**Fishery Data Series No. 13-55**

# Stock Assessment of Lake Trout in Fielding Lake, 2010-2011

**by**

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**December 2013**

**Alaska Department of Fish and Game** **Divisions of Sport Fish and Commercial Fisheries**

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**Weights and measures (metric)**

| | |
|---|---|
| centimeter | cm |
| deciliter | dL |
| gram | g |
| hectare | ha |
| kilogram | kg |
| kilometer | km |
| liter | L |
| meter | m |
| milliliter | mL |
| millimeter | mm |

**Weights and measures (English)**

| | |
|---|---|
| cubic feet per second | $ft^3/s$ |
| foot | ft |
| gallon | gal |
| inch | in |
| mile | mi |
| nautical mile | nmi |
| ounce | oz |
| pound | lb |
| quart | qt |
| yard | yd |

**Time and temperature**

| | |
|---|---|
| day | d |
| degrees Celsius | °C |
| degrees Fahrenheit | °F |
| degrees kelvin | K |
| hour | h |
| minute | min |
| second | s |

**Physics and chemistry**

| | |
|---|---|
| all atomic symbols | |
| alternating current | AC |
| ampere | A |
| calorie | cal |
| direct current | DC |
| hertz | Hz |
| horsepower | hp |
| hydrogen ion activity (negative log of) | pH |
| parts per million | ppm |
| parts per thousand | ppt, ‰ |
| volts | V |
| watts | W |

**General**

| | |
|---|---|
| Alaska Administrative Code | AAC |
| all commonly accepted abbreviations | e.g., Mr., Mrs., AM, PM, etc. |
| all commonly accepted professional titles | e.g., Dr., Ph.D., R.N., etc. |
| at | @ |
| compass directions: | |
| east | E |
| north | N |
| south | S |
| west | W |
| copyright | © |
| corporate suffixes: | |
| Company | Co. |
| Corporation | Corp. |
| Incorporated | Inc. |
| Limited | Ltd. |
| District of Columbia | D.C. |
| et alii (and others) | et al. |
| et cetera (and so forth) | etc. |
| exempli gratia (for example) | e.g. |
| Federal Information Code | FIC |
| id est (that is) | i.e. |
| latitude or longitude | lat or long |
| monetary symbols (U.S.) | $, ¢ |
| months (tables and figures): first three letters | Jan,...,Dec |
| registered trademark | ® |
| trademark | ™ |
| United States (adjective) | U.S. |
| United States of America (noun) | USA |
| U.S.C. | United States Code |
| U.S. state | use two-letter abbreviations (e.g., AK, WA) |

**Mathematics, statistics**

| | |
|---|---|
| *all standard mathematical signs, symbols and abbreviations* | |
| alternate hypothesis | $H_A$ |
| base of natural logarithm | *e* |
| catch per unit effort | CPUE |
| coefficient of variation | CV |
| common test statistics | (F, t, $\chi^2$, etc.) |
| confidence interval | CI |
| correlation coefficient (multiple) | R |
| correlation coefficient (simple) | r |
| covariance | cov |
| degree (angular ) | ° |
| degrees of freedom | df |
| expected value | *E* |
| greater than | > |
| greater than or equal to | ≥ |
| harvest per unit effort | HPUE |
| less than | < |
| less than or equal to | ≤ |
| logarithm (natural) | ln |
| logarithm (base 10) | log |
| logarithm (specify base) | $log_{2,}$ etc. |
| minute (angular) | ' |
| not significant | NS |
| null hypothesis | $H_O$ |
| percent | % |
| probability | P |
| probability of a type I error (rejection of the null hypothesis when true) | α |
| probability of a type II error (acceptance of the null hypothesis when false) | β |
| second (angular) | " |
| standard deviation | SD |
| standard error | SE |
| variance | |
| population | Var |
| sample | var |

# *FISHERY DATA REPORT NO. 13-55*

# STOCK ASSESSMENT OF LAKE TROUT IN FIELDING LAKE, 2010-2011

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# ABSTRACT

A two-event mark-recapture experiment was conducted on the spawning population of male lake trout at Fielding Lake. The first event spanned 13–17 September 2010 and the second event spanned a 3-week period in 2011 with sampling occurring on 15, 20, 21, and 27 September. A beach seine and gillnet were used to capture and mark 67 mature male lake trout in the first event. During the second event, only a beach seine was used and 184 unique mature male lake trout were examined, 41 of which had been marked in the first event. Abundance was estimated to be 299 (SE=25; 95% CI=250-347) mature male lake trout using Chapman's modification of the Petersen model. Abundance was also estimated for male lake trout ≥500 mm FL at 270 (SE=23; 95% CI=225-315) and at 125 (SE=12; 95% CI=102-148) for male lake trout ≥600 mm FL. No dominant length categories (25-mm FL) were observed and four of the categories exceeded 10% of the estimated population: 525-549, 550-574, 575-599 and 600-624 mm FL. Information gathered from this study suggest the prior estimate of 193 (SE=35; 95% CI=124-262) mature male lake trout from 1999 was biased low.

Key words: lake trout, *Salvelinus namaycush*, Fielding Lake, abundance, length composition, mark-recapture

# INTRODUCTION

## OVERVIEW

Fielding Lake is located in the upper drainage of the Delta River and is a picturesque and popular recreational destination for many, including anglers targeting lake trout *Salvelinus namaycush*, Arctic grayling *Thymallus arcticus* and burbot *Lota lota* (Figure 1). Fielding Lake can be accessed from the Richardson Highway at milepost 200.5 by a 2-mi gravel road; and has a campground and public-use cabin operated by the Alaska Department of Natural Resources, a boat launch, and numerous private cabins. The lake (elevation = 906 m, surface area = 538 ha, max depth = 23 m) lies within the Alaska Range, has several small inlets, and a single outlet stream that drains into the glacially fed Delta River. The lake begins to freeze by the middle of October and breakup of ice usually occurs by mid-June. Other fish species present include round whitefish *Coregonus sardinella* and slimy sculpin *Cottus cognatus*.

The sport fishery for lake trout in Fielding Lake is managed under the guidelines of the Wild Lake Trout Management Plan (Burr 2006; 5 AAC 74.040) that uses the Lake Area Model to estimate yield potential. Under this plan, management actions are warranted when sustainability of the fishery is at risk, which is evaluated based on harvest, effort, and catch data attained from the statewide harvest survey, on-site creel surveys, stock assessments, and inferential comparisons with other fisheries (Burr 2006). The lake area model was developed by Evans et al. (1991) and estimates sustainable annual harvest levels of biomass (kg lake trout/year), or yield potential, based on a surface area of the lake. Under the current regulation (one fish per day with a minimum size limit of 26 in), the recommended annual harvest level is 78 fish (Burr 2006).

Fielding Lake remains one of the most intensely managed lake trout fisheries in Interior Alaska. Multiple regulatory restrictions have been enacted with the current regulation being one lake trout in possession with a minimum size limit of 26 inches, only one unbaited single-hook artificial lure may be used, and fishing for lake trout and burbot is not allowed from 1–30 September. Overall sport fishing effort has been relatively stable with the latest 5-year mean being 1,086 angler days (Table 1). Estimated catch and effort has been more sporadic likely due to small sample sizes of participating anglers, but the most recent 5-year means are 365 for catch and 44 for harvest.

Only one assessment of the spawning population in Fielding Lake has been conducted (Parker et al. 2001). Sampling was conducted in mid-September 1998, 1999, and 2000 by beach seining at

the only known spawning area during fall. The abundance of mature male lake trout for 1999 was estimated at 193 fish (SE=35; 95% CI=124-262). Females were not estimated because adequate sample sizes were not attained, but a 1:1 ratio of males to females is assumed for making population inferences.

The primary purpose of this study was to reassess the spawning population of lake trout at Fielding Lake. This was accomplished by utilizing a two-event mark-recapture experiment where mature lake trout were captured in fall 2010 (first event) and fall 2011 (second event).

## OBJECTIVES

The research objectives for Fielding Lake in 2010 and 2011were to:

1) estimate the abundance of the male lake trout population ≥500 mm FL such that the estimate was within 25 percentage points of the actual value 95% of the time; and,
2) estimate the length composition in 25-mm length categories of the spawning lake trout population in Fielding Lake in 2010 and 2011.

# METHODS

## FISH CAPTURE

Lake trout were captured using a beach seine (120 m long x 2.5 m deep) with a large bag in the center (3.7 m wide), and a gillnet (65 m long, 3 m deep, with variable bar mesh ranging from 19 to 40 mm). The seine was deployed in a semi-circle around the spawning aggregation with a small skiff. This was only performed once per night to minimize stress on lake trout. The gillnet was only used in 2010 and was set on the outside perimeter of the spawning grounds in an attempt to catch lake trout that avoided the beach seine.

