FISHERY DATA SERIES NO. 78

STOCK ASSESSMENT OF ARCTIC GRAYLING IN FIELDING LAKE[1]

By

Robert A. Clark

Alaska Department of Fish and Game
Division of Sport Fish
Juneau, Alaska 99802

March 1989

[1] This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-4, Job No. G-8-4.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

During 1986 through 1988, boat electrofishing, fyke nets, and seines were used to capture and mark 1,883 Arctic grayling *Thymallus arcticus* in Fielding Lake. The Jolly-Seber method was chosen to estimate population size because it allowed for adequate mixing of marked and unmarked Arctic grayling while allowing for mortality and recruitment between sampling events. Mark-recapture estimates of population size (fish greater than 199 millimeter fork length) were 6,578 fish in June 1986 and 3,924 fish in June 1987. Estimated annual survival rate of marked Arctic grayling between 1986 and 1987 was 49.0 percent, while recruitment during the same period was 788 fish. The most abundant age class of Arctic grayling in Fielding Lake varied from age 7 in 1986 and 1987 to age 5 in 1988. Growth of Fielding Lake Arctic grayling was successfully modelled with a two parameter version of the von Bertalanffy growth equation. Formulation of an age-structured analysis of the Fielding Lake stock was impaired by incomplete recruitment of age 3 and age 4 Arctic grayling into the defined population.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, population abundance, age composition, size composition, relative stock density, growth, recruitment, survival rate, Fielding Lake.

INTRODUCTION

Background

Fielding Lake (63°10′ N, 145°58′ W; Figure 1) supports a recreational fishery that targets on Arctic grayling *Thymallus arcticus*, lake trout *Salvelinus namaycush*, burbot *Lota lota*, and round whitefish *Prosopium cylindraceum*. The Arctic grayling fishery supports the largest annual harvest of the four species in Fielding Lake. Over the past seven years annual harvests have averaged 1,598 Arctic grayling and 1,497 angler days of fishing effort (Table 1). Although not a major Arctic grayling fishery in interior Alaska, road access and availability of quality Arctic grayling fishing make Fielding Lake potentially susceptible to increased fishing pressure in the future.

Stock assessment of Fielding Lake Arctic grayling began in earnest in 1986 with an initial attempt at estimating population size (Clark and Ridder 1987b). However, investigations of Arctic grayling spawning habits (Warner 1955b) and sport angling pressure and success rate (Warner 1959; Peckham 1977, 1983, 1984, 1985; Holmes et al. 1986; Clark and Ridder 1987a; and Baker 1988) have been performed since 1955.

Stock Assessment Goals and Objectives

Very little is known about laucustrine populations of Arctic grayling in Alaska. The annual stock assessment project at Fielding Lake was designed to fill gaps in knowledge of basic life history and population dynamics in lakes of interior Alaska. Stock assessment at Fielding Lake involves annual estimation of population abundance, age composition, size composition, growth, recruitment, and survival. The ultimate goals of stock assessment at Fielding Lake are:

1) to accurately and precisely describe the stock status of Fielding Lake Arctic grayling on an annual basis;

2) to formulate models of stock dynamics in Fielding Lake that allow estimation of sustained yield on an annual basis; and,

3) to provide fishery managers with stock status data and sustained yield computations, so that informed management decisions can be made.

As part of attaining stock assessment goal 1, the objectives of the 1988 research efforts were:

1) to estimate abundance of Arctic grayling greater than 199 mm FL in Fielding Lake;

2) to estimate age composition of the Arctic grayling population in Fielding Lake; and,

3) to estimate Relative Stock Density (RSD) of the Arctic grayling population in Fielding Lake.

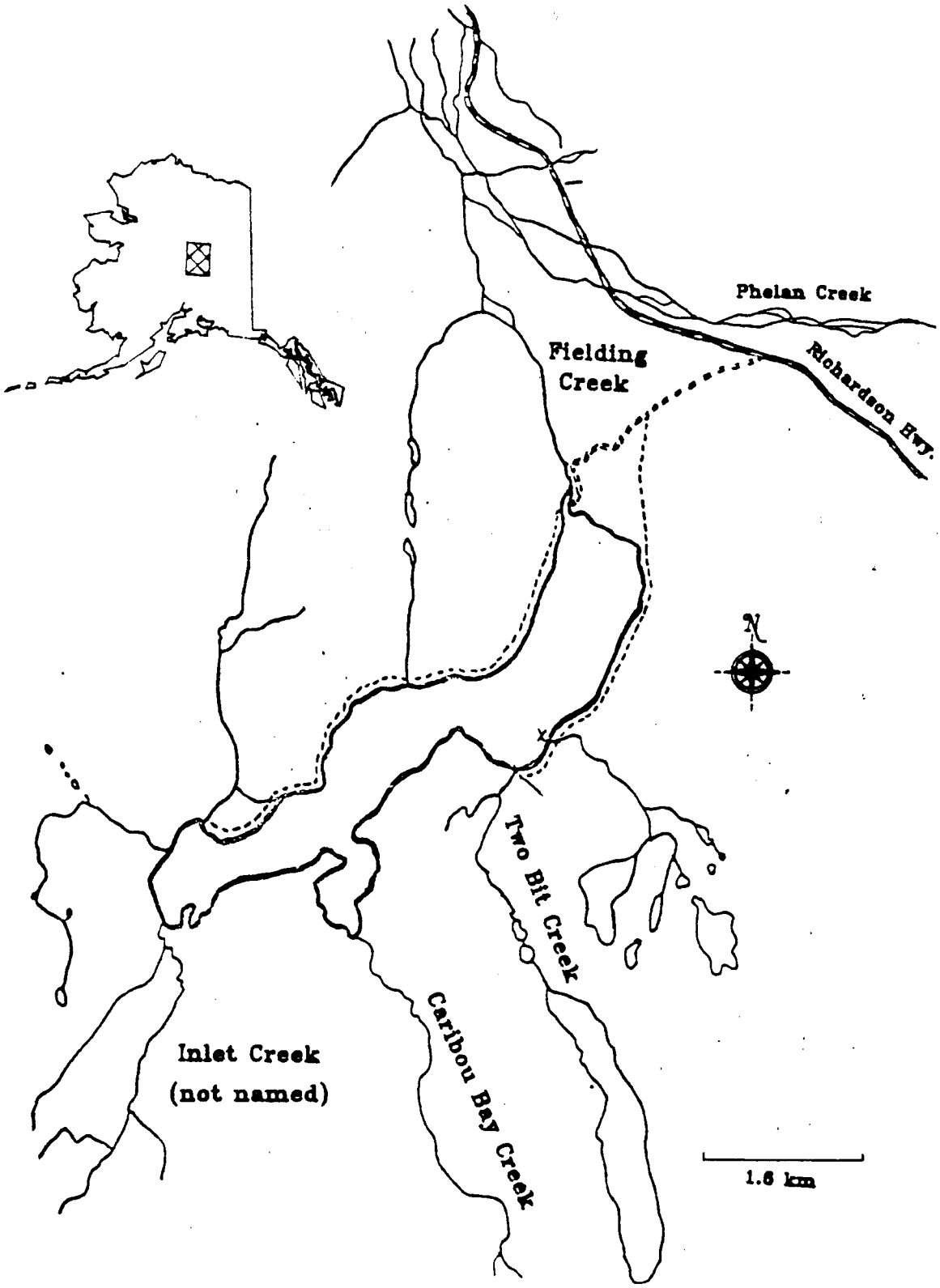

Figure 1. Fielding Lake.

Table 1. Summary of total angling effort and Arctic grayling harvest at Fielding Lake, 1981-1987 (from Mills 1982-1988).

Year	Total Angler-days	Arctic grayling Harvest
1981	1,369	1,913
1982	2,764	3,044
1983	1,737	2,035
1984	871	935
1985	1,023	1,023
1986	1,682	1,329
1987	1,032	910
Averages	1,497	1,598

METHODS

Sampling Gear and Techniques

Fyke nets, seines, and electrofishing gear were used to capture Arctic grayling in Fielding Lake between 1986 and 1988. The fyke nets used in Fielding Lake were the New Hampshire style with 10 mm meshes. Fyke nets were used in two ways. One method was to place the net out from shore with a lead stretching from the throat of the trap to the shore. Fish moving along the shore of the lake would be guided into the trap. A second method of deployment was to block off inlet creeks at their mouths. Wings were attached to the aforementioned type of fyke net and then anchored along the bank of the lake inlets with the throat facing upstream. Arctic grayling migrating downstream after spawning were caught with these "fyke weirs".

Seines were used to capture Arctic grayling in the outlet of Fielding Lake and one of the inlets (Caribou Bay Creek; see Figure 1) during 1986 through 1988. These seines were 15 m X 2 m with 10 mm mesh and a 1 m deep bag. Capture of Arctic grayling was accomplished by hauling the seine downstream with the current, and then sweeping the seine towards shore. Hauls were 30 m long on average. In 1987, a large seine (30 m X 3 m with 25 mm mesh) was used to capture Arctic grayling in Fielding Lake proper. Hauls were made by anchoring one end of the seine on shore and pulling the body of the seine into the lake with a gas powered boat. The other end of the seine was then retrieved back to shore with a rope.

Pulsed direct-current (DC) and alternating-current (AC) electrofishing boats were used to capture Arctic grayling during 1986 through 1988. Both types of electrofishing current were used from 6.1 m river boats fitted with a 3 m long "T-boom" attached to a platform at the bow of the boat. Anodes were constructed of 9.5 mm diameter and 1.5 m long twisted steel cable or 12.5 mm diameter and 1.5 m long flexible conduit filled with lead shot. On the DC system, the aluminum hull of the boat was used as the cathode. Input voltage (120 VAC) was provided by a 3,500 or 4,000 W single-phase gas powered generator. A variable voltage pulsator was used to generate output current. Output voltages during sampling varied from 200 to 300 VDC and 150 to 185 VAC. Amperage varied from 2.0 to 4.0 amp using DC and 1.0 to 2.0 amp using AC. Duty cycle and pulse rate were held constant at 40% and 80 Hz, respectively.

Sampling with electrofishing boats was conducted along the shoreline of Fielding Lake during hours of darkness. Although most of the shoreline of Fielding Lake was sampled with electrofishing gear during all three years, greatest catches of Arctic grayling occurred on the windward side of the lake and over cobble and boulder substrate. To reduce capture related stress, Arctic grayling were held in an aerated holding tub and subsequently transferred to a 2.4 m X 1.2 m holding pen anchored near the lake shore. Fish were sampled for age, sex, maturity, and length within 24 hours of capture.

Regardless of sampling gear, each captured Arctic grayling was measured to the nearest 1 millimeter fork length (FL). Sex was determined by external

morphology as described in Clark and Ridder (1987b) or the presence of sex products. A sample of scales was taken from the preferred zone[1] of each newly captured Arctic grayling. Arctic grayling greater than 199 mm FL were marked with individually numbered Floy FD-68 internal anchor tags inserted at the base of the dorsal fin. The tip of the right pelvic fin was removed to identify marked fish in case the numbered tag was shed. Arctic grayling exhibiting signs of injury or imminent mortality were immediately sacrificed. Sacrificed fish were examined for sex and maturity, and the sagittal otoliths removed for comparison with age determined by scales.

Population Abundance, Survival, and Recruitment

In order to satisfy the project goals for Arctic grayling at Fielding Lake, a method of estimating population abundance was needed that would also give reliable estