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Genetic relationships of lake trout *Salvelinus namaycush* on Togiak National Wildlife Refuge, Alaska

2006 Progress Report

Togiak National Wildlife Refuge
Dillingham, Alaska
and
Conservation Genetics Laboratory
Anchorage, Alaska

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Genetic relationships of lake trout *Salvelinus namaycush* on Togiak National Wildlife Refuge, Alaska

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Abstract

Fin clips for genetic analysis, length, and weight data were collected from lake trout *Salvelinus namaycush* in 14 populations within six separate watersheds on or near Togiak National Wildlife Refuge during the period 2004-2006. Data are being analyzed to determine the genetic relationships between populations, and to characterize the size structure of each population. A sediment core was collected from the floor of one land-locked lake that contains lake trout. Analysis of the levels of $\delta^{15}N$ suggest that this lake, throughout its history, has remained consistent with lakes not subject to inputs of marine nitrogen from salmon carcasses and therefore isolated from the surrounding watershed since establishment.

Introduction

This project is focused on understanding the genetic relationships of lake trout populations occurring within Togiak National Wildlife Refuge. These populations have a patchy distribution, both within and among individual watersheds. Some relatively large watersheds are apparently uncolonized, while neighboring watersheds are occupied. Additionally, lake trout appear to be widely distributed within some watersheds, while they are known to occur in a small fraction of others. Togiak Refuge lake trout are used in both sport and subsistence fisheries, and harvest limits are relatively liberal, ranging from four fish per day in the sport fishery to no limits in the subsistence fishery. Understanding the metapopulation relationships of lake trout in this area will provide insights into how habitats are colonized, how populations persist, and will aid management in determining appropriate harvest strategies.

Objectives

1. Determine the relationships and degree of genetic exchange of lake trout within and among the watersheds of Togiak National Wildlife Refuge.
2. Characterize and compare the size structure of lake trout populations within and among the watersheds of Togiak Refuge.

Background

Status of lake trout on Togiak Refuge

Fish species inventories have been performed on the lakes and rivers of Togiak Refuge for the past two decades to understand species distribution. Lake trout have been documented in some lakes and appear to be absent in others, and seem to be more common in watersheds that drain

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into Kuskokwim Bay rather than those that drain into Bristol Bay. The species is known to occur in six separate watersheds on or adjacent to the refuge (Figs. 1 and 2), including:

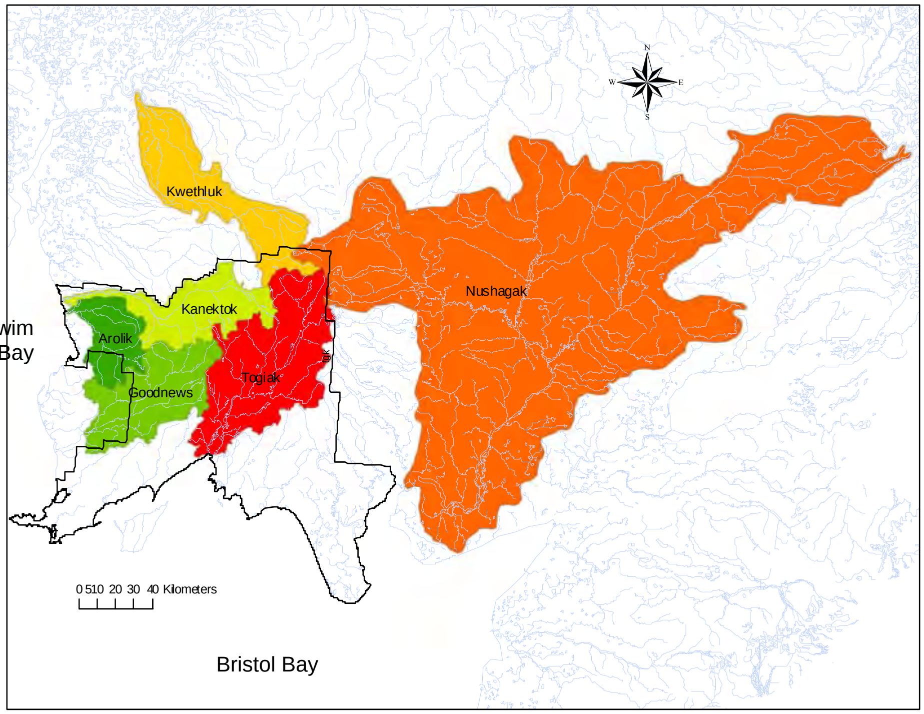

Figure 1. Watersheds of Togiak National Wildlife Refuge known to include lake trout populations.

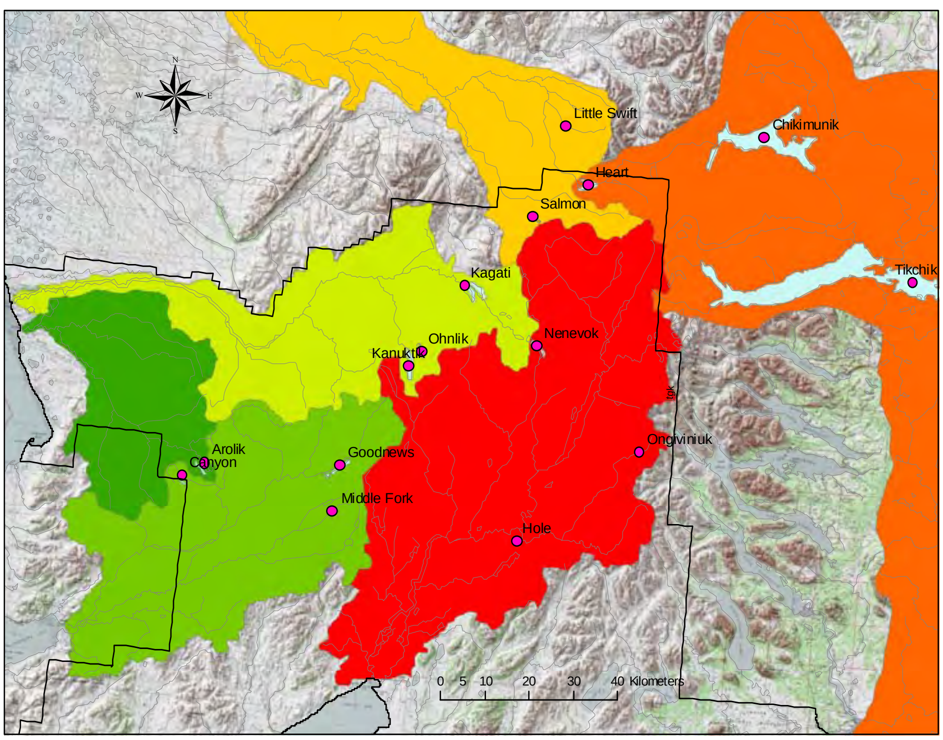

Figure 2. Location of lake trout populations and their associated watersheds within Togiak National Wildlife Refuge, southwest Alaska.

1. Togiak River watershed. Draining approximately 4,572 km^2, this is the largest watershed on Togiak Refuge, and is almost wholly enclosed within the refuge boundary. Lake trout are known to occur in three lakes in this watershed, including Nenevok Lake (MacDonald 1996), Hole Lake (Nelle 2002) and Ongivinuk Lake (B. Sweeney, pers. comm.). Fish inventories have been performed in an additional six lakes in the Togiak River watershed without detecting lake trout, including High, Nagugun, Upper Togiak, West Togiak Lakes (MacDonald 1996) and two unnamed lakes (Nelle 2002).
2. Goodnews River watershed. At 2,704 km^2 in area, the Goodnews River watershed is the second largest on Togiak Refuge, although about a third of this watershed occurs outside of the refuge. Lake trout appear to be well distributed in this watershed. The species is known to occur in Goodnews and Canyon Lakes (MacDonald 1996) and Middle Fork Lake (Nelle 2002). Reports from sport anglers have also been made of lake trout occurring in the Goodnews River itself. A survey of a small unnamed lake associated with the Middle Fork Goodnews River did not encounter lake trout (Nelle 2002).
3. Kanektok River watershed. The Kanektok River watershed is approximately 2,267 km^2 in area and almost wholly enclosed within the refuge boundary. As with the Goodnews River watershed, lake trout appear to be widely distributed here as well. Surveys of three large lakes in this watershed (Kagati, Kanuktik, and Ohnlik) all encountered lake trout (MacDonald 1996). A survey of Klak Lake did not reveal lake trout (Nelle 2002).
4. Arolik River watershed. This watershed is 1,328 km^2 in area and is located between the Kanektok and Goodnews River watersheds. It contains a single large lake, Arolik Lake, and lake trout have been documented to occur there (MacDonald 1996).
5. Nushagak River watershed. At 31,203 km^2 this is largest watershed in the vicinity of Togiak Refuge, although all but a small fraction occurs beyond the Refuge boundary. Heart Lake is located in the upper reaches of this watershed within Togiak Refuge and contains lake trout (MacDonald 1996). Heart Lake is drained by Milk Creek, which flows off Togiak Refuge into Chikimunik Lake, which drains through Chauekuktuli Lake, then into Tikchik Lake. Lake trout occur in both Chikimunik and Tikchik Lakes, which are also the largest lake trout lakes within this study.
6. Kwethluk River watershed. This watershed is 3,311 km^2 in area and is largely located outside of the Togiak Refuge boundary to the north. This watershed includes at least two lake trout populations at Salmon Lake and Little Swift Lake.

Lake surveys were conducted in two additional lakes, both in separate watersheds, and lake trout were not documented in either. These were Kulukak Lake, in the Kulukak River watershed (MacDonald 1996) and Amanka Lake, located in the Igushik River watershed (Gwinn 2005a). Additionally, stream surveys that did not detect lake trout have been performed in the following watersheds, including the Osviak River of the Osviak River watershed (Nelle 2002b), the Tuklung River of the Igushik River watershed (Nelle 2002a), the Slug River of the Slug River watershed (Nelle 2002a), the Weary River of the Snake River watershed (Nelle 2000a), the Salmon River of the Salmon River watershed (M. Lisac, pers. comm.), the Ungalikthluk and Neglukthlik Rivers of the Neglukthlik River watershed (Lisac 1996, Gwinn 2005b). No formal lake or stream surveys have been performed in the remaining Refuge watersheds, including the Kinegnak, Matogak, Quigmy, Kanik, and numerous small watersheds without large lakes.

Harvest of Togiak Refuge lake trout

Lake trout are harvested on Togiak Refuge lakes and rivers in both the sport and subsistence fisheries. Under the state sport fishing rules, up to four lake trout may be harvested per day, and under the subsistence rules, there are no harvest limits. Under the statewide sport fish harvest survey (ADFG 2005), an average annual harvest of 44 lake trout was reported for the years 2000-2003 for the Goodnews, Kanektok, and Togiak River systems. Reported subsistence harvests from the communities of Togiak and Manokotak included an annual average of 181 lake trout from four general areas during the period 1994-1995, including: 1) watersheds near Manokotak, including the Igushik and Snake River watersheds; 2) the Goodnews River watershed; 3) Togiak Lake; and 4) an area west of Togiak Lake that includes elements of the Kemuk River, Nayorurun River, Togiak River and smaller tributary watersheds of the Togiak River (BBNA and ADFG 1996). However, it would be inadvisable to assign too much importance to the harvest estimates or distribution implications from these studies, as lake trout are a relatively minor constituent of a larger list of species reported on, and misidentification with other salmonid taxa is possible.

Life history of lake trout

The lake trout is a young species thought to have diverged from other species of *Salvelinus* approximately one to three million years ago (Wilson and Mandrak 2004). Its divergence is believed to be a response to environmental changes occurring during the Pleistocene Epoch (1,800,000 to 10,000 years ago), and its current distribution closely matches the North American limits of the Wisconsinan glaciation (~20,000 years ago), where it is largely restricted to lakes of glacial origin. Lake trout have the most extensive freshwater distribution of any salmonid, and are different from all other salmonids by being the only species lacking the ability to survive in salt water, suggesting their evolution in a purely freshwater environment. Lake trout, highly specialized for habitats that did not exist before the Pleistocene, are well adapted to a dynamic aquatic environment that has shifted multiple times as glacial and interglacial periods came and went (Gunn and Pitblado 2004). The species is large, long-lived, has a metabolism suitable for life and growth at low temperature; it can withstand long periods of food deprivation; it is a food generalist; it is a strong, long-distance swimmer; and it is able to use thermal refugia (lake hypolimion, groundwater springs) to survive climate extremes. It performs best in the absence of competitors and predators and is often most productive in small lakes with fish communities of low species diversity (Gunn and Pitblado 2004).

Because of the lake trout life strategy of large size, long life, and late maturation, it is vulnerable to modern threats, including introduction of competitors, exploitation by humans, habitat modification, climate warming, and nutrient and pollutant increases (Krueger and Ebener 2004). Prior to European colonization of the Great Lakes area, all five lakes contained lake trout populations. By the late 1950s, native lake trout were gone from Lake Ontario, Lake Erie, and Lake Michigan, nearly gone in Lake Huron, and depleted at most near-shore locations in Lake Superior. Overfishing was implicated among other factors. Rehabilitation efforts centered on restocking began in the 1950s, have continued to the present, and have met limited success.

Justification and Need

There is a lack of information on the status of lake trout in general on Togiak National Wildlife Refuge. Lake inventory studies have provided a beginning at understanding the distribution of lake trout throughout the refuge watersheds. However, there have been no studies of the genetic relationships or life history of Togiak Refuge lake trout. The species is harvested in both sport and subsistence fisheries, and the impact and magnitude of these fisheries is poorly understood. Lake trout populations are easily disruptable and difficult to restore (Gunn and Pitblado 2004, Krueger and Ebener 2004). Lake inventory and genetic data will provide baseline information to aid in sustaining lake trout populations in the Togiak Refuge and maintaining their genetic diversity. Investigating the genetic relationships of Togiak Refuge lake trout will provide an understanding of the origin and recolonization of refuge lakes.

Study Area

Togiak Refuge is a ~1.7 million ha federal conservation unit located at the confluence of the Bristol and Kuskokwim Bays of the Bering Sea. It extends inland >100km; thus the climate can be characterized as subarctic maritime near the coastal areas, gradually approaching subarctic continental toward the interior. The mean monthly maximum and minimum temperature averages -6.3 and -11.3^{o} C in February, the coldest month, and 11.9 and 8.4^{o} C in August, the warmest month (NCDC 1971-2000, Western Regional Climate Center, data for Cape Newenham). Precipitation averages 90.1 cm annually and total snowfall averages 197.8 cm annually.

The Togiak Refuge includes all or portions of 35 major rivers, 25 major lakes, and hundreds of smaller lakes, ponds, and streams (USFWS 1990). The Ahklun Mountains occupy the central portion of the refuge while the Nushagak and Kanektok River lowlands occur to the northwest and southeast. The modern-day landscape, and the distribution of lake trout within this landscape, is strongly influenced by glacial activity in the recent past (15,000-20,000 years ago).

Fluctuating climate is the force that shaped the modern-day Togiak Refuge landscape more so than anything else. Changing climate through the Quaternary Period modified temperature and moisture patterns (Hu et al. 2001a and 2001b, Hu et al. 2003, Kaufman et al. 2001b, Kaufman et al. 2003), causing drastic changes in plant (Young 1982, Ager 1994, Hu et al. 2002, Hu et al. 1995) and animal communities (Gutherie 1982, Matheus 1994). Climate change caused glaciers to advance and retreat multiple times (Briner and Kaufman 2000, Kaufman et al. 2001a, Kaufman et al. 2001b), which modified the physical character of the land, scouring the land surface and redepositing huge quantities of sediments in new areas. Lakes were created and destroyed and watercourses were rerouted (Wilson and Mandrake 2004). Sea levels fell by ~125m during the glacial maxima due to the development of massive continental ice sheets. This caused the shoreline to extend from its modern position to more than 600 km to the southwest, causing tundra environments to develop under the modern-day Bristol and Kuskokwim Bays.

Glaciers covered almost all of the refuge ~70,000 years ago (Briner et al. 2002, Manley and Kaufman 2002) although Beringia, the unglaciated portions of Alaska and Asia and the Bering Land Bridge, adjoins the northern boundary of the refuge. Beringia has been demonstrated to have served as a lake trout refugium during the ice ages, after which colonists reoccupied watersheds throughout parts of Canada and the Great Lakes region of the United States (Wilson and Mandrak 2004). As such, it is the most likely source for the recolonization of Togiak

Refuge lake trout populations following the various glacial periods. However, it is also possible that lake trout refugia existed at the southern margin of the glaciated areas--an area which is currently under the Bering Sea but which would have been above sea level during the Pleistocene.

During the most recent glacial maximum (~20,000 years ago) glaciers occupied approximately half of the refuge (Manley and Kaufman 2002, Fig. 3). At that time, most of the large lakes that occur on the present Refuge landscape were under glacial ice. Of the 14 lakes in the vicinity of Togiak Refuge that currently are known to contain lake trout, only two (Arolik and Canyon Lakes) were ice-free at that time. It is conceivable that fish from one of these watersheds served as the source of colonists for the remainder of the refuge during the Holocene Epoch**.**

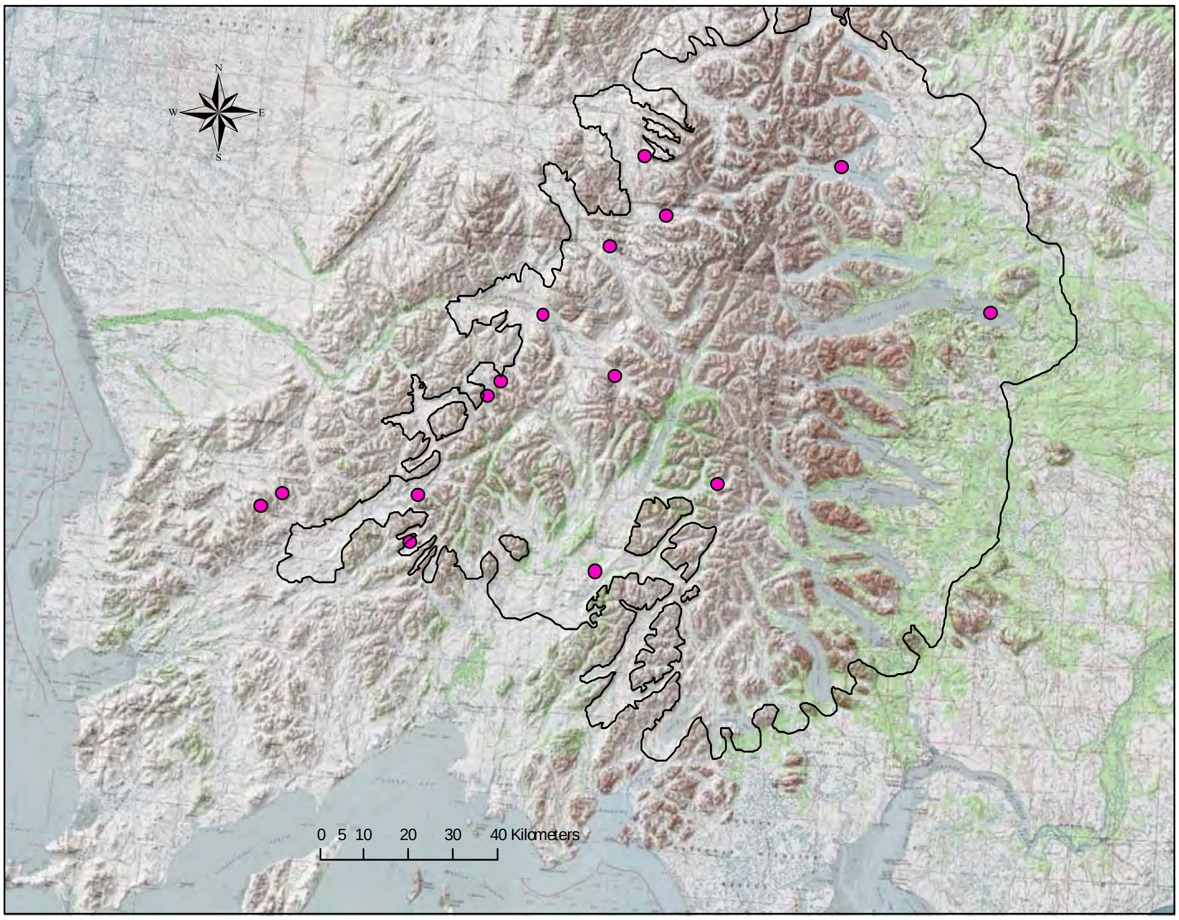

Figure 3. Lakes currently occupied by lake trout on Togiak National Wildlife Refuge in relation to maximum extent of ice during the Wisconsinan glaciation (approx. 20,000 years ago). Glacial delineation taken from Manley and Kaufman 2002.

Of the lake trout lakes in the vicinity of Togiak Refuge, all are connected to the surrounding watersheds by inlet and outlet streams, except for Hole Lake. Hole Lake is an approximately 50 ha glacial kettle within the Togiak River watershed. It is roughly circular in shape and is 27 m at its greatest depth (Nelle 2002). It is located approximately 0.5 km from the Ongivinuck River, a major tributary of the Togiak River. There is no current connection between Hole Lake and the Ongivinuck River or any other riparian area in the Togiak River watershed.

The fish community in Hole Lake shows little diversity but high density. In addition to lake trout, only three other species (ninespine stickleback-*Pungitius pungitius,* coastrange sculpins-*Cottus aleuticus*, and Alaska blackfish-*Dallia pectoralis)* were detected during surveys in 2001 and 2004 (Nelle 2002, Jaecks 2004). Given that threespine sticklebacks (*Gasterosteus aculeatus*) are a common member of Togiak Refuge fish communities (Nelle 2002), their possible absence in Hole Lake argues for an isolated system that has been difficult for fish to colonize. A hydroacoustic survey of Hole Lake conducted in 2002 (Hartman and Margraf 2003) detected high variability in fish density and number and size of fish both spatially and temporally. Fish density ranged from 14.05 fish per 10,000 m^3 at dusk in one transect to 9,834.06 fish per 10,000 m^3 during daylight at another transect. According to the investigator, "Densities of fish in Hole Lake were among the highest this researcher has ever encountered in systems ranging from the coastal Atlantic Ocean, Chesapeake Bay, Hudson River Estuary, inland rivers, reservoirs, the Great Lakes, and the Ugashik Lakes" (Hartman and Margraf 2003).

Methods

Fin clips for genetic analysis and morphological information were collected from lake trout in the following lakes (Fig. 2): Arolik, Canyon, Goodnews, Heart, Hole, Kagati, Kanuktik, Middle Fork, Nenevok, Ohnlik, Salmon, Little Swift, Tikchik, and Chikimunik Lakes.

<u>Sampling method:</u>

Collection of fish-Capture methods included angling, seines, experimental gill nets, and minnow traps. Angling methods included fly, spinning and trolling gear. When angling methods failed to capture lake trout, nets and traps were used. Baited minnow traps were fished overnight. Experimental gillnets were deployed at various depths and were fished for periods up to one hour. Fin tissue for genetic analysis was collected by clipping a portion of a pelvic fin from approximately 50 fish per lake and preserving the samples in 90% ethyl alcohol. Fish were weighed to the nearest 25 g and fork length was measured to the nearest mm. Fish were released alive.

<u>Morphological comparisons:</u>

A size index was calculated by determining the ratio of length/weight (mm/g) for each fish. Normality within data sets was examined with skewness, kurtosis, and omnibus normality of residuals tests. Equal variance was tested with a modified-Levene equal-variance test. In the case of data determined to be normal and having equal variance structure, one-way analysis of variance on the means was selected as the test to determine whether all size structures were similar. If data were determined to be non-normal or have unequal variance structures, Kruskal-Wallis test on ranks was selected to test for difference among lake trout population size structure. In the case that differences were found, the Tukey-Kramer multiple comparison test was used to determine similarity and differences among lakes. Size structure testing was performed with statistics program NCSS (Hintze 2001). Differences were considered significant at an α level of 0.05.

Genetic analysis:

Laboratory Analysis:

Total genomic DNA was isolated from approximately 10-20mg of fin tissue from each fish sampled using the Qiagen 96-well DNeasy® procedure. Variation at approximately 10 microsatellite loci will be surveyed. Loci will be selected from those used in previous lake trout studies (Piller et al. 2005; Page et al. 2004; and Timothy King, USGS, Kearneysville, WV, unpulished data). Products amplified via PCR will be size fractionated on denaturing polyacrylamide gels and visualized and scored using a Li-Cor IR$^{2®}$ scanner with Li-Cor Saga^{TM} GT ver 2.0 software (Lincoln, NE). Li-Cor 50-350bp or 50-700 size standards will be loaded in the first and last lanes and at intervals of 14 lanes or less across each gel. Positive controls, consisting of alleles of predetermined size, will be loaded in four lanes distributed evenly across the gels to ensure consistency of allele scores. Two researchers will score genotypes independently. Samples with score discrepancies between researchers will be re-amplified at loci in question and rescored.

Within population variation:

Each locus and lake sample will be tested for conformity to Hardy-Weinberg equilibrium (HWE) using the probability test in the program GENEPOP Version 3.4 (Raymond and Rousset 1995). Genotypic disequilibrium will be tested for all pairwise combinations of loci using probability tests in GENEPOP Version 3.4 (Raymond and Rousset 1995). Loci that consistently do not conform to HWE in putative population samples may be due to non-amplifying alleles. These will be deleted from subsequent analysis, along with loci with suspected linkage will be deleted from subsequent analyses.

Lake samples that do not conform to HWE may indicate the presence of admixed populations within lakes which may have arisen through multiple founding populations or through the development of reproductive isolation after a founding event. Lake samples will be further analyzed using the computer program HWLER to determine if each sample comprises one or multiple Hardy-Weinberg linkage disequilibrium groups (Pella and Masuda 2006).

P-values for statistical tests will be evaluated after adjusting the threshold for statistical significance (α=0.05) for simultaneous tests using the sequential Bonferroni technique (Rice 1989).

Estimates of heterozygosity and allele richness for each lake will be calculated as within-population measures of genetic diversity using FSTAT Version 2.9.3 (Goudet 2001).

Origins and relationships among populations:

Cavalli-Sforza & Edwards (CSE; 1967) chord distances will be calculated from allele frequencies between all pairwise combinations of populations using MSA (Dieringer and Schlötterer 2003). Genetic similarity among lake samples will be visualized using multidimensional scaling (MDS) in NTSYS (Exeter Software, Seatauket, NY).

The program HWLER (Pella and Masuda 2006) will be used to create a tree based on overall similarities between individuals. This analysis does not assume *a prioi* population membership

as does the analysis above. Overall similarity between individuals is calculated as Bayesian co-assignment probabilities of the membership of individuals to Hardy-Weinberg linkage disequilibrium groups.

To determine if current genetic relationships follow expectations based on current or Pleistocene hydrology, we will follow the analysis of Poissant et al. (2005). Isolation by distance (IBD) among populations will be tested by plotting pairwise F_{ST} and geographic distance between the extant lake and its likely colonization source based on hydrological patterns during deglaciation (to be obtained from D. Kaufman). Further analyses will plot pairwise F_{ST} versus elevation difference between lakes and current geographic distances between lakes to determine if genetic relationships are correlated with current hydrology. Pairwise F_{ST} will be calculated according to the method of Weir and Cockerham (1984) using FSTAT 2.3.1 (Goudet 2001). Closest geographic distances will be measured using a U.S. Geological Survey Alaska Topographic map. Significance of the linear regressions will be evaluated through Mantel tests where the rows and columns of the matrices are permuted 1000 using FSTAT Version 2.3.1.

The origin of lake trout in Hole Lake may have been through an anthropogenic, i.e. stocking event. In this case, it might be expected that the population was founded with very few individuals, and the genetic signature of a recent bottleneck may be detectable and more extreme than in other Togiak Refuge lakes. The statistic M (number of alleles/range of alleles; Garza and Williamson 2001) will be calculated for each putative population and the computer program Bottleneck version 1.1.03 (Cornuet and Luikart 1996) will be used to test for differences between the expected heterozygosity observed in the sample and the expected heterozygosity, assuming equilibrium between genetic drift and migration. The results of these analyses will be compared among lakes to evaluate there is evidence for a severe bottleneck in the Hole Lake sample.

<u>Lake sediment analysis:</u>

Hole Lake is the only land-locked lake known to contain a lake trout population in the vicinity of Togiak Refuge. Thus, understanding how and when it was a part of the surrounding metapopulation of lake trout may require additional information than is possible from the genetics analysis alone. To this end, the timing and duration of past connections of this lake to the surrounding watershed were investigated. Lake sediments were collected from Hole Lake in order to test for the presence of marine-derived nutrients. Sediments were analyzed for presence of $\delta^{15}N$, which, if present above background levels, would indicate that marine nutrients were deposited. If present, ^{14}C dating of the strata bearing the $\delta^{15}N$ will establish the timing and duration that anadromous salmon used the lake, thus establishing that there was a connection with an adjacent riparian system. That will indicate timing of isolation and connection of this lake with other water bodies, from which lake trout could have immigrated. If $\delta^{15}N$ is not found above background levels, this will suggest isolation of this population of fish since the retreat of Togiak River valley glaciers approximately 11,000 years ago, at which time glacial floodwater likely connected Hole Lake to other lake trout populations.

<u>Watershed mapping</u>

Watershed delineation was performed using ArcView 3.3 on a hydrologic coverage derived from the Digital Chart of the World for Alaska (ESRI 1996). Distances between lake trout populations within watersheds was calculated by measuring the distances of the shortest connecting streams.

Results

Lake Sampling

<u>Hole Lake</u>

During the period 2-8 August 2004, lake trout fin clips were collected at Hole Lake. Monofilament experimental gillnets were set for approximately one hour periods and captured 24 lake trout in a total of 39.03 hours fished. Lake trout fork length ranged from 222 mm to 565 mm with a mean of 415.48 mm (SD 109.50). Weight ranged from 150 g to 2,650 g with a mean of 1,185 g (SD 834.51). Seven mortalities occurred. These mortalities appeared to be mostly due to smaller fish (mean FL 335.57 mm, SD 91.03) asphyxiating when trapped in the larger mesh sizes of net. No other species were captured in monofilament gillnets. Multifilament experimental gillnet was also set at various depths for a total of 13.32 hours but did not capture any fish. Similarly, angling with spinning gear was attempted by two technicians for a total of 5.75 hours with no fish captured. A fyke net with a 30.5 m lead was set at various depths perpendicular from shore for a total of 84.75 hours but did not capture any fish. Three minnow traps were fished for a total of 256.4 hours and caught one ninespine stickleback (*Pungitius pungitius)*, 94 coastrange sculpins (*Cottus aleuticus*) and one Alaska blackfish (*Dallia pectoralis*). Two 20-m seine transects were pulled in shallow, vegetated areas of the lake to target species present and captured 184 ninespine sticklebacks and 5 coastrange sculpins.

On 17 August 2004, D. Gwinn and P. Abraham interviewed eight residents from the village of Togiak on lake trout distribution. Most of the respondents were aware that lake trout occurred in Hole Lake, and stated that they were present for as long as they remember, arguing against a recent establishment such as an intentional release. One respondent also referred to the Hole Lake lake trout as the fish one "cannot catch", referring to the propensity for these fish not to be susceptible to fishing lures used by anglers.

On 28 June 2005, three anglers attempted to catch lake trout in Hole Lake. One angler used spinning tackle to fish the entire shoreline while the other two anglers used casting and jigging methods in deep water in the lake center. No lake trout or any other fish were caught. This is consistent with the results from the August 2004 survey, in that lake trout were not caught via angling methods. Additionally, during a three-day lake inventory in August 2001, lake trout were not caught at Hole Lake by four anglers, although three specimens were caught in gill nets (Nelle 2002).

F. Hu, University of Illinois, collected a 3 m sediment core from the deepest part of Hole Lake on 21 July 2005. The $\delta^{15}N$ levels at Hole Lake varied between ~.013 - .037% (Fig. 4). $\delta^{15}N$ levels at Grandfather Lake (a non-salmon lake located on the eastern edge of the study area) varied between ~0 - .027% from about 14,000 yr. BP until present (Hu et al. 2001). $\delta^{15}N$ levels at High Lake (another non-salmon lake located within the study area) varied between ~.022 - .047% from about 1650 AD until present (pers. comm. D. Schindler). Thus, $\delta^{15}N$ levels in Hole Lake are intermediate between the non-salmon lakes and lower than Togiak Lake (a salmon lake within the study area), which varied from .033 - .058% from ~1650 AD until present (pers. comm. D. Schindler). Thus, Hole Lake $\delta^{15}N$ levels are consistent with other local non-salmon lakes throughout its entire history, arguing for isolation of this lake since establishment.

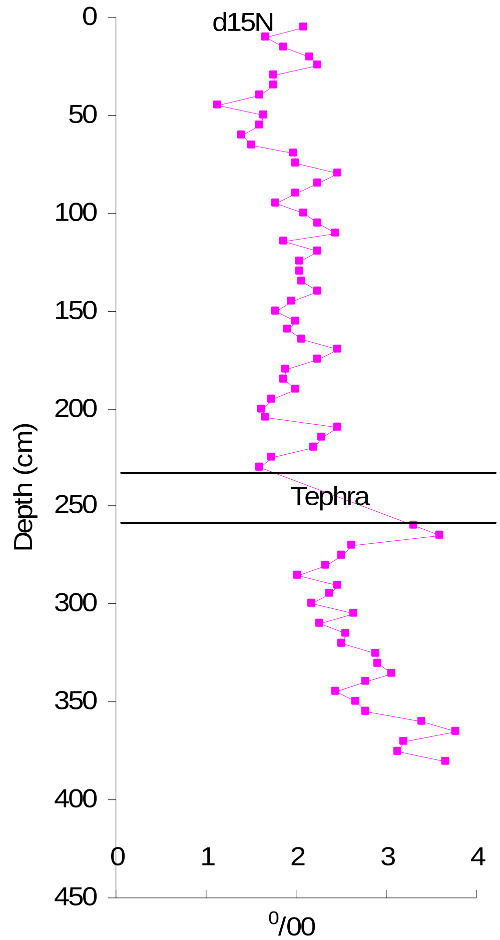

Fig. 4. Stable isotope ratio of nitrogen in the sediments of Hole Lake. The tephra layer likely represents the Aniakchak eruption (3,550 yr. BP). Core has not yet been dated.

<u>Middle Fork Lake</u>

During the period 20-21 June 2005, lake trout fin clips were collected at Middle Fork Lake by three anglers. Forty-three lake trout were captured using angling methods, both by casting and by trolling from an inflatable motor boat. Lake trout occurred in the shallows and at varying depths to ~15m. The only other species encountered was Arctic char (*S. alpinus*). On 28 June 2005, two anglers returned to Middle Fork Lake and collected an additional 4 lake trout samples. Of the 47 fish captured, three had tags from a lake survey conducted on 18 June and 8 August 2001 at which time 18 lake trout were captured and fin clips were collected from 10. Thus, the total number of genetic specimens from Middle Fork Lake totals 54. Photographs were taken from a total of 20 lake trout.

Lake trout fork length ranged from 395 mm to 565 mm with a mean of 484.94 mm (SD 33.45). Weight ranged from 820 g to 2,140 g with a mean of 1,344 g (SD 244.69). No mortalities were documented in Middle Fork Lake lake trout. Length and weight data from the three lake trout originally captured in 2001, then recaptured in 2005, indicate growth in all fish. However, growth rate was variable. Length increases ranged from 3.9 to 17.8% and weight increases ranged from 5.1 to 28.6%, with the shortest and lightest individual growing at the greatest rate, and the longest and heaviest individual growing at the slowest rate.

Canyon Lake

During the period 21-22 June 2005, fin clips were collected from lake trout at Canyon Lake by three anglers. Fifty lake trout were captured using angling methods, including by casting and by trolling. Arctic char was the only other species captured at Canyon Lake.

Canyon Lake lake trout fork length ranged from 395 mm to 600 mm with a mean of 463.4 mm (SD 31.89 mm). Weight ranged from 720 g to 3,020 g with a mean of 1,201.1 g (SD 344.46). A single hooking mortality was documented at Canyon Lake.

Arolik Lake

During the period, 23-24 June 2005, Arolik Lake was surveyed. Fifty lake trout were captured using angling methods, including casting and trolling from shore and by boat. A single rainbow trout (*Oncorhynchus mykiss*) was the only non-target fish captured. The Arolik Lake lake trout appeared darker and more "football" shaped than lake trout from the other lakes surveyed.

The lake trout fork length ranged from 370 mm to 477 mm with a mean of 426.9 mm (SD 27.26 mm). Weight ranged from 595 g to 1,545 g with a mean of 962.9 g (SD 226.62 mm). A single mortality was documented at Arolik Lake. This fish contained snails in its gut. Palpating the abdomens from a sample of the other lake trout caught and released indicated that many of them also contained snails. This was not noticed in other lakes.

Goodnews Lake

During the period 24-25 June 2005, Goodnews Lake was surveyed. Three anglers captured fifty lake trout using angling methods. An additional single dead lake trout was found in the lake immediately after a party of sport fishermen departed. This fish had an injury on a gill raker, and was assumed to be a hooking mortality. In addition to this, a total of two mortalities were caused by our sampling at Goodnews Lake.

Fork length in Goodnews Lake lake trout ranged from 392 mm to 570 mm with a mean of 481.3 mm (SD 42.78 mm). Weight ranged from 670 g to 2,420 g with a mean of 1,362.65 g (SD 382.44 mm). Non-target species caught at Goodnews Lake included ~20 Arctic char and a single northern pike (*Esox lucius*), which is the first documented record of a northern pike in this lake.

Ongivinuk Lake

During the period 26-27 June 2005, Ongivinuk Lake was surveyed. On 26 June, three anglers casted, trolled, and jigged at all likely locations in the lake, including at the surface, in deep water, at the mouth of all inlet streams, at the lake outlet, and at underwater structure, but caught no lake trout. Approximately 35 Arctic char were caught. On 27 June, a monofilament experimental gill net was set at eight locations for time durations ranging from 7-45 minutes (mean = 32.4 minutes). A total of three whitefish (identity uncertain, but probably *Prosopium cylindraceum*), 16 Arctic char, and three sockeye salmon (*Oncorhynchus nerka*) were captured. No lake trout were caught. Of the fish captured there were four mortalities including two whitefish and two Arctic char.

The original report that lake trout occur in this lake is based on a single specimen caught by B. Sweeney in June 2004. The fish was caught on spinning tackle at the lake outlet. A clear photo was taken that identifies the fish as a lake trout, so we rule out the possibility of mis-identification. Given the results of the lake survey in 2005, we find it unlikely that a lake trout population occurs in Ongivinuk Lake. We find it more likely that the individual captured in 2004 was a pioneer that had originated from another lake.

Kagati Lake

During the period 7-9 August 2005, Kagati Lake was surveyed by 2-4 anglers. Although all likely locations were fished, only six lake trout were caught. Those caught were relatively deep (~7m). Water temperature was 14^{o}C, which was likely near the lake's annual maximium. A sampling crew of 3 anglers returned to the lake during the period 14-15 June 2006 and captured an additional 46 lake trout. The 2006 sampling period occurred at the time of ice-out, at which approximately 10% of the lake was still ice covered.

Fork length in Kagati Lake lake trout ranged from 368 mm to 555 mm with a mean of 495.6 mm (SD 32.65 mm). Weight ranged from 470 g to 2,020 g with a mean of 1,376.86 g (SD 299.71 mm). Non-target species caught at Kagati Lake included 2 Arctic char and ~10 sockeye salmon during the 2005 trip and 2 Arctic char and 1 round whitefish in 2006. Leech-like external parasites were found attached to about 25% of the Kagati Lake lake trout. The "leeches" were approximately 2-3 cm in length, ~3 mm in diameter, and olive green in color. They were not noticed on any of the lakes sampled in 2005, but were noticed at Kagati Lake and all subsequent lakes sampled in 2006.

Tikchik Lake

During the period 19-20 July 2005, fin clips were collected from 50 lake trout at Tikchik Lake by C. Schwanke. Fork length in Tikchik Lake lake trout ranged from 450 mm to 665 mm with a mean of 545.26 mm (SD 40.32 mm). Weight ranged from 1,000 g to 3,160 g with a mean of 2,038 g (SD 441.54 mm).

Salmon Lake

During the period 17-19 June 2006, Salmon Lake was sampled by four anglers. Thirty-four lake trout were captured using angling methods, including by casting and by trolling. Arctic char was the only other species captured at Canyon Lake. Salmon Lake lake trout were more colorful than those at any other lake, with brighter orange in fins. Non-target fish caught included ~6 Arctic grayling *(Thymallus arcticus)*, 1 whitefish (in the mouth of a lake trout), 1 burbot (*Lota lota*), in the gills of a lake trout), and one salmon (probably *O. tshawytscha)*.

Salmon Lake lake trout fork length ranged from 460 mm to 675 mm with a mean of 542.06 mm (SD 53.60 mm). Weight ranged from 920 g to 4,020 g with a mean of 2,081.77 g (SD 766.34). No hooking mortality or injuries were documented at Salmon Lake.

Heart Lake

During the period, 19-21 June 2006, Heart Lake was surveyed by four anglers. Fifty-three lake trout were captured using angling methods, including casting and trolling from shore and by boat. Non-target fish included ~6 Arctic char and a single sculpin. Lake trout fork length ranged from 405 mm to 540 mm with a mean of 446.89 mm (SD 21.42 mm). Weight ranged from 620 g to 1,770 g with a mean of 1,044.53 g (SD 193.62 mm). One hooking injury and no confirmed mortalities were documented at Heart Lake.

<u>Little Swift Lake</u>

During the period 21-22 June 2006, Little Swift Lake was surveyed. Two anglers captured 24 lake trout using angling methods from the lake shore. No other species were caught. A total of two mortalities and one hooking injury was attributed to our sampling at Little Swift Lake.

Fork length in Little Swift Lake lake trout ranged from 400 mm to 595 mm with a mean of 457.71 mm (SD 46.01 mm). Weight ranged from 570 g to 2,720 g with a mean of 1,032.50 g (SD 433.20 mm).

<u>Nenevok Lake</u>

During the period 7-8 July 2006, fin clips were collected from lake trout at Nenevok Lake by two anglers. Fifty lake trout were captured using angling methods, including by casting and by trolling. A single chum salmon (*O. keta*) and 25-30 Arctic char were also captured at Nenevok Lake. Unlike most other lakes, lake trout were abundant in the upper 400m of the outflow stream where water depth was <1m.

Nenevok Lake lake trout fork length ranged from 390 mm to 570 mm with a mean of 465.7 mm (SD 36.26 mm). Weight ranged from 620 g to 2,120 g with a mean of 1,275.0 g (SD 298.51). Three mortalities and two hooking injuries were documented at Nenevok Lake. One of the mortalities included two shrews in its gut. Approximately four of the Nenevok Lake lake trout had fin deformities, including shortened caudal, dorsal, and pelvic fins, and caudal fins more deeply indented to a u-shape than normal.

<u>Kanuktik Lake</u>

During the period, 10-11 July 2006, Kanuktik Lake was surveyed by two anglers. Fifty lake trout were captured using angling methods, including casting and trolling from shore and by boat. A single Arctic char was the only non-target fish captured.

Fork length in Kanuktik Lake lake trout ranged from 370 mm to 580 mm with a mean of 451.4 mm (SD 32.68 mm). Weight ranged from 620 g to 2,270 g with a mean of 1,047 g (SD 266.73 mm). Three hooking mortalities and one injury were documented at Kanuktik Lake.

<u>Ohnlik Lake</u>

During the period 12-13 July 2006, Ohnlik Lake was surveyed. Two anglers captured fifty lake trout using angling methods. Our sampling resulted in two mortalities and two injuries.

Fork length in Ohnlik Lake lake trout ranged from 395 mm to 490 mm with a mean of 440.7 mm (SD 21.86 mm). Weight ranged from 620 g to 1,270 g with a mean of 952.0 g (SD 150.77 mm). Sockeye salmon were observed and a single Arctic char was caught.

Chikimunik Lake

On 6 July 2006, C. Schwanke collected fin clips from 50 lake trout at Chikimunik Lake. Fork length ranged from 420 mm to 624 mm with a mean of 440.7 mm (SD 32.42 mm). Weight ranged from 750 g to 2,750 g with a mean of 1,049.0 g (SD 304.47).

Size Structure

Size indices were calculated for all 14 lake trout populations (Appendix A, Fig. 5). Comparisons among lake trout populations were performed for all lakes except Hole Lake, which was not included since the capture method (entanglement netting) was different from all other lakes (where angling was used exclusively). Size structure data were determined to be both non-normal and have unequal variance structure. The Kruskal-Wallis test indicated that not all size

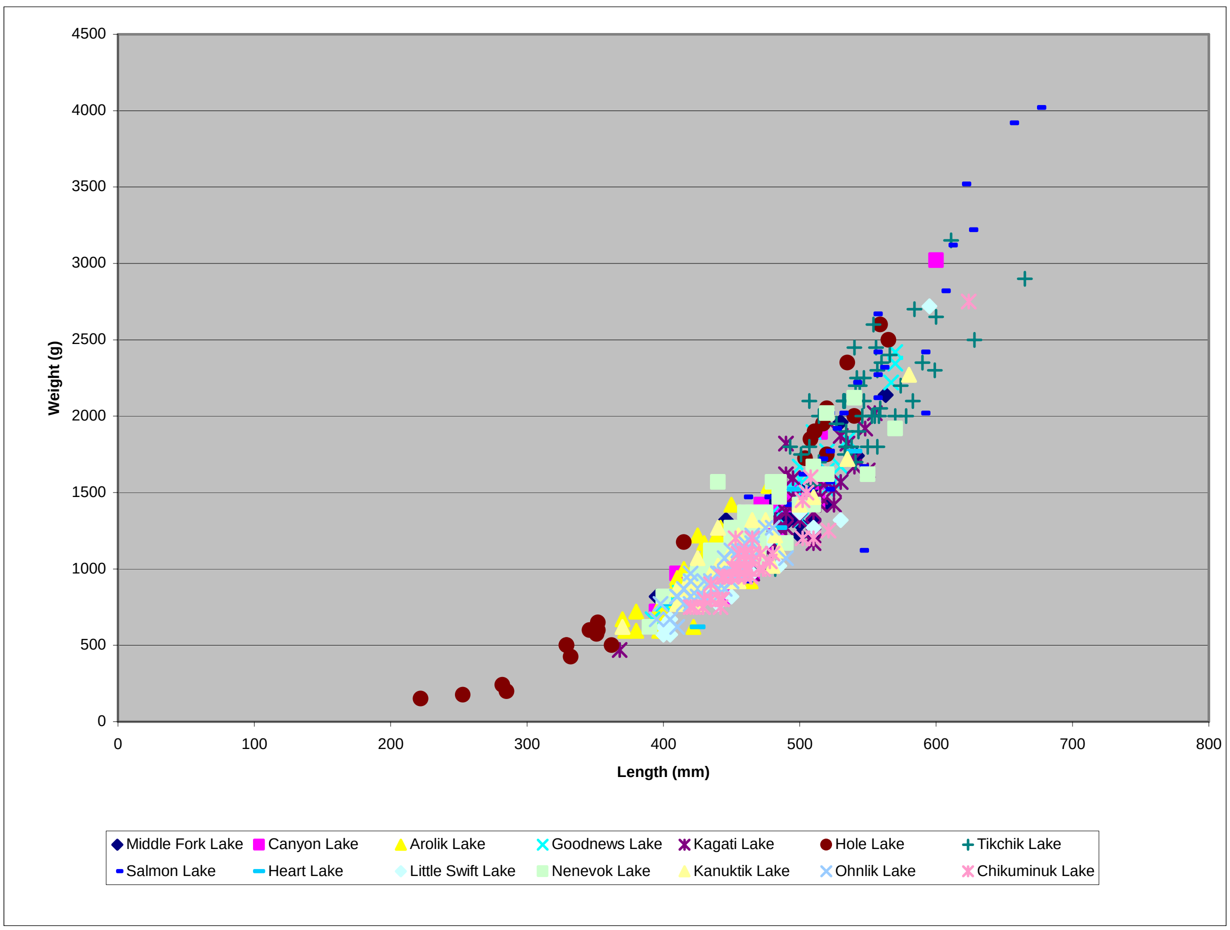

Fig. 5. Length-weight relationships of lake trout in 14 populations in the vicinity of Togiak National Wildlife Refuge, Alaska.

structures were equal among lakes (P < 0.00001, Chi square = 272.85, d.f. = 12). The Tukey-Kramer multiple comparison test indicated that the lake trout populations fell into three general groups (Fig. 6) as such:

a) Lake trout in Salmon and Tikchik Lakes were similar in size structure, and larger than all other lakes.
b) Lake trout in Ohnlik, Little Swift, Arolik, Chikuminuk, Kanuktik, and Heart Lakes were not different from each other, and were significantly smaller than the remaining lakes (except that Ohnlik Lake was the only lake in this group different from Canyon Lake).
c) Lake trout in Nenevok, Kagati, Middle Fork, and Goodnews Lakes were not different from each other, were significantly smaller than the Salmon and Tikchik Lake fish, but significantly larger than the Ohnlik, Little Swift, Arolik, Chikuminuk, Kanuktik, and Heart Lakes group.
d) Canyon Lake lake trout were significantly smaller than those in Salmon and Tikchik Lakes, larger than those in Ohnlik Lake, but not different from the remaining nine lakes.

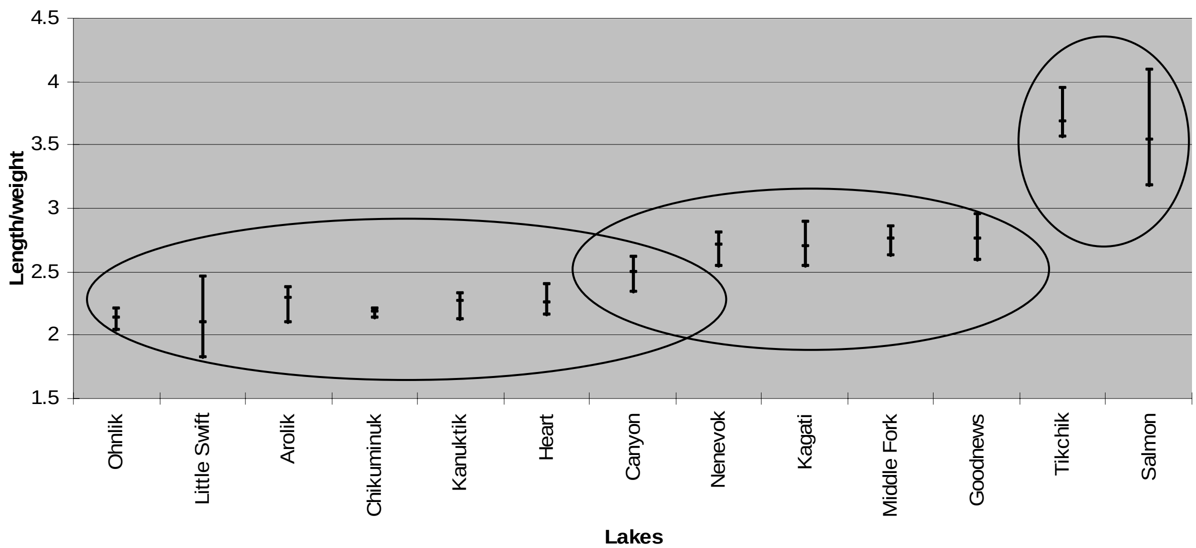

Figure 6. Size structure of lake trout lakes on and near Togiak National Wildlife Refuge. Values are median weight/length (g/mm) indices and 95% confidence intervals around the median. Populations within circled groups have similar size structures.

Geographic Distances Between Populations

Geographic distances between populations within watersheds were determined for 11 lakes in four watersheds (Table 1, Fig. 7). No distances were calculated for Arolik Lake, as it contains the sole lake trout population in the Arolik Watershed, or for Nenevok and Hole Lakes, as they are not currently connected, even though both are in the Togiak Watershed.

Table 1. Geographic distances between lake trout populations connected by existing streams in Togiak Refuge watersheds.

Watershed	From:	To:	Distance (m)
Goodnews	Middle Fork	Canyon	144803
	Canyon	Goodnews	61333
	Goodnews	Middle Fork	161378
Kanektok	Ohnlik	Kanuktik	9261
	Kanuktik	Kanektok	47389
	Kanektok	Ohnlik	50836
Kwethluk	Salmon	Little Swift	88915
Nushagak	Heart	Chikimunik	32747
	Chikimunik	Tikchik	24016
	Tikchik	Heart	56763

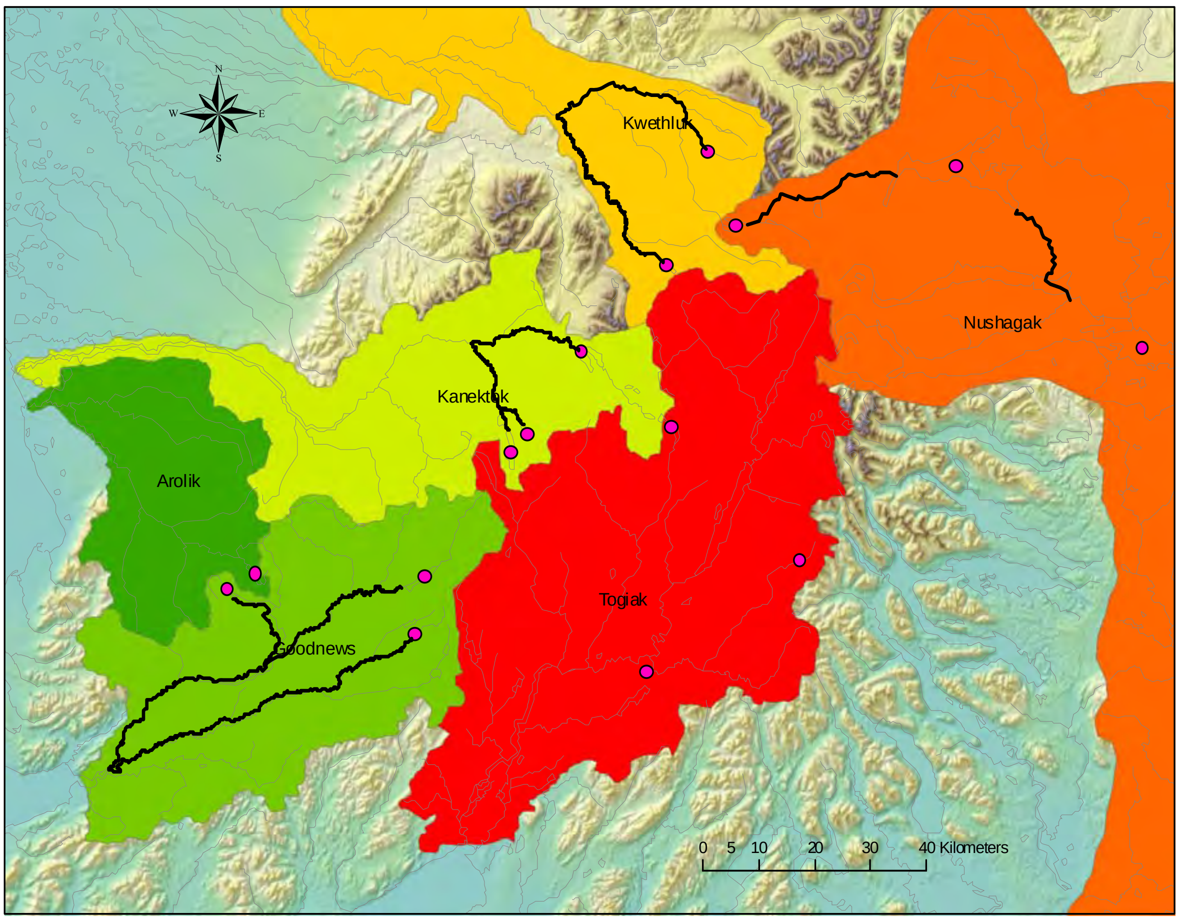

Figure 7. Connecting streams between lake trout populations within Togiak Refuge watersheds.

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knowledge on lake trout distribution from residents of Togiak. A Hole Lake sediment core was collected and analyzed by F. Hu and his team.

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Appendix A. Length/weight indices and summary size statistics for lake trout populations on and near Togiak National Wildlife Refuge.

Lake	**Length**	**Weight**	**Length/weight index**
Hole	517	1950	0.265128
Hole	565	2500	0.226
Hole	282	240	1.175
Hole	504	1725	0.292174
Hole	508	1850	0.274595
Hole	415	1175	0.353191
Hole	511	1900	0.268947
Hole	540	2000	0.27
Hole	520	2050	0.253659
Hole	559	2600	0.215
Hole	346	600	0.576667
Hole	329	500	0.658
Hole	253	175	1.445714
Hole	329	500	0.658
Hole	352	600	0.586667
Hole	351	575	0.610435
Hole	520	1750	0.297143
Hole	285	200	1.425
Hole	535	2350	0.22766
Hole	362	500	0.724
Hole	485	1475	0.328814
Hole	352	650	0.541538
Hole	332	425	0.781176
Hole	222	150	1.48
Middle Fork	456	1200	0.38
Middle Fork	481	1520	0.316447
Middle Fork	498		
Middle Fork	510	1320	0.386364
Middle Fork	500	1220	0.409836
Middle Fork	446	1320	0.337879
Middle Fork	473	1220	0.387705
Middle Fork	508	1520	0.334211
Middle Fork	483	1120	0.43125
Middle Fork	500	1520	0.328947
Middle Fork	500	1295	0.3861
Middle Fork	508	1520	0.334211
Middle Fork	485	1330	0.364662
Middle Fork	542	1740	0.311494
Middle Fork	420	870	0.482759
Middle Fork	412	920	0.447826
Middle Fork	510	1220	0.418033
Middle Fork	563	2140	0.263084
Middle Fork	488	1320	0.369697

	Hole	
	Length	*Weight*
Mean	415.5833	1185
Standard Error	22.35095	170.3441
Median	388.5	912.5
Mode	520	500
Standard Deviation	109.4968	834.5124
Sample Variance	11989.56	696410.9
Kurtosis	-1.509	-1.54764
Skewness	-0.12286	0.26312
Range	343	2450
Minimum	222	150
Maximum	565	2600
Sum	9974	28440
Count	24	24
Largest(1)	565	2600
Smallest(1)	222	150
Confidence Level(95.0%)	46.2364	352.3832
Weight/length (g/mm)	2.851414	

	Middle Fork	
	Length	*Weight*
Mean	484.9362	1344
Standard Error	4.87915	36.4756
Median	488	1320
Mode	480	1520
Standard Deviation	33.44977	244.6858
Sample Variance	1118.887	59871.14
Kurtosis	1.166586	2.337322
Skewness	-0.19366	0.726459
Range	170	1320
Minimum	395	820
Maximum	565	2140
Sum	22792	60480
Count	47	45
Largest(1)	565	2140
Smallest(1)	395	820
Confidence Level(95.0%)	9.821211	73.51175

Middle Fork	491	1370	0.358394
Middle Fork	498	1380	0.36087
Middle Fork	476	1320	0.360606
Middle Fork	530	1960	0.270408
Middle Fork	503	1520	0.330921
Middle Fork	472	1120	0.421429
Middle Fork	565		
Middle Fork	440	1170	0.376068
Middle Fork	480	1420	0.338028
Middle Fork	480	1245	0.385542
Middle Fork	457	1195	0.382427
Middle Fork	478	1270	0.376378
Middle Fork	488	1345	0.362825
Middle Fork	445	1170	0.380342
Middle Fork	496	1445	0.343253
Middle Fork	480	1370	0.350365
Middle Fork	450	1245	0.361446
Middle Fork	490	1520	0.322368
Middle Fork	395	820	0.481707
Middle Fork	492	1320	0.372727
Middle Fork	480	1370	0.350365
Middle Fork	494	1520	0.325
Middle Fork	481	1520	0.316447
Middle Fork	513	1620	0.316667
Middle Fork	460	1120	0.410714
Middle Fork	520	1420	0.366197
Middle Fork	458	1020	0.44902
Middle Fork	497	1370	0.362774
Canyon	425	900	0.472222
Canyon	440	920	0.478261
Canyon	445	820	0.542683
Canyon	515	1570	0.328025
Canyon	470	1170	0.401709
Canyon	454	1170	0.388034
Canyon	600	3020	0.198675
Canyon	462	1370	0.337226
Canyon	513	1445	0.355017
Canyon	458	1070	0.428037
Canyon	486	1420	0.342254
Canyon	430	920	0.467391
Canyon	451	1170	0.38547
Canyon	486	1520	0.319737
Canyon	395	720	0.548611
Canyon	475	1170	0.405983
Canyon	455	1070	0.425234
Canyon	493	1420	0.347183
Canyon	504	1470	0.342857
Canyon	475	1220	0.389344

Weight/length (g/mm)	2.771499

	Canyon	
	Length	*Weight*
Mean	463.4	1201.1
Standard Error	4.509582	48.71372
Median	460	1170
Mode	475	1170
Standard Deviation	31.88756	344.458
Sample Variance	1016.816	118651.3
Kurtosis	5.985821	15.43471
Skewness	1.572451	3.194165
Range	205	2300
Minimum	395	720
Maximum	600	3020
Sum	23170	60055
Count	50	50
Largest(1)	600	3020
Smallest(1)	395	720
Confidence Level(95.0%)	9.062338	97.89382
Weight/length (g/mm)	2.591929	

Canyon	450	970	0.463918
Canyon	460	1170	0.393162
Canyon	440	1020	0.431373
Canyon	515	1895	0.271768
Canyon	448	1170	0.382906
Canyon	485	1220	0.397541
Canyon	448	1020	0.439216
Canyon	465	970	0.479381
Canyon	436	970	0.449485
Canyon	461	1120	0.411607
Canyon	438	1020	0.429412
Canyon	410	970	0.42268
Canyon	465	1220	0.381148
Canyon	450	1220	0.368852
Canyon	435	1020	0.426471
Canyon	465	1120	0.415179
Canyon	475	1320	0.359848
Canyon	472	1420	0.332394
Canyon	460	1270	0.362205
Canyon	455	1070	0.425234
Canyon	433	870	0.497701
Canyon	460	1020	0.45098
Canyon	496	1520	0.326316
Canyon	452	970	0.465979
Canyon	485	1220	0.397541
Canyon	475	1270	0.374016
Canyon	468	1320	0.354545
Canyon	444	1170	0.379487
Canyon	452	1045	0.432536
Canyon	440	920	0.478261
Arolik	380	595	0.638655
Arolik	450	1070	0.420561
Arolik	410	820	0.5
Arolik	440	1120	0.392857
Arolik	400	595	0.672269
Arolik	450	1070	0.420561
Arolik	446	1020	0.437255
Arolik	432	1020	0.423529
Arolik	425	770	0.551948
Arolik	395	720	0.548611
Arolik	372	595	0.62521
Arolik	447	1220	0.366393
Arolik	465	1295	0.359073
Arolik	398	745	0.534228
Arolik	400	695	0.57554
Arolik	430	920	0.467391
Arolik	440	1020	0.431373
Arolik	422	620	0.680645
Arolik	477	1545	0.308738

	Arolik	
	Length	*Weight*
Mean	426.9	962.9
Standard Error	3.855158	32.04942
Median	430	965
Mode	430	1070
Standard Deviation	27.26009	226.6236
Sample Variance	743.1122	51358.26
Kurtosis	-0.39565	-0.30455
Skewness	-0.37117	0.131421
Range	107	950
Minimum	370	595
Maximum	477	1545
Sum	21345	48145
Count	50	50
Largest(1)	477	1545
Smallest(1)	370	595
Confidence	7.747226	64.40567

Level(95.0%)	
Weight/length (g/mm)	2.255563

Arolik	430	895	0.480447
Arolik	430	1070	0.401869
Arolik	420	970	0.43299
Arolik	450	960	0.46875
Arolik	470	1180	0.398305
Arolik	410	940	0.43617
Arolik	428	900	0.475556
Arolik	458	1120	0.408929
Arolik	440	940	0.468085
Arolik	415	1000	0.415
Arolik	397	740	0.536486
Arolik	452	1070	0.42243
Arolik	464	920	0.504348
Arolik	475	1195	0.39749
Arolik	450	1045	0.430622
Arolik	380	720	0.527778
Arolik	370	670	0.552239
Arolik	438	945	0.463492
Arolik	430	1170	0.367521
Arolik	441	1120	0.39375
Arolik	406	795	0.510692
Arolik	430	1095	0.392694
Arolik	430	1070	0.401869
Arolik	420	920	0.456522
Arolik	370	620	0.596774
Arolik	425	1220	0.348361
Arolik	442	1270	0.348031
Arolik	450	1420	0.316901
Arolik	439	1220	0.359836
Arolik	409	895	0.456983
Arolik	397	595	0.667227
Goodnews	430	845	0.508876
Goodnews	498	1570	0.317197
Goodnews	480	1195	0.401674
Goodnews	520	1620	0.320988
Goodnews	445	1045	0.425837
Goodnews	520	1770	0.293785
Goodnews	500	1420	0.352113
Goodnews	460	1270	0.362205
Goodnews	520	1645	0.316109
Goodnews	438	970	0.451546
Goodnews	432	1020	0.423529
Goodnews	498	1470	0.338776
Goodnews	438	1020	0.429412
Goodnews	412	845	0.487574
Goodnews	502	1570	0.319745
Goodnews	490	1420	0.34507
Goodnews	480	1220	0.393443

	Goodnews	
	Length	*Weight*
Mean	481.3333	1362.647
Standard Error	5.990494	53.55176
Median	480	1320
Mode	520	1570
Standard Deviation	42.78068	382.4361
Sample Variance	1830.187	146257.4
Kurtosis	-0.34355	0.741322
Skewness	0.00324	0.661525
Range	178	1750
Minimum	392	670
Maximum	570	2420
Sum	24548	69495
Count	51	51
Largest(1)	570	2420

Goodnews	465	1320	0.352273
Goodnews	470	1295	0.362934
Goodnews	470	1270	0.370079
Goodnews	530	1670	0.317365
Goodnews	520	1520	0.342105
Goodnews	400	770	0.519481
Goodnews	567	2220	0.255405
Goodnews	470	1220	0.385246
Goodnews	480	1370	0.350365
Goodnews	478	1295	0.369112
Goodnews	460	1045	0.440191
Goodnews	522	1545	0.337864
Goodnews	570	2420	0.235537
Goodnews	510	1895	0.269129
Goodnews	510	1620	0.314815
Goodnews	392	670	0.585075
Goodnews	460	1170	0.393162
Goodnews	525	1570	0.334395
Goodnews	490	1520	0.322368
Goodnews	420	845	0.497041
Goodnews	530	1570	0.33758
Goodnews	407	795	0.51195
Goodnews	483	1345	0.359108
Goodnews	501	1320	0.379545
Goodnews	470	1145	0.41048
Goodnews	520	1620	0.320988
Goodnews	454	1070	0.424299
Goodnews	570	2345	0.24307
Goodnews	500	1670	0.299401
Goodnews	460	1270	0.362205
Goodnews	456	1245	0.366265
Goodnews	430	920	0.467391
Goodnews	535	1845	0.289973
Goodnews	460	1170	0.393162
Tikchik	540	2450	0.220408
Tikchik	507	2100	0.241429
Tikchik	560	2350	0.238298
Tikchik	547	2250	0.243111
Tikchik	533	1750	0.304571
Tikchik	501	1750	0.286286
Tikchik	507	1800	0.281667
Tikchik	493	1800	0.273889
Tikchik	559	2050	0.272683
Tikchik	542	2250	0.240889
Tikchik	557	2300	0.242174
Tikchik	514	2000	0.257
Tikchik	590	2350	0.251064
Tikchik	600	2650	0.226415

Smallest(1)	392	670
Confidence Level(95.0%)	12.03227	107.5619
Weight/length (g/mm)	2.830984	

	Tikchik	
	Length	*Weight*
Mean	545.26	2038
Standard Error	5.702761	62.44279
Median	545	2025
Mode	507	2000
Standard Deviation	40.32461	441.5372
Sample Variance	1626.074	194955.1
Kurtosis	1.309307	1.189382
Skewness	0.139764	-0.37532
Range	215	2150
Minimum	450	1000
Maximum	665	3150

Tikchik	532	2100	0.253333	Sum	27263	101900
Tikchik	554	2600	0.213077	Count	50	50
Tikchik	541	2200	0.245909	Largest(1)	665	3150
Tikchik	527	1950	0.270256	Smallest(1)	450	1000
Tikchik	584	2700	0.216296	Confidence Level(95.0%)	11.46012	125.4834
Tikchik	556	2450	0.226939	Weight/length (g/mm)	3.737666	
Tikchik	611	3150	0.193968			
Tikchik	628	2500	0.2512			
Tikchik	599	2300	0.260435			
Tikchik	557	1800	0.309444			
Tikchik	456	1000	0.456			
Tikchik	533	2100	0.25381			
Tikchik	547	2100	0.260476			
Tikchik	514	1700	0.302353			
Tikchik	583	2100	0.277619			
Tikchik	468	1050	0.445714			
Tikchik	555	2000	0.2775			
Tikchik	550	1800	0.305556			
Tikchik	570	2000	0.285			
Tikchik	450	1000	0.45			
Tikchik	665	2900	0.22931			
Tikchik	558	2000	0.279			
Tikchik	566	2400	0.235833			
Tikchik	546	2000	0.273			
Tikchik	543	1900	0.285789			
Tikchik	541	1700	0.318235			
Tikchik	578	2000	0.289			
Tikchik	534	1900	0.281053			
Tikchik	553	2000	0.2765			
Tikchik	534	1800	0.296667			
Tikchik	544	2200	0.247273			
Tikchik	532	2100	0.253333			
Tikchik	574	2200	0.260909			
Tikchik	538	1800	0.298889			
Tikchik	510	1550	0.329032			
Tikchik	482	1000	0.482			
Kagati	482	1320	0.365152		*Kagati*	
Kagati	540	1670	0.323353		*Length*	*Weight*
Kagati	464	1170	0.396581			
Kagati	495	1595	0.310345	Mean	495.6275	1376.863
Kagati	368	470	0.782979	Standard Error	4.571777	41.968
Kagati	550	1645	0.334347	Median	495	1370
Kagati	465	1120	0.415179	Mode	490	1170
Kagati	460	1070	0.429907	Standard Deviation	32.64902	299.7115
Kagati	505	1470	0.343537	Sample Variance	1065.958	89826.96
Kagati	515	1420	0.362676	Kurtosis	3.446589	0.692287
Kagati	535	1820	0.293956	Skewness	-1.00221	-0.07069
Kagati	435	870	0.5	Range	187	1550

Kagati	525	1420	0.369718
Kagati	475	1220	0.389344
Kagati	490	1820	0.269231
Kagati	500	1420	0.352113
Kagati	510	1270	0.401575
Kagati	465	1120	0.415179
Kagati	515	1470	0.35034
Kagati	470	1170	0.401709
Kagati	548	1920	0.285417
Kagati	540	1720	0.313953
Kagati	495	1470	0.336735
Kagati	520	1970	0.263959
Kagati	490	1370	0.357664
Kagati	475	1120	0.424107
Kagati	465	970	0.479381
Kagati	485	1120	0.433036
Kagati	510	1220	0.418033
Kagati	475	1120	0.424107
Kagati	530	1870	0.283422
Kagati	515	1620	0.317901
Kagati	500	1320	0.378788
Kagati	510	1370	0.372263
Kagati	555	2020	0.274752
Kagati	530	1570	0.33758
Kagati	515	1570	0.328025
Kagati	520	1570	0.33121
Kagati	480	1170	0.410256
Kagati	485	1270	0.38189
Kagati	480	1170	0.410256
Kagati	510	1170	0.435897
Kagati	495	1470	0.336735
Kagati	490	1270	0.385827
Kagati	480	1220	0.393443
Kagati	450	1020	0.441176
Kagati	490	1420	0.34507
Kagati	480	1270	0.377953
Kagati	480	1170	0.410256
Kagati	490	1620	0.302469
Kagati	525	1520	0.345395
Salmon	555	2120	0.261792
Salmon	490	1420	0.34507
Salmon	520	1570	0.33121
Salmon	460	920	0.5
Salmon	510	1620	0.314815
Salmon	545	1670	0.326347
Salmon	460	1470	0.312925
Salmon	540	2220	0.243243
Salmon	510	1670	0.305389

Minimum	368	470
Maximum	555	2020
Sum	25277	70220
Count	51	51
Largest(1)	555	2020
Smallest(1)	368	470
Confidence Level(95.0%)	9.182684	84.29521
Weight/length (g/mm)	2.77802	

	Salmon	
	Length	*Weight*
Mean	542.0588	2081.765
Standard Error	9.192237	131.4267
Median	527.5	1970
Mode	520	2020
Standard Deviation	53.59949	766.343
Sample Variance	2872.906	587281.6

Salmon	620	3520	0.176136
Salmon	520	2020	0.257426
Salmon	505	1520	0.332237
Salmon	500	1620	0.308642
Salmon	520	2020	0.257426
Salmon	460	1220	0.377049
Salmon	555	2670	0.207865
Salmon	525	1920	0.273438
Salmon	510	1420	0.359155
Salmon	555	2420	0.229339
Salmon	675	4020	0.16791
Salmon	560	2320	0.241379
Salmon	655	3920	0.167092
Salmon	530	2020	0.262376
Salmon	475	1470	0.323129
Salmon	515	1720	0.299419
Salmon	520	1520	0.342105
Salmon	545	1120	0.486607
Salmon	590	2420	0.243802
Salmon	605	2820	0.214539
Salmon	555	2270	0.244493
Salmon	520	1770	0.293785
Salmon	610	3120	0.195513
Salmon	590	2020	0.292079
Salmon	625	3220	0.194099

Kurtosis	0.144965	0.652153
Skewness	0.674814	1.053413
Range	215	3100
Minimum	460	920
Maximum	675	4020
Sum	18430	70780
Count	34	34
Largest(1)	675	4020
Smallest(1)	460	920
Confidence Level(95.0%)	18.70175	267.3897
Weight/length (g/mm)	3.840477	

Heart	430	970	0.443299
Heart	430	970	0.443299
Heart	435	870	0.5
Heart	440	920	0.478261
Heart	450	970	0.463918
Heart	440	970	0.453608
Heart	425	1020	0.416667
Heart	440	870	0.505747
Heart	425	870	0.488506
Heart	450	1070	0.420561
Heart	430	970	0.443299
Heart	430	920	0.467391
Heart	450	1120	0.401786
Heart	420	920	0.456522
Heart	450	1020	0.441176
Heart	460	970	0.474227
Heart	425	870	0.488506
Heart	430	920	0.467391
Heart	445	1070	0.415888
Heart	425	970	0.438144
Heart	445	1120	0.397321
Heart	445	920	0.483696

	Heart	
	Length	*Weight*
Mean	446.8868	1044.528
Standard Error	2.94244	26.59542
Median	445	1020
Mode	450	970
Standard Deviation	21.42129	193.6175
Sample Variance	458.8716	37487.75
Kurtosis	6.02267	3.138607
Skewness	1.731883	1.212764
Range	135	1150
Minimum	405	620
Maximum	540	1770
Sum	23685	55360
Count	53	53
Largest(1)	540	1770
Smallest(1)	405	620
Confidence Level(95.0%)	5.904438	53.3676
Weight/length (g/mm)	2.337344	

Heart	405	770	0.525974
Heart	455	1120	0.40625
Heart	450	1120	0.401786
Heart	450	920	0.48913
Heart	450	1170	0.384615
Heart	460	1370	0.335766
Heart	465	1270	0.366142
Heart	435	870	0.5
Heart	435	970	0.448454
Heart	465	1070	0.434579
Heart	475	1370	0.346715
Heart	430	920	0.467391
Heart	425	620	0.685484
Heart	470	1220	0.385246
Heart	450	1170	0.384615
Heart	495	1520	0.325658
Heart	465	1120	0.415179
Heart	540	1770	0.305085
Heart	450	1220	0.368852
Heart	440	945	0.465608
Heart	440	970	0.453608
Heart	435	795	0.54717
Heart	470	1220	0.385246
Heart	455	1220	0.372951
Heart	440	1020	0.431373
Heart	450	1120	0.401786
Heart	450	1020	0.441176
Heart	425	820	0.518293
Heart	485	1270	0.38189
Heart	455	1020	0.446078
Heart	450	1070	0.420561
Little Swift	405	670	0.604478
Little Swift	450	970	0.463918
Little Swift	400	570	0.701754
Little Swift	480	1220	0.393443
Little Swift	470	1120	0.419643
Little Swift	450	1220	0.368852
Little Swift	475	1170	0.405983
Little Swift	450	1120	0.401786
Little Swift	465	970	0.479381
Little Swift	400	620	0.645161
Little Swift	500	1370	0.364964
Little Swift	440	920	0.478261
Little Swift	530	1320	0.401515
Little Swift	440	770	0.571429
Little Swift	450	820	0.54878
Little Swift	415	820	0.506098
Little Swift	510	1270	0.401575
Little Swift	470	1070	0.439252

	Little Swift	
	Length	*Weight*
Mean	457.7083	1032.5
Standard Error	9.392697	88.42677
Median	450	970
Mode	450	970
Standard Deviation	46.01463	433.2009
Sample Variance	2117.346	187663
Kurtosis	2.148949	9.891041
Skewness	1.119074	2.607135
Range	195	2150
Minimum	400	570
Maximum	595	2720
Sum	10985	24780
Count	24	24
Largest(1)	595	2720
Smallest(1)	400	570

Little Swift	485	1020	0.47549
Little Swift	435	870	0.5
Little Swift	460	970	0.474227
Little Swift	595	2720	0.21875
Little Swift	405	570	0.710526
Little Swift	405	620	0.653226
Nenevok	390	620	0.629032
Nenevok	440	870	0.505747
Nenevok	465	1220	0.381148
Nenevok	470	1070	0.439252
Nenevok	455	1220	0.372951
Nenevok	440	1120	0.392857
Nenevok	435	1020	0.426471
Nenevok	470	1120	0.419643
Nenevok	435	1120	0.388393
Nenevok	440	1020	0.431373
Nenevok	400	820	0.487805
Nenevok	460	1270	0.362205
Nenevok	470	1320	0.356061
Nenevok	515	1620	0.317901
Nenevok	420	920	0.456522
Nenevok	450	1220	0.368852
Nenevok	425	970	0.438144
Nenevok	440	1570	0.280255
Nenevok	420	870	0.482759
Nenevok	550	1620	0.339506
Nenevok	485	1570	0.308917
Nenevok	468	1320	0.354545
Nenevok	470	1220	0.385246
Nenevok	460	1370	0.335766
Nenevok	510	1420	0.359155
Nenevok	460	1370	0.335766
Nenevok	460	1270	0.362205
Nenevok	470	1170	0.401709
Nenevok	540	2120	0.254717
Nenevok	570	1920	0.296875
Nenevok	510	1670	0.305389
Nenevok	425	920	0.461957
Nenevok	520	2020	0.257426
Nenevok	500	1420	0.352113
Nenevok	520	1620	0.320988
Nenevok	480	1570	0.305732
Nenevok	460	1120	0.410714
Nenevok	485	1470	0.329932
Nenevok	465	1370	0.339416
Nenevok	490	1170	0.418803
Nenevok	435	1070	0.406542

Confidence Level(95.0%)	19.43027	182.9247
Weight/length (g/mm)	2.255803	

	Nenevok	
	Length	*Weight*
Mean	465.7	1275
Standard Error	5.128492	42.21543
Median	460	1245
Mode	460	1220
Standard Deviation	36.26391	298.5082
Sample Variance	1315.071	89107.14
Kurtosis	0.867113	0.956661
Skewness	0.699609	0.668644
Range	180	1500
Minimum	390	620
Maximum	570	2120
Sum	23285	63750
Count	50	50
Largest(1)	570	2120
Smallest(1)	390	620
Confidence Level(95.0%)	10.30609	84.83509
Weight/length (g/mm)	2.737814	

Nenevok	467	1270	0.367717
Nenevok	450	1120	0.401786
Nenevok	475	1320	0.359848
Nenevok	430	970	0.443299
Nenevok	475	1370	0.346715
Nenevok	460	1220	0.377049
Nenevok	450	1170	0.384615
Nenevok	450	1270	0.354331
Nenevok	455	1270	0.358268
Kanuktik	425	770	0.551948
Kanuktik	460	1070	0.429907
Kanuktik	450	970	0.463918
Kanuktik	440	1270	0.346457
Kanuktik	445	1020	0.436275
Kanuktik	430	820	0.52439
Kanuktik	425	870	0.488506
Kanuktik	410	870	0.471264
Kanuktik	420	920	0.456522
Kanuktik	435	820	0.530488
Kanuktik	435	920	0.472826
Kanuktik	435	970	0.448454
Kanuktik	425	1070	0.397196
Kanuktik	445	1020	0.436275
Kanuktik	510	1470	0.346939
Kanuktik	445	920	0.483696
Kanuktik	415	870	0.477011
Kanuktik	450	970	0.463918
Kanuktik	450	1070	0.420561
Kanuktik	440	1020	0.431373
Kanuktik	450	1120	0.401786
Kanuktik	455	920	0.494565
Kanuktik	458	1120	0.408929
Kanuktik	475	1320	0.359848
Kanuktik	450	970	0.463918
Kanuktik	455	1070	0.425234
Kanuktik	465	1120	0.415179
Kanuktik	425	770	0.551948
Kanuktik	482	1220	0.395082
Kanuktik	440	1020	0.431373
Kanuktik	465	1320	0.352273
Kanuktik	410	770	0.532468
Kanuktik	455	1220	0.372951
Kanuktik	455	1020	0.446078
Kanuktik	460	1070	0.429907
Kanuktik	460	1070	0.429907
Kanuktik	480	1020	0.470588
Kanuktik	450	970	0.463918
Kanuktik	440	820	0.536585

	Kanuktik Length	Weight
Mean	451.4	1047
Standard Error	4.622041	37.72105
Median	450	1020
Mode	450	1070
Standard Deviation	32.68277	266.7281
Sample Variance	1068.163	71143.88
Kurtosis	4.874991	8.567905
Skewness	1.369246	2.335526
Range	210	1650
Minimum	370	620
Maximum	580	2270
Sum	22570	52350
Count	50	50
Largest(1)	580	2270
Smallest(1)	370	620
Confidence Level(95.0%)	9.288339	75.80328
Weight/length (g/mm)	2.319451	

Kanuktik	485	1120	0.433036
Kanuktik	465	1070	0.434579
Kanuktik	440	820	0.536585
Kanuktik	445	920	0.483696
Kanuktik	500	1420	0.352113
Kanuktik	535	1720	0.311047
Kanuktik	370	620	0.596774
Kanuktik	580	2270	0.255507
Kanuktik	470	1120	0.419643
Kanuktik	420	820	0.512195
Kanuktik	440	820	0.536585

Ohnlik	430	820	0.52439
Ohnlik	465	1070	0.434579
Ohnlik	450	1020	0.441176
Ohnlik	450	1020	0.441176
Ohnlik	450	1120	0.401786
Ohnlik	430	820	0.52439
Ohnlik	420	920	0.456522
Ohnlik	450	1020	0.441176
Ohnlik	410	820	0.5
Ohnlik	435	920	0.472826
Ohnlik	410	820	0.5
Ohnlik	440	870	0.505747
Ohnlik	410	620	0.66129
Ohnlik	460	970	0.474227
Ohnlik	430	920	0.467391
Ohnlik	455	1120	0.40625
Ohnlik	460	1120	0.410714
Ohnlik	420	970	0.43299
Ohnlik	415	770	0.538961
Ohnlik	455	1120	0.40625
Ohnlik	480	1270	0.377953
Ohnlik	440	970	0.453608
Ohnlik	410	820	0.5
Ohnlik	398	770	0.516883
Ohnlik	455	970	0.469072
Ohnlik	460	1170	0.393162
Ohnlik	450	920	0.48913
Ohnlik	445	870	0.511494
Ohnlik	450	920	0.48913
Ohnlik	425	820	0.518293
Ohnlik	405	670	0.604478
Ohnlik	460	970	0.474227
Ohnlik	465	1170	0.397436
Ohnlik	440	870	0.505747
Ohnlik	420	820	0.512195
Ohnlik	465	1070	0.434579
Ohnlik	445	970	0.458763

	Ohnlik	
	Length	Weight
Mean	440.7	952
Standard Error	3.091694	21.32164
Median	443.5	970
Mode	450	820
Standard Deviation	21.86158	150.7667
Sample Variance	477.9286	22730.61
Kurtosis	-0.5114	-0.28748
Skewness	-0.1646	0.077148
Range	95	650
Minimum	395	620
Maximum	490	1270
Sum	22035	47600
Count	50	50
Largest(1)	490	1270
Smallest(1)	395	620
Confidence Level(95.0%)	6.212991	42.84743
Weight/length (g/mm)	2.1602	

Ohnlik	415	870	0.477011
Ohnlik	455	1070	0.425234
Ohnlik	465	1220	0.381148
Ohnlik	395	670	0.589552
Ohnlik	420	770	0.545455
Ohnlik	490	1070	0.457944
Ohnlik	435	920	0.472826
Ohnlik	440	820	0.536585
Ohnlik	475	1270	0.374016
Ohnlik	442	970	0.45567
Ohnlik	440	970	0.453608
Ohnlik	460	1020	0.45098
Ohnlik	445	1070	0.415888

Chikuminuk	453	1200	0.3775
Chikuminuk	455	1000	0.455
Chikuminuk	420	750	0.56
Chikuminuk	470	1000	0.47
Chikuminuk	502	1200	0.418333
Chikuminuk	452	1000	0.452
Chikuminuk	505	1500	0.336667
Chikuminuk	435	900	0.483333
Chikuminuk	443	800	0.55375
Chikuminuk	478	1050	0.455238
Chikuminuk	455	1000	0.455
Chikuminuk	452	1000	0.452
Chikuminuk	454	1000	0.454
Chikuminuk	453	1000	0.453
Chikuminuk	429	750	0.572
Chikuminuk	456	1000	0.456
Chikuminuk	435	800	0.54375
Chikuminuk	441	800	0.55125
Chikuminuk	444	950	0.467368
Chikuminuk	429	750	0.572
Chikuminuk	480	1100	0.436364
Chikuminuk	459	1100	0.417273
Chikuminuk	422	750	0.562667
Chikuminuk	508	1600	0.3175
Chikuminuk	461	1100	0.419091
Chikuminuk	462	1000	0.462
Chikuminuk	510	1200	0.425
Chikuminuk	455	1000	0.455
Chikuminuk	460	1000	0.46
Chikuminuk	464	950	0.488421
Chikuminuk	452	1000	0.452
Chikuminuk	430	800	0.5375
Chikuminuk	442	750	0.589333
Chikuminuk	443	950	0.466316
Chikuminuk	461	1000	0.461

	Chikimunik Length	Weight
Mean	462.48	1049
Standard Error	4.585446	43.05881
Median	455	1000
Mode	455	1000
Standard Deviation	32.424	304.4718
Sample Variance	1051.316	92703.06
Kurtosis	11.87273	19.8689
Skewness	2.789724	3.810653
Range	204	2000
Minimum	420	750
Maximum	624	2750
Sum	23124	52450
Count	50	50
Largest(1)	624	2750
Smallest(1)	420	750
Confidence Level(95.0%)	9.214799	86.52992
Weight/length (g/mm)	2.268206	

Chikuminuk	473	1000	0.473
Chikuminuk	465	1100	0.422727
Chikuminuk	460	950	0.484211
Chikuminuk	463	1000	0.463
Chikuminuk	471	1100	0.428182
Chikuminuk	445	950	0.468421
Chikuminuk	502	1450	0.346207
Chikuminuk	455	950	0.478947
Chikuminuk	450	950	0.473684
Chikuminuk	465	1200	0.3875
Chikuminuk	455	1100	0.413636
Chikuminuk	521	1250	0.4168
Chikuminuk	445	950	0.468421
Chikuminuk	624	2750	0.226909
Chikuminuk	460	1000	0.46