During the first event, each unmarked captured lake trout ≥400 mm FL was marked with an individually numbered Floy™ FD-94 internal anchor tag and a partial left-pectoral finclip in case of tag loss. Although the objective was to estimate abundance of male lake trout ≥500 mm FL, tagging all fish ≥400 mm FL potentially allowed a better assessment of gear selectivity and assess the abundance of smaller lake trout should they be present. During the second event all fish received a tag and a right-pectoral fin clip to prevent resampling.

For each captured lake trout, the following information was recorded: date, time, fork length (mm), sex, tag number and color, secondary mark type, recapture status (Y or N), and any other pertinent comments. Sex was determined by expulsion of gametes. This information has been archived for retrieval (Appendix A).

## STUDY DESIGN

The study design was similar to that previously used in Fielding, Paxson, and Susitna lakes as well as Lake Louise where an event consisted of capturing male lake trout from known spawning areas using a combination of beach seines and sometimes gillnets, with one event occurring per year (Burr 1991; Parker et. al. 2001; Szarzi 1992, 1993; Szarzi and Bernard 1994, 1997; Wuttig 2010). A critical assumption of this design is that all known spawning areas are identified because lake trout can exhibit fidelity to a given spawning shoal (Szarzi 1997; Wuttig 2010). Failure to sample all spawning areas could isolate a large fraction of the population from the experiment and bias the estimate. Considerable efforts to locate all spawning sites in Fielding

Lake were conducted in 1990 (Burr 1991) and in 1998 and 1999 (Parker et al. 2001), and only one spawning area has been identified (Figure 2).

This study design was changed after sampling in 2010 to better evaluate the assumptions (i.e., equal probability of capture) of this study as well as the 1999 study. The previous lake trout study at Fielding Lake was conducted under the assumption that all male lake trout spawn and are subject to capture during a 1-week period in mid-September. Consequentially, sampling during the previous study was only conducted during a span of <1 week each year. This study was originally planned the same way. After conducting sampling from 13–17 September 2010, it became our belief that there was a strong possibility that not all male lake trout had come to the spawning grounds and hence, were isolated from the first sampling event. That is, there was a potential for late and early spawning fish. If late spawners were isolated from sampling during 1998–2000, the resulting abundance estimate would be biased low. An estimate that is biased low would explain why exploitation rates appeared so high (i.e., roughly 50% for fish ≥600 mm FL) from 2003-2006 (Table 1; Parker et. al. 2001). To examine this, the sampling strategy was changed in 2011 to extend sampling into late September, which occurred during 14–15, 20–21 and 26–27 September.

In order to attain an unbiased estimate of abundance using two-event Petersen mark-recapture techniques for a closed population (Seber 1982), the following assumptions must be met:

1. the population was closed (lake trout do not enter the population, via growth or immigration, or leave the population, via death or emigration, during the experiment);
2. all lake trout will have a similar probability of capture in the first event or in the second event, or marked and unmarked lake trout will mix completely between events;
3. marking of lake trout will not affect the probability of capture in the second event;
4. marked lake trout will be identifiable during the second event; and,
5. all marked lake trout will be reported when recovered in the second event.

Failure to satisfy these assumptions may result in biased estimates; therefore, the experiment was designed to allow the validity of these assumptions to be ensured or tested. Sufficient data was collected to perform diagnostic tests to identify heterogeneous capture probabilities (violations of Assumption 2) and prescribed model selection procedures were followed in the event of such violations. Diagnostic tests were not available to evaluate Assumptions 1, 3, 4, and 5; instead, the experiment was designed to ensure that these assumptions were met thereby avoiding potential biases. The design ensured that sample sizes would be adequate to meet objective precision criteria and to perform reliable diagnostic tests.

## Evaluation of Assumptions

**Assumption 1:** Fielding Lake is a closed system for lake trout. Inlet and outlet stream exists but are not utilized by lake trout and are considered too small to serve as a migration corridor for non-juvenile fish.

Immigration due to growth recruitment was expected to be insignificant (e.g., ~10 mm) and was expected to be within the range of measurement error. In Fielding Lake, average growth between fall 1998 and 1999 was 13 mm. In nearby Paxson Lake, annual growth of mature lake

trout during 2003 to 2004 was judged to be inconsequential because it ranged from 1.5 to 10.9 mm FL (Wuttig 2010).

Emigration may have occurred due to fishing and natural mortality. This was expected to occur at the same rate for marked and unmarked lake trout; therefore, the estimated abundance was considered germane to the first event. Emigration due to natural mortality was assumed to be inconsequential because mature lake trout are very long lived once mature. The magnitude of harvest between events was inconsequential as well. The fishery went to single-hook artificial lure in 2007 and the mean annual harvest has since only been 28 fish (Table 1).

Lastly, it was assumed that only one spawning area existed and that all male lake trout used the one known spawning area during each year of sampling.

**Assumption 2:** The assumption of equal probability of capture was likely satisfied because all mature male lake trout present on the one known spawning ground were subjected to the same probability of capture during at least one event. Although previous sampling and sampling in 2010 (first event) may not have subjected the entire spawning population of males, the extended sampling period in 2011 did.

The degree of mixing between years within the spawning ground was unknown because of the potential for early and late spawning male lake trout. If early and late spawning fish mixed temporally between spawning years, then the assumption of equal probability of capture would also be satisfied.

Differences in capture probability related to fish size and time was examined. Size-selective sampling was tested using two Kolmogorov-Smirnov (K-S) tests. The tests and possible actions for data analysis are outlined in Appendix B. If stratification by size was required, capture probability was examined for each stratum, and total abundance and its variance estimate would be calculated by summing strata estimates.

**Assumption 3**: No handling or marking induced behavioral effects were anticipated. In the rare event a fish appeared injured or overly stressed it was not tagged.

**Assumption 4:** This assumption was addressed by double-marking each male lake trout captured during the first event. Every fish from the second event was inspected by checking for the secondary mark. In addition, tag placement was standardized, which enabled the fish handler to verify tag loss by locating recent tag wounds. Tag loss was not expected to be a common occurrence. For example, during the 1998 to 2000 Fielding Lake study, evidence of tag loss was observed for only one lake trout.

**Assumption 5:** All fish were thoroughly examined for tags or recent fin clips. All markings (tag number, tag color, fin clip, and tag wound) for each fish were recorded.

## DATA ANALYSIS

### Abundance Estimate (Objective 1)

Violations of Assumption 2 relative to size-selective sampling were tested by using results of two Kolmogorov-Smirnov two-sample tests (K-S tests; $\alpha = 0.05$) that compared length frequency distributions of 1) fish captured during the first event and recaptured fish; and, 2) fish captured during the second event and recaptured fish. There were four possible combinations of outcomes

of these two tests, each of which required using different procedures to calculate a population abundance estimate (Appendix B).

The abundance of lake trout in Fielding Lake was estimated using Chapman's modification of the Petersen two-sample model (Bailey 1951, 1952; Chapman 1951). This estimate was calculated using:

$$\hat{N} = \frac{(n_2+1)(n_1+1)}{m_2+1} - 1 \tag{1}$$

where:

$\hat{N}$ = the abundance of male lake trout in the Fielding Lake study area;
$n_1$ = the number of male lake trout marked and released during the first event;
$n_2$ = the number of male lake trout examined for marks during the second event; and,
$m_2$ = the number of male lake trout recaptured in the second event.

Variance of this estimator was calculated as:

$$V\hat{a}r\left[\hat{N}\right] = \frac{(n_1+1)(n_2+1)(n_1-m_2)(n_2-m_2)}{(m_2+1)^2(m_2+2)} \tag{2}$$

Abundance estimates were created for multiple size classes of lake trout. Estimates were generated for all mature male lake trout, male lake trout ≥500 mm FL and for male lake trout ≥600 mm FL. The 500 mm FL length was chosen to serve as a future index since Burr (1993) found that 100% maturity of male lake trout was reached from Fielding Lake at this length. The final length class (i.e., ≥600 mm FL) represents a total length of 26 in, which is the minimum size limit for harvest.

## Length Composition (Objective 2)

K-S tests were performed to test for size-selective sampling and test outcomes were used to determine if stratification was necessary and if data from the first, second, or both events were to be used (Appendix B). For cases I-III stratification would not be necessary and length proportions and variances of proportions for male lake trout would be estimated using samples from the event(s) without size-selectivity using:

$$\hat{p}_k = \frac{n_k}{n} \tag{3}$$

where:

$\hat{p}_k$ = the proportion of lake trout that were within length category $k$;

$n_k$ = the number of lake trout sampled that were within length category $k$; and,

$n$ = the total number of lake trout sampled.

The unbiased variance of this proportion was estimated as (Cochran 1977):

$$\hat{V}\left[\hat{p}_k\right] = \frac{\hat{p}_k(1-\hat{p}_k)}{n-1} \tag{4}$$

If diagnostic tests indicated case IV, there was size-selectivity during both events and data would have to be stratified to eliminate variability in capture probabilities within strata for at least one or both sampling events. Formulae to adjust length composition estimates are presented in Appendix B.

### WATER TEMPERATURE

Lake trout found in northern latitudes commence spawning around 9°C, but other factors influence the timing of spawning such as available light and wind (Scott and Crossman 1973; Morrow 1980). In 2010, daily temperature measurements were taken with a hand held thermometer during the nights fish were sampled. In 2011, a Hobo Water Temp Pro temperature data logger recorded temperatures hourly from 15–28 September. The logger was deployed on the bottom of the lake in 3 m of water adjacent to the spawning grounds.

## RESULTS

### SUMMARY OF FISH CAPTURED

Sampling was conducted from 13–17 September 2010 (Table 2). Each night, typically between 2200 and 2400 h, one gillnet was set for <15 minutes on the outside edge of the spawning area and within the gillnet perimeter a seine haul was simultaneously attempted. A total of 67 unique male lake trout and 10 unique female lake trout were tagged (Table 3). Three other lake trout were captured with gillnet on 15 September but were not tagged due to questionable survival.

In 2011, only a beach seine was used to capture lake trout. A single seine haul was made each night (15, 20, 21, and 27 September) between 2200 h and 2400 h (Table 2). A seine attempt was planned for 16 September but no fish were seen on the spawning grounds. Sampling was also planned on 26 September but severe weather prevented sampling. A total of 184 unique male lake trout were captured and 41 of these were tagged from 2010 (Table 3). Seventy unique female lake trout were captured, 4 of which had been tagged in 2010.

### ABUNDANCE ESTIMATES

Before the diagnostic tests outlined in Appendix B (K-S tests for size selectivity) could be done, gear selectivity between gillnets and beach seines needed to be evaluated. Cumulative relative frequencies of fish captured in 2010 between gear types were very similar (Figure 3). There also was not a difference in recapture rates of fish captured in gillnets and beach seines (Table 4). Therefore, data from both gear types were pooled for subsequent analyses.

The data collected was sufficient to estimate abundance of all mature males, males ≥500 mm FL and males ≥600 mm FL. Only 4 female lake trout were recaptured so their abundance was not estimated. For each size category of male lake trout, K-S tests revealed a Case III scenario, resulting in no need to stratify by length (Appendix B; Table 5 and Figure 4). The abundance of all mature males was estimated at 299 (SE=25; 95% CI=250-347; Table 6). Abundance was estimated at 270 (SE=23; 95% CI=225-315) for males ≥500 mm FL and at 125 (SE=12; 95% CI=102-148) for males ≥600 mm FL.

## LENGTH COMPOSITION

Mean length of male lake trout was 640 mm FL (SD=87) in 2010 and 604 mm FL (SD=93) in 2011 (Table 7). Mean length of female lake trout was similar both years with a mean of 638 mm FL (SD=101) in 2010 and a mean of 635 mm FL (SD=100) in 2011.

K-S tests using lengths of all mature male lake trout indicated a Case III scenario meaning there was size selectivity detected in the first event, but not the second event (Appendix B; Figure 4). Therefore, lengths from the second event were used to estimate length composition of the mature male population (Objective 2). The estimated length composition of male lake trout was relatively flat, an expected trait of a slow growing long-lived population (Figure 5). There was no dominant 25-mm FL length category, and only four length categories comprised more than 10% of the estimated population: 525-549, 550-574, 575-599 and 600-624 mm FL (Figure 5). K-S test results for the other two length ranges (≥500 mm FL and ≥600 mm FL) also indicated a Case III scenario (Table 5).

## WATER TEMPERATURE

In 2010 nightly water temperature for 13–18 September were measured at 7°C, 9°C, 7°C, 7°C, 8°C, and 8°C, respectively. In 2011, hourly water temperature ranged from 7.7-9.4°C (Figure 6). Mean daily water temperatures during the second event ranged from 9.3°C on 15 September to 7.8°C on 28 September.

# DISCUSSION

Sustainability for managed lake trout populations is often limited to examining changes to estimated abundance over time. However, for Fielding Lake, such comparisons should be approached cautiously. The only prior abundance estimate in Fielding Lake used a Jolly-Seber multi-year mark-recapture experiment from 1998–2000 when 193 (SE=35; 95% CI=124-262) mature male lake trout were estimated (Parker et al. 2001). The abundance estimate of mature male lake trout in this study was 299 (SE=25; 95% CI=250-347).

We now believe the 1999 estimate is biased low because sampling did not occur throughout the entire spawning period and some fish were likely isolated from the experiment. In 1998, fish capture only took place on 16 and 17 September (Parker et al. 2001). In 1999, lake trout were captured on 9–12 and 14 September, and in 2000 sampling occurred on 14, 16, and 18 September. For this study, the first event (2010) was performed during similar dates with fish being captured from 13–17 September (Table 3). The second event (2011) spanned three weeks with 184 unique male lake trout fish being captured on 15, 21, 22, and 27 September, however 132 of these were sampled the last two weeks (20, 21, and 28 September)–later than when sampling occurred in 1998–2000 (Table 3).

Potential bias in 1999 was investigated by examining changes to length composition, capture probabilities, and abundance estimates over the three-week sampling period in 2011. In order for bias with length composition estimation to occur, temporal segregation of spawning males must occur annually, meaning there were “early” and “late” spawning fish with potentially different length compositions. Anderson-Darling tests revealed no significant change in cumulative relative frequency of mature male lake trout over time (Figure 7). This provided evidence that the length composition did not change over the three-week sampling period and it was acceptable to isolate or pool data by weekly strata.

Next, we chose to examine capture probabilities over time. Recapture rates of male lake trout marked during the first event (2010) were examined over weekly sampling periods in 2011 to identify late spawning fish–a decreasing ratio would indicate "new" fish moving into the spawning area. For the first week (13–17 September 2011), 52 male lake trout were captured and 18 (35%) were marked (Table 8). This ratio decreased to 19% during the second weekly sampling period, and dropped to 10% during the third week. When testing ratios across all weeks, the result was insignificant (chi-square=4.51; P-value=0.10), but appeared to be biologically meaningfully (Table 8). When week 1 was tested against weeks 2 and 3 combined, the result was significant (chi-square=3.13, P-value=0.05; Table 8). This second test is more meaningful because weeks 2 and 3 corresponded to the period that was not sampled in 2010, and it provides clear evidence that "new" fish came to the spawning grounds after sampling was ceased on 17 September 2010.

Exploratory abundance estimates using early- and late-arriving fish help to illustrate the potential bias if we had restricted sampling to the first week in 2011 (Table 9). If sampling would have been concluded after capturing 52 fish (18 were recaptures) on 15 September 2011, the abundance estimate would have been statistically different than when including all fish thereafter. Further complicating interpretation was the relative precision (RP=0.30) attained had we only looked at early arriving fish (Table 9). This precision was relatively good and could have misled us into having good confidence in our results that had poor accuracy.

These investigations illustrate the importance of sampling the entire spawning period of lake trout for mark-recapture experiments. We provided evidence that individual fish in Fielding Lake may be temporally segregated during spawning consecutive years. In the previous study, sampling was restricted to mid-September, and no female lake trout were captured in which eggs flowed freely (Parker et al. 2001). During this study, we had similar observations on 15 September 2011, but subsequent sampling had females with free flowing eggs and females that were partially spent. At the same time, new male lake trout were entering the spawning grounds. Assuming similar behavior over the three-year span of the Jolly-Seber estimate (1998, 1999, and 2000) and a similar overall spawning duration, the 1999 estimate would be biased low, with the level of bias unknown.

Despite the probable biases associated with the 1999 estimate, the data from this study can be used to make historical comparisons by truncating the data from this study to the same time period (i.e., mid-September) as the previous study (assuming similar spawning timing and duration among studies). The 2011 truncated estimate (189 fish, SE=29; 95% CI=132-245; Table 9) was nearly the same as the 1999 estimate (193 fish, SE=35; 95% CI=124-262; Parker et al. 2001). Furthermore, a Petersen two-event model was used to estimate abundance using data collected from 1998 and 1999 at 184 (SE=17; 95% CI=151-217) mature male lake trout (unpublished, memorandum, ADF&G, Klaus Wuttig, Fisheries Biologist, 2000, Fairbanks). All three estimates used similar sampling protocols during similar dates and suggest that lake trout in Fielding Lake have not experienced any substantial changes in abundance since 1999. Furthermore, cumulative length composition of captured male lake trout has not changed since 1999 (Figure 8).

Previous studies have reported that males stay on the spawning grounds longer than females and that female lake trout may not spawn annually once mature (Burr 1991, 1992; Martin and Oliver 1980). This study provided clear evidence that females spend much less time on the spawning

areas than males, and provided evidence that skip spawning is not prevalent with females. No female lake trout (0 out of 70) were ever sampled two consecutive weeks, whereas 80 (43%) of the 184 male lake were sampled during two or more periods, and 17 (9%) were captured all 3 weeks (Table 10). Skip spawning does not appear to be common with female lake trout at Fielding Lake. Of the 10 female lake trout tagged in 2010 in spawning condition, 4 were recaptured in spawning condition in 2011. This 40% recapture rate (4 out 10) is lower than the 63% recapture rate (41 out of 65) on spawning male lake trout, but not statistically different (chi-square = 0.53, P-value=0.46). Also, one would suspect a lower proportion of female lake trout being recaptured in this study since more female lake trout came to the spawning grounds on the second and third sampling weeks in 2011 (i.e., they likely were not sampled as well as males in 2010; Table 11). Examining all fish captured by sampling week, regardless if they had been captured on a previous sampling week, females comprised 21% of the sample during both sampling weeks 2 and 3 (Table 11). Considering only new fish (males and females) to the spawning grounds on a given sampling week, the percentage of females increased from 9% during sampling week 1, to 28% during sampling week 2, and to 50% during sampling week 3 (Table 11). For these reasons, it is not recommended that abundance of female lake trout should ever be estimated at Fielding Lake. Intense sampling would be needed to ensure all female lake trout are subjected to capture (i.e., every night or every other night throughout the entire spawning period), and that intense of sampling could have adverse effects on the population (i.e., be too disruptive on spawning).

Assuming a 1:1 ratio of male to female lake trout similar to other studies (Martin and Oliver 1980; Szarzi 1992, 1993; Szarzi and Bernard 1994, 1997; Wuttig et al. 2010), 598 mature lake trout, 540 lake trout ≥500 mm FL and 250 lake trout ≥600 mm FL were estimated to be in Fielding Lake during 2010. These expanded estimates, combined with the estimated harvests, generate exploitation rates which are now more in line with sustainability. For example, 4 of the last 5 years estimated harvest has been <10% of the estimated abundance of all mature fish. Also, the 5-year mean harvest of 44 lake trout ≥600 mm FL is 18% of the estimated abundance of fish ≥600 mm FL. With the improved understanding of lake trout abundance in Fielding Lake, the actual exploitation is about 65% of what was previous thought; therefore, more restrictive regulatory changes are probably not warranted at this time. Lastly, the 5-year annual estimated mean harvest of 44 lake trout is well below the yield potential of 78 lake trout ≥600 mm FL (26 in TL) estimated from the lake area model (Burr 2006).

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# TABLES AND FIGURES

Table 1.–Estimates of fishing effort (angler days) and estimates of harvest and catch of lake trout in Fielding Lake, 1981–2010. Data from Mills (1982-1994); Howe et al. (1995-1996, 2001a-d); Jennings et al. (2004-2011a-b), and Walker et al. (2003).

| Year | Effort | Harvest | Catch |
|---|---|---|---|
| 1981 [ab] | 1,369 | 295 | - |
| 1982 [ab] | 2,764 | 364 | - |
| 1983 [ab] | 1,737 | 294 | - |
| 1984 [ab] | 871 | 169 | - |
| 1985 [b] | 1,023 | 347 | - |
| 1986 [b] | 1,682 | 136 | - |
| 1987 [b] | 1,023 | 127 | - |
| 1988 [b] | 1,728 | 364 | - |
| 1989 [c] | 1,664 | 195 | - |
| 1990 [c] | 1,255 | 186 | 321 |
| 1991 [c] | 1,572 | 295 | 870 |
| 1992 [c] | 1,910 | 170 | 247 |
| 1993 [c] | 1,827 | 276 | 939 |
| 1994 [d] | 2,129 | 52 | 213 |
| 1995 [d] | 3,735 | 44 | 486 |
| 1996 [d] | 960 | 42 | 222 |
| 1997 [d] | 1,259 | 55 | 245 |
| 1998 [d] | 1,602 | 19 | 341 |
| 1999 [d] | 1,154 | 43 | 279 |
| 2000 [d] | 827 | 18 | 221 |
| 2001 [ef] | 525 | 12 | 106 |
| 2002 [ef] | 826 | 0 | 137 |
| 2003 [ef] | 840 | 83 | 423 |
| 2004 [ef] | 1,010 | 101 | 520 |
| 2005 [ef] | 1,248 | 112 | 862 |
| 2006 [ef] | 1,034 | 108 | 634 |
| 2007 [efg] | 1,139 | 40 | 227 |
| 2008 [efg] | 1,203 | 7 | 103 |
| 2009 [efg] | 569 | 18 | 552 |
| 2010 [efg] | 1,483 | 48 | 309 |
| | Average | | |
| 2006–2010 | 1,086 | 44 | 365 |

[a] Unattended set lines were permitted.
[b] Ten fish per day, two of which may be greater than 20 in.
[c] Two fish per day with a minimum size limit of 18 in.
[d] One fish per day with a minimum size limit of 22 in.
[e] One fish per day with a minimum size limit of 26 in.
[f] No fishing for lake trout permitted from 1–30 September.
[g] Single-hook artificial lure only year round.

Table 2.–Sampling dates, crew sizes, and gear used to capture lake trout at Fielding Lake, 2010–2011.

| Event | Dates | Crew Size | Gear[a] |
|---|---|---|---|
| Fall 2010 | 9/13–9/17 | Varied from a 3- to 5-person crew | Beach seine and gillnet |
| Fall 2011 | 9/15 | 4-person crew | Beach seine |
| | 9/20 & 9/21 | 4-person crew | Beach seine |
| | 9/27 | 4-person crew | Beach seine |

[a] The beach seine was 120 m wide by 2.5 m deep with a 3.7-m wide bag in the middle. The gillnet was 65 m long, 3 m deep, and had variable bar mesh ranging from 19-40 mm.

Table 3.–Catch information of lake trout from Fielding Lake, 2010 and 2011.

| Date | Gear | New Males (Recaptured) | New Females (Recaptured) |
|---|---|---|---|
| **2010** | | | |
| 9/13/2010 | Seine | 3 | 0 |
| 9/13/2010 | Gillnet | 2 | 1 |
| 9/14/2010 | Seine | 7 | 0 |
| 9/14/2010 | Gillnet | 0 | 0 |
| 9/15/2010 | Seine | 28 | 3 |
| 9/15/2010 | Gillnet | 14 | 2 |
| 9/16/2010 | Seine | 6 | 1 |
| 9/16/2010 | Gillnet | 5 | 1 |
| 9/17/2010 | Seine | 2 | 2 |
| 9/17/2010 | Gillnet | 0 | 0 |
| | Total | 67 | 10 |
| **2011** | | | |
| 9/15/2011 | Seine | 52 (18) | 5 (1) |
| 9/20/2011 | Seine | 63 (13) | 23 (1) |
| 9/21/2011 | Seine | 48 (8) | 21 (1) |
| 9/27/2011 | Seine | 21 (2) | 21 (1) |
| | Total | 184 (41) | 70 (4) |

*Note:* This table does not include fish that had been previously captured in the same year. It also does not include three fish that were not tagged due to their questionable survival (all three from the gillnet set on 9/15/2010).

Table 4.–Contingency table used to determine if gear selectivity occurred, Fielding Lake, 2010.

| Gear | n1 | m2 | % recap | Chi-square | Degrees of Freedom | P-Value |
|---|---|---|---|---|---|---|
| Gillnet | 21 | 11 | 52% | | | |
| Beach Seine | 46 | 30 | 65% | 0.25 | 1 | 0.62 |

Table 5.–Results of diagnostic tests used to detect and correct for size selective sampling (Appendix B) for estimating abundance and length composition of lake trout in Fielding Lake.

| Size Class | Test Results | | Conclusion |
|---|---|---|---|
| | M vs. R | C vs. R | |
| All mature males | D = 0.135<br>P-value = 0.640<br>Fail to reject $H_0$ | D = 0.308<br>P-value = 0.001<br>Reject $H_0$ | Case III, do not stratify, use lengths from second event for composition analysis |
| Males ≥500 mm FL | D = 0.143<br>P-value = 0.596<br>Fail to reject $H_0$ | D = 0.308<br>P-value = 0.001<br>Reject $H_0$ | Case III, do not stratify, use lengths from second event for composition analysis |
| Males ≥600 mm FL | D = 0.194<br>P-value = 0.586<br>Fail to reject $H_0$ | D = 0.297<br>P-value = 0.046<br>Reject $H_0$ | Case III, do not stratify, use lengths from second event for composition analysis |

Table 6.–Estimated abundance of male lake trout in Fielding Lake, 2010.

| Population of Inference | Abundance (SE) | 95% CI |
|---|---|---|
| All mature males | 299 (25) | 250–347 |
| Males ≥500 mm FL | 270 (23) | 225–315 |
| Males ≥600 mm FL | 125 (12) | 102–148 |

Table 7.–Mean length (mm FL) of lake trout captured during sampling events at Fielding Lake, 2010 and 2011.

| Year | Dates | Statistic | Male | Female |
|---|---|---|---|---|
| 2010 | 9/13–9/17 | Mean | 640 | 638 |
| | | SD | 87 | 101 |
| | | Sample Size | 70 | 10 |
| 2011 | 9/15, 9/20, 9/21, 9/27 | Mean | 604 | 635 |
| | | SD | 93 | 100 |
| | | Sample Size | 184 | 70 |

Table 8.–Recapture rates of male lake trout by sampling week, Fielding Lake, 2011.

| Sampling Week | n2 | m2 | % recap | Chi-square | Degrees of Freedom | P-Value |
|---|---|---|---|---|---|---|
| Week 1 = 9/15 | 52 | 18 | 0.35 | | | |
| Week 2 = 9/20&21 | 111 | 21 | 0.19 | 4.51 | 2 | 0.10 |
| Week 3 = 9/27 | 21 | 2 | 0.10 | | | |
| Week 1=9/15 | 52 | 18 | 0.35 | | | |
| Weeks 2 and 3 = 9/20, 21 and 27 | 132 | 23 | 0.17 | 3.83 | 1 | 0.05 |

Table 9.–Experimental abundance estimates outlining the presence of bias due to temporal isolation of male lake trout from spawning grounds. For all estimates, $n_1$=67, or all mature males sampled in 2010.

| Data set | Abundance (SE) | 95% CI |
|---|---|---|
| **Week 1** | | |
| $n_2$ = 52 fish (15 Sept) | 189 (29) [a] | 132–245 |
| **Weeks 1 & 2** | | |
| $n_2$ = 163 fish (15, 20-21 Sept) | 278 (24) [a] | 230–325 |
| **Weeks 1, 2, & 3** | | |
| $n_2$ = 184 fish (15, 20-21, and 27 Sept) | 299 (25) [b] | 250–347 |

[a] These estimates are assumed to be biased because lake trout which come to the spawning grounds later in September were isolated from sampling in 2010.

[b] This estimate is assumed to be unbiased (meets the assumption of the Petersen model that every fish has a similar probability of capture during at least one event - 2nd event in this case).

Table 10.–Catch and percentage of lake trout by sampling week, Fielding Lake, 2011. Each fish was only assigned one capture category.

| Sampling week | 1[a] | 2[b] | 3[c] | 1,2 | 1,3 | 2,3 | 1,2,3 |
|---|---|---|---|---|---|---|---|
| # of males (%) | 4 (2%) | 79 (43%) | 21 (11%) | 28 (15%) | 3 (2%) | 32 (17%) | 17 (9%) |
| # of females (%) | 5 (7%) | 44 (63%) | 21 (30%) | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) |

[a] Sampling week 1 - September 15.

[b] Sampling week 2 - September 20&21.

[c] Sampling week 3 - September 27.

Table 11.–Number of male and female lake trout captured each sampling week, Fielding Lake, 2011.

| | Sampling Week [a] | | |
|---|---|---|---|
| Sex of fish sampled | 1 | 2 | 3 |
| | All Fish [b] | | |
| # of male lake trout | 52 | 161 | 77 |
| # of female lake trout | 5 | 44 | 21 |
| Percent female | 9% | 21% | 21% |
| | New Fish [c] | | |
| # of male lake trout | 52 | 111 | 21 |
| # of female lake trout | 5 | 44 | 21 |
| Percent female | 9% | 28% | 50% |

[a] Sampling week 1- September 15;
Sampling week 2- September 20&21;
Sampling week 3- September 27.

[b] All fish represents every unique fish captured that week.

[c] New fish represents only fish that were captured for the first time in 2011.

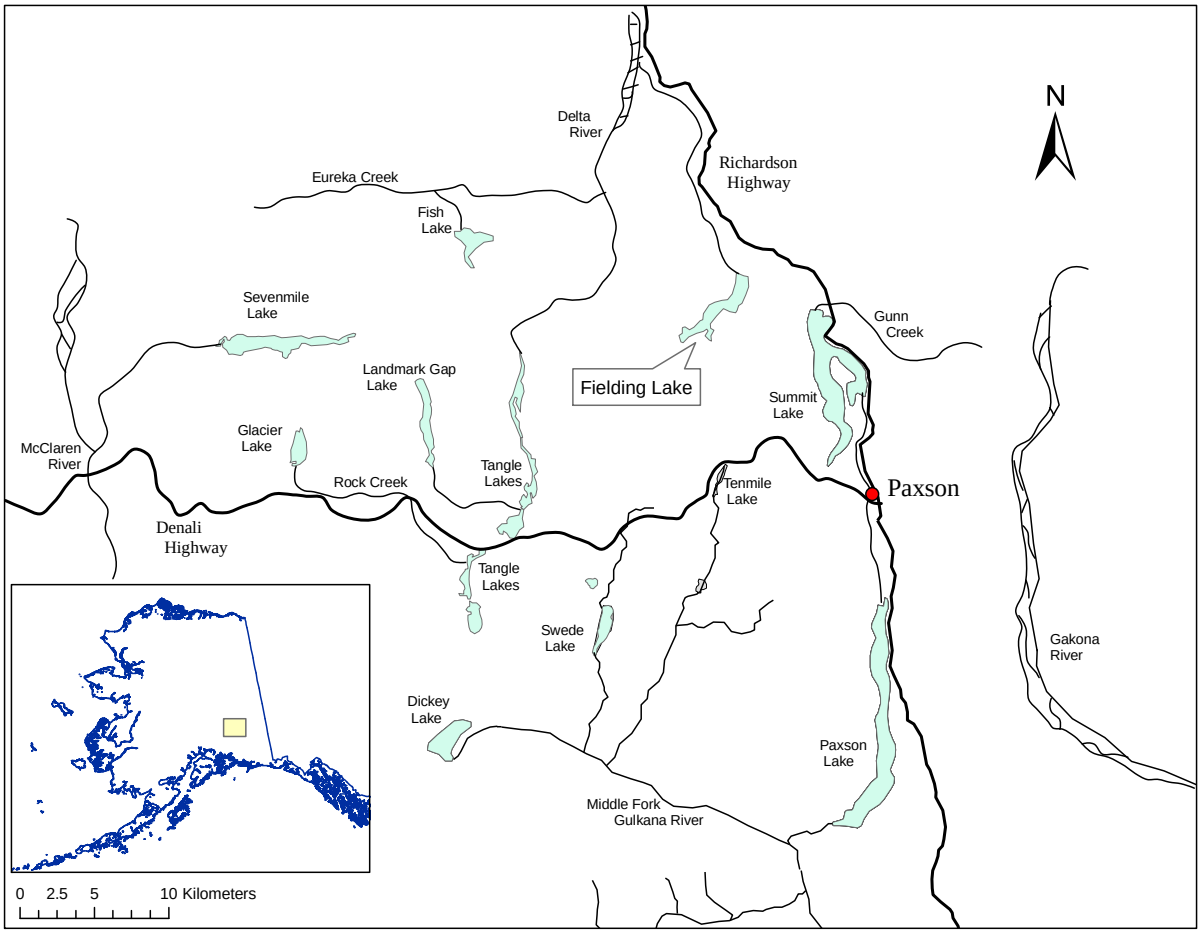


Figure 1.–Location of Fielding Lake.

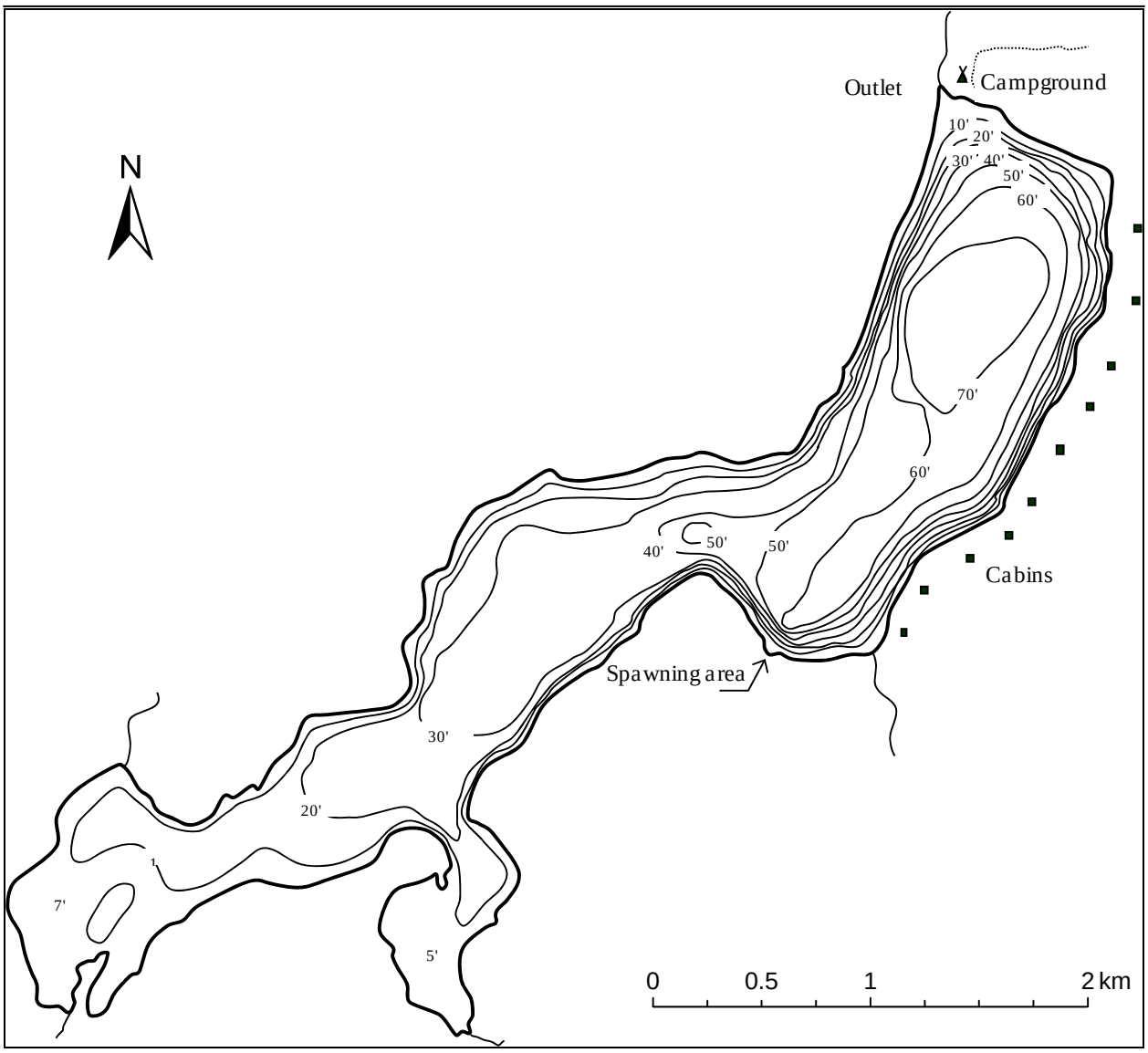

Figure 2.–Map of Fielding Lake.

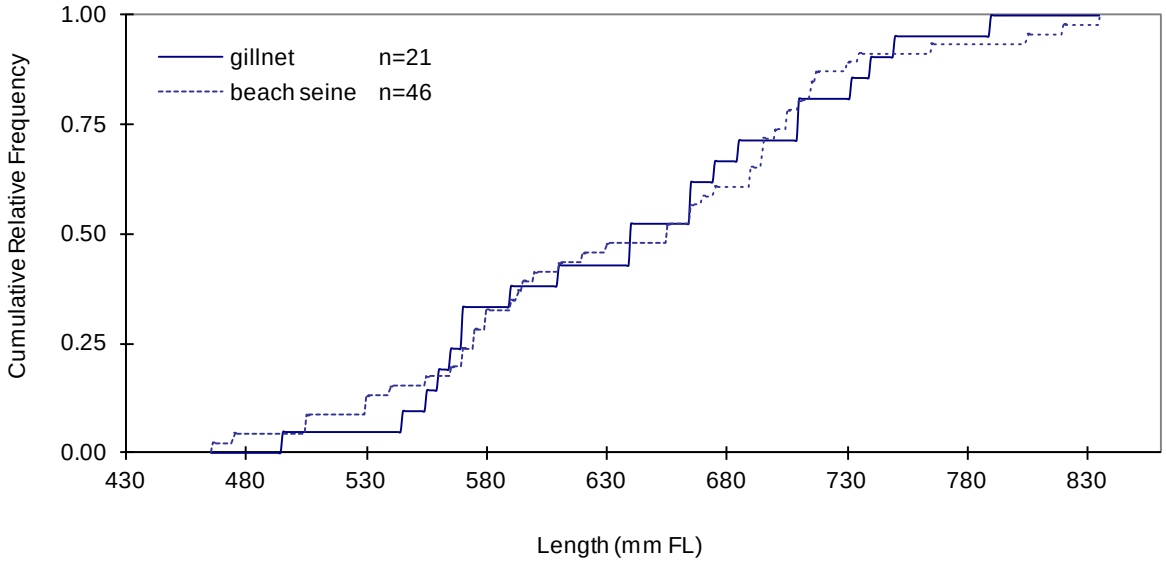


Figure 3.–Cumulative relative length frequency distributions of lake trout captured with gillnet and beach seine, Fielding Lake, 2010.

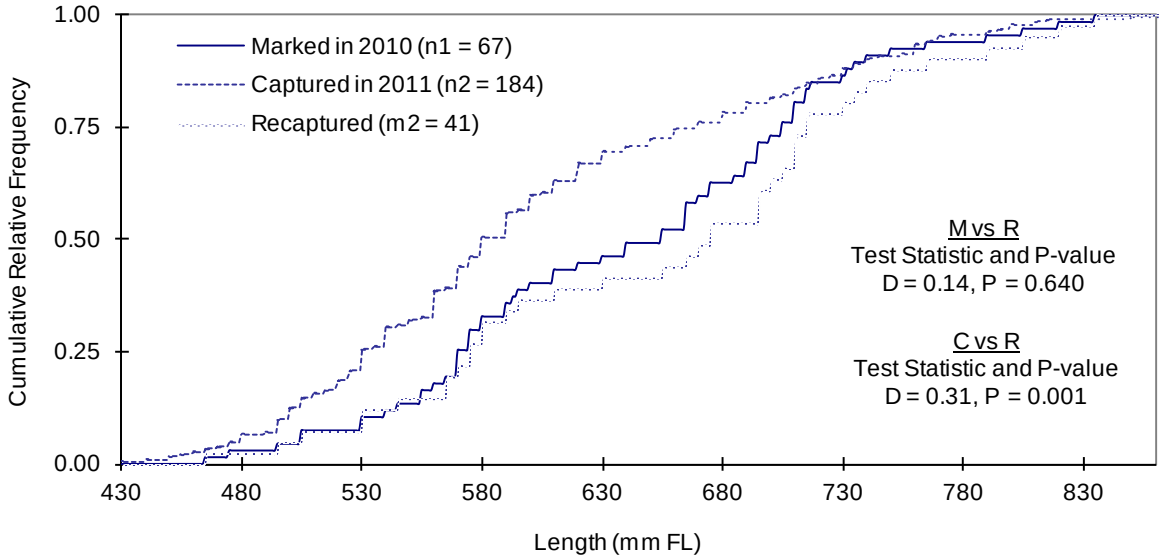


Figure 4.–Cumulative relative length frequency distributions of mature male trout used in the mark-recapture experiment, Fielding Lake, 2011.

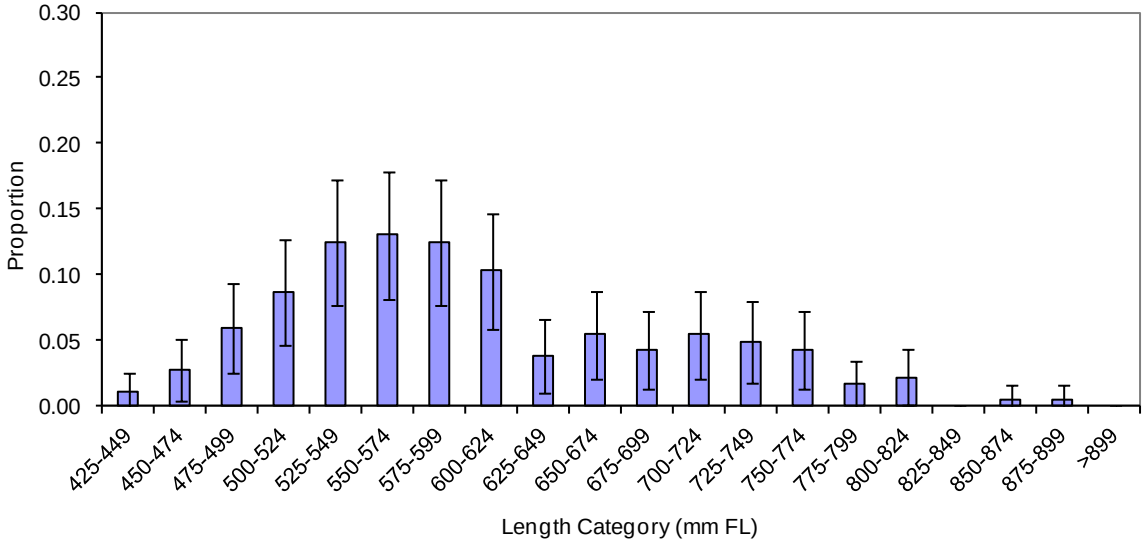


Figure 5.–Estimated length composition of mature male lake trout, Fielding Lake, 2011.

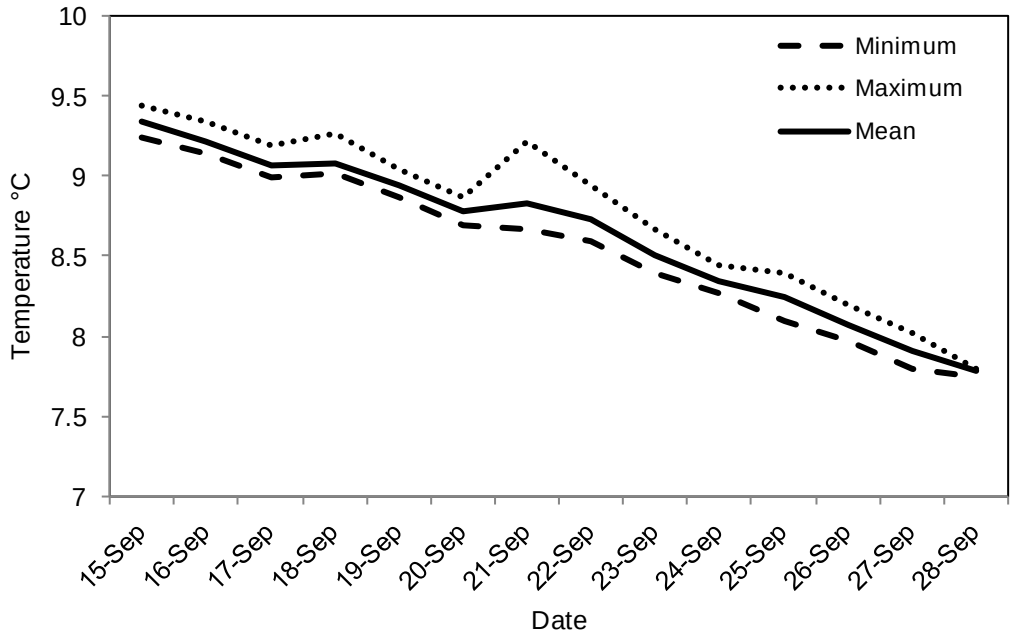


Figure 6.–Water temperature data collected from adjacent to the spawning area of lake trout, Fielding Lake, 2011.

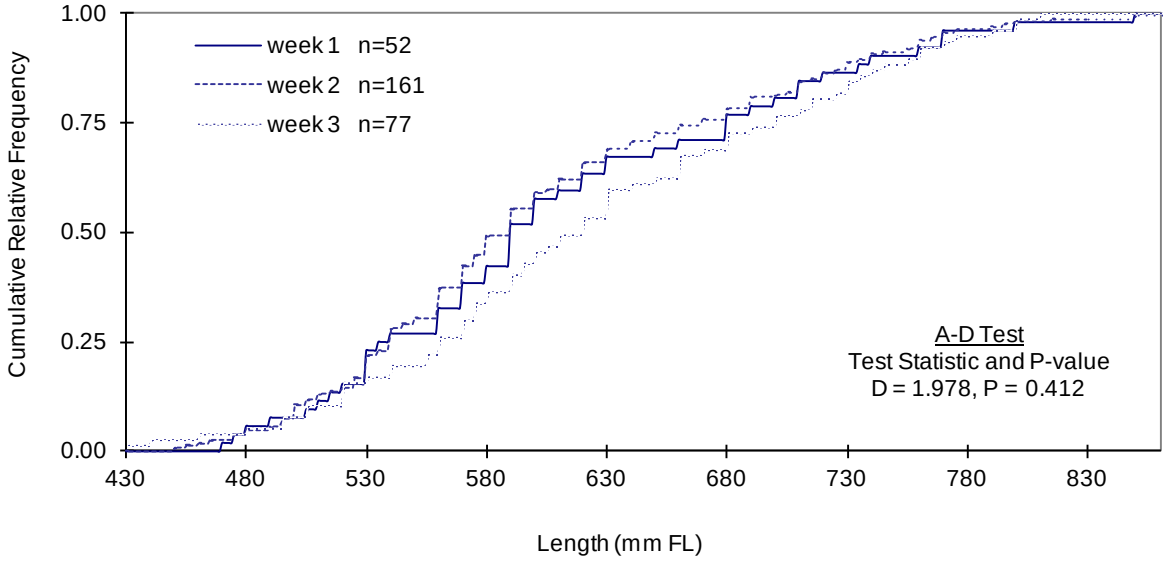


Figure 7.–Cumulative relative length frequency distributions of mature male trout captured during three sampling weeks, Fielding Lake, 2011.

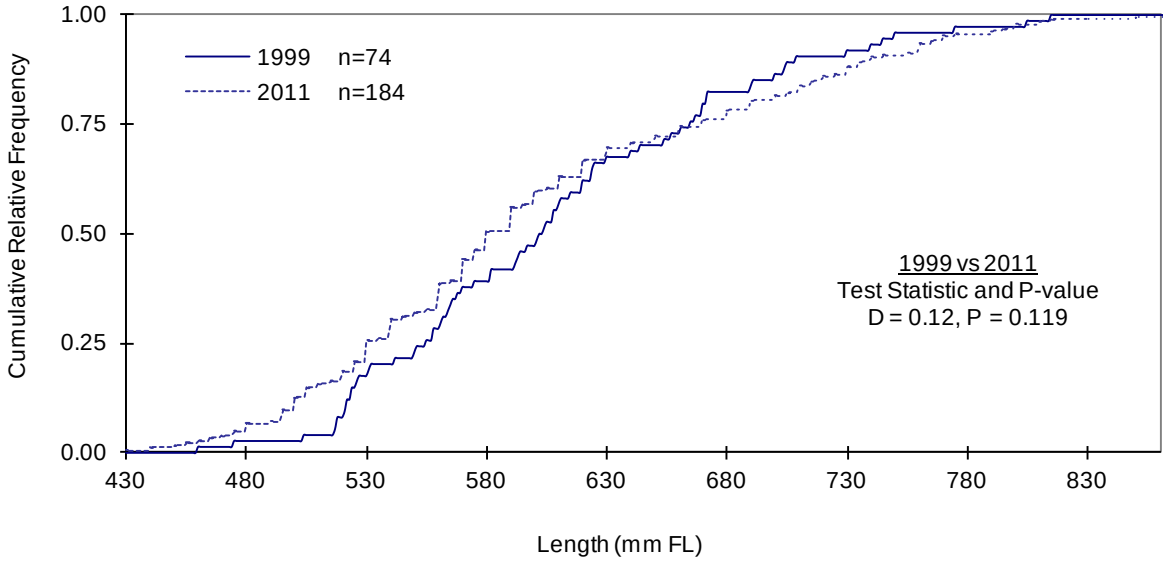


Figure 8.–Cumulative relative length frequency distributions of mature male trout, Fielding Lake, 1999 and 2011.

# APPENDIX A:
# SUMMARY OF DATA FILE ARCHIVES

Appendix A1.–Summary of data archives.

Project leader: Corey Schwanke; 822-3309

| Year | Data File[a] | Software |
|---|---|---|
| 2010 | Fielding Lake lake trout 2010.dta[b] | Microsoft Excel |
| 2011 | Fielding Lake lake trout 2011.dta[b] | Microsoft Excel |

[a] Data files are archived at and are available from the Alaska Department of Fish and Game, Sport Fish Division, Research and Technical Services, 333 Raspberry Road, Anchorage, Alaska 99518-1599.

[b] The excel file contains the following information for all captured lake trout: date, time, fork length, sex (mm), tag number and color, secondary mark type, recaptured status (Y or N), and any other pertinent comments.

# APPENDIX B:

# METHODS FOR TESTING ASSUMPTIONS OF THE PETERSON ESTIMATOR AND ESTIMATING ABUNDANCE

Appendix B1.–Procedures for detecting and adjusting for size or sex selective sampling during a 2-sample mark recapture experiment.

## Overview

Size and sex selective sampling may result in the need to stratify by size and/or sex in order to obtain unbiased estimates of abundance and composition. In addition, the nature of the selectivity determines whether the first, second or both event samples are used for estimating composition. The Kolmogorov-Smirnov two sample (K-S) test (Conover 1980) is used to detect significant evidence that size selective sampling occurred during the first or second sampling events and contingency table analysis (Chi-square test) is generally used to detect significant evidence that sex selective sampling occurred during the first or second sampling events.

K-S tests are used to evaluate the second sampling event by comparing the length frequency distribution of all fish marked during the first event (M) with that of marked fish recaptured during the second event (R), using the null test hypothesis ($H_o$) of no difference. The first sampling event is evaluated by comparing the length frequency distribution of all fish inspected for marks during the second event (C) with that of R. Chi-square tests are used to compare the counts of observed males to females between M&R and C&R according to the null hypothesis that the probability that a sampled fish is male or female is independent of the sample. When the proportions by gender are estimated for a subsample (usually from C), rather than observed for all fish in the sample, contingency table analysis is not appropriate and the proportions of females (or males) are compared using a two sample test (e.g. Student's t-test).

Mark-recapture experiments are designed to obtain sample sizes sufficient to 1) achieve precision objectives for abundance and composition estimates and 2) ensure that the diagnostic tests (i.e., tests for selectivity) have power adequate for identifying selectivity that could result in significantly biased estimates. Despite careful design, experiments may result in inadequate sample sizes leading to unreliable diagnostic test results due to low power. As a result, detection and adjusting for size and sex selectivity involves evaluating the power of the diagnostic tests.

The protocols that follow are used to classify the experiment into one of four cases. For each case the following are specified: 1) whether stratification is necessary, 2) which sample event's data should be used when estimating composition, and 3) the estimators to be used for composition estimates when stratifying. The first protocols assume adequate power. These are followed by supplemental protocols to be used when power is suspect and guidelines for evaluating power.

## Protocols given Adequate Power

*Case I:*

| **M vs. R** | **C vs. R** |
|---|---|
| Fail to reject $H_o$ | Fail to reject $H_o$ |

There is no size/sex selectivity detected during either sampling event. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated after pooling length, sex, and age data from both sampling events.

*Case II:*

| **M vs. R** | **C vs. R** |
|---|---|
| Reject $H_o$ | Fail to reject $H_o$ |

There is no size/sex selectivity detected during the first event but there is during the second event sampling. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the first sampling event without stratification. If composition is estimated from second event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the M vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type formula.

-continued-

Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

*Case III:*

| **M vs. R** | **C vs. R** |
|---|---|
| Fail to reject $H_o$ | Reject $H_o$ |

There is no size/sex selectivity detected during the second event but there is during the first event sampling. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the second sampling event without stratification. If composition is estimated from first event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the C vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

*Case IV:*

| **M vs. R** | **C vs. R** |
|---|---|
| Reject $H_o$ | Reject $H_o$ |

There is size/sex selectivity detected during both the first and second sampling events. The ratio of the probability of captures for size of sex categories can either be the same or different between events. Data must be stratified to eliminate variability in capture probability within strata for at least one or both sampling events. Abundance is calculated using a Petersen-type model for each stratum, and estimates are summed across strata to estimate overall abundance. Composition parameters may be estimated within the strata as determined above, but only using data from sampling events where stratification has eliminated variability in capture probabilities within strata. If data from both sampling events are to be used, further stratification may be necessary to meet the condition of capture homogeneity within strata for both events. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance.

When stratification by sex or length is necessary prior to estimating composition parameters, overall composition ($p_k$) is estimated by combining within stratum composition estimates using:

$$\hat{p}_k = \sum_{i=1}^{j} \frac{\hat{N}_i}{\hat{N}_\Sigma} \hat{p}_{ik} \text{ , and} \tag{B1-1}$$

$$\hat{V}[\hat{p}_k] \approx \frac{1}{\hat{N}_\Sigma^2} \left( \sum_{i=1}^{j} \hat{N}_i^2 \hat{V}[\hat{p}_{ik}] + \left( \hat{p}_{ik} - \hat{p}_k \right)^2 \hat{V}[\hat{N}_i] \right) \tag{B1-2}$$

where:

| | | |
|---|---|---|
| $j$ | = | the number of sex/size strata; |
| $\hat{p}_{ik}$ | = | the estimated proportion of fish that were age or size $k$ among fish in stratum $i$; |
| $\hat{N}_i$ | = | the estimated abundance in stratum $i$; |
| $\hat{N}_\Sigma$ | = | sum of the $\hat{N}_i$ across strata. |

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Protocols when Power Suspect (re-classifying the experiment)

When sample sizes are small (guidelines provided in next section) power needs to be evaluated when diagnostic tests fail to reject the null hypothesis. If this failure to identify selectivity is due to low power (that is, if selectivity is actually present) data will be pooled when stratifying is necessary for unbiased estimates. For example, if the both the M vs. R and C vs. R tests failed to identify selectivity due to low power, Case I may be selected when Case IV is true. In this scenario, the need to stratify could have been overlooked leading to biased estimates. The following protocols should be followed when sample sizes are small.

*Case I:*

| **M vs. R** | **C vs. R** | **Implication** |
|---|---|---|
| Fail to reject Ho | Fail to reject Ho | re-evaluate both tests |
| Power OK/retain test result | Power OK/retain test result | Case I |
| Power suspect/change to Reject Ho | Power OK/retain test result | Case II |
| Power OK/retain test result | Power suspect/change to Reject Ho | Case III |
| Power suspect/change to Reject Ho | Power suspect/change to Reject Ho | Case IV |

*Case II:*

| **M vs. R** | **C vs. R** | **Implication** |
|---|---|---|
| Reject Ho | Fail to reject Ho | re-evaluate C vs. R |
| | Power OK/retain test result | Case II |
| | Power suspect/change to Reject Ho | Case IV |

*Case III:*

| **M vs. R** | **C vs. R** | **Implication** |
|---|---|---|
| Fail to reject Ho | Reject Ho | re-evaluate M vs. R |
| Power OK/retain test result | | Case III |
| Power suspect/change to Reject Ho | | Case IV |

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Guidelines for evaluating power:

The following guidelines to assess power are based upon the experiences of Sport Fish biometricians; they have not been comprehensively evaluated by simulation. Because some "art" in interpretation remains these guidelines are not intended to be used in lieu of discussions with biometricians when possible. When the evaluation does not lead to a clear choice, a stratified estimator should be selected (i.e., the experiment should be classified as Case IV) in order to minimize potential bias.

The reliability of M vs. R and C vs. R tests that fail to reject $H_o$ are called into question when 1) sample sizes M or C are < 100 and the sample size for R is < 30, 2) p-values are not large (~0.20 or less), and the D statistics are large (≥ 0.2). If sample sizes are small, the p-value is not large, and the D statistic is large then the power of the test is suspect and, when re-classifying the experiment, the test should be considered as having rejected the null hypothesis. If for example, sample sizes are marginal (close to the recommended values), the p-value is large, and the D-statistic is not large then the test result may be considered reliable. It is when results are close to the recommended "cutoffs" that interpretation becomes somewhat more complicated.

Apparent inconsistencies between the combination of the M vs. R and C vs. R test results and the M vs. C test results may also arise from low power. For example, if one of the tests involving R rejects the null hypothesis and the other fails to reject one could infer a difference between M & C; however, the M vs. C test may still fail to reject the null indicating no difference between the M & C. In this case, the apparent inconsistency may be due to low power in the test involving R that failed to reject the null. Finally, an additional Case I scenario is flagged by an apparent inconsistency between test results, this time resulting from power being too high. Under this scenario both the M vs. R and C vs. R tests fail to reject the null hypothesis and their power is thought to be sufficient; however, the M vs. C test rejects $H_o$: no difference between the M & C. The apparent inconsistency may result from the M vs. C test being so powerful as to detect selectivity that would result in insignificant bias when estimating abundance and composition. The reliability of M vs. C tests that reject are called into question when 1) sample sizes M or C are > 500, 2) p-values are not extremely small (~0.010-0.049), and the D statistics are small (<0.08). In general all three K-S tests should be performed to permit these evaluations.