG015	CS04463	M	SM	33.79	16.23	8.38	8.63	16.06	24.73	19.79	27.05	10.18	11.94	11.00	159
PG015	CS031287	M	SM	36.73		7.89	9.86	17.53	26.40	21.79	34.08	9.91		10.00	154
PG015	CS04457	M	SM	37.78	19.65	8.79	9.14	17.72	27.43	22.08	36.33	12.19	15.64	14.00	160
PG015	CS04459	M	SM	36.64	19.66	8.82	8.10	16.42	25.28	19.21	39.45	10.48	14.85	12.00	162
PG015	CS04465	M	SM	35.65	18.11	9.23	8.87	16.98	25.05	19.73	28.28	11.08	14.48	11.00	163
PG015	CS031291	M	SM	36.43	18.50	8.34	9.46	17.24	27.11	23.98	36.91	11.57		14.00	162
PG015	CS031302	M	SM	38.57		8.01	8.13	16.67	25.95	20.90	30.24	9.78		15.00	152
PG015	CS04484	M	SM	37.64	20.23	8.53	9.04	15.63	28.09	20.46	37.92	10.62	14.91	11.00	172

LOC	Sample #	SEX	MAT	Head Len (mm)	Head Dep (mm)	Eye Len (mm)	Snout Len (mm)	Up Jaw Len (mm)	Pec Fin Len (mm)	Pelv Fin Len (mm)	Body Dep (mm)	Caud Ped (mm)	Low Arch Len (mm)	Fork Dep (mm)	Stand Len (mm)
PG015	CS031804	F	UD	34.30	18.71	6.48	8.47	14.46	22.31	16.94	34.36	10.60	12.79	12.00	180
PG015	CS031277	F	UD	35.92	18.21	8.32	9.39	15.37	21.62	18.28	25.61	9.75	14.43	14.00	176
PG015	CS031278	F	UD	36.16	19.76	7.37	9.48	15.43	20.05	16.35	32.50	10.22	13.83	12.00	166
PG015	CS04455	M	UD	36.87	20.72	7.33	9.09	15.44	21.71	18.25	39.25	12.20	14.85	8.00	189
PG015	CS04489	M	UD	34.79	15.19	6.89	9.97	14.87	21.11	15.85	39.88	10.66	15.19	12.00	185
PG015	CS031805	M	UD	38.93	19.29	8.58	9.85	15.07	23.04	19.01	33.85	11.60	15.90	10.00	187
PG015	CS031803	F	UD	37.55	19.96	7.75	9.66	16.88	24.25	21.31	39.56	11.63	15.44	12.00	186
PG015	CS04483	M	UD	40.05	21.87	7.67	11.61	16.14	22.44	16.76	34.94	12.27	15.99	9.00	194
PG015	CS04485	F	UD	37.99	22.86	8.10	9.44	15.14	25.39	17.21	38.02	10.63	15.34	10.00	199
PG015	CS04526	M	UD	40.19	18.71	7.38	9.53	16.37	23.76	19.14	42.96	13.20	16.32	11.00	204
PG015	CS031350	F	UD	40.45	21.46	8.83	10.13	17.18	27.41	22.95	38.35	12.49	17.66	10.00	192
PG015	CS04486	M	UD	41.32	20.29	8.24	10.69	17.93	26.58	22.03	42.28	11.27	15.90	12.00	205
PG015	CS031346	F	UD	40.76	18.45	7.29	10.25	17.63	25.54	19.97	40.07	11.91	16.30	11.00	210
PG015	CS031347	F	UD	44.57	22.14	8.28	11.07	18.14	25.53	22.18	38.93	12.49	17.09	12.00	213
PG015	CS031342	M	UD	42.48	24.17	8.87	10.60	16.92	25.03	19.95	47.17	12.80	15.07	12.00	215
PG015	CS031801	F	UD	40.14	25.53	7.84	11.60	18.60	27.49	23.87	56.51	16.43	16.44	14.00	216
PG015	CS031354	F	UD	43.70	22.72	8.71	10.44	18.49	26.93	20.67	42.83	14.57	17.34	16.00	206
PG015	CS031370	F	UD	44.36	21.88	8.82	11.73	19.52	27.26	22.11	46.76	13.21	17.98	12.00	217
PG015	CS04454	M	UD	44.51	25.08	8.54	10.66	19.56	26.89	22.16	46.55	13.50	13.86	10.00	223
PG015	CS031343	M	UD	42.88	22.28	7.79	11.45	20.52	24.63	21.08	47.67	14.13	17.76	12.00	225
PG015	CS031279	F	UD	44.92	24.68	8.53	11.14	18.80	29.16	25.86	45.75	14.24	17.65	14.00	222
PG015	CS031351	M	UD	45.68	27.08	8.52	13.16	19.77	29.41	21.76	51.98	15.68		14.00	232
PG015	CS031802	F	UD	39.57	19.71	8.60	12.15	20.84	29.80	23.95	43.56	17.59	19.39	14.00	237
PG015	CS031349	M	UD	47.99	23.55	9.14	13.22	22.40	27.75	23.30	46.03	16.34	18.96	9.00	236
PG015	CS031367	F	UD	48.95	25.06	9.17	9.78	20.51	29.28	24.52		16.19	19.58	15.00	251

LOC	Sample #	SEX	MAT	Head Len (mm)	Head Dep (mm)	Eye Len (mm)	Snout Len (mm)	Up Jaw Len (mm)	Pec Fin Len (mm)	Pelv Fin Len (mm)	Body Dep (mm)	Caud Ped (mm)	Low Arch Len (mm)	Fork Dep (mm)	Stand Len (mm)
PG015	CS04462	F	UD	30.59	16.41	7.35	7.78	13.52	19.96	15.50	29.89	10.51	11.61	10.00	145
PG015	CS031357	F	UD	31.91	16.35	7.05	8.64	13.90	20.58	16.56	29.96	10.86	17.94	10.00	155
PG015	CS031380	M	UD	26.74	13.46	6.81	7.32	14.78	19.71	14.50	28.29	10.25	10.43	14.00	151
PG015	CS04467	M	UD	31.10	15.93	7.02	8.30	13.42	19.00	15.90	26.29	9.25	13.44	9.00	162
PG015	CS04490	M	UD	32.80	16.50	7.63	6.78	13.16	19.76	16.70	28.56	9.90	13.54	10.00	155
PG015	CS04492	F	UD	31.66	16.30	6.66	7.46	13.14	20.62	16.88	28.48	10.57	12.58	10.00	159
PG015	CS031335	M	UD	28.31	15.88	7.31	6.46	13.39	17.71	15.72	31.04	9.91	12.77	8.00	161
PG015	CS04461	M	UD	30.57	15.86	6.21	7.33	13.01	17.84	14.77	29.61	10.20	12.68	11.00	161
PG015	CS031304	M	UD	35.64	19.01	7.33	8.67	14.41	21.61	16.51	28.00	9.52	13.05	12.00	159
PG015	CS031355	M	UD	34.56	18.97	7.99	7.41	13.55	21.97	15.37	31.71	12.78	11.22	7.00	155
PG015	CS04470	M	UD	32.43	14.47	7.03	7.93	13.51	20.56	15.97	29.58	9.83	12.51	9.00	165
PG015	CS04534	F	UD	32.23	15.87	6.83	8.09	13.24	22.34	17.24	30.41	10.64	20.76	9.00	160
PG015	CS04487	F	UD	31.22	17.30	6.99	8.17	13.15	19.66	14.98	32.57	8.85	12.80	9.00	169
PG015	CS04499	F	UD	33.68	15.20	7.34	8.14	15.09	20.48	16.72	29.16	10.31	11.55	10.00	169
PG015	CS04488	M	UD	33.53	18.58	7.27	8.91	14.07	21.72	15.42	36.77	9.62	12.25	9.00	170
PG015	CS04491	F	UD	32.47	16.28	7.08	7.69	13.42	22.07	17.91	28.15	10.49	12.95	9.00	161
PG015	CS031379	F	UD	32.54	16.84	7.18	8.64	14.17	16.05	18.60	31.96	9.63	13.19	15.00	160
PG015	CS031800	F	UD	33.35	20.24	6.88	8.35	13.61	21.30	19.17	34.97	10.21	13.63	11.00	167
PG015	CS04471	M	UD	33.93	15.08	7.33	8.55	13.87	19.89	16.90	30.30	9.85	14.27	8.00	174
PG015	CS04466	M	UD	36.10	18.44	6.83	7.64	14.35	22.16	16.80	31.07	9.47	15.11	10.00	172
PG015	CS04468	M	UD	31.07	14.78	6.93	7.39	13.12	20.76	14.49	33.01	10.28	12.88	10.00	173
PG015	CS031356	M	UD	34.06	18.32	7.36	8.53	14.52	21.59	17.52	37.67	10.54	13.89	15.00	161
PG015	CS04497	F	UD	34.44	16.62	7.04	7.71	14.62	22.53	18.70	35.69	10.57	13.20	9.00	176
PG015	CS04494	M	UD	34.97	18.01	7.09	9.11	15.55	21.78	18.18	30.53	10.30	14.50	10.00	175
PG015	CS04495	M	UD	36.08	17.76	7.61	8.80	15.47	23.73	18.24	31.57	9.36	14.12	9.00	181

LOC	Sample #	SEX	MAT	Head Len (mm)	Head Dep (mm)	Eye Len (mm)	Snout Len (mm)	Up Jaw Len (mm)	Pec Fin Len (mm)	Pelv Fin Len (mm)	Body Dep (mm)	Caud Ped (mm)	Low Arch Len (mm)	Fork Dep (mm)	Stand Len (mm)
LH001	MIP05063	F	UD	43.48	19.68	9.68	11.88	19.58	27.86	23.34	30.97	11.11	17.19	13.00	194
LH001	MIP04367	F	UD	41.56	20.65	7.93	11.05	17.77	25.63	18.65	34.77	12.10	13.94	11.00	194
LH001	MIP05054	F	UD	48.12	23.33	9.67	12.15	21.35	36.35	24.76	41.46	13.55	18.35	18.00	210
LH001	MIP04360	F	UD	43.80	20.72	9.21	10.94	18.55	30.92	24.65	35.59	13.82	16.23	14.00	217
LH001	MIP04364	F	UD	52.85	25.37	10.80	13.73	23.48	34.87	28.10	40.48	15.61	17.50	16.00	246
PG015	CS04496	M	UD	20.68	11.10	5.85	4.29	8.41	15.05	11.58	18.44	5.78	9.07	9.00	89
PG015	CS04478	M	UD	21.78	11.48	6.31	4.35	9.28	15.72	11.92	16.06	6.32	8.87	7.00	95
PG015	CS04536	M	UD	22.68	11.17	6.57	5.15	9.19	18.08	13.89	15.67	6.39	8.41	7.00	99
PG015	CS04524	M	UD	21.75	10.60	5.95	5.26	8.45	15.97	12.23	15.06	7.00	7.42	8.00	87
PG015	CS04535	M	UD	24.98	13.19	7.15	5.62	9.35	17.50	15.25	17.19	7.26	9.03	8.00	102
PG015	CS04476	M	UD	23.40	11.49	6.22	5.60	10.18	14.44	11.72	20.82	6.55	9.37	8.00	106
PG015	CS04477	M	UD	23.61	13.56	6.30	6.32	10.31	18.44	14.03	19.87	7.29	9.37	7.00	112
PG015	CS031283	U	UD	23.53	12.89	6.51	5.76	10.37	17.73	13.58	20.34	6.60		8.00	107
PG015	CS04473	M	UD	24.34	9.60	6.32	6.01	8.39	12.96	10.95	18.68	6.78	9.51	9.00	105
PG015	CS04475	M	UD	27.48	12.80	6.77	5.81	10.66	18.64	14.81	19.80	7.22	11.32	8.00	112
PG015	CS031282	F	UD	24.17	12.18	7.01	5.57	9.40	19.20	13.89	20.09	8.13	9.85	10.00	110
PG015	CS04460	M	UD	26.52	13.59	6.78	6.19	10.67	19.56	13.94	23.28	6.21	10.75	10.00	115
PG015	CS04472	M	UD	26.06	12.50	6.78	5.31	10.79	17.70	12.49	27.03	7.40	9.59	9.00	116
PG015	CS04537	M	UD	26.21	13.87	6.84	6.36	10.44	18.62	13.45	25.32	8.52	11.12	8.00	123
PG015	CS04474	M	UD	26.60	12.88	7.04	6.41	9.85	17.61	14.03	20.02	7.42	11.71	8.00	126
PG015	CS04538	M	UD	27.04	13.87	7.15	6.52	11.36	17.06	14.22	21.84	8.41	10.22	8.00	127
PG015	CS04498	F	UD	27.89	13.56	6.45	6.74	11.83	17.41	12.70	24.93	8.95	12.35	8.00	135
PG015	CS031371	M	UD	31.85	15.10	7.20	8.05	13.41	18.04	14.50	28.18	9.83	11.18	9.00	146
PG015	CS04452	F	UD	30.17	16.14	6.66	7.35	12.42	20.41	16.65	28.18	9.78	12.13	9.00	151
PG015	CS04533	M	UD	32.42	16.81	6.90	7.76	13.47	20.13	16.65	29.09	11.35	12.60	10.00	155

LOC	Sample #	SEX	MAT	Head Len (mm)	Head Dep (mm)	Eye Len (mm)	Snout Len (mm)	Up Jaw Len (mm)	Pec Fin Len (mm)	Pelv Fin Len (mm)	Body Dep (mm)	Caud Ped (mm)	Low Arch Len (mm)	Fork Dep (mm)	Stand Len (mm)
PG082	CS01247	M	SM	40.26	23.65	9.13	10.34	19.84	30.48	26.47	34.32	13.50	17.11	17.07	179
PG082	CS01195	M	SM	42.26	23.73	9.61	10.45	21.42	30.93	27.04	30.97	13.49	16.44	12.36	187
PG082	CS04597	M	SM	42.80	22.14	8.96	12.85	23.74	32.67	24.91	30.23	12.37	16.20	15.00	185
PG082	CS04595	M	SM	46.57	22.84	9.45	13.41	23.59	34.47	25.58	35.18	11.61	17.75	18.00	183
PG082	CS04626	M	SM	45.18	25.08	8.89	12.23	22.57	34.65	27.56	30.98	12.43	17.65	16.00	188
PG082	CS04638	M	SM	41.92	23.35	8.61	11.14	18.77	30.75	25.91	30.28	13.62	16.78	19.00	191
PG082	CS04596	M	SM	52.48	28.15	9.61	16.40	28.68	40.61	29.80	41.76	15.77	20.53	17.00	208
PG082	CS04613	M	SM	55.29	29.33	10.63	15.46	29.43	42.81	32.44	42.55	15.53	20.26	18.00	212
PG082	CS04640	M	SM	51.08	25.08	9.34	14.03	26.33	35.52	26.37	37.08	13.61	21.20	15.00	220
PG082	CS04605	M	SM	59.13	31.24	10.72	16.82	31.41	47.04	34.52	47.35	15.60	21.82	20.00	223
PG082	CS04628	M	UD	34.83	18.42	8.04	9.82	16.27	22.61	19.17	31.64	11.51	13.34	11.00	161
PG082	CS04632	M	UD	37.38	19.47	8.01	10.36	17.51	24.33	19.36	19.79	10.32	14.82	11.00	169
PG082	CS01251	M	UD	43.01	25.64	9.84	9.54	21.32	32.59	23.83	32.70	12.26	16.71	16.32	169
PG082	CS04631	M	UD	38.13	21.29	8.93	10.19	17.93	26.65	23.13	31.69	11.77	15.93	15.00	174
PG082	CS04636	F	UD	49.74	23.18	9.10	13.39	22.44	32.22	25.61	34.09	13.29	19.93	16.00	215
PG082	CS04579	F	UD	50.01	26.30	9.80	12.48	23.67	31.59	23.77	35.83	15.55	19.79	12.00	225
PG082	CS04629	M	UD	50.51	27.53	9.27	12.97	23.76	33.17	29.27	39.02	15.18	19.55	18.00	225

APPENDIX 1.2

Meristic data used in MANOVA analysis in **Chapter 2**. Classification is undeveloped (UD) and small-maturing (SM).

Location	Sample #	Classification	Stand Length (mm)	Upper Gillraker #	Lower Gillraker #
LH001	MIP05020	UD	88	9	12
LH001	MIP04351	UD	89	6	11
LH001	MIP05050	UD	90	9	12
LH001	MIP04355	UD	100	7	9
LH001	MIP05019	UD	102	11	15
LH001	MIP04347	UD	103	6	11
LH001	MIP04350	UD	104	9	13
LH001	MIP04343	UD	105	6	13
LH001	MIP04338	UD	108	4	10
LH001	MIP04354	UD	108	9	11
LH001	MIP04353	UD	109	5	13
LH001	MIP04349	UD	112	6	12
LH001	MIP04342	UD	112	6	12
LH001	MIP04337	UD	122	11	15
LH001	MIP04359	UD	133	8	14
LH001	MIP05122	UD	136	9	16
LH001	MIP04339	UD	137	6	15
LH001	MIP05060	UD	151	10	14
LH001	MIP05119	UD	155	9	15
LH001	MIP05121	UD	158	8	11
LH001	MIP05052	UD	161	9	15
LH001	MIP05029	UD	162	7	12
LH001	MIP05059	UD	162	9	12
LH001	MIP04363	UD	162	6	11
LH001	MIP05112	UD	163	11	14
LH001	MIP04357	UD	164	9	17
LH001	MIP04362	UD	165	6	14
LH001	MIP05056	UD	167	11	15
LH001	MIP05045	UD	169	9	15
LH001	MIP05047	UD	169	11	16
LH001	MIP05117	UD	169	10	14
LH001	MIP05068	UD	175	7	14
LH001	MIP05113	UD	178	9	14
LH001	MIP05116	UD	181	10	15

Location	Sample #	Classification	Stand Length (mm)	Upper Gillraker #	Lower Gillraker #
LH001	MIP05067	UD	182	12	16
LH001	MIP05039	UD	183	10	16
LH001	MIP05061	UD	184	11	14
LH001	MIP04361	UD	184	6	9
LH001	MIP05123	UD	185	8	15
LH001	MIP05058	UD	186	8	13
LH001	MIP05064	UD	186	10	16
LH001	MIP04356	UD	187	10	13
LH001	MIP05110	UD	187	8	16
LH001	MIP05037	UD	187	9	11
LH001	MIP05043	UD	189	11	14
LH001	MIP05115	UD	192	10	13
LH001	MIP05038	UD	194	10	15
LH001	MIP05109	UD	195	11	15
LH001	MIP04371	UD	197	6	10
LH001	MIP05118	UD	197	10	15
LH001	MIP05055	UD	198	10	15
LH001	MIP05046	UD	199	10	13
LH001	MIP05114	UD	199	10	13
LH001	MIP05062	UD	200	9	13
LH001	MIP05036	UD	205	9	14
LH001	MIP05033	UD	207	10	14
LH001	MIP05150	UD	207	10	14
LH001	MIP05111	UD	221	10	15
LH001	MIP05035	UD	222	10	14
LH001	MIP05042	UD	229	8	16
LH001	MIP05023	UD	231	10	14
LH001	MIP05032	UD	232	8	15
LH001	MIP05034	UD	232	11	14
LH001	MIP05026	UD	246	9	10
LH001	MIP05040	UD	250	10	16
LH001	MIP05027	UD	253	10	14
LH001	MIP04370	UD	257	5	12
LH001	MIP05041	UD	257	8	15
LH001	MIP05025	UD	259	12	18
LH001	MIP04368	UD	267	8	13
LH001	MIP05024	UD	270	9	13
LH001	MIP04446	UD	361	7	13
LH001	MIP05139	UD	377	9	11
LH001	MIP05065	SM	103	9	15
LH001	MIP05106	SM	113	11	15
LH001	MIP04341	SM	121	6	14

Location	Sample #	Classification	Stand Length (mm)	Upper Gillraker #	Lower Gillraker #
LH001	MIP04346	SM	128	9	12
LH001	MIP05049	SM	129	10	15
LH001	MIP05044	SM	131	9	15
LH001	MIP05048	SM	134	11	13
LH001	MIP05057	SM	142	12	16
LH001	MIP05108	SM	144	8	17
LH001	MIP04345	SM	146	11	14
LH001	MIP04340	SM	152	10	17
LH001	MIP05031	SM	155	10	17
LH001	MIP05030	SM	156	12	18
LH001	MIP05107	SM	169	11	14
LH001	MIP05028	SM	174	10	11
LH001	MIP05051	SM	178	12	16
LH001	MIP05053	SM	197	10	15
LH001	MIP05105	SM	198	11	15
LH001	MIP04366	SM	203	7	11
LH001	MIP05022	SM	206	9	14
LH001	MIP04365	SM	212	6	11
PG015	CS04524	UD	87	12	16
PG015	CS04496	UD	89	8	13
PG015	CS04478	UD	95	11	15
PG015	CS04536	UD	99	8	14
PG015	CS04535	UD	102	9	15
PG015	CS04473	UD	105	9	16
PG015	CS04476	UD	106	10	16
PG015	CS031282	UD	110	9	13
PG015	CS04475	UD	112	10	16
PG015	CS04477	UD	112	13	17
PG015	CS04460	UD	115	13	15
PG015	CS04472	UD	116	11	16
PG015	CS04537	UD	123	8	17
PG015	CS04474	UD	126	11	14
PG015	CS04538	UD	127	8	17
PG015	CS04498	UD	135	12	16
PG015	CS04462	UD	145	9	15
PG015	CS031371	UD	146	7	15
PG015	CS031380	UD	151	8	14
PG015	CS04452	UD	151	7	16
PG015	CS031355	UD	155	7	13
PG015	CS031357	UD	155	12	16
PG015	CS04490	UD	155	11	15
PG015	CS04533	UD	155	10	16

Location	Sample #	Classification	Stand Length (mm)	Upper Gillraker #	Lower Gillraker #
PG015	CS031304	UD	159	10	16
PG015	CS04492	UD	159	10	15
PG015	CS031379	UD	160	13	16
PG015	CS04534	UD	160	9	16
PG015	CS031335	UD	161	11	17
PG015	CS031356	UD	161	12	17
PG015	CS04461	UD	161	6	15
PG015	CS04491	UD	161	8	15
PG015	CS04467	UD	162	11	15
PG015	CS04470	UD	165	9	18
PG015	CS031278	UD	166	9	13
PG015	CS031800	UD	167	11	15
PG015	CS04487	UD	169	11	15
PG015	CS04499	UD	169	8	13
PG015	CS04488	UD	170	9	16
PG015	CS04466	UD	172	11	16
PG015	CS04468	UD	173	11	15
PG015	CS04471	UD	174	9	16
PG015	CS04494	UD	175	12	14
PG015	CS031277	UD	176	9	12
PG015	CS04497	UD	176	11	15
PG015	CS031804	UD	180	11	14
PG015	CS04495	UD	181	10	15
PG015	CS04489	UD	185	12	16
PG015	CS031803	UD	186	10	16
PG015	CS031805	UD	187	12	16
PG015	CS04455	UD	189	11	16
PG015	CS031350	UD	192	10	17
PG015	CS04483	UD	194	13	15
PG015	CS04485	UD	199	11	15
PG015	CS04526	UD	204	8	19
PG015	CS04486	UD	205	12	13
PG015	CS031354	UD	206	6	15
PG015	CS031346	UD	210	12	14
PG015	CS031347	UD	213	12	17
PG015	CS031342	UD	215	8	16
PG015	CS031801	UD	216	12	17
PG015	CS031370	UD	217	13	15
PG015	CS031279	UD	222	11	13
PG015	CS04454	UD	223	8	16
PG015	CS031343	UD	225	11	17
PG015	CS031349	UD	236	12	16

Location	Sample #	Classification	Stand Length (mm)	Upper Gillraker #	Lower Gillraker #
PG015	CS031802	UD	237	10	15
PG015	CS031353	UD	242	12	14
PG015	CS031366	UD	243	8	16
PG015	CS031369	UD	243	10	15
PG015	CS031288	UD	245	7	16
PG015	CS031367	UD	251	12	15
PG015	CS031368	UD	261	12	15
PG015	CS031378	UD	265	11	16
PG015	CS04532	SM	120	11	16
PG015	CS04458	SM	126	10	14
PG015	CS04464	SM	129	10	17
PG015	CS04450	SM	155	8	17
PG015	CS031285	SM	156	9	14
PG015	CS04463	SM	159	8	15
PG015	CS04457	SM	160	13	17
PG015	CS04459	SM	162	12	16
PG015	CS04465	SM	163	7	18
PG015	CS04484	SM	172	6	15
PG015	CS04527	SM	181	8	14
PG015	CS04525	SM	183	12	18
PG082	CS02448	UD	161	9	15
PG082	CS04591	UD	114	7	15
PG082	CS04583	UD	124	9	12
PG082	CS04620	UD	124	8	13
PG082	CS04600	UD	126	7	14
PG082	CS04615	UD	131	10	14
PG082	CS04604	UD	139	9	13
PG082	CS04593	UD	145	11	13
PG082	CS04601	UD	151	10	14
PG082	CS01243	UD	155	10	15
PG082	CS02454	UD	156	13	15
PG082	CS01244	UD	157	11	14
PG082	CS01245	UD	158	11	15
PG082	CS04619	UD	159	5	14
PG082	CS01194	UD	160	10	14
PG082	CS02462	UD	161	8	13
PG082	CS02452	UD	163	10	14
PG082	CS01242	UD	163	8	15
PG082	CS04599	UD	164	11	16
PG082	CS04621	UD	164	9	15
PG082	CS01301	UD	165	10	17
PG082	CS02405	UD	165	12	14

Location	Sample #	Classification	Stand Length (mm)	Upper Gillraker #	Lower Gillraker #
PG082	CS02458	UD	165	12	17
PG082	CS04623	UD	165	12	15
PG082	CS02467	UD	166	9	13
PG082	CS04603	UD	166	7	13
PG082	CS04635	UD	166	8	13
PG082	CS04637	UD	166	8	15
PG082	CS04592	UD	167	7	12
PG082	CS01203	UD	168	11	16
PG082	CS02461	UD	168	8	16
PG082	CS01204	UD	168	10	13
PG082	CS04614	UD	169	10	14
PG082	CS04634	UD	169	8	15
PG082	CS02453	UD	170	11	14
PG082	CS02459	UD	172	10	13
PG082	CS02466	UD	174	11	17
PG082	CS02468	UD	174	10	15
PG082	CS04590	UD	174	11	15
PG082	CS04609	UD	175	10	14
PG082	CS02460	UD	176	10	16
PG082	CS04581	UD	177	9	14
PG082	CS04624	UD	177	11	15
PG082	CS01297	UD	177	10	15
PG082	CS04608	UD	178	7	13
PG082	CS04616	UD	178	9	15
PG082	CS01206	UD	179	11	16
PG082	CS02464	UD	179	12	15
PG082	CS02441	UD	180	11	17
PG082	CS02463	UD	180	11	14
PG082	CS02465	UD	181	10	15
PG082	CS04633	UD	182	8	14
PG082	CS04586	UD	184	11	15
PG082	CS04607	UD	184	8	14
PG082	CS01200	UD	184	9	14
PG082	CS02451	UD	185	9	15
PG082	CS01205	UD	185	12	17
PG082	CS02449	UD	186	12	16
PG082	CS04594	UD	186	10	15
PG082	CS02406	UD	187	10	16
PG082	CS02450	UD	187	10	14
PG082	CS04617	UD	189	6	12
PG082	CS04622	UD	189	12	16
PG082	CS04585	UD	190	8	14

Location	Sample #	Classification	Stand Length (mm)	Upper Gillraker #	Lower Gillraker #
PG082	CS01197	UD	191	11	13
PG082	CS04618	UD	192	7	15
PG082	CS02457	UD	194	11	14
PG082	CS04598	UD	194	8	14
PG082	CS02471	UD	199	11	15
PG082	CS01198	UD	201	11	14
PG082	CS04611	UD	201	8	15
PG082	CS02408	UD	202	10	15
PG082	CS02470	UD	202	8	14
PG082	CS02404	UD	205	11	16
PG082	CS02474	UD	206	11	16
PG082	CS02472	UD	207	11	17
PG082	CS01201	UD	207	10	14
PG082	CS04580	UD	210	11	14
PG082	CS02442	UD	214	11	17
PG082	CS01241	UD	217	9	15
PG082	CS02475	UD	217	10	15
PG082	CS01300	UD	221	10	16
PG082	CS04582	UD	223	11	15
PG082	CS01202	UD	231	9	13
PG082	CS01273	UD	234	9	11
PG082	CS02402	UD	237	8	14
PG082	CS02447	UD	246	11	17
PG082	CS02476	UD	246	9	15
PG082	CS01274	UD	247	10	15
PG082	CS02407	UD	255	10	15
PG082	CS01275	UD	262	9	16
PG082	CS02411	UD	289	10	15
PG082	CS01290	UD	291	10	17
PG082	CS02410	UD	300	10	13
PG082	CS02412	UD	300	10	14
PG082	CS02429	UD	308	11	13
PG082	CS02477	UD	314	12	14
PG082	CS02478	UD	314	10	15
PG082	CS02413	UD	336	12	16
PG082	CS04602	SM	144	8	14
PG082	CS04627	SM	144	7	16
PG082	CS02456	SM	145	10	14
PG082	CS04610	SM	148	8	14
PG082	CS02455	SM	152	10	13
PG082	CS01248	SM	154	10	15
PG082	CS02469	SM	162	10	15

Location	Sample #	Classification	Stand Length (mm)	Upper Gillraker #	Lower Gillraker #
PG082	CS01249	SM	162	11	16
PG082	CS01199	SM	162	10	14
PG082	CS04606	SM	168	9	13
PG082	CS02403	SM	171	11	14
PG082	CS04612	SM	172	10	14
PG082	CS01250	SM	173	10	14
PG082	CS04639	SM	173	5	14
PG082	CS01196	SM	174	11	15
PG082	CS04588	SM	175	10	14
PG082	CS04630	SM	175	12	15
PG082	CS04589	SM	177	10	16
PG082	CS01247	SM	179	11	15
PG082	CS04584	SM	179	8	15
PG082	CS04625	SM	179	8	15
PG082	CS04587	SM	182	9	13
PG082	CS04595	SM	183	12	14
PG082	CS01246	SM	184	12	16
PG082	CS04597	SM	185	7	14
PG082	CS01195	SM	187	10	16
PG082	CS04626	SM	188	8	15
PG082	CS04638	SM	191	8	13
PG082	CS04596	SM	208	9	15
PG082	CS04613	SM	212	8	15
PG082	CS04640	SM	220	12	17
PG082	CS04605	SM	223	7	16

APPENDIX 1.3

Range of Sr and maximum Sr (Max Sr) used in MANOVA analysis. Location (LOC) refers to lake system of the study (**Chapter 2**).

LOC	Group Classification	Range Sr (ppm)	Max Sr (ppm)
LH001	Large-maturing	1731	2408
LH001	Large-maturing	1875	2604
LH001	Large-maturing	1800	2365
LH001	Large-maturing	1342	2135
LH001	Large-maturing	1680	2321
LH001	Large-maturing	1527	2125
LH001	Large-maturing	1835	2464
LH001	Large-maturing	1548	2543
LH001	Large-maturing	1368	2038
LH001	Large-maturing	2553	2553
LH001	Small-maturing	1043	1433
LH001	Small-maturing	1038	1712
LH001	Small-maturing	1060	1666
LH001	Small-maturing	988	1539
LH001	Small-maturing	1047	1517
LH001	Small-maturing	1529	1956
LH001	Small-maturing	1158	1619
LH001	Small-maturing	1083	1689
LH001	Small-maturing	993	1562
PG015	Large-maturing	1860	2894
PG015	Large-maturing	2851	3382
PG015	Large-maturing	2882	3628
PG015	Large-maturing	2348	3379
PG015	Large-maturing	2171	3083
PG015	Large-maturing	2168	2969
PG015	Large-maturing	1868	2419
PG015	Large-maturing	2171	2610
PG015	Large-maturing	2650	3268
PG015	Large-maturing	2520	3254
PG015	Small-maturing	1407	2251
PG015	Small-maturing	1829	2788
PG015	Small-maturing	2452	3287
PG015	Small-maturing	2569	3409
PG082	Large-maturing	1503	1878
PG082	Large-maturing	1273	1649
PG082	Large-maturing	1570	1809
PG082	Large-maturing	1261	1535
PG082	Large-maturing	1380	1793
PG082	Large-maturing	1975	2135
PG082	Large-maturing	1570	1886
PG082	Large-maturing	1790	2021
PG082	Large-maturing	1550	1678
PG082	Large-maturing	1388	1730
PG082	Small-maturing	910	1224
PG082	Small-maturing	1006	1378
PG082	Small-maturing	717	1021
PG082	Small-maturing	1163	1644
PG082	Small-maturing	1147	1420
PG082	Small-maturing	840	1173
PG082	Small-maturing	994	1268
PG082	Small-maturing	880	1211
PG082	Small-maturing	625	1020
PG082	Small-maturing	1028	1322
PG015	Small-maturing	1438	2253
PG015	Small-maturing	1502	2072
PG015	Small-maturing	2054	2607
PG015	Small-maturing	2376	3346
PG015	Small-maturing	2381	3187
PG015	Small-maturing	1818	2761

APPENDIX 1.4

Sample R code for MANOVA used for both Sr and gillraker analysis (**Chapter 2**).

```
attach(m_lh001)
# attach file named m_lh001

Y = cbind(up_gillraker, lo_gillraker)
# Bind two factors together for multivariate analysis in
this case upper and lower gillraker number.

model = manova(Y~classification)
# MANOVA model with classification groups

summary(model)
# overall model summary

summary.aov(model)
# model summary for each individual factor

detach(m_lh001)
# detach cvs file called m_lh001
```

APPENDIX 1.5

Sample R code for PFA with rotation (**Chapter 2**).

```
attach(mlh001)
# attach data file

FA <-
factanal(~bod_dep+caud_ped+eye_len+fork_dep+head_dep+head_l
en+lal+pecfin_len+pelfin_len+snout_len+stand_len+upjaw_len,
factors=2, rotation="varimax", scores="regression",
data=mlh001)
# principal factor analysis model with two factors choosen
as important with varimax rotation
# scores choosen were regression and were saved with this
command in the mlh001 data file

FA$loadings[,1]
# factor analysis model loadings for factor 1

FA$loadings[,2]
# factor analysis model loadings for factor 2

plot(F1, F2,pch=19+as.numeric(classification))
# plot factor 1 (x-axis) and factor 2 (y-axis)according to
maturity grouping (small-maturing and not mature groups)
```

APPENDIX 1.6

Sample R code for univariate morphological trait analysis (**Chapter 2**).

```
attach(lh001_1)
# attach cvs file named lh001_1

model_1= lm(bod_dep~stand_len*class)
# linear model for the morphological character bod_dep

summary(model_1)
# summary of model_1 is printed out

plot(stand_len, bod_dep, pch=1+as.numeric(class),
col=c("black", "grey")[as.numeric(class)], xlim=c(0;850),
ylim=c(1,200))
abline(lm(bod_dep[class=="NM"]~stand_len[class=="NM"]),lty=
2, lwd=3)
abline(lm(bod_dep[class=="SM"]~stand_len[class=="SM"]),lty=
3, col="grey", lwd=3)
# plots data to by classification group to examine linear
regression model in graphical format

par(mfrow= c(2,2))
hist(resid(model_1), xlab= "Residual", main="")
qqnorm(resid(model_1))
qqline(resid(model_1))
plot(resid(model_1)~stand_len, xlab = "length",
ylab="residuals")
# preliminary analysis of normality
```

APPENDIX 2.1

Life history data used in **Chapter 3** analyses. Sex was classified as male (M), female (F) or unknown (U). Maturity was classified as unknown (0), immature (I), mature (M), resting (R), running ripe (RR), and spent (S).

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
LH001	MIP031591	6	246	138.00	U	0	
LH001	MIP031511	8	417	778.00	F	I	2.30
LH001	MIP031512	7	422	718.00	F	I	5.50
LH001	MIP031513	8	364	542.00	M	I	0.30
LH001	MIP031515	9	466	1188.00	F	I	7.20
LH001	MIP031516	13	461	906.00	M	I	0.20
LH001	MIP031519	7	401	654.00	M	I	0.50
LH001	MIP031520	6	373	644.00	F	I	2.30
LH001	MIP031521	6	299	238.00	M	I	0.20
LH001	MIP031525	8	359	442.00	F	I	1.20
LH001	MIP031526	6	296	260.00	M	I	0.10
LH001	MIP031527	8	315	330.00	F	I	0.90
LH001	MIP031528	4	235	142.00	M	I	<0.1
LH001	MIP031529	7	236	130.00	M	I	<0.1
LH001	MIP031530	5	227	127.00	M	I	<0.1
LH001	MIP031531	6	246	1353.00	M	I	0.10
LH001	MIP031532	3	199	89.10	M	I	<0.1
LH001	MIP031533	5	240	156.60	F	I	<0.1
LH001	MIP031535	5	253	162.00	F	I	0.50
LH001	MIP031536	6	188	61.10	M	I	<0.1
LH001	MIP031537		220	112.50	M	I	<0.1
LH001	MIP031538	4	219	82.70	M	I	<0.1
LH001	MIP031559	9	441	970.00	M	I	0.60
LH001	MIP031560	3	186	68.70	F	I	<0.1
LH001	MIP031561	4	215	91.40	M	I	<0.1
LH001	MIP031562		194	74.90	F	I	0.20
LH001	MIP031563	4	193	69.20	F	I	<0.1
LH001	MIP031564	4	221	119.40	F	I	0.30
LH001	MIP031565	9	183	58.80	F	I	0.10
LH001	MIP031566	3	183	60.30	F	I	<0.1
LH001	MIP031567	3	195	70.40	F	I	0.20
LH001	MIP031568	5	211	92.60	F	I	0.20
LH001	MIP031569	3	192	64.20	F	I	<0.1
LH001	MIP031570	8	457	1060.00	F	I	3.60
LH001	MIP031574	8	349	416.00	F	I	1.10
LH001	MIP031578	5	296	270.00	M	I	0.10
LH001	MIP031579	7	224	273.00	F	I	0.50
LH001	MIP031580	6	336	398.00	F	I	1.10

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
LH001	MIP031581	6	288	254.00	F	I	0.50
LH001	MIP031582	6	306	302.00	F	I	0.60
LH001	MIP031583	7	320	366.00	F	I	0.90
LH001	MIP031584	5	266	212.00	M	I	<0.1
LH001	MIP031585	6	252	176.00	F	I	0.10
LH001	MIP031586	7	291	282.00	M	I	<0.1
LH001	MIP031587	6	301	336.00	F	I	0.70
LH001	MIP031588	6	245	162.00	F	I	0.30
LH001	MIP031589	7	260	190.00	F	I	0.10
LH001	MIP031590	5	245	180.00	M	I	0.10
LH001	MIP031594	6	242	136.00	F	I	0.30
LH001	MIP031595	7	345	454.00	M	I	0.10
LH001	MIP031596	8	327	400.00	F	I	0.60
LH001	MIP031597	7	319	402.00	F	I	0.70
LH001	MIP031600	7	370	584.00	M	I	0.30
LH001	MIP031601	5	309	346.00	F	I	0.60
LH001	MIP031602	9	370	522.00	M	I	0.40
LH001	MIP031603	6	330	390.00	F	I	0.80
LH001	MIP031604	9	367	552.00	M	I	0.30
LH001	MIP031605	6	364	528.00	M	I	0.50
LH001	MIP031606	6	326	366.00	F	I	0.70
LH001	MIP031607	8	326	352.00	F	I	0.90
LH001	MIP031608	6	293	242.00	M	I	0.10
LH001	MIP031609	5	303	300.00	M	I	<0.1
LH001	MIP031610	6	297	322.00	M	I	<0.1
LH001	MIP031611	6	285	258.00	F	I	0.50
LH001	MIP031612	6	257	196.00	F	I	0.10
LH001	MIP031613	5	280	254.00	F	I	0.30
LH001	MIP031614	7	265	222.00	M	I	<0.1
LH001	MIP031615	6	295	274.00	M	I	0.10
LH001	MIP031616	6	274	194.00	F	I	0.30
LH001	MIP031617	6	325	386.00	F	I	0.70
LH001	MIP031618	4	194	80.20	F	I	0.10
LH001	MIP031619	6	295	278.00	M	I	0.20
LH001	MIP031620	6	271	218.00	F	I	0.40
LH001	MIP031621	6	292	272.00	F	I	0.30
LH001	MIP031622	5	284	238.00	M	I	0.10
LH001	MIP031623	8	273	220.00	F	I	0.30
LH001	MIP031624	4	206	82.40	F	I	0.10
LH001	MIP031625	5	218	99.70	F	I	0.20

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
LH001	MIP031626	7	267	190.00	F	I	0.50
LH001	MIP031627	4	200	107.30	F	I	0.10
LH001	MIP031647	6	376	518.00	F	I	2.00
LH001	MIP031656	6	344	420.00	M	I	<2
LH001	MIP031664	6	263	208.00	F	I	2.00
LH001	MIP04292	8	434	852.00	M	I	0.50
LH001	MIP04337	4	139	29.26	U	I	
LH001	MIP04338		123	20.87	M	I	0.01
LH001	MIP04339	3	152	37.65	M	I	0.01
LH001	MIP04342	8	126	23.38	M	I	0.01
LH001	MIP04343	4	120	21.36	F	I	0.03
LH001	MIP04347		115	19.37	U	I	
LH001	MIP04349	5	126	23.04	F	I	0.07
LH001	MIP04350	3	116	20.01	M	I	0.01
LH001	MIP04351	1	100	15.20	M	I	0.01
LH001	MIP04353	5	123	22.48	M	I	0.03
LH001	MIP04354	3	122	21.20	F	I	0.09
LH001	MIP04355	3	114	19.90	M	I	0.01
LH001	MIP04356	4	206	97.48	M	I	0.01
LH001	MIP04357	4	179	63.65	M	I	0.01
LH001	MIP04359	5	150	36.55	M	I	0.01
LH001	MIP04361	4	205	91.91	M	I	0.01
LH001	MIP04362	2	191	67.62	F	I	0.15
LH001	MIP04363	5	180	60.28	F	I	0.09
LH001	MIP04368	5	298	286.99	M	I	0.60
LH001	MIP04369	5	286	287.56	M	I	0.06
LH001	MIP04370	6	285	204.42	M	I	0.09
LH001	MIP04371	9	216	94.27	F	I	0.16
LH001	MIP04446	9	401	647.02	F	I	1.34
LH001	MIP05019	3	115	14.50	M	I	<0.05
LH001	MIP05020	2	101	10.00	M	I	<0.01
LH001	MIP05021	4	179	63.00	M	I	0.02
LH001	MIP05023	6	257	178.00	F	I	0.36
LH001	MIP05024	6	290	257.50	F	I	0.52
LH001	MIP05025	6	290	252.50	M	I	0.13
LH001	MIP05026	5	270	188.50	F	I	0.32
LH001	MIP05027	7	276	224.50	F	I	0.57
LH001	MIP05029	5	179	59.50	M	I	0.14
LH001	MIP05032	6	255	171.00	F	I	0.09
LH001	MIP05033	6	233	128.00	M	I	0.09

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
LH001	MIP05034	5	247	171.00	F	I	0.38
LH001	MIP05035	5	244	154.50	F	I	0.13
LH001	MIP05036	5	220	96.50	F	I	0.10
LH001	MIP05037	8	211	82.00	F	I	0.58
LH001	MIP05038	5	210	98.00	F	I	0.18
LH001	MIP05039	5	207	83.00	F	I	0.13
LH001	MIP05040	7	272	225.50	M	I	0.11
LH001	MIP05041	6	275	217.00	M	I	0.09
LH001	MIP05042	6	245	175.50	F	I	0.41
LH001	MIP05043	6	207	88.50	F	I	0.15
LH001	MIP05045	5	191	69.50	F	I	0.26
LH001	MIP05046	7	221	104.00	F	I	0.27
LH001	MIP05047	4	188	74.50	F	I	0.10
LH001	MIP05050	2	96	7.50	U	I	<0.5
LH001	MIP05052	4	173	52.50	F	I	0.08
LH001	MIP05055	4	216	107.00	F	I	0.07
LH001	MIP05056	4	185	71.00	F	I	0.08
LH001	MIP05058	5	205	90.50	M	I	0.04
LH001	MIP05059	5	176	58.00	M	I	0.01
LH001	MIP05060	4	170	55.50	M	I	0.02
LH001	MIP05061	4	199	80.50	M	I	0.02
LH001	MIP05062	6	223	119.00	F	I	0.23
LH001	MIP05064	7	208	97.00	M	I	0.01
LH001	MIP05066	7	196	78.00	M	I	0.06
LH001	MIP05067	6	202	81.50	M	I	0.02
LH001	MIP05068	4	187	65.50	M	I	0.04
LH001	MIP05070	5	256	184.50	M	I	<0.5
LH001	MIP05071	7	255	176.50	M	I	<0.5
LH001	MIP05072	5	286	251.00	M	I	<0.5
LH001	MIP05073		257	2055.00	M	I	<0.5
LH001	MIP05100	6	312	311.00	M	I	7.50
LH001	MIP05101	6	345	421.00	F	I	1.00
LH001	MIP05102	6	249	155.50	M	I	<0.5
LH001	MIP05103	10	262	214.50	M	I	<0.5
LH001	MIP05104	6	275	184.00	M	I	<0.5
LH001	MIP05109	6	227	102.50	M	I	0.04
LH001	MIP05110	5	203	89.00	F	I	0.12
LH001	MIP05111	5	245	147.00	F	I	0.27
LH001	MIP05112	4	182	57.50	F	I	0.12
LH001	MIP05113	3	192	71.00	M	I	<0.04

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
LH001	MIP05114	5	220	112.00	M	I	0.10
LH001	MIP05115	5	208	89.00	M	I	0.02
LH001	MIP05116	5	198	79.50	F	I	0.21
LH001	MIP05117	5	191	77.00	M	I	0.01
LH001	MIP05118	5	216	99.00	M	I	0.06
LH001	MIP05119	4	179	59.00	F	I	0.06
LH001	MIP05120	5	214	98.00	F	I	0.07
LH001	MIP05121	5	171	54.00	M	I	0.02
LH001	MIP05122	5	152	32.50	M	I	<0.5
LH001	MIP05123	5	208	105.00	M	I	0.02
LH001	MIP05139	7	407	414.08	M	I	1.00
LH001	MIP05150	5	225	231.81	F	I	0.50
LH001	MIP031501	12	702	3708.00	M	M	49.40
LH001	MIP031505	18	710	3910.00	M	M	119.30
LH001	MIP031507	14	590	2732.00	F	M	266.40
LH001	MIP031509	18	685	3456.00	M	M	103.60
LH001	MIP031517	15	582	2416.00	F	M	223.60
LH001	MIP031522	12	588	2436.00	F	M	225.00
LH001	MIP031534	14	244	142.70	M	M	5.80
LH001	MIP031544	15	720	3804.00	M	M	132.70
LH001	MIP031545	14	618	2626.00	F	M	73.40
LH001	MIP031546	16	721	4274.00	M	M	138.20
LH001	MIP031547	17	730	3874.00	M	M	183.20
LH001	MIP031548	14	629	2766.00	F	M	277.90
LH001	MIP031549	17	720	4232.00	M	M	165.20
LH001	MIP031551	14	705	4056.00	M	M	150.50
LH001	MIP031552	13	705	4466.00	M	M	171.20
LH001	MIP031553	13	733	4036.00	M	M	118.70
LH001	MIP031554	14	627	3136.00	M	M	80.00
LH001	MIP031555	13	699	3620.00	M	M	180.20
LH001	MIP031556	14	634	2896.00	F	M	265.00
LH001	MIP031558		722	4648.00	M	M	154.90
LH001	MIP031577	15	683	3710.00	M	M	98.40
LH001	MIP031593	10	521	1930.00	F	M	128.10
LH001	MIP031598	12	548	1762.00	F	M	82.60
LH001	MIP031628	13	582	2402.00	F	M	158.00
LH001	MIP031631	15	696	4170.00	M	M	104.00
LH001	MIP031632	21	745	4342.00	M	M	172.00
LH001	MIP031633	12	567	2406.00	F	M	228.00
LH001	MIP031635	15	584	2324.00	F	M	232.00

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
LH001	MIP031636	13	602	2816.00	F	M	202.00
LH001	MIP031637	16	750	4616.00	M	M	182.00
LH001	MIP031638	18	724	3530.00	M	M	48.00
LH001	MIP031645	14	595	2422.00	M	M	186.00
LH001	MIP031646	12	690	3828.00	M	M	92.00
LH001	MIP031650	12	558	2248.00	F	M	174.00
LH001	MIP031652	18	757	4884.00	M	M	232.00
LH001	MIP031655	15	675	3594.00	M	M	328.00
LH001	MIP031657	11	544	2116.00	F	M	200.00
LH001	MIP031662	13	694	3728.00	M	M	94.00
LH001	MIP031663	21	743	4924.00	M	M	174.00
LH001	MIP031668		599	2100.00	F	M	
LH001	MIP04205	14	680	3456.00	M	M	78.00
LH001	MIP04209	19	710	3241.00	M	M	45.50
LH001	MIP04213	14	645	2813.00	M	M	64.50
LH001	MIP04215	12	634	2588.00	F	M	117.50
LH001	MIP04217	16	612	2775.00	F	M	163.00
LH001	MIP04227	17	704	3686.00	M	M	45.50
LH001	MIP04235	13	689	3085.00	M	M	76.50
LH001	MIP04239	14	704	3820.00	M	M	30.50
LH001	MIP04248	13	640	3147.00	F	M	169.00
LH001	MIP04251	14	731	4023.00	M	M	65.50
LH001	MIP04254	13	652	2995.00	F	M	117.00
LH001	MIP04257	13	693	3923.00	M	M	68.50
LH001	MIP04258	13	715	3979.00	M	M	67.50
LH001	MIP04259		637	2875.00	F	M	27.50
LH001	MIP04291	13	606	2788.00	F	M	68.00
LH001	MIP04340	9	172	48.93	F	M	4.74
LH001	MIP04341	7	133	33.48	F	M	1.99
LH001	MIP04345	8	163	45.01	M	M	1.55
LH001	MIP04346	8	143	34.77	M	M	1.31
LH001	MIP04365	10	240	135.30	F	M	4.69
LH001	MIP04366	10	224	110.82	M	M	4.53
LH001	MIP04435	12	595	2433.49	F	M	133.74
LH001	MIP04447	15	719	3797.23	M	M	130.21
LH001	MIP04449	12	600	2256.13	F	M	161.09
LH001	MIP05001	17	773	4545.00	M	M	80.50
LH001	MIP05006	16	646	3239.00	F	M	178.00
LH001	MIP05018	13	587	2217.00	F	M	292.00
LH001	MIP05022	8	228	113.00	M	M	5.43

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
LH001	MIP05028	15	197	82.00	M	M	2.01
LH001	MIP05030	12	168	48.50	M	M	1.21
LH001	MIP05031	6	170	49.50	M	M	0.98
LH001	MIP05044	8	145	30.50	F	M	5.19
LH001	MIP05048	4	148	29.50	M	M	0.39
LH001	MIP05049	9	151	30.00	M	M	1.00
LH001	MIP05051	8	195	70.50	M	M	1.18
LH001	MIP05053	14	217	95.00	M	M	1.21
LH001	MIP05057	7	153	41.00	M	M	1.22
LH001	MIP05065	6	117	16.00	M	M	0.34
LH001	MIP05080		686	3300.00	M	M	33.50
LH001	MIP05084	14	665	3795.00	M	M	49.50
LH001	MIP05085	13	700	4276.00	M	M	109.50
LH001	MIP05086	16	709	3833.00	M	M	64.50
LH001	MIP05088	14	780	5502.00	M	M	157.50
LH001	MIP05089	13	610	2601.00	F	M	285.50
LH001	MIP05090	18	635	3273.00	F	M	417.50
LH001	MIP05091	14	750	4394.00	M	M	148.50
LH001	MIP05095	13	659	3256.00	M	M	92.00
LH001	MIP05105	8	220	103.50	M	M	2.09
LH001	MIP05106	5	127	21.50	M	M	1.17
LH001	MIP05107	12	188	68.50	M	M	3.25
LH001	MIP05108	7	157	43.00	M	M	0.80
LH001	MIP05137	13	636	643.68	M	M	61.00
LH001	MIP05142	16	722	730.28	M	M	202.00
LH001	MIP05143	12	720	728.27	M	M	154.00
LH001	MIP05149	13	558	565.13	F	M	240.00
LH001	MIP05151	15	613	620.52	F	M	395.00
LH001	MIP05152	15	579	586.28	F	M	232.00
LH001	MIP05153	11	639	646.70	M	M	147.00
LH001	MIP05154	14	567	574.20	F	M	399.00
LH001	MIP05155	12	704	712.16	M	M	67.00
LH001	MIP031500	13	704	3568.00	M	R	8.60
LH001	MIP031502	14	707	4612.00	M	R	6.80
LH001	MIP031503	20	676	3246.00	F	R	19.50
LH001	MIP031504	17	625	3302.00	F	R	35.50
LH001	MIP031506	13	685	3736.00	M	R	7.50
LH001	MIP031508	9	549	1870.00	F	R	10.30
LH001	MIP031510	12	497	1208.00	F	R	9.30
LH001	MIP031514	12	501	1284.00	F	R	10.20

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
LH001	MIP031518	10	590	2304.00	M	R	2.20
LH001	MIP031523	12	555	1794.00	F	R	11.40
LH001	MIP031524	12	627	2558.00	M	R	1.90
LH001	MIP031539	14	666	3568.00	M	R	2.80
LH001	MIP031540	14	569	2040.00	M	R	2.40
LH001	MIP031541	14	652	2882.00	M	R	3.80
LH001	MIP031542	17	714	4088.00	M	R	4.30
LH001	MIP031543	9	564	2380.00	M	R	2.40
LH001	MIP031550	14	673	3662.00	M	R	3.90
LH001	MIP031557	12	612	2092.00	M	R	2.60
LH001	MIP031571	13	550	1852.00	F	R	14.30
LH001	MIP031572	11	534	1638.00	M	R	1.00
LH001	MIP031573	8	428	854.00	M	R	0.50
LH001	MIP031575	12	593	2288.00	M	R	2.40
LH001	MIP031576	12	621	2694.00	F	R	14.80
LH001	MIP031592	12	477	1198.00	M	R	0.80
LH001	MIP031599	14	615	2768.00	M	R	2.20
LH001	MIP031629	15	705	3952.00	M	R	10.00
LH001	MIP031630	12	604	2920.00	M	R	2.00
LH001	MIP031634	14	653	3206.00	M	R	4.00
LH001	MIP031639	18	708	3918.00	M	R	2.00
LH001	MIP031640	12	580	2346.00	M	R	<2
LH001	MIP031641	13	611	2868.00	F	R	36.00
LH001	MIP031642	16	675	3458.00	M	R	6.00
LH001	MIP031643	16	710	3722.00	M	R	10.00
LH001	MIP031644	15	699	4564.00	M	R	6.00
LH001	MIP031648	14	630	1900.00	M	R	4.00
LH001	MIP031649	9	555	2082.00	F	R	30.00
LH001	MIP031651	14	618	2756.00	F	R	20.00
LH001	MIP031653	13	666	2996.00	F	R	20.00
LH001	MIP031654	13	637	2912.00	M	R	<2
LH001	MIP031658	14	684	3946.00	M	R	<2
LH001	MIP031659	12	634	3180.00	M	R	2.00
LH001	MIP031660	12	677	4158.00	M	R	2.00
LH001	MIP031661	16	748	4834.00	M	R	14.00
LH001	MIP031665	17	670	3228.00	M	R	
LH001	MIP031666	14	715	4400.00	M	R	
LH001	MIP031667	16	740	4350.00	M	R	
LH001	MIP031669	15	683	4150.00	M	R	
LH001	MIP031670	16	725	4250.00	M	R	

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
LH001	MIP031671	13	591	2325.00	F	R	
LH001	MIP031672	15	688	3350.00	F	R	
LH001	MIP04200	13	647	3537.00	M	R	2.50
LH001	MIP04201	12	648	3333.00	M	R	1.50
LH001	MIP04202	15	705	3092.00	M	R	6.50
LH001	MIP04203	13	642	3009.00	F	R	21.50
LH001	MIP04204	14	598	2491.00	M	R	2.00
LH001	MIP04206	17	738	3708.00	M	R	17.00
LH001	MIP04207		600	2508.00	F	R	18.50
LH001	MIP04208	14	610	2244.00	F	R	18.00
LH001	MIP04210	11	540	1876.00	F	R	11.50
LH001	MIP04211	21	734	2773.00	M	R	6.00
LH001	MIP04212	14	644	2757.00	F	R	22.00
LH001	MIP04214	14	676	3532.00	M	R	7.00
LH001	MIP04216	11	670	3379.00	M	R	32.00
LH001	MIP04218	13	698	2759.00	M	R	7.00
LH001	MIP04219	13	652	3843.00	M	R	6.00
LH001	MIP04220	16	637	2984.00	M	R	2.50
LH001	MIP04221	14	609	2679.00	F	R	32.00
LH001	MIP04222	16	751	3166.00	M	R	7.50
LH001	MIP04223	12	611	2646.00	M	R	2.50
LH001	MIP04224	12	601	2894.00	M	R	2.00
LH001	MIP04225	10	635	2965.00	M	R	2.50
LH001	MIP04226	13	644	3498.00	M	R	3.00
LH001	MIP04228	11	605	2364.00	M	R	3.00
LH001	MIP04229	16	629	2338.00	F	R	21.20
LH001	MIP04230	14	661	3368.00	M	R	2.50
LH001	MIP04231	15	690	3664.00	M	R	1.50
LH001	MIP04232	14	680	3036.00	M	R	1.50
LH001	MIP04233	12	614	2810.00	M	R	2.00
LH001	MIP04234	15	659	3269.00	M	R	4.50
LH001	MIP04236	14	691	4067.00	M	R	5.50
LH001	MIP04237	10	574	2286.00	F	R	17.00
LH001	MIP04238	14	606	2595.00	F	R	19.00
LH001	MIP04240	17	616	2740.00	F	R	37.50
LH001	MIP04241	14	687	3661.00	M	R	3.00
LH001	MIP04242	12	645	2880.00	M	R	8.00
LH001	MIP04243	12	648	2869.00	M	R	4.00
LH001	MIP04244	12	660	3380.00	M	R	2.50
LH001	MIP04245	13	645	3275.00	M	R	3.00

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
LH001	MIP04246	12	687	2480.00	F	R	
LH001	MIP04247	12	656	2977.00	M	R	2.00
LH001	MIP04249	15	745	5035.00	M	R	7.50
LH001	MIP04250	15	506	2620.00	F	R	24.00
LH001	MIP04252	13	652	3180.00	M	R	4.00
LH001	MIP04253	14	711	3680.00	M	R	5.00
LH001	MIP04255	12	611	2634.00	M	R	3.50
LH001	MIP04256	14	685	3759.00	M	R	11.00
LH001	MIP04260	13	645	3100.00	M	R	4.50
LH001	MIP04261	11	655	3086.00	M	R	3.00
LH001	MIP04262	15	605	2009.00	F	R	17.50
LH001	MIP04263	11	613	2707.00	M	R	2.50
LH001	MIP04264	12	673	3861.00	M	R	5.50
LH001	MIP04265	11	577	2158.00	M	R	1.50
LH001	MIP04266	11	649	3082.00	M	R	3.00
LH001	MIP04267	10	610	2412.00	M	R	3.00
LH001	MIP04268	14	598	2514.00	M	R	2.50
LH001	MIP04269	14	636	2654.00	M	R	2.00
LH001	MIP04270	10	624	2709.00	M	R	2.50
LH001	MIP04271	12	622	2800.00	M	R	3.00
LH001	MIP04272	13	654	3269.00	M	R	1.50
LH001	MIP04273	14	685	3801.00	M	R	8.50
LH001	MIP04274	15	644	2688.00	M	R	5.50
LH001	MIP04275	12	585	2525.00	F	R	20.00
LH001	MIP04276	15	580	2532.00	F	R	16.50
LH001	MIP04277	12	629	3036.00	M	R	3.00
LH001	MIP04278	17	600	2297.00	F	R	17.00
LH001	MIP04279	17	762	3395.00	M	R	7.50
LH001	MIP04280	13	660	3079.00	F	R	19.50
LH001	MIP04281	18	585	2218.00	M	R	2.00
LH001	MIP04282	11	595	2694.00	M	R	2.50
LH001	MIP04283	11	602	2450.00	M	R	1.50
LH001	MIP04284	13	663	3185.00	M	R	3.00
LH001	MIP04285	12	634	3146.00	M	R	4.50
LH001	MIP04286	14	665	2814.00	M	R	3.50
LH001	MIP04287	18	654	3221.00	F	R	63.00
LH001	MIP04288	13	602	2538.00	F	R	23.00
LH001	MIP04289	11	614	2723.00	M	R	3.50
LH001	MIP04290	13	630	2632.00	M	R	2.50
LH001	MIP04293	13	626	2642.00	F	R	17.00

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
LH001	MIP04294	19	696	3562.00	F	R	49.00
LH001	MIP04295	14	655	2707.00	M	R	3.50
LH001	MIP04296	15	629	2360.00	F	R	16.00
LH001	MIP04297	13	604	2390.00	F	R	22.50
LH001	MIP04298		616	2875.00	M	R	2.00
LH001	MIP04299	15	670	3546.00	M	R	6.50
LH001	MIP04300	11	608	2803.00	M	R	2.50
LH001	MIP04301	11	584	2459.00	M	R	3.00
LH001	MIP04302	15	677	3433.00	F	R	72.00
LH001	MIP04303	13	649	3236.00	F	R	29.50
LH001	MIP04304	15	655	2769.00	M	R	3.50
LH001	MIP04305	12	568	1914.00	M	R	1.50
LH001	MIP04306	12	665	3304.00	M	R	5.50
LH001	MIP04307	16	670	3502.00	M	R	12.00
LH001	MIP04308	15	671	3183.00	M	R	4.50
LH001	MIP04309	12	561	1964.00	M	R	2.50
LH001	MIP04310	13	633	2685.00	M	R	8.00
LH001	MIP04311	13	612	2565.00	M	R	1.50
LH001	MIP04312	14	629	2811.00	M	R	2.00
LH001	MIP04313	15	733	3668.00	M	R	6.00
LH001	MIP04314	13	546	1944.00	F	R	13.00
LH001	MIP04315	13	652	2909.00	M	R	2.50
LH001	MIP04316	11	625	2762.00	M	R	3.00
LH001	MIP04317	14	696	2405.00	M	R	6.50
LH001	MIP04318	16	623	2713.00	F	R	4.00
LH001	MIP04319	14	645	3446.00	M	R	2.50
LH001	MIP04320	10	574	2081.00	M	R	2.00
LH001	MIP04321	16	660	2321.00	M	R	10.50
LH001	MIP04322	12	610	2464.00	M	R	2.50
LH001	MIP04323	14	760	4948.00	M	R	23.50
LH001	MIP04324	16	663	3454.00	M	R	6.00
LH001	MIP04325	17	732	3766.00	M	R	5.50
LH001	MIP04326		780	3631.00	M	R	10.50
LH001	MIP04327	16	600	2320.00	M	R	3.00
LH001	MIP04328	13	653	3196.00	M	R	4.50
LH001	MIP04329	16	715	3618.00	M	R	6.00
LH001	MIP04330	12	706	3506.00	M	R	8.00
LH001	MIP04331	14	613	2527.00	F	R	75.00
LH001	MIP04332	14	647	3184.00	M	R	4.00
LH001	MIP04333	16	692	4038.00	M	R	14.00

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
LH001	MIP04334	13	742	4266.00	M	R	7.00
LH001	MIP04335	12	648	3184.00	M	R	3.50
LH001	MIP04336		590	2550.00	F	R	17.50
LH001	MIP04344	3	180	62.01	M	R	0.06
LH001	MIP04348	8		64.70	M	R	0.26
LH001	MIP04352	8	170	47.34	F	R	0.17
LH001	MIP04358	14	192	67.93	F	R	0.68
LH001	MIP04360	5	242	135.54	F	R	1.90
LH001	MIP04364	14	274	172.41	F	R	1.36
LH001	MIP04367	7	215	102.98	F	R	0.13
LH001	MIP04415	9	561	1627.88	F	R	17.66
LH001	MIP04416	8	462	1003.52	F	R	6.80
LH001	MIP04417	10	630	2236.22	F	R	79.66
LH001	MIP04418	9	558	1624.20	M	R	1.50
LH001	MIP04419	14	621	2249.46	F	R	27.46
LH001	MIP04420	6	452	1068.44	M	R	0.51
LH001	MIP04421	6	457	914.29	F	R	4.01
LH001	MIP04422	7	469	1132.37	F	R	4.28
LH001	MIP04423	12	677	3173.66	M	R	3.53
LH001	MIP04424	6	514	1440.08	F	R	6.36
LH001	MIP04425	9	583	2079.08	F	R	37.57
LH001	MIP04426		629	2668.40	M	R	1.89
LH001	MIP04427	15	738	3927.68	M	R	7.30
LH001	MIP04428	14	652	2552.58	F	R	17.38
LH001	MIP04429	8	441	822.48	M	R	0.48
LH001	MIP04430	8	458	950.64	F	R	8.10
LH001	MIP04431	9	565	1894.56	M	R	2.21
LH001	MIP04432	8	428	822.78	F	R	4.09
LH001	MIP04433	12	593	1987.47	F	R	15.01
LH001	MIP04434	7	501	1274.08	F	R	7.70
LH001	MIP04436	7	436	751.98	M	R	0.19
LH001	MIP04437	7	393	606.19	F	R	2.04
LH001	MIP04438	12	613	2411.08	F	R	19.65
LH001	MIP04439	9	451	1014.17	F	R	4.23
LH001	MIP04440	7	452	965.28	F	R	5.26
LH001	MIP04441	9	561	1839.59	F	R	14.76
LH001	MIP04442	7	445	619.64	M	R	0.59
LH001	MIP04443	7	385	663.95	M	R	0.37
LH001	MIP04444	17	676	2487.86	M	R	2.71
LH001	MIP04445	11	620	2249.76	F	R	15.94

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
LH001	MIP04448	15	741	3789.27	M	R	1.73
LH001	MIP04450	10	577	1976.71	M	R	0.28
LH001	MIP05002		725	3865.00	M	R	8.00
LH001	MIP05003	13	650	3308.00	M	R	5.00
LH001	MIP05004	14	626	3084.00	F	R	26.50
LH001	MIP05005	17	712	4724.00	M	R	14.50
LH001	MIP05007	11	690	3820.00	M	R	8.00
LH001	MIP05008	12	775	4456.00	M	R	9.00
LH001	MIP05009	14	717	3517.00	M	R	7.00
LH001	MIP05010		689	3794.00	M	R	6.50
LH001	MIP05011	16	747	4903.00	M	R	11.50
LH001	MIP05012	16	620	3077.00	F	R	25.00
LH001	MIP05013	11	580	2505.00	F	R	16.50
LH001	MIP05014	13	762	5431.00	M	R	16.50
LH001	MIP05015	15	620	2870.00	F	R	52.50
LH001	MIP05016	16	500	1082.00	M	R	<0.5
LH001	MIP05017	12	564	1964.00	F	R	17.50
LH001	MIP05054	10	227	101.00	F	R	2.50
LH001	MIP05063	6	213	64.00	F	R	2.11
LH001	MIP05069	8	196	63.00	M	R	0.01
LH001	MIP05074	14	715	4725.00	M	R	12.00
LH001	MIP05075	16	724	4120.00	M	R	11.50
LH001	MIP05076	14	715	4223.00	M	R	11.50
LH001	MIP05077	15	703	4091.00	F	R	18.50
LH001	MIP05078	11	570	2232.00	M	R	2.00
LH001	MIP05079	13	677	4011.00	M	R	8.00
LH001	MIP05081	13	717	4649.00	M	R	10.50
LH001	MIP05082	14	740	4476.00	M	R	13.50
LH001	MIP05083	16	645	2831.00	F	R	16.00
LH001	MIP05087	12	640	2827.00	M	R	4.00
LH001	MIP05092	13	690	4066.00	M	R	6.00
LH001	MIP05093	14	740	4658.00	M	R	12.00
LH001	MIP05094	13	744	4359.00	M	R	11.50
LH001	MIP05096	11	685	3747.00	M	R	6.00
LH001	MIP05097	15	610	2765.00	F	R	17.00
LH001	MIP05098	10	590	2214.00	M	R	3.50
LH001	MIP05099	11	617	2436.00	M	R	2.50
LH001	MIP05124	14	685	4061.00	M	R	4.00
LH001	MIP05125	11	716	4502.00	M	R	10.00
LH001	MIP05126	12	715	4155.00	M	R	12.00

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
LH001	MIP05127	18	808	4809.00	M	R	11.00
LH001	MIP05128	13	715	3886.00	M	R	9.00
LH001	MIP05129	13	709	4267.00	M	R	5.00
LH001	MIP05130	11	662	3274.00	M	R	4.00
LH001	MIP05131	14	715	4594.00	M	R	10.00
LH001	MIP05132	13	654	3239.00	F	R	17.00
LH001	MIP05133	12	672	3636.00	M	R	4.00
LH001	MIP05134	15	694	702.09	M	R	6.00
LH001	MIP05135	20	673	680.94	F	R	20.00
LH001	MIP05136	11	695	703.09	M	R	6.00
LH001	MIP05138	14	642	649.72	M	R	6.00
LH001	MIP05140	12	599	606.42	M	R	2.00
LH001	MIP05141	11	598	605.41	M	R	2.00
LH001	MIP05144	13	653	660.80	M	R	3.00
LH001	MIP05145	14	608	615.48	F	R	21.00
LH001	MIP05146	10	629	636.63	M	R	2.00
LH001	MIP05147	16	672	679.93	M	R	4.00
LH001	MIP05148	12	615	622.53	M	R	2.00
PG015	CS031806	1	54	7.26	U	0	
PG015	CS031230	7	399	800.00	M	I	0.60
PG015	CS031275	5	293	275.00	F	I	0.32
PG015	CS031276	5	226	103.40	M	I	0.03
PG015	CS031277	5	202	68.00	F	I	0.07
PG015	CS031278		202	86.30	F	I	0.06
PG015	CS031279	8	253	179.50	F	I	0.39
PG015	CS031282	4	128	17.10	F	I	0.01
PG015	CS031283	4	121	16.00	U	I	
PG015	CS031288	6	290	235.00	M	I	0.07
PG015	CS031299	5	396	735.00	F	I	1.90
PG015	CS031301	5	376	680.00	M	I	0.30
PG015	CS031304	5	179	59.40	M	I	0.03
PG015	CS031310	5	299	295.00	M	I	1.10
PG015	CS031311		341	385.00	F	I	1.10
PG015	CS031314	8	434	990.00	M	I	5.50
PG015	CS031315		390	735.00	M	I	0.20
PG015	CS031317	5	360	525.00	M	I	0.20
PG015	CS031318	9	409	755.00	M	I	0.50
PG015	CS031319	5	391	715.00	M	I	0.50
PG015	CS031320	4	317	415.00	F	I	1.70
PG015	CS031321	8	340	455.00	F	I	2.70

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
PG015	CS031334	4	285	260.00	F	I	1.20
PG015	CS031335	3	177	60.62	M	I	0.01
PG015	CS031342	5	239	139.60	M	I	0.04
PG015	CS031343	4	245	166.90	M	I	0.06
PG015	CS031346	5	230	133.10	F	I	0.14
PG015	CS031347	5	237	138.60	F	I	0.18
PG015	CS031349	5	264	200.00	M	I	0.05
PG015	CS031350	5	223	121.80	F	I	0.13
PG015	CS031351	5	257	173.60	M	I	*
PG015	CS031353	5	279	235.00	M	I	0.08
PG015	CS031354	4	241	139.20	F	I	0.14
PG015	CS031355	6	179	53.40	M	I	0.02
PG015	CS031356		193	67.70	M	I	0.01
PG015	CS031357	3	170	50.70	F	I	0.05
PG015	CS031359	6	394	780.00	F	I	1.80
PG015	CS031361	5	349	515.00	F	I	1.80
PG015	CS031362	8	347	445.00	M	I	<0.1
PG015	CS031363	6	332	415.00	F	I	0.60
PG015	CS031364	8	341	345.00	M	I	0.60
PG015	CS031365	6	315	330.00	F	I	0.70
PG015	CS031366	4	284	265.00	M	I	0.10
PG015	CS031367	5	275	230.00	F	I	0.27
PG015	CS031368	5	295	260.00	F	I	0.24
PG015	CS031369	4	280	245.00	F	I	0.22
PG015	CS031370	5	242	163.00	F	I	0.23
PG015	CS031371	5	166	42.90	M	I	0.01
PG015	CS031373	7	345	425.00	M	I	0.30
PG015	CS031374	4	290	275.00	F	I	0.90
PG015	CS031376	5	270	205.00	F	I	0.20
PG015	CS031378	7	301	300.00	M	I	0.14
PG015	CS031379	4	186	64.00	F	I	0.10
PG015	CS031380	3	172	52.40	M	I	0.01
PG015	CS031381	4	375	610.00	M	I	0.30
PG015	CS031382	7	389	675.00	F	I	1.90
PG015	CS031383	9	384	665.00	M	I	0.60
PG015	CS031384	6	408	830.00	M	I	0.30
PG015	CS031385	6	345	440.00	F	I	0.80
PG015	CS031386	9	400	635.00	F	I	2.30
PG015	CS031387		440	960.00	F	I	2.50
PG015	CS031390	5	348	550.00	F	I	1.90

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
PG015	CS031391	7	390	640.00	F	I	2.40
PG015	CS031393	7	430	860.00	M	I	0.30
PG015	CS031394	10	417	905.00	F	I	3.00
PG015	CS031395	8	442	1035.00	F	I	2.20
PG015	CS031396	6	397	740.00	M	I	0.20
PG015	CS031397	7	401	805.00	F	I	2.20
PG015	CS031398	8	370	605.00	F	I	2.60
PG015	CS031399	4	294	260.00	F	I	0.60
PG015	CS031401	8	429	1015.00	F	I	5.50
PG015	CS031402	5	425	990.00	F	I	4.60
PG015	CS031800	6	186	70.57	F	I	0.10
PG015	CS031801	3	241	187.85	F	I	0.14
PG015	CS031802	5	263	193.80	F	I	0.16
PG015	CS031803	4	207	99.92	F	I	0.15
PG015	CS031804	4	201	83.18	F	I	0.08
PG015	CS031805	5	206	89.27	M	I	0.00
PG015	CS04452	3	166	41.50	F	I	0.03
PG015	CS04454	6	243	137.00	M	I	0.10
PG015	CS04455	4	202	87.00	M	I	0.06
PG015	CS04460	4	129	18.50	M	I	0.01
PG015	CS04461	4	178	53.00	M	I	0.04
PG015	CS04462	3	169	48.50	F	I	0.05
PG015	CS04466	6	189	65.50	M	I	0.02
PG015	CS04467	4	175	53.50	M	I	0.02
PG015	CS04468	2	190	61.50	M	I	0.02
PG015	CS04470	3	179	56.00	M	I	0.01
PG015	CS04471	4	187	65.00	M	I	0.01
PG015	CS04472	3	135	23.00	M	I	0.01
PG015	CS04473	3	124	17.50	M	I	0.01
PG015	CS04474	4	139	21.00	M	I	0.01
PG015	CS04475	4	125	19.00	M	I	0.01
PG015	CS04476	4	119	18.00	M	I	0.01
PG015	CS04477	4	119	15.00	M	I	0.01
PG015	CS04478	4	102	10.00	M	I	0.01
PG015	CS04483	4	215	103.50	M	I	0.04
PG015	CS04485	6	215	95.50	F	I	0.20
PG015	CS04486	5	224	108.00	M	I	0.01
PG015	CS04487	2	184	58.00	F	I	0.05
PG015	CS04488	4	185	56.50	M	I	0.01
PG015	CS04489	3	205	88.00	M	I	0.04

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
PG015	CS04490	5	175	53.00	M	I	0.01
PG015	CS04491	4	185	57.50	F	I	0.06
PG015	CS04492	5	175	54.50	F	I	0.10
PG015	CS04494	3	196	71.00	M	I	0.01
PG015	CS04495	4	196	70.50	M	I	0.01
PG015	CS04496	2	99	10.00	M	I	0.01
PG015	CS04497	5	193	78.50	F	I	0.04
PG015	CS04498	4	150	34.00	F	I	0.07
PG015	CS04499	3	184	66.50	F	I	0.06
PG015	CS04524	3	109	9.00	M	I	0.01
PG015	CS04526	4	221	110.00	M	I	0.01
PG015	CS04533	4	168	51.00	M	I	0.01
PG015	CS04534	4	180	58.50	F	I	0.08
PG015	CS04535	5	115	14.00	M	I	0.01
PG015	CS04536	4	107	13.00	M	I	0.01
PG015	CS04537	3	135	26.50	M	I	0.01
PG015	CS04538	6	140	24.00	M	I	0.01
PG015	CS04539	4	178	51.50	M	I	0.01
PG015	CS04556	6	409	737.00	M	I	0.50
PG015	CS031201	10	563	2090.00	M	M	85.10
PG015	CS031202	9	561	2150.00	M	M	73.90
PG015	CS031203	12	649	3960.00	M	M	97.70
PG015	CS031204	10	560	2400.00	F	M	283.30
PG015	CS031205	10	548	2130.00	F	M	272.30
PG015	CS031206	12	574	2260.00	F	M	228.40
PG015	CS031208	9	534	1955.00	F	M	247.00
PG015	CS031209	14	652	3260.00	M	M	105.40
PG015	CS031211	12	555	2070.00	F	M	176.70
PG015	CS031213	16	679	4345.00	M	M	155.60
PG015	CS031214	10	520	1700.00	M	M	54.00
PG015	CS031215	10	603	3025.00	M	M	107.20
PG015	CS031216	14	644	3670.00	M	M	120.40
PG015	CS031217	13	641	3450.00	M	M	128.20
PG015	CS031219	12	567	2295.00	F	M	302.20
PG015	CS031220	12	665	3755.00	M	M	153.90
PG015	CS031221	10	645	3440.00	M	M	42.90
PG015	CS031222	11	669	3755.00	M	M	125.70
PG015	CS031223	11	550	2150.00	F	M	231.40
PG015	CS031224	10	625	3135.00	M	M	94.20
PG015	CS031225	12	575	2340.00	F	M	367.50

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
PG015	CS031226	10	615	3015.00	M	M	79.10
PG015	CS031227	11	554	2495.00	F	M	374.60
PG015	CS031231	8	525	1905.00	F	M	196.50
PG015	CS031233	9	513	1880.00	M	M	53.50
PG015	CS031234	15	574	2835.00	M	M	114.10
PG015	CS031235	12	571	2575.00	M	M	101.70
PG015	CS031236	12	660	3685.00	M	M	150.00
PG015	CS031238	10	524	1910.00	F	M	289.10
PG015	CS031239	12	579	2720.00	M	M	91.50
PG015	CS031240	12	604	2830.00	F	M	421.60
PG015	CS031241	12	549	2095.00	F	M	255.00
PG015	CS031242	10	595	2775.00	M	M	130.00
PG015	CS031243	10	645	3665.00	M	M	94.20
PG015	CS031244	15	521	3110.00	M	M	142.40
PG015	CS031245	15	637	3475.00	M	M	113.00
PG015	CS031246	12	608	3050.00	F	M	352.40
PG015	CS031247	12	585	2705.00	F	M	435.00
PG015	CS031248	11	579	2380.00	F	M	315.30
PG015	CS031249	9	620	3275.00	M	M	85.80
PG015	CS031250	9	525	1985.00	F	M	249.70
PG015	CS031251	11	555	2160.00	F	M	310.10
PG015	CS031252	9	476	1425.00	F	M	208.50
PG015	CS031253	8	477	1835.00	F	M	206.30
PG015	CS031254	17	645	3815.00	M	M	133.30
PG015	CS031255	12	544	2170.00	F	M	205.70
PG015	CS031256	11	505	1575.00	F	M	146.10
PG015	CS031258	8	494	1590.00	F	M	108.90
PG015	CS031264	10	634	3095.00	M	M	92.60
PG015	CS031265	10	482	1425.00	M	M	49.10
PG015	CS031267	10	592	2665.00	F	M	340.00
PG015	CS031272	11	554	2175.00	F	M	245.00
PG015	CS031274		504	1895.00	F	M	175.00
PG015	CS031280	7	248	156.50	M	M	7.05
PG015	CS031281	12	209	87.90	M	M	4.41
PG015	CS031284	8	156	40.10	M	M	2.43
PG015	CS031287		175	61.00	M	M	3.74
PG015	CS031290	12	206	75.50	M	M	3.75
PG015	CS031291	13	187	56.60	M	M	3.48
PG015	CS031292	8	162	45.30	M	M	2.32
PG015	CS031294	16	629	2950.00	F	M	375.00

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
PG015	CS031295	9	521	1814.00	F	M	240.00
PG015	CS031296	11	679	3700.00	M	M	131.60
PG015	CS031297	13	614	2880.00	M	M	91.60
PG015	CS031300	8	431	985.00	F	M	109.20
PG015	CS031302	10	189	52.90	M	M	3.05
PG015	CS031303	7	137	25.70	M	M	1.84
PG015	CS031305	10	165	42.20	M	M	2.63
PG015	CS031309		345	395.00	F	M	2.00
PG015	CS031312	10	639	3410.00	M	M	109.20
PG015	CS031313	4	296	295.00	M	M	<0.1
PG015	CS031316	7	471	1245.00	F	M	144.90
PG015	CS031322	7	445	1125.00	F	M	148.80
PG015	CS031323	13	646	2995.00	F	M	305.00
PG015	CS031324	10	490	1470.00	F	M	197.70
PG015	CS031328		626	2695.00	F	M	470.00
PG015	CS031329	8	169	45.80	M	M	2.73
PG015	CS031330	12	568	2465.00	F	M	328.00
PG015	CS031372	5	334	490.00	F	M	1.00
PG015	CS031375	9	525	1915.00	F	M	231.70
PG015	CS04450	6	173	56.00	M	M	3.02
PG015	CS04457	9	176	57.50	M	M	4.19
PG015	CS04458	8	138	25.00	M	M	2.04
PG015	CS04463	8	173	48.50	M	M	2.50
PG015	CS04464	6	140	28.50	M	M	1.55
PG015	CS04465	9	180	51.00	M	M	2.60
PG015	CS04479	9	594	2562.00	M	M	59.35
PG015	CS04480	10	472	1286.00	F	M	157.86
PG015	CS04481	10	480	1275.00	F	M	201.03
PG015	CS04484	9	189	63.50	M	M	3.41
PG015	CS04500	10	515	1447.00	F	M	170.72
PG015	CS04503	10	500	1516.00	M	M	38.99
PG015	CS04504	13	745	4925.00	M	M	166.50
PG015	CS04506	10	590	2522.00	F	M	297.00
PG015	CS04510	11	613	3305.00	M	M	80.00
PG015	CS04512	16	583	2122.00	F	M	236.00
PG015	CS04513	11	616	3397.00	M	M	80.50
PG015	CS04516	14	582	2432.00	F	M	308.50
PG015	CS04517	9	567	2189.00	M	M	77.00
PG015	CS04518	10	478	1290.00	F	M	158.00
PG015	CS04520	11	665	4110.00	M	M	112.00

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
PG015	CS04521	12	550	2215.00	F	M	382.00
PG015	CS04522	8	467	1319.00	F	M	165.79
PG015	CS04523	10	537	2077.00	F	M	314.05
PG015	CS04525	10	202	79.50	M	M	4.14
PG015	CS04527	10	205	78.50	F	M	6.35
PG015	CS04532	5	134	24.00	M	M	1.20
PG015	CS04540	13	566	2416.00	F	M	296.89
PG015	CS04541	14	590	2672.00	F	M	542.79
PG015	CS04543	12	630	3529.00	M	M	72.60
PG015	CS04545	12	631	3534.00	M	M	100.58
PG015	CS04546	10	608	2648.00	M	M	60.12
PG015	CS04548	15	702	4206.00	M	M	124.27
PG015	CS04555	11	648	3369.00	F	M	535.50
PG015	CS04557	12	611	2827.00	M	M	86.00
PG015	CS04560	13	621	3130.00	M	M	103.00
PG015	CS04561	12	645	3389.00	M	M	85.50
PG015	CS04562	11	579	2465.00	M	M	321.50
PG015	CS04563		649	3528.00	M	M	84.50
PG015	CS04564	10	530	1883.00	F	M	261.50
PG015	CS04565	7	425	958.00	F	M	103.50
PG015	CS04566	12	638	3308.00	M	M	108.50
PG015	CS04567	13	635	3273.00	M	M	81.00
PG015	CS04568	11	579	2600.00	F	M	374.00
PG015	CS04571	10	610	2852.00	M	M	61.00
PG015	CS04572	12	640	3782.00	M	M	121.50
PG015	CS04573	12	611	2999.00	M	M	86.00
PG015	CS04574	10	554	2134.00	F	M	325.50
PG015	CS04577	12	579	2708.00	M	M	103.50
PG015	CS04578	9	507	1602.00	M	M	50.50
PG015	CS031200	9	566	2150.00	M	R	1.30
PG015	CS031207	11	623	3320.00	M	R	2.90
PG015	CS031210	11	560	2215.00	M	R	2.00
PG015	CS031212	11	571	2300.00	M	R	0.80
PG015	CS031218	9	633	3365.00	M	R	2.40
PG015	CS031228	10	512	1785.00	F	R	13.20
PG015	CS031229	9	605	2925.00	M	R	3.70
PG015	CS031232	9	559	2065.00	M	R	1.60
PG015	CS031237	9	571	2320.00	M	R	2.20
PG015	CS031257	8	527	2030.00	F	R	14.00
PG015	CS031259	8	455	1235.00	M	R	0.70

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
PG015	CS031260	8	494	1705.00	M	R	2.50
PG015	CS031261	7	435	1080.00	F	R	5.70
PG015	CS031262	11	596	2830.00	M	R	3.20
PG015	CS031263	11	528	2140.00	F	R	11.40
PG015	CS031266	6	435	970.00	F	R	2.10
PG015	CS031268	5	451	1165.00	F	R	3.60
PG015	CS031269	10	460	1215.00	F	R	4.60
PG015	CS031270	8	469	1155.00	M	R	0.80
PG015	CS031271	7	465	1125.00	M	R	2.10
PG015	CS031273	7	431	1000.00	F	R	3.30
PG015	CS031289	8	190	62.20	M	R	0.01
PG015	CS031293	8	489	1455.00	F	R	6.00
PG015	CS031298	9	519	1865.00	F	R	10.50
PG015	CS031306	8	494	1580.00	F	R	4.10
PG015	CS031307	7	434	965.00	M	R	2.20
PG015	CS031308	7	383	615.00	F	R	2.00
PG015	CS031325	13	458	1075.00	M	R	0.60
PG015	CS031326	10	497	1605.00	F	R	8.50
PG015	CS031327	8	486	1360.00	M	R	0.80
PG015	CS031331	8	510	1630.00	M	R	0.90
PG015	CS031332	7	461	1200.00	M	R	0.70
PG015	CS031333	8	428	935.00	M	R	0.50
PG015	CS031344	7	239	130.00	F	R	0.29
PG015	CS031345	6	250	151.10	F	R	0.19
PG015	CS031348	6	244	129.10	F	R	0.21
PG015	CS031352	6	290	220.00	F	R	0.37
PG015	CS031358	6	487	1470.00	F	R	5.90
PG015	CS031360	5	395	670.00	M	R	0.20
PG015	CS031377	7	479	1285.00	F	R	6.10
PG015	CS031388	9	586	2250.00	M	R	1.80
PG015	CS031389	9	439	1025.00	M	R	0.90
PG015	CS031392	8	433	1035.00	M	R	0.60
PG015	CS031400	13	585	2645.00	M	R	2.40
PG015	CS031403	6	404	815.00	M	R	1.20
PG015	CS04451	9	159	42.50	M	R	0.16
PG015	CS04453	5	188	62.50	M	R	0.01
PG015	CS04456	3	189	54.00	M	R	0.01
PG015	CS04469	8	194	59.50	F	R	0.59
PG015	CS04493	6	185	40.00	M	R	0.09
PG015	CS04501	6	441	1012.00	F	R	5.27

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
PG015	CS04502	8	443	1093.00	F	R	5.11
PG015	CS04505	10	565	2155.00	M	R	2.50
PG015	CS04507	8	471	1262.00	M	R	1.50
PG015	CS04508	7	422	897.00	F	R	4.50
PG015	CS04509	7	411	739.00	M	R	0.50
PG015	CS04511	7	548	2098.00	M	R	2.00
PG015	CS04514	12	671	3661.00	M	R	4.00
PG015	CS04515	10	558	2114.00	M	R	4.00
PG015	CS04519	9	575	2262.00	M	R	2.00
PG015	CS04528	9	225	95.50	M	R	0.08
PG015	CS04529	9	164	42.00	M	R	0.01
PG015	CS04530	5	176	49.50	M	R	0.01
PG015	CS04531	4	185	61.50	M	R	0.01
PG015	CS04547	5	418	841.00	F	R	2.17
PG015	CS04549	7	435	964.00	M	R	0.74
PG015	CS04550	9	596	2506.00	M	R	3.50
PG015	CS04551	11	605	2654.00	M	R	3.50
PG015	CS04552	10	586	2539.00	F	R	22.50
PG015	CS04553	10	585	2461.00	M	R	3.50
PG015	CS04554	13	580	3099.00	F	R	20.50
PG015	CS04558	9	456	1140.00	M	R	1.00
PG015	CS04559	11	605	2466.00	F	R	17.00
PG015	CS04569	11	600	2480.00	M	R	2.50
PG015	CS04570	9	630	3182.00	M	R	4.00
PG015	CS04575	16	595	2242.00	F	R	26.00
PG015	CS04576	9	625	2961.00	M	R	2.00
PG015	CS04459	9	179	60.00	M	RR	3.35
PG015	CS04482	11	521	1741.00	F	RR	186.81
PG015	CS04542	11	605	3134.00	F	RR	408.08
PG015	CS04544	11	655	3662.00	M	RR	104.16
PG015	CS031285	7	159	41.50	M	S	0.01
PG082	CS01207	3	197	64.00	U	0	
PG082	CS01302	4	178	62.18	U	0	0.02
PG082	CS02448	4	196	85.00	U	0	
PG082	CS01183	9	370	585.00	F	I	<2
PG082	CS01184	6	364	555.00	F	I	<2
PG082	CS01186	6	398	940.00	F	I	<2
PG082	CS01192	7	395	905.00	M	I	<2
PG082	CS01193	5	223	140.00	M	I	<2
PG082	CS01194	3	180	76.00	F	I	0.06

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
PG082	CS01197	7	217	92.00	M	I	<2
PG082	CS01198	10	223	128.00	M	I	0.02
PG082	CS01200	4	205	86.00	F	I	0.07
PG082	CS01201	5	229	108.00	M	I	0.03
PG082	CS01202	5	258	190.00	F	I	0.1
PG082	CS01203	5	189	58.00	F	I	0.08
PG082	CS01204	6	186	64.00	F	I	0.05
PG082	CS01205	7	205	82.00	F	I	0.12
PG082	CS01206	9	200	72.00	F	I	0.23
PG082	CS01209	10	521	1965.00	M	I	<2
PG082	CS01213	7	396	830.00	M	I	<2
PG082	CS01217	5	265	180.00	F	I	<2
PG082	CS01223	4	220	135.00	F	I	<2
PG082	CS01224	8	378	525.00	F	I	<2
PG082	CS01231	5	320	460.00	F	I	<2
PG082	CS01237	9	285	270.00	F	I	<2
PG082	CS01238	7	356	435.00	M	I	<2
PG082	CS01239	5	285	280.00	F	I	<2
PG082	CS01240	6	254	180.00	M	I	<2
PG082	CS01241	6	240	160.00	M	I	0.05
PG082	CS01242	5	175	60.00	F	I	0.12
PG082	CS01243	4	171	55.00	F	I	0.07
PG082	CS01244	4	171	60.00	M	I	0.02
PG082	CS01245	3	174	60.00	F	I	0.1
PG082	CS01271	11	365	562.07	F	I	1.15
PG082	CS01273	7	264	244.00	F	I	0.2
PG082	CS01274	6	280	266.83	F	I	0.3
PG082	CS01275	6	292	353.46	F	I	0.55
PG082	CS01277	4	299	299.95	F	I	0.22
PG082	CS01278	8	266	158.87	F	I	0.37
PG082	CS01285	6	354	527.43	M	I	0.23
PG082	CS01289	6	270	239.84	F	I	0.23
PG082	CS01290	6	321	463.36	F	I	0.72
PG082	CS01297	3	202	82.62	M	I	0.05
PG082	CS01298	4	198	97.80	F	I	0.12
PG082	CS01300	7	246	172.03	M	I	0.07
PG082	CS01301	5	183	61.18	F	I	0.07
PG082	CS01303	4	193	88.82	F	I	0.05
PG082	CS01304	5	181	68.31	F	I	0.05
PG082	CS02402	6	265	180.00	F	I	0.13

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
PG082	CS02404	4	228	120.00	M	I	0.05
PG082	CS02405	4	182	55.00	M	I	0.01
PG082	CS02406	5	218	110.00	F	I	0.06
PG082	CS02407	8	277	280.00	F	I	0.36
PG082	CS02408	4	225	115.00	F	I	0.06
PG082	CS02410	5	330	430.00	M	I	0.12
PG082	CS02411	5	312	400.00	F	I	0.37
PG082	CS02412	6	335	455.00	F	I	0.53
PG082	CS02413	6	366	610.00	M	I	0.33
PG082	CS02419	12	543	1465.00	M	I	
PG082	CS02429	8	340	335.00	M	I	0.05
PG082	CS02440	8	468	850.00	M	I	
PG082	CS02441	5	215	105.00	M	I	0.03
PG082	CS02442	5	240	140.00	F	I	0.18
PG082	CS02447	6	287	270.00	M	I	0.07
PG082	CS02449	5	210	90.00	M	I	
PG082	CS02450	6	290	105.00	F	I	0.19
PG082	CS02451	5	214	95.00	M	I	0.02
PG082	CS02452		184	60.00	M	I	0.50
PG082	CS02453	6	200	75.00	M	I	0.01
PG082	CS02454	4	180	50.00	M	I	0.01
PG082	CS02457	6	220	100.00	F	I	0.16
PG082	CS02458	8	185	55.00	F	I	0.11
PG082	CS02459	3	193	85.00	M	I	0.02
PG082	CS02460	6	198	75.00	M	I	0.01
PG082	CS02461	4	191	75.00	F	I	0.11
PG082	CS02462	4	176	65.00	M	I	0.01
PG082	CS02463	6	203	90.00	M	I	0.02
PG082	CS02464	4	200	80.00	M	I	0.02
PG082	CS02465	3	198	75.00	F	I	0.10
PG082	CS02466	5	199	80.00	M	I	0.01
PG082	CS02467	5	181	55.00	F	I	0.05
PG082	CS02468	5	195	70.00	M	I	0.01
PG082	CS02470	5	227	120.00	F	I	0.23
PG082	CS02471	5	224	130.00	M	I	0.01
PG082	CS02472	6	233	135.00	F	I	0.12
PG082	CS02473	5	241	155.00	F	I	0.23
PG082	CS02474	5	230	145.00	F	I	0.31
PG082	CS02475	5	240	160.00	F	I	0.25
PG082	CS02476	5	266	240.00	M	I	0.09

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
PG082	CS02477	8	354	380.00	M	I	0.21
PG082	CS02478		345	480.00	F	I	0.23
PG082	CS02489		440	740.00	M	I	
PG082	CS04580	5	234	124.84	M	I	0.04
PG082	CS04581	5	195	80.36	F	I	0.07
PG082	CS04582	7	247	180.69	M	I	0.05
PG082	CS04583	5	142	29.18	M	I	0.03
PG082	CS04585	5	209	83.99	M	I	0.01
PG082	CS04586	5	204	95.99	M	I	0.10
PG082	CS04590	5	194	67.01	F	I	0.13
PG082	CS04591	2	129	24.23	M	I	0.01
PG082	CS04592	7	192	62.50	F	I	0.13
PG082	CS04593	5	162	42.80	M	I	0.07
PG082	CS04594	4	206	82.56	M	I	0.01
PG082	CS04598	5	215	98.17	M	I	0.07
PG082	CS04599	4	183	69.05	M	I	0.02
PG082	CS04600	3	140	36.68	F	I	0.04
PG082	CS04601	4	169	52.98	M	I	0.01
PG082	CS04603	5	184	62.40	M	I	0.16
PG082	CS04604	5	156	35.92	M	I	0.13
PG082	CS04607	5	208	75.91	F	I	0.22
PG082	CS04608	6	199	67.22	F	I	0.15
PG082	CS04609	3	197	89.31	F	I	0.07
PG082	CS04611	5	223	104.87	M	I	0.03
PG082	CS04614	5	191	66.20	M	I	0.01
PG082	CS04615	3	148	32.75	F	I	0.06
PG082	CS04616	5	201	76.17	M	I	0.16
PG082	CS04617	5	208	101.03	F	I	0.06
PG082	CS04618	6	216	80.15	F	I	0.26
PG082	CS04619	6	179	60.72	M	I	0.01
PG082	CS04620	3	138	29.94	F	I	0.04
PG082	CS04621	4	181	59.17	M	I	0.01
PG082	CS04622	7	208	90.34	M	I	0.03
PG082	CS04623	4	184	58.27	M	I	0.01
PG082	CS04624	5	194	71.44	M	I	0.01
PG082	CS04633	5	203	83.02	M	I	0.01
PG082	CS04634	9	189	60.62	M	I	0.01
PG082	CS04635	7	185	59.92	F	I	0.18
PG082	CS04637	4	187	59.75	M	I	0.01
PG082	CS01161	10	560	2525.00	F	M	312

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
PG082	CS01162	10	540	2430.00	F	M	246
PG082	CS01164	7	520	1695.00	F	M	136
PG082	CS01168	10	460	1260.00	F	M	100
PG082	CS01170	8	458	1310.00	F	M	108
PG082	CS01171	11	423	1160.00	F	M	116
PG082	CS01174	8	470	1360.00	F	M	74
PG082	CS01175	11	500	1875.00	F	M	282
PG082	CS01176	12	554	2205.00	F	M	286
PG082	CS01179	10	480	1485.00	F	M	130
PG082	CS01180	10	520	2075.00	F	M	270
PG082	CS01181	11	516	1705.00	F	M	160
PG082	CS01182	10	490	1670.00	F	M	224
PG082	CS01188	8	525	2020.00	F	M	166
PG082	CS01189	8	525	1980.00	F	M	244
PG082	CS01190	9	530	1695.00	F	M	232
PG082	CS01191	10	520	1605.00	F	M	164
PG082	CS01208	11	490	1630.00	F	M	220
PG082	CS01210	10	520	1905.00	F	M	216
PG082	CS01211	9	480	1665.00	F	M	174
PG082	CS01215	14	600	2885.00	F	M	312
PG082	CS01216	9	468	1280.00	F	M	138
PG082	CS01219	10	460	1480.00	F	M	132
PG082	CS01220	9	540	1940.00	F	M	272
PG082	CS01221	7	494	1585.00	F	M	170
PG082	CS01222	9	500	1600.00	F	M	125
PG082	CS01225	9	525	1690.00	F	M	210
PG082	CS01226	12	570	2100.00	F	M	275
PG082	CS01227	8	430	1095.00	F	M	110
PG082	CS01229	9	450	1215.00	F	M	160
PG082	CS01230	11	540	1810.00	F	M	260
PG082	CS01233	9	499	1710.00	F	M	244
PG082	CS01235	15	565	2200.00	F	M	170
PG082	CS01253	11	512	169.83	F	M	216.2
PG082	CS01254	9	514	1678.45	F	M	202.26
PG082	CS01255	11	545	2128.31	F	M	278.38
PG082	CS01256	10	506	1970.77	F	M	228.93
PG082	CS01257	16	516	1903.58	F	M	275.25
PG082	CS01258	10	540	1966.66	F	M	255.5
PG082	CS01259	9	533	1831.18	F	M	231.32
PG082	CS01260	9	529	1764.29	F	M	220.96

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
PG082	CS01261	8	555	2192.69	F	M	236.64
PG082	CS01262	11	518	1964.95	F	M	223.25
PG082	CS01265	13	576	2642.14	F	M	296.81
PG082	CS01267	7	553	2419.72	F	M	237.65
PG082	CS01270	10	523	1735.21	F	M	201.92
PG082	CS01272	9	505	1632.72	F	M	242.78
PG082	CS01281	11	516	1759.18	F	M	204.9
PG082	CS01283	9	523	1885.13	F	M	231.71
PG082	CS01284	12	557	1872.79	F	M	328.43
PG082	CS01287	9	512	1912.81	F	M	201.93
PG082	CS01288	10	551	2018.40	F	M	311.54
PG082	CS01292	7	495	1450.01	F	M	134.36
PG082	CS01293	10	489	1604.24	F	M	192.5
PG082	CS01294	10	522	1734.71	F	M	232.32
PG082	CS01305	10	548	1895.16	F	M	209.64
PG082	CS01306	9	505	1685.47	F	M	170.9
PG082	CS01307	10	553	2312.12	F	M	295.93
PG082	CS02403	9	195	85.00	M	M	3.29
PG082	CS02409	10	550	1630.00	F	M	275
PG082	CS02414		436	1105.00	F	M	95
PG082	CS02415	9	475	1440.00	F	M	130
PG082	CS02418	11	522	1780.00	F	M	270
PG082	CS02420	11	528	1695.00	F	M	290
PG082	CS02421	13	590	2910.00	F	M	490
PG082	CS02422	11	490	1415.00	F	M	248
PG082	CS02423	11	530	1685.00	F	M	256
PG082	CS02424		515	1840.00	F	M	310
PG082	CS02425	13	515	1660.00	F	M	304
PG082	CS02431	10	529	1675.00	F	M	294
PG082	CS02433	13	525	1940.00	F	M	332
PG082	CS02434	10	560	2290.00	F	M	470
PG082	CS02436	9	530	1450.00	F	M	170
PG082	CS02445		540	1765.00	F	M	310
PG082	CS02446	8	484	1430.00	F	M	320
PG082	CS02455	6	171	45.00	M	M	2.00
PG082	CS02456	5	166	40.00	M	M	1.76
PG082	CS02469	8	182	45.00	M	M	1.50
PG082	CS02479	10	512	1430.00	F	M	216
PG082	CS02481	12	555	1855.00	F	M	310
PG082	CS02484	11	500	1385.00	F	M	122

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
PG082	CS02487	9	500	1375.00	F	M	216
PG082	CS02488	7	519	1550.00	F	M	186
PG082	CS02492	10	570	1980.00	F	M	320
PG082	CS02495	12	543	2010.00	F	M	348
PG082	CS02496	12	540	1745.00	F	M	320
PG082	CS02497		490	1335.00	F	M	238
PG082	CS02498	13	510	1785.00	F	M	376
PG082	CS02500	8	536	2150.00	F	M	438
PG082	CS02506	11	617	2990.00	F	M	636
PG082	CS02507	12	619	2260.00	F	M	414
PG082	CS02509	14	560	2590.00	F	M	434
PG082	CS02510	8	500	1285.00	F	M	218
PG082	CS02511	10	560	2300.00	F	M	294
PG082	CS02512	11	500	1545.00	F	M	296
PG082	CS04584	8	203	80.50	M	M	2.25
PG082	CS04587	9	202	80.99	M	M	2.14
PG082	CS04588	7	198	75.01	M	M	2.76
PG082	CS04589	9	197	72.97	M	M	1.65
PG082	CS04595	8	210	103.43	M	M	5.52
PG082	CS04602	8	161	46.29	M	M	1.90
PG082	CS04605	12	254	178.20	M	M	4.60
PG082	CS04606	7	189	67.99	M	M	2.43
PG082	CS04610	5	170	53.89	M	M	1.85
PG082	CS04612	5	196	72.87	M	M	2.21
PG082	CS04625	8	202	76.78	M	M	2.85
PG082	CS04626	9	214	76.00	M	M	2.40
PG082	CS04627	6	162	47.93	M	M	1.32
PG082	CS04630	8	197	22.30	M	M	2.66
PG082	CS04638	6	220	91.12	M	M	2.68
PG082	CS04641	11	472	1355.23	F	M	139.85
PG082	CS04643	13	481	1367.98	F	M	165.81
PG082	CS04644	11	589	2574.59	F	M	337.68
PG082	CS04645	12	600	2880.10	F	M	400.57
PG082	CS04646	10	495	1460.49	F	M	161.99
PG082	CS04647	12	628	2537.75	M	M	68.33
PG082	CS04648	10	550	2000.41	F	M	361.42
PG082	CS04649	10	505	1797.77	F	M	225.66
PG082	CS04650	9	511	1571.12	F	M	175.89
PG082	CS04651		541	1776.26	F	M	327.96
PG082	CS04652	14	538	2314.19	F	M	391.74

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
PG082	CS04654	12	549	1764.81	M	M	50.47
PG082	CS04655	10	593	2529.58	F	M	356.27
PG082	CS04656	11	637	3345.34	M	M	83.59
PG082	CS04657	9	583	2482.78	M	M	62.50
PG082	CS04658	13	666	3005.77	M	M	77.88
PG082	CS04659		590	2863.57	F	M	372.34
PG082	CS04660	9	591	3009.36	M	M	132.81
PG082	CS04661	9	547	2074.20	F	M	320.30
PG082	CS04662		595	2424.72	M	M	79.92
PG082	CS04663	8	508	1547.92	F	M	172.70
PG082	CS04664	11	550	2163.63	F	M	337.29
PG082	CS04665	9	566	2269.68	F	M	370.11
PG082	CS04666	11	529	1983.78	F	M	181.02
PG082	CS04667	13	635	2712.81	F	M	614.60
PG082	CS04668	11	566	2019.73	M	M	58.95
PG082	CS04669	10	618	2919.24	M	M	78.87
PG082	CS01163		550	2490.00	M	R	<2
PG082	CS01165	7	460	1455.00	M	R	<2
PG082	CS01166	8	426	985.00	F	R	<2
PG082	CS01169	9	415	1075.00	F	R	<2
PG082	CS01172	8	450	1160.00	F	R	4
PG082	CS01173	8	455	1170.00	M	R	<2
PG082	CS01177	8	450	1370.00	F	R	6
PG082	CS01187	13	620	1475.00	F	R	8
PG082	CS01212	8	455	1350.00	M	R	<2
PG082	CS01214	7	460	1475.00	F	R	<2
PG082	CS01218	8	450	805.00	F	R	15
PG082	CS01228	7	440	1150.00	M	R	<2
PG082	CS01232	7	370	655.00	F	R	<2
PG082	CS01234	8	510	1730.00	F	R	6
PG082	CS01236	10	460	1395.00	M	R	<2
PG082	CS01251	10	194	56.00	M	R	0.2
PG082	CS01263	8	481	1524.32	M	R	0.92
PG082	CS01268	9	435	1097.63	F	R	4.12
PG082	CS01269	8	496	1628.11	M	R	1.26
PG082	CS01276	7	412	825.67	M	R	0.32
PG082	CS01279	7	419	780.44	M	R	0.38
PG082	CS01280	7	429	921.74	F	R	3.4
PG082	CS01291	8	485	1680.16	F	R	8.69
PG082	CS01295	9	435	943.50	M	R	0.27

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
PG082	CS01296	8	491	1475.08	M	R	1.07
PG082	CS01299	11	501	1657.29	M	R	1
PG082	CS01308	8	495	1523.72	F	R	7.27
PG082	CS02432	12	510	1200.00	M	R	
PG082	CS02435	10	496	1370.00	M	R	
PG082	CS02490	10	570	1540.00	F	R	18
PG082	CS02499	10	545	1580.00	F	R	32
PG082	CS04579	7	248	135.03	F	R	0.14
PG082	CS04628	9	180	60.39	M	R	0.01
PG082	CS04629	5	254	134.84	M	R	0.01
PG082	CS04631	5	198	70.07	M	R	0.06
PG082	CS04632	6	189	57.74	M	R	0.08
PG082	CS04636	6	242	124.28	F	R	0.36
PG082	CS04642	10	426	608.09	F	R	5.21
PG082	CS04653	10	564	2170.89	M	R	1.60
PG082	CS01167	9	435	1070.00	M	RR	34
PG082	CS01178	11	564	2223.00	M	RR	46
PG082	CS01185	12	620	3050.00	M	RR	82
PG082	CS01195	8	209	68.00	M	RR	8
PG082	CS01196	8	203	84.00	M	RR	10
PG082	CS01199	8	183	58.00	M	RR	6
PG082	CS01246	6	204	70.00	M	RR	1.17
PG082	CS01247	9	205	76.00	M	RR	2.5
PG082	CS01248	9	179	46.00	M	RR	1.55
PG082	CS01249		189	56.00	M	RR	1.68
PG082	CS01250	8	194	62.00	F	RR	6.26
PG082	CS01252	14	472	1095.00	M	RR	26.14
PG082	CS01264		545	1650.87	M	RR	39.7
PG082	CS01266	10	601	2491.32	M	RR	66.55
PG082	CS01282	11	629	2496.34	M	RR	68.08
PG082	CS01286	10	622	2280.73	M	RR	58.6
PG082	CS02416		619	2870.00	M	RR	50
PG082	CS02417	12	638	2520.00	M	RR	58
PG082	CS02426	13	635	2855.00	M	RR	86
PG082	CS02427	13	620	2810.00	M	RR	70
PG082	CS02428	10	580	2345.00	M	RR	40
PG082	CS02430	10	595	2340.00	M	RR	56
PG082	CS02437	12	595	2630.00	M	RR	74
PG082	CS02438	10	598	2270.00	M	RR	72
PG082	CS02439	12	520	1960.00	M	RR	42

Location	Sample #	Age (years)	Fork Length (mm)	Weight (g)	Sex	Maturity	Gonad Weight (g)
PG082	CS02443	10	640	2620.00	M	RR	50
PG082	CS02444		605	2650.00	M	RR	68
PG082	CS02480	10	591	2300.00	M	RR	50
PG082	CS02482	9	610	2715.00	M	RR	58
PG082	CS02483	9	650	3010.00	M	RR	84
PG082	CS02485	14	620	2740.00	M	RR	80
PG082	CS02486	12	500	1790.00	F	RR	234
PG082	CS02491	14	584	2050.00	M	RR	44
PG082	CS02493	14	600	2250.00	M	RR	56
PG082	CS02494	9	615	2650.00	M	RR	96
PG082	CS02501	10	520	1925.00	F	RR	256
PG082	CS02502	11	621	2750.00	M	RR	70
PG082	CS02503	11	630	2650.00	M	RR	66
PG082	CS02504	17	680	3620.00	M	RR	116
PG082	CS02505	10	668	3090.00	M	RR	76
PG082	CS02508	8	576	1935.00	M	RR	42
PG082	CS04596	11	236	120.84	M	RR	4.04
PG082	CS04597	8	209	80.73	M	RR	1.87
PG082	CS04613	12	241	132.32	M	RR	5.08
PG082	CS04639	10	198	80.06	M	RR	2.81
PG082	CS04640	10	246	127.94	M	RR	4.66

APPENDIX 2.2

Fecundity and egg diameter data used in **Chapter 3** analyses.

Location	Classification	Sample #	Fork Length (mm)	Egg Number	Egg Diameter (mm)
LH001	small-maturing	MIP04341	133	40	4.10
LH001	small-maturing	MIP05044	145	90	4.10
LH001	small-maturing	MIP04340	172	82	4.30
PG082	small-maturing	CS01250	194	165	3.48
PG015	small-maturing	CS04527	205	133	3.00
PG082	large-maturing	CS01171	423	1984	4.42
PG082	large-maturing	CS01227	430	1667	4.88
PG015	large-maturing	CS031300	431	1799	4.60
PG082	large-maturing	CS02414	436	1872	4.60
PG015	large-maturing	CS031322	445	1961	4.70
PG082	large-maturing	CS01229	450	2481	4.53
PG082	large-maturing	CS01170	458	2064	4.30
PG082	large-maturing	CS01168	460	2069	4.15
PG082	large-maturing	CS01219	460	2197	4.58
PG015	large-maturing	CS04522	467	2582	4.80
PG082	large-maturing	CS01216	468	2312	4.68
PG082	large-maturing	CS01174	470	2576	3.40
PG015	large-maturing	CS031316	471	2413	4.50
PG015	large-maturing	CS04480	472	2973	4.40
PG082	large-maturing	CS04641	472	3083	4.00
PG082	large-maturing	CS02415	475	2063	4.60
PG015	large-maturing	CS031252	476	3235	4.90
PG015	large-maturing	CS031253	477	4065	4.50
PG015	large-maturing	CS04481	480	2498	5.00
PG082	large-maturing	CS01179	480	2585	4.10
PG082	large-maturing	CS01211	480	3500	4.18
PG082	large-maturing	CS04643	481	3369	4.30
PG082	large-maturing	CS02446	484	2867	4.90
PG082	large-maturing	CS01293	489	2698	4.50
PG015	large-maturing	CS031324	490	2884	5.00
PG082	large-maturing	CS01182	490	3757	4.62
PG082	large-maturing	CS01208	490	2756	5.05
PG082	large-maturing	CS02422	490	2855	5.20
PG082	large-maturing	CS02497	490	2853	5.10
PG015	large-maturing	CS031258	494	3454	3.30
PG082	large-maturing	CS01221	494	2402	4.75
PG082	large-maturing	CS01292	495	2149	4.47

Location	Classification	Sample #	Fork Length (mm)	Egg Number	Egg Diameter (mm)
PG082	large-maturing	CS04646	495	2132	4.80
PG082	large-maturing	CS01233	499	3031	4.97
PG082	large-maturing	CS01175	500	3517	4.75
PG082	large-maturing	CS01222	500	2561	4.05
PG082	large-maturing	CS02484	500	2345	4.50
PG082	large-maturing	CS02486	500	2777	4.80
PG082	large-maturing	CS02487	500	2191	5.20
PG082	large-maturing	CS02510	500	2526	5.10
PG082	large-maturing	CS02512	500	3133	5.20
PG015	large-maturing	CS031274	504	2365	5.00
PG015	large-maturing	CS031256	505	3634	3.80
PG082	large-maturing	CS01272	505	3420	4.82
PG082	large-maturing	CS01306	505	2699	4.38
PG082	large-maturing	CS04649	505	3838	4.40
PG082	large-maturing	CS01256	506	3062	4.77
PG082	large-maturing	CS04663	508	2568	4.70
PG082	large-maturing	CS02498	510	3664	5.30
PG082	large-maturing	CS04650	511	2404	5.00
PG082	large-maturing	CS01253	512	4106	4.13
PG082	large-maturing	CS01287	512	3715	4.33
PG082	large-maturing	CS02479	512	2407	4.80
PG082	large-maturing	CS01254	514	3003	4.65
PG015	large-maturing	CS04500	515	2431	5.00
PG082	large-maturing	CS02424	515	3449	5.10
PG082	large-maturing	CS02425	515	3675	5.20
PG082	large-maturing	CS01181	516	3012	4.23
PG082	large-maturing	CS01257	516	3040	4.95
PG082	large-maturing	CS01281	516	3459	4.38
PG082	large-maturing	CS01262	518	4222	4.47
PG082	large-maturing	CS02488	519	2889	4.40
PG082	large-maturing	CS01164	520	3883	4.20
PG082	large-maturing	CS01180	520	3217	4.87
PG082	large-maturing	CS01191	520	1785	5.12
PG082	large-maturing	CS01210	520	3471	4.25
PG082	large-maturing	CS02501	520	2605	5.20
LH001	large-maturing	MIP031593	521	4389	3.30
PG015	large-maturing	CS031295	521	2811	5.10
PG015	large-maturing	CS04482	521	2923	4.10
PG082	large-maturing	CS01294	522	3192	4.73
PG082	large-maturing	CS02418	522	3616	5.10
PG082	large-maturing	CS01270	523	3165	4.52

Location	Classification	Sample #	Fork Length (mm)	Egg Number	Egg Diameter (mm)
PG082	large-maturing	CS01283	523	3706	4.45
PG015	large-maturing	CS031238	524	3815	5.10
PG015	large-maturing	CS031231	525	2824	5.30
PG015	large-maturing	CS031250	525	3382	4.90
PG015	large-maturing	CS031375	525	3100	4.70
PG082	large-maturing	CS01188	525	3345	4.20
PG082	large-maturing	CS01189	525	3478	4.68
PG082	large-maturing	CS01225	525	3629	4.37
PG082	large-maturing	CS02433	525	3786	5.10
PG082	large-maturing	CS02420	528	2586	5.60
PG082	large-maturing	CS01260	529	2764	4.80
PG082	large-maturing	CS02431	529	3798	5.00
PG082	large-maturing	CS04666	529	3944	4.10
PG082	large-maturing	CS01190	530	4450	4.17
PG082	large-maturing	CS02423	530	2643	4.80
PG082	large-maturing	CS02436	530	1790	4.70
PG082	large-maturing	CS01259	533	3468	4.67
PG015	large-maturing	CS031208	534	3529	5.20
PG082	large-maturing	CS02500	536	4686	5.10
PG082	large-maturing	CS04652	538	3908	5.20
PG082	large-maturing	CS04652	538	4403	5.10
PG082	large-maturing	CS01162	540	3447	4.55
PG082	large-maturing	CS01220	540	4464	4.52
PG082	large-maturing	CS01230	540	3976	4.48
PG082	large-maturing	CS01258	540	3478	4.97
PG082	large-maturing	CS02445	540	3744	4.70
PG082	large-maturing	CS02496	540	4036	5.00
PG082	large-maturing	CS04651	541	3870	4.90
PG082	large-maturing	CS02495	543	3071	5.50
LH001	large-maturing	MIP031657	544	4749	3.70
PG015	large-maturing	CS031255	544	4046	4.10
PG082	large-maturing	CS01255	545	4685	4.38
PG082	large-maturing	CS04661	547	3597	5.30
LH001	large-maturing	MIP031598	548	4615	2.60
PG015	large-maturing	CS031205	548	3172	5.10
PG082	large-maturing	CS01305	548	3397	4.33
PG015	large-maturing	CS031241	549	6237	4.10
PG015	large-maturing	CS031223	550	2741	5.30
PG015	large-maturing	CS04521	550	4590	5.20
PG082	large-maturing	CS02409	550	3019	5.20
PG082	large-maturing	CS04648	550	4077	5.00

Location	Classification	Sample #	Fork Length (mm)	Egg Number	Egg Diameter (mm)
PG082	large-maturing	CS04664	550	5399	4.50
PG082	large-maturing	CS01288	551	4010	4.83
PG082	large-maturing	CS01267	553	3455	4.60
PG082	large-maturing	CS01307	553	4331	4.67
PG015	large-maturing	CS031227	554	5308	4.90
PG015	large-maturing	CS031272	554	4361	4.50
PG082	large-maturing	CS01176	554	3931	4.98
PG015	large-maturing	CS031211	555	4924	3.50
PG015	large-maturing	CS031251	555	4060	5.30
PG082	large-maturing	CS01261	555	3059	4.80
PG082	large-maturing	CS02481	555	3597	5.20
PG082	large-maturing	CS01284	557	3781	5.05
LH001	large-maturing	MIP031650	558	4634	3.80
LH001	large-maturing	MIP05149	558	3854	4.80
PG015	large-maturing	CS031204	560	3347	4.90
PG082	large-maturing	CS01161	560	4565	4.52
PG082	large-maturing	CS02434	560	5470	4.90
PG082	large-maturing	CS02509	560	4634	5.10
PG082	large-maturing	CS02511	560	3874	4.70
PG082	large-maturing	CS01235	565	4866	3.78
PG015	large-maturing	CS04540	566	4446	4.60
PG082	large-maturing	CS04665	566	5443	4.60
LH001	large-maturing	MIP031633	567	4739	4.30
PG015	large-maturing	CS031219	567	4956	4.50
LH001	large-maturing	MIP05154	567	5712	5.10
PG015	large-maturing	CS031330	568	4810	4.60
PG082	large-maturing	CS01226	570	3423	4.93
PG082	large-maturing	CS02492	570	3689	5.10
PG015	large-maturing	CS031206	574	4214	4.80
PG015	large-maturing	CS031225	575	5593	4.80
PG082	large-maturing	CS01265	576	6067	4.18
PG015	large-maturing	CS031248	579	4885	4.90
LH001	large-maturing	MIP05152	579	3869	4.50
LH001	large-maturing	MIP031517	582	6353	3.60
LH001	large-maturing	MIP031628	582	4671	3.30
LH001	large-maturing	MIP031635	584	3977	4.90
PG015	large-maturing	CS031247	585	4853	5.10
LH001	large-maturing	MIP05018	587	4673	4.90
LH001	large-maturing	MIP031522	588	5200	4.30
PG082	large-maturing	CS04644	589	5989	4.20
LH001	large-maturing	MIP031507	590	6168	3.60

Location	Classification	Sample #	Fork Length (mm)	Egg Number	Egg Diameter (mm)
PG015	large-maturing	CS04541	590	6303	5.00
PG082	large-maturing	CS02421	590	4602	5.20
PG082	large-maturing	CS04659	590	5774	4.80
PG015	large-maturing	CS031267	592	3994	4.90
PG082	large-maturing	CS-04655	593	5149	4.90
LH001	large-maturing	MIP031645	595	5445	4.00
LH001	large-maturing	MIP031668	599	3582	4.20
PG082	large-maturing	CS01215	600	5155	4.45
LH001	large-maturing	MIP031636	602	5714	3.60
PG015	large-maturing	CS031240	604	4826	4.80
PG015	large-maturing	CS04542	605	4533	4.90
LH001	large-maturing	MIP04291	606	6689	2.00
PG015	large-maturing	CS031246	608	5155	4.90
LH001	large-maturing	MIP05089	610	4534	5.20
LH001	large-maturing	MIP05151	613	5781	5.30
PG082	large-maturing	CS02506	617	6639	5.10
LH001	large-maturing	MIP031545	618	5391	2.50
PG082	large-maturing	CS02507	619	4250	5.60
PG015	large-maturing	CS031328	626	5920	5.00
LH001	large-maturing	MIP031548	629	5305	4.30
PG015	large-maturing	CS031294	629	6301	4.50
LH001	large-maturing	MIP031556	634	6130	3.70
PG082	large-maturing	CS04667	635	7645	5.30
LH001	large-maturing	MIP05090	635	6972	4.90
PG015	large-maturing	CS031323	646	5588	4.20
LH001	large-maturing	MIP04254	652	7304	2.50
LH001	large-maturing	MIP031655	675	7773	3.50

APPENDIX 2.3

Back-calculated data used for growth model analysis in **Chapter 3** (mature fish only). Locations (LOC), classification (CL) are headings in the data table. Large-maturing (LM) and small-maturing (SM) are classification groups. Back-calculated fork length (mm) is listed for each annulus year (Yr 1, Yr 2 ....Yr 21).

LOC	Sample #	CL	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13	Yr 14	Yr 15	Yr 16	Yr 17	Yr 18	Yr 19	Yr 20	Yr 21
LH001	MIP-05-0151	LM	72	92	118	185	228	254	276	301	318	342	364	386	407	434							
LH001	MIP-03-1522	LM	77	146	179	237	288	356	409	453	493	521	546	572									
LH001	MIP-03-1522	LM	77	146	179	237	288	356	409	453	493	521	546	572									
LH001	MIP-05-0152	LM	82	117	153	204	233	291	327	369	402	433	455	488	520	543							
LH001	MIP-05-0149	LM	92	133	170	234	292	327	354	383	424	462	488	521									
LH001	MIP-05-0137	LM	101	151	190	257	292	354	411	449	500	535	562	599									
LH001	MIP-03-1635	LM	102	142	177	206	231	269	317	371	411	442	461	496	523	544	561						
LH001	MIP-03-1633	LM	102	135	190	237	299	332	372	406	441	482	512	539									
LH001	MIP-03-1633	LM	102	135	190	237	299	332	372	406	441	482	512	539									
LH001	MIP-05-0143	LM	103	177	252	365	451	515	565	614	640	671	698										
LH001	MIP-05-0095	LM	106	182	235	353	388	417	449	486	527	568	603	631									
LH001	MIP-03-1638	LM	109	155	185	216	245	279	318	369	413	445	479	522	564	607	641	668	685	705			
LH001	MIP-03-1638	LM	109	155	185	216	245	279	318	369	413	445	479	522	564	607	641	668	685	705			
LH001	MIP-03-1545	LM	117	150	182	223	253	316	359	403	438	479	504	531	566	602							
LH001	MIP-03-1545	LM	117	150	182	223	253	316	359	403	438	479	504	531	566	602							
LH001	MIP-05-0080	LM	121	164	214	325	371	419	460	503	553	601	634										
LH001	MIP-05-0090	LM	122	163	205	314	352	398	443	469	493	521	542	559	577	586	594	603	612	623			
LH001	MIP-03-1554	LM	124	162	196	225	240	258	285	351	400	454	492	530	566	596							
LH001	MIP-03-1554	LM	124	162	196	225	240	258	285	351	400	454	492	530	566	596							
LH001	MIP-03-1663	LM	126	160	208	249	293	324	365	385	412	436	460	494	528	569	603	627	658	682	706	719	733
LH001	MIP-03-1663	LM	126	160	208	249	293	324	365	385	412	436	460	494	528	569	603	627	658	682	706	719	733
LH001	MIP-03-1662	LM	129	200	245	281	362	416	467	515	556	589	619	658	676								
LH001	MIP-03-1662	LM	129	200	245	281	362	416	467	515	556	589	619	658	676								
LH001	MIP-03-1645	LM	129	154	190	224	264	304	371	405	443	479	511	540	561	580							
LH001	MIP-03-1645	LM	129	154	190	224	264	304	371	405	443	479	511	540	561	580							
LH001	MIP-05-0153	LM	129	182	232	332	385	440	486	535	582	620											
LH001	MIP-03-1628	LM	132	184	230	266	311	357	398	425	446	489	514	546	566								
LH001	MIP-03-1628	LM	132	184	230	266	311	357	398	425	446	489	514	546	566								
LH001	MIP-03-1552	LM	134	196	247	307	351	421	467	506	548	582	622	652	673								

LOC	Sample #	CL	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13	Yr 14	Yr 15	Yr 16	Yr 17	Yr 18	Yr 19	Yr 20	Yr 21
LH001	MIP-03-1552	LM	134	196	247	307	351	421	467	506	548	582	622	652	673								
LH001	MIP-03-1593	LM	135	179	218	235	254	280	344	376	421	451	472	500									
LH001	MIP-03-1593	LM	135	179	218	235	254	280	344	376	421	451	472	500									
LH001	MIP-03-1556	LM	135	188	232	267	321	377	451	481	512	540	568	593	611								
LH001	MIP-03-1556	LM	135	188	232	267	321	377	451	481	512	540	568	593	611								
LH001	MIP-03-1551	LM	143	191	234	280	348	402	454	499	537	574	602	625	656	685							
LH001	MIP-03-1551	LM	143	191	234	280	348	402	454	499	537	574	602	625	656	685							
LH001	MIP-03-1657	LM	143	180	232	286	329	387	424	455	484	510	530										
LH001	MIP-03-1657	LM	143	180	232	286	329	387	424	455	484	510	530										
LH001	MIP-03-1546	LM	144	168	196	229	269	296	370	415	470	525	562	599	632	663	687	700					
LH001	MIP-03-1546	LM	144	168	196	229	269	296	370	415	470	525	562	599	632	663	687	700					
LH001	MIP-05-0089	LM	144	187	251	369	401	436	471	499	529	551	569	585									
LH001	MIP-03-1548	LM	148	165	185	228	268	288	366	403	436	466	489	511	551	591							
LH001	MIP-03-1548	LM	148	165	185	228	268	288	366	403	436	466	489	511	551	591							
LH001	MIP-03-1637	LM	149	207	245	274	315	356	402	454	505	538	582	620	655	685	715	731					
LH001	MIP-03-1637	LM	149	207	245	274	315	356	402	454	505	538	582	620	655	685	715	731					
LH001	MIP-03-1655	LM	150	187	219	260	306	358	415	447	485	511	534	568	606	640	658						
LH001	MIP-03-1655	LM	150	187	219	260	306	358	415	447	485	511	534	568	606	640	658						
LH001	MIP-03-1646	LM	150	195	231	267	316	381	428	480	545	597	633	667									
LH001	MIP-03-1646	LM	150	195	231	267	316	381	428	480	545	597	633	667									
LH001	MIP-03-1650	LM	151	191	230	294	348	387	421	454	479	499	522	538									
LH001	MIP-03-1650	LM	151	191	230	294	348	387	421	454	479	499	522	538									
LH001	MIP-05-0086	LM	153	187	227	295	328	382	440	486	530	558	583	611	637	667	692						
LH001	MIP-03-1631	LM	153	203	244	271	326	381	449	480	534	570	606	625	638	666	685						
LH001	MIP-03-1631	LM	153	203	244	271	326	381	449	480	534	570	606	625	638	666	685						
LH001	MIP-05-0155	LM	155	215	257	380	440	487	528	576	615	644	671										
LH001	MIP-03-1632	LM	156	191	215	258	315	379	422	463	500	535	554	578	605	632	654	672	694	705	710	723	737
LH001	MIP-03-1632	LM	156	191	215	258	315	379	422	463	500	535	554	578	605	632	654	672	694	705	710	723	737
LH001	MIP-03-1598	LM	157	187	230	269	327	371	410	454	477	497	513	530									
LH001	MIP-03-1598	LM	157	187	230	269	327	371	410	454	477	497	513	530									
LH001	MIP-03-1544	LM	168	203	255	305	345	392	444	473	499	540	581	615	642	679	700						

LOC	Sample #	CL	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13	Yr 14	Yr 15	Yr 16	Yr 17	Yr 18	Yr 19	Yr 20	Yr 21
LH001	MIP-03-1544	LM	168	203	255	305	345	392	444	473	499	540	581	615	642	679	700						
LH001	MIP-03-1549	LM	172	225	254	284	341	415	446	479	525	551	582	615	646	666	682	702	712				
LH001	MIP-03-1549	LM	172	225	254	284	341	415	446	479	525	551	582	615	646	666	682	702	712				
LH001	MIP-05-0085	LM	176	236	299	419	450	490	530	572	608	634	654	674									
LH001	MIP-03-1547	LM	178	239	264	285	313	368	420	480	514	549	578	615	641	658	675	696	713				
LH001	MIP-03-1547	LM	178	239	264	285	313	368	420	480	514	549	578	615	641	658	675	696	713				
LH001	MIP-05-0142	LM	180	220	253	340	398	416	439	476	512	543	576	604	621	651	676						
LH001	MIP-03-1501	LM	183	244	288	366	424	468	509	549	597	627	655	678									
LH001	MIP-03-1501	LM	183	244	288	366	424	468	509	549	597	627	655	678									
LH001	MIP-03-1555	LM	190	214	250	304	374	410	452	506	536	569	600	639	678								
LH001	MIP-03-1555	LM	190	214	250	304	374	410	452	506	536	569	600	639	678								
LH001	MIP-05-0084	LM	199	239	275	334	392	429	463	502	529	559	586	605	626								
LH001	MIP-03-1553	LM	216	272	323	405	468	498	527	566	592	616	648	677	699								
LH001	MIP-03-1553	LM	216	272	323	405	468	498	527	566	592	616	648	677	699								
LH001	mip-04-0209	LM	113	165	210	246	277	331	365	411	442	469	505	529	568	600	626	647	665	683	695		
LH001	MIP-05-0030	SM	34	44	59	88	100	111	122	133	142	148	155										
LH001	MIP-05-0106	SM	35	57	73	112																	
LH001	MIP-05-0028	SM	35	44	54	84	101	121	129	138	146	157	167	178	185	189							
LH001	MIP-05-0065	SM	38	53	64	93	103																
LH001	MIP-05-0053	SM	39	63	81	105	121	135	148	157	167	175	188	199	205								
LH001	MIP-05-0057	SM	44	60	75	116	130	141															
LH001	MIP-05-0107	SM	52	71	92	121	135	146	153	160	166	173	181										
LH001	MIP-05-0108	SM	54	65	77	114	128	148															
LH001	MIP-05-0048	SM	54	83	103																		
LH001	MIP-05-0031	SM	56	75	90	128	145																
LH001	MIP-05-0044	SM	57	74	87	108	118	128	136														
LH001	MIP-05-0051	SM	60	72	90	137	150	165	177														
LH001	MIP-05-0105	SM	66	102	122	162	179	192	205														
LH001	MIP-05-0022	SM	78	94	116	174	192	217															
LH001	MIP-03-1534	SM	55	81	97	110	126	148	164	180	195	205	216	226	232								
LH001	MIP-04-0340	SM	56	73	84	103	122	132	145	155	164												

LOC	Sample #	CL	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13	Yr 14	Yr 15	Yr 16	Yr 17	Yr 18	Yr 19	Yr 20	Yr 21
LH001	MIP-04-0341	SM	31	50	65	75	88	104	123														
LH001	MIP-04-0345	SM	60	69	84	99	117	135	147														
LH001	MIP-04-0346	SM	48	67	79	88	99	112	124	132													
LH001	MIP-04-0365	SM	76	105	123	145	164	180	193	207	220	230											
LH001	MIP-04-0366	SM	60	88	109	133	155	169	181	190	202	215											
PG015	CS-03-1225	LM	61	116	162	213	282	326	370	425	463	494	531	552									
PG015	CS-04-0512	LM	68	90	124	160	211	278	318	354	394	433	464	509	526	541	555	566					
PG015	CS-04-0567	LM	69	108	156	205	260	322	383	412	458	493	523	567	605								
PG015	CS-03-1272	LM	69	115	165	226	277	329	384	419	453	498	527										
PG015	CS-04-0572	LM	74	131	193	259	292	322	392	439	479	527	573	615									
PG015	CS-03-1223	LM	75	122	197	235	286	332	368	408	443	485	522										
PG015	CS-03-1235	LM	76	141	204	237	270	305	375	417	456	496	534	555									
PG015	CS-04-0517	LM	78	127	165	239	294	369	449	493	533												
PG015	CS-04-0510	LM	82	140	195	247	294	337	378	428	475	526	579										
PG015	CS-04-0574	LM	82	153	234	290	338	371	425	459	496	535											
PG015	CS-04-0540	LM	82	123	152	185	239	291	317	351	375	422	462	494	525								
PG015	CS-04-0521	LM	85	118	148	188	221	249	289	322	369	417	465	517									
PG015	CS-03-1252	LM	86	140	199	253	294	335	381	421													
PG015	CS-04-0481	LM	87	154	201	245	284	325	358	386	432	457											
PG015	CS-04-0482	LM	90	128	182	214	298	338	385	409	431	468	496										
PG015	CS-04-0523	LM	90	146	176	217	278	331	379	440	483	516											
PG015	CS-03-1246	LM	91	145	180	231	271	327	369	413	455	505	549	587									
PG015	CS-03-1203	LM	93	132	172	207	274	318	364	420	470	518	562	613									
PG015	CS-04-0542	LM	95	136	173	220	283	331	398	453	495	528	571										
PG015	CS-03-1264	LM	96	144	194	260	326	402	452	495	541	604											
PG015	CS-03-1213	LM	96	142	193	232	264	295	331	386	427	457	484	504	538	575	613	657					
PG015	CS-04-0565	LM	97	173	225	276	316	354	394														
PG015	CS-03-1253	LM	97	139	169	268	314	366	412	458													
PG015	CS-03-1316	LM	98	156	198	265	327	395	441														
PG015	CS-03-1222	LM	98	161	223	316	366	412	479	515	556	603	644										
PG015	CS-03-1323	LM	98	151	196	253	292	345	382	432	466	503	575	607	623	635							

LOC	Sample #	CL	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13	Yr 14	Yr 15	Yr 16	Yr 17	Yr 18	Yr 19	Yr 20	Yr 21
PG015	CS-03-1294	LM	98	134	181	259	304	353	401	439	473	499	520	545	570	584	604	619					
PG015	CS-03-1234	LM	99	158	238	270	285	305	360	398	434	461	491	506	524	542	561						
PG015	CS-04-0518	LM	100	155	188	239	302	333	367	388	419	457											
PG015	CS-03-1375	LM	100	152	198	249	317	354	395	435	475	507											
PG015	CS-03-1241	LM	101	148	189	237	272	309	354	402	437	465	504	527									
PG015	CS-03-1236	LM	101	159	219	251	287	337	373	418	466	517	553	602									
PG015	CS-03-1233	LM	102	145	181	219	271	313	373	436	483												
PG015	CS-03-1250	LM	103	155	190	230	304	352	410	461	497												
PG015	CS-04-0500	LM	103	161	206	232	275	310	353	408	438	488											
PG015	CS-03-1244	LM	104	136	187	211	238	261	293	325	348	381	410	435	463	478	501						
PG015	CS-03-1256	LM	105	152	205	227	248	301	340	386	436	463	484										
PG015	CS-03-1251	LM	106	156	225	278	309	353	406	443	473	514	537										
PG015	CS-03-1254	LM	107	141	170	222	261	296	327	383	412	445	470	499	522	554	579	603	622				
PG015	CS-04-0561	LM	111	173	204	251	315	384	439	488	542	573	603	622									
PG015	CS-03-1219	LM	111	154	208	258	324	354	404	438	466	495	530	554									
PG015	CS-03-1231	LM	112	162	200	229	303	366	427	472													
PG015	CS-04-0564	LM	113	181	209	259	295	338	373	430	466	513											
PG015	CS-03-1206	LM	113	148	177	221	278	307	344	405	436	477	525	557									
PG015	CS-03-1208	LM	114	178	213	261	330	362	404	445	505												
PG015	CS-03-1242	LM	115	169	223	277	312	348	395	441	493	550											
PG015	CS-04-0506	LM	116	173	209	254	307	346	456	496	529	570											
PG015	CS-03-1324	LM	117	154	190	212	258	317	350	395	428	467											
PG015	CS-04-0522	LM	117	172	201	247	295	345	392	440													
PG015	CS-04-0578	LM	120	193	237	284	346	407	461														
PG015	CS-03-1255	LM	121	159	204	259	324	356	395	440	465	493	518										
PG015	CS-03-1209	LM	121	169	229	253	276	335	393	419	461	510	544	574	602	628							
PG015	CS-04-0513	LM	121	178	223	277	314	350	411	442	481	543	580										
PG015	CS-03-1227	LM	122	181	231	281	323	354	403	446	478	510	531										
PG015	CS-03-1258	LM	124	167	217	287	351	385	427	470													
PG015	CS-03-1211	LM	124	159	202	261	281	314	351	384	418	444	475	509									
PG015	CS-04-0555	LM	125	189	235	262	292	343	388	444	504	563	618										

LOC	Sample #	CL	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13	Yr 14	Yr 15	Yr 16	Yr 17	Yr 18	Yr 19	Yr 20	Yr 21
PG015	CS-03-1297	LM	126	163	189	227	295	326	366	425	453	498	541	577	593								
PG015	CS-04-0557	LM	126	200	245	282	342	386	421	448	477	510	547	590									
PG015	CS-04-0544	LM	127	200	253	318	361	410	454	487	517	571	622										
PG015	CS-04-0566	LM	127	175	212	281	319	352	383	422	481	530	566	613									
PG015	CS-03-1243	LM	128	178	248	294	345	423	460	519	575	614											
PG015	CS-03-1204	LM	128	173	222	265	318	385	419	458	498	531											
PG015	CS-03-1214	LM	129	199	226	257	307	354	390	420	456	493											
PG015	CS-03-1239	LM	131	177	211	242	287	350	410	433	460	483	511	549									
PG015	CS-04-0546	LM	131	193	253	307	361	413	444	498	535	579											
PG015	CS-03-1224	LM	132	175	260	312	342	404	458	493	519	557											
PG015	CS-03-1205	LM	137	183	225	294	323	374	414	461	511	532											
PG015	CS-03-1245	LM	139	175	221	265	303	339	385	413	441	467	510	532	561	591	611						
PG015	CS-04-0480	LM	141	170	193	233	263	295	327	365	406	445											
PG015	CS-03-1216	LM	150	198	242	273	298	330	373	413	450	493	526	553	584	615							
PG015	CS-03-1330	LM	153	193	240	279	318	358	398	434	462	500	534	554									
PG015	CS-04-0573	LM	153	203	235	275	318	362	400	448	504	545	568	586									
PG015	CS-03-1295	LM	155	206	245	281	318	366	411	465	504												
PG015	CS-04-0545	LM	164	206	250	287	325	354	385	420	467	532	568	601									
PG015	CS-04-0479	LM	176	235	265	300	350	420	465	513	556												
PG015	CS-03-1221	LM	188	250	301	366	398	438	509	538	572	611											
PG015	CS-04-504	LM	115	142	175	208	229	252	274	313	348	391	448	521	557	596	638	686	721				
PG015	CS-04-520	LM	101	149	191	218	260	257	345	405	454	518	585	639									
PG015	CS-04-541	LM	101	135	176	200	221	253	292	334	374	422	467	499	524	551							
PG015	CS-04-543	LM	106	175	230	300	353	398	446	479	508	538	573	602									
PG015	CS-04-548	LM	81	123	177	206	235	284	331	386	430	482	526	560	596	642	676						
PG015	CS-04-578	LM	125	158	188	232	264	326	368	423	462												
PG015	CS-04463	SM	26	57	70	80	101	118	137	152													
PG015	CS-03-1291	SM	27	39	49	60	70	85	99	123	138	153	164	172	180								
PG015	CS-03-1284	SM	41	70	82	93	112	124	135	147													
PG015	CS-03-1290	SM	44	69	95	107	119	134	144	154	166	177	186	198									
PG015	CS-03-1305	SM	48	68	86	103	113	124	135	143	152	158											

LOC	Sample #	CL	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13	Yr 14	Yr 15	Yr 16	Yr 17	Yr 18	Yr 19	Yr 20	Yr 21
PG015	CS-04532	SM	49	69	88	105	121																
PG015	CS-03-1329	SM	52	69	96	113	130	142	153	161													
PG015	CS-03-1302	SM	53	61	73	88	104	123	145	156	168	176	182										
PG015	CS-04577	SM	54	111	155	205	224	241	314	352	420	470	515	547									
PG015	CS-03-1282	SM	54	72	93	110																	
PG015	CS-03-1292	SM	60	80	92	105	119	133	146	154													
PG015	CS-03-1280	SM	68	94	139	164	194	218	236														
PG015	CS-03-1372	SM	83	133	188	250	292																
PG015	CS-03-1313	SM	101	160	248																		
PG015	CS-03-1303	SM	34	55	70	83	100	116	128														
PG015	CS-04-450	SM	53	74	98	124	151	162															
PG015	CS-04-457	SM	48	79	100	121	132	145	152	160	169												
PG015	CS-04-459	SM	54	72	90	114	125	135	148	158	168												
PG015	CS-04-464	SM	49	61	79	100	117	130															
PG015	CS-04-465	SM	50	66	80	97	114	128	140	153	167												
PG015	CS-04-484	SM	47	69	91	112	135	148	158	170	180												
PG015	CS-04-525	SM	58	85	108	124	136	148	159	170	180	193											
PG015	CS-04-527	SM	63	78	92	105	117	130	152	163	178	194											
PG082	CS01216	LM	60	134	193	253	295	335	385	416	443												
PG082	CS01233	LM	72	102	162	209	246	270	302	327	346												
PG082	CS01191	LM	75	149	216	250	279	323	362	404	446	481											
PG082	CS01270	LM	81	131	187	253	322	367	395	421	460	495											
PG082	CS-02-488	LM	84	164	229	273	341	410	451														
PG082	CS01230	LM	85	140	206	263	321	379	424	472	498	510	523										
PG082	CS01220	LM	86	149	211	266	338	393	451	486	518												
PG082	CS01256	LM	87	148	200	247	296	355	391	422	455	476											
PG082	CS-02-512	LM	88	128	192	241	296	326	351	377	398	427	452	478									
PG082	CS-02-495	LM	89	113	144	186	232	260	296	341	382	420	454	494	520								
PG082	CS01252	LM	91	153	194	227	260	282	299	324	348	373	396	419	441	459							
PG082	CS-02-480	LM	92	120	159	236	295	342	415	488	527	565											
PG082	CS01258	LM	93	154	231	269	297	334	390	423	460	492											

LOC	Sample #	CL	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13	Yr 14	Yr 15	Yr 16	Yr 17	Yr 18	Yr 19	Yr 20	Yr 21
PG082	CS-04641	LM	94	168	213	265	300	332	368	387	409	428	452										
PG082	CS01284	LM	95	146	203	230	282	320	345	404	424	454	493	533									
PG082	CS01294	LM	96	150	231	278	316	361	409	443	469	499											
PG082	CS-02-487	LM	96	151	225	278	322	376	402	448	474												
PG082	CS-04664	LM	97	149	212	254	296	344	387	429	461	496	523										
PG082	CS-04646	LM	98	169	213	253	315	353	385	422	452	475											
PG082	CS-02-507	LM	98	132	197	256	302	367	414	469	497	528	560	590									
PG082	CS-02-417	LM	101	164	194	269	324	367	408	443	487	528	564	606									
PG082	CS01254	LM	101	177	224	276	315	373	420	457	477												
PG082	CS-02-434	LM	102	155	188	232	299	353	412	457	495	530											
PG082	CS01190	LM	102	186	247	297	326	370	413	443	482												
PG082	CS01253	LM	102	180	239	268	295	345	371	394	433	464	491										
PG082	CS01210	LM	103	170	245	307	353	401	425	449	471	497											
PG082	CS01189	LM	104	200	258	306	366	428	480	509													
PG082	CS-02-508	LM	106	184	225	282	356	412	475	545													
PG082	CS01260	LM	107	159	243	303	346	407	451	488	508												
PG082	CS01185	LM	108	168	217	242	279	325	357	408	455	511	552	587									
PG082	CS01293	LM	109	170	224	294	331	371	398	424	450	471											
PG082	CS-02-446	LM	110	140	202	274	317	392	441	465													
PG082	CS01286	LM	111	165	242	302	365	410	460	506	551	582											
PG082	CS-02-496	LM	112	176	238	268	306	324	366	425	457	470	505	524									
PG082	CS01229	LM	112	156	177	252	281	320	371	397	426												
PG082	CS01259	LM	113	176	240	302	355	419	466	498	520												
PG082	CS01261	LM	114	165	226	271	337	440	494	522													
PG082	CS01235	LM	114	156	211	252	285	320	347	388	427	447	466	494	519	535	551						
PG082	CS01219	LM	115	169	226	264	291	317	358	383	410	438											
PG082	CS01162	LM	115	195	253	309	353	397	438	472	498	519											
PG082	CS01272	LM	116	194	252	315	360	399	432	461	484												
PG082	CS-02-494	LM	118	164	227	275	336	413	463	524	576												
PG082	CS01181	LM	119	160	214	267	292	340	379	408	450	471	495										
PG082	CS-04652	LM	120	164	203	228	245	270	298	321	351	388	421	453	492	518							

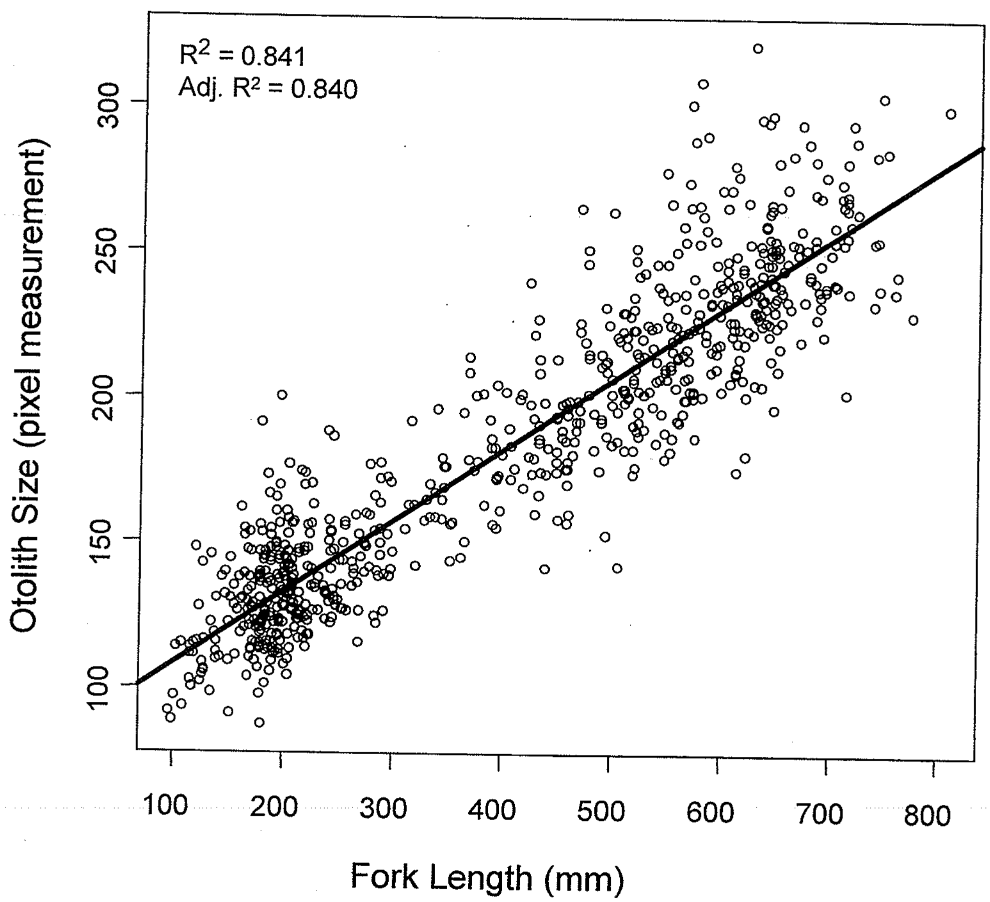
LOC	Sample #	CL	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13	Yr 14	Yr 15	Yr 16	Yr 17	Yr 18	Yr 19	Yr 20	Yr 21
PG082	CS01306	LM	120	192	260	313	356	397	429	465	490												
PG082	CS-04656	LM	120	184	262	325	384	437	468	510	545	570	607										
PG082	CS01211	LM	120	185	247	291	329	351	393	426	452												
PG082	CS-02-510	LM	121	165	229	276	340	391	436	479													
PG082	CS-02-425	LM	121	163	194	232	266	293	333	380	423	467	498										
PG082	CS-02-431	LM	121	174	220	273	297	335	378	415	446	491											
PG082	CS01167	LM	121	168	215	258	309	337	359	379	410												
PG082	CS01282	LM	122	169	225	281	336	391	439	482	524	559	602										
PG082	CS01170	LM	123	196	243	296	332	368	396	435													
PG082	CS-02-422	LM	123	160	194	226	252	287	304	345	387	417	449										
PG082	CS01215	LM	124	177	228	266	295	336	378	415	451	484	502	538	562	580							
PG082	CS01225	LM	125	198	254	309	354	389	440	469	497												
PG082	CS01283	LM	126	180	247	304	352	388	416	455	497												
PG082	CS-02-500	LM	127	193	236	295	364	411	465	506													
PG082	CS01168	LM	131	199	247	297	347	369	409	435													
PG082	CS-04668	LM	133	197	267	308	353	397	432	460	489	516	540										
PG082	CS01180	LM	133	219	294	329	370	393	411	433	457	493											
PG082	CS-02-418	LM	133	170	198	247	308	346	395	420	451	477	496										
PG082	CS01188	LM	134	195	259	318	379	416	447	496													
PG082	CS01208	LM	134	174	202	262	298	338	370	397	426	452	473										
PG082	CS-04650	LM	135	192	225	268	315	349	413	449	477												
PG082	CS-04654	LM	135	203	257	308	350	380	415	440	461	485	514	533									
PG082	CS-04647	LM	135	196	212	266	329	374	427	470	508	528											
PG082	CS-02-492	LM	135	228	274	322	378	406	456	471	521	554											
PG082	CS01176	LM	136	179	221	260	295	349	399	442	464	485	513	538									
PG082	CS-02-443	LM	136	182	223	294	340	405	476	517	553	601											
PG082	CS01307	LM	139	208	270	339	380	428	455	477	497	532											
PG082	CS01164	LM	139	212	261	320	385	422	483														
PG082	CS-04645	LM	143	205	237	292	356	400	435	457	504	533	556	578									
PG082	CS01287	LM	146	190	244	298	347	385	417	445	476												
PG082	CS01174	LM	148	192	229	281	330	367	407	443													

LOC	Sample #	CL	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13	Yr 14	Yr 15	Yr 16	Yr 17	Yr 18	Yr 19	Yr 20	Yr 21
PG082	CS01161	LM	148	201	261	320	354	404	451	490	513	540											
PG082	CS-02-438	LM	151	215	292	334	393	436	472	510	549	579											
PG082	CS-02-479	LM	156	186	227	265	305	360	409	452	486												
PG082	CS01305	LM	159	210	265	321	368	410	449	477	504	530											
PG082	CS-02-502	LM	164	205	246	307	375	419	457	502	542	582											
PG082	CS01226	LM	168	225	284	340	369	393	413	450	477	499	518	543									
PG082	CS-04660	LM	172	282	321	357	399	438	476	519	558												
PG082	CS-02-504	LM	173	227	276	308	337	380	415	437	460	479	512	538	563	587	606	624	642	665			
PG082	CS-04665	LM	174	227	271	320	368	418	474	517	546												
PG082	CS-02-430	LM	181	224	276	329	369	424	466	513	545	572											
PG082	CS-04657	LM	182	230	295	364	407	447	480	520	554												
PG082	CS-02-501	LM	186	226	275	304	336	367	417	451	478	500											
PG082	CS01292	LM	209	250	288	331	397	439	470														
PG082	CS-02-483	LM	243	292	364	409	464	516	543	591	629												
PG082	CS-04-643	LM	138	164	199	230	250	264	294	324	350	378	413	434	455								
PG082	CS-04-647	LM	130	155	179	221	250	300	357	428	467	518	560	595									
PG082	CS-04-649	LM	121	173	215	262	323	357	390	422	447	480											
PG082	CS-04-655	LM	191	259	304	352	401	444	481	513	540	574											
PG082	CS-04-658	LM	120	168	228	267	314	368	410	463	505	535	572	606	631								
PG082	CS-04-666	LM	136	190	229	266	303	336	365	403	437	473	501										
PG082	CS-04-667	LM	173	218	240	266	297	347	406	447	485	523	556	600	617								
PG082	CS-04-669	LM	149	188	241	295	366	399	468	509	551	585											
PG082	CS-04588	SM	31	70	92	104	129	151	167	186													
PG082	CS-02-469	SM	34	58	83	109	128	142	157	166													
PG082	CS01248	SM	35	55	69	93	111	137	150	161	171												
PG082	CS-04587	SM	44	63	93	124	137	149	168	187	196												
PG082	CS-04639	SM	46	78	106	123	136	150	158	170	180	188											
PG082	CS-04610	SM	49	82	114	137	158																
PG082	CS-04602	SM	53	79	93	106	127	135	145	153													
PG082	CS01247	SM	54	72	87	106	134	146	161	175	192												
PG082	CS-02-455	SM	57	90	113	138	151	160															

LOC	Sample #	CL	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13	Yr 14	Yr 15	Yr 16	Yr 17	Yr 18	Yr 19	Yr 20	Yr 21
PG082	CS-04627	SM	57	80	99	120	141	152															
PG082	CS-02-456	SM	59	91	112	136	150	159															
PG082	CS-04612	SM	60	92	128	155	182																
PG082	CS01246	SM	61	85	116	140	163	184															
PG082	CS-04606	SM	63	98	115	131	152	171															
PG082	CS-04640	SM	63	93	119	136	153	176	189	201	216	229											
PG082	CS01195	SM	64	78	110	133	153	170	187	201													
PG082	CS01199	SM	71	96	120	144	155	165	172	178													
PG082	CS-04613	SM	73	87	107	134	148	161	177	188	201	212	218	224									
PG082	CS-04589	SM	74	99	126	139	155	169	176	185	192												
PG082	CS-04638	SM	75	102	133	163	183	203															
PG082	CS-04597	SM	80	98	126	144	158	179	192	202													
PG082	CS01250	SM	80	95	109	135	158	171	182	190													
PG082	CS01196	SM	84	110	120	136	152	167	181	192	198												
PG082	CS-02-403	SM	46	64	83	109	132	150	162	175	187												
PG082	CS-02-469	SM	67	87	112	124	133	147	161	174													
PG082	CS-04-584	SM	77	99	121	144	162	175	185	195													
PG082	CS-04-595	SM	62	98	124	135	148	171	185	199													
PG082	CS-04-605	SM	84	100	114	134	158	177	190	207	214	226	237	245									
PG082	CS-04-625	SM	74	94	112	131	151	167	182	193													
PG082	CS-04-626	SM	81	104	120	132	150	167	181	193	202												
PG082	CS-04-630	SM	55	70	100	123	143	158	170	183													
PG082	CS-04-640	SM	80	108	137	158	176	190	203	214	227	237											

APPENDIX 2.4

Otolith size and body size relationship for back-calculated data (**Chapter 3**). A positive linear relationship was observed in preliminary analysis. Data were compiled for analysis for all three lake systems and all years. When analysed by year group as done when back-calculation occurred, the same relationship is observed as shown below. The linear regression model fit for otolith size and body size relationship. The x-intercept for the model is 84.122 (S.E. = 1.764) and the slope is 0.244 (S.E. = 0.004). The residual standard error was 20.5 on 732 degrees of freedom with a multiple R^2 value of 0.8406 and an adjusted R^2 value of 0.8404.



APPENDIX 2.5

Sample R code used for fecundity and egg diameter linear models with confidence and prediction intervals (**Chapter 3**).

```
attach(fecundity)
# attach fecundity data

fecundity.lm= lm(ln_totnumeggs~ln_forklength)
summary(fecundity.lm)
# linear model and model summary command

plot(ln_forklength, ln_totnumeggs, xlim =c(4.1,7.1), ylim
=c(3.5, 9.0), pch=16)
# plots the data and sets the x and y limits of the graph

abline(fecundity.lm, lwd=3, lty=1)
# adds linear regression line of the model to plot

curve(predict(fecundity.lm, data.frame(ln_forklength=x),
 interval="confidence") [,2], add=T, lty = 5)
curve(predict(fecundity.lm, data.frame(ln_forklength=x),
interval="confidence") [,3], add=T, lty = 5)
# adds upper and lower confidence intervals to the plot

curve(predict(fecundity.lm, data.frame(ln_forklength=x),
 interval="prediction") [,2], add=T, lty=3)
curve(predict(fecundity.lm, data.frame(ln_forklength=x),
 interval="prediction") [,3], add=T, lty=3)
# adds upper and lower prediction intervals to the plot

points(4.890, 3.689,pch=15, col="black")
# adds new data points to the graph that are not part of
the intial linear regression model

newVal5=5.323
predict(fecundity.lm, data.frame(ln_forklength=newVal5),
interval = "prediction")
# adds new data point and then provides the prediction
interval of the new data point fit to the fecundity model
```

APPENDIX 2.6

Sample r code used for VonBertalanffy growth model (**Chapter 3**).

```
attach(lh001res)

boxplot(length~age,main="Aggregate Growth
Curve",xlab="age",ylab="Length (mm)")
nn=length(length)
len_t=as.numeric(NULL)
len_tPlus=as.numeric(NULL)
for (i in 1:(nn-1)) {
  if(age[i+1]==age[i]+1 && sample[i]==sample[i+1]) {
  lt=length[i]
  ltp=length[i+1]
  }
  len_t=c(len_t,lt)
  len_tPlus=c(len_tPlus,ltp)
 }
# Initial parameter estimates from Ford-Walford plot of all
data
 # Create L and L[t+1] vectors for all fish samples (data
already ordered by sample & age)
 # as new vectors without missing values for final age

# Ford-Walford fit
plot(len_tPlus~len_t,pch=".")
xMin=min(len_t)
xMax=max(len_t)
lines(c(xMin,xMax),c(xMin,xMax),col='red')
fordWalford.line=lm(len_tPlus~len_t)
a=fordWalford.line$coef[1]
b=0.974576
LinfEST=a/(1-b)
kEST=-log(b)
# Use Ford-Walford estimates as initial values for
nonlinear least squares

model.nls <- nls(length ~ Linf*(1-exp(-k*(age-t0))),
     data=lh001res,
     start=list(Linf=LinfEST,k=kEST,t0=-1),
     nls.control(maxiter = 50, tol = 1e-05, minFactor =
1/2048),
     trace=T)

summary(model.nls)
# summary of the above model
```

```
# Fit Nonlinear Models Using Generalized Least Squares
library(nlme)
# open the nlme library

model.1 <- gnls(length ~ vonBertalanffy3(Linf,k,t0,age),
                       data=lh001res,
                       control=gnlsControl(minScale=1e-12),
start=list(Linf=30,k=0.1,t0=-0.7))
# Von Bertalanffy Fit, 3 parameter model, independent
errors

model.2 <- gnls(length ~ vonBertalanffy3(Linf,k,t0,age),
                       data=lh001res,
                       control=gnlsControl(minScale=1e-12),
start=list(Linf=350,k=0.2,t0=-0.7),
correlation=corAR1(form=~ age | sample))
# Von Bertalanffy Fit, 3 parameter model, AR(1) correlated
errors

anova(model.1,model.2)
# comparison of models with and without autocorrelation

summary(model.1)
summary(model.2)
# model fits

# r code for side by side boxplot graphics
attach(lh001a)
attach(lh001res)
# attach two data sets that you want as part of the graphic

par(mfrow=c(1,2))
# create a graphic frame that states two graphs will be
made side by side

boxplot(lh001a$length~lh001a$age,main="Large-
maturing",xlab="Age (years)",ylab="Fork Length (mm)",
xlim=c(0, 22), ylim=c(0, 800))
boxplot(lh001res$length~lh001res$age,main="Small-maturing",
xlab="Age (years)",ylab="Fork Length (mm)", xlim=c(0, 22),
ylim=c(0, 800))
# creates boxplots for two data sets in this case lh001a
and lh001res
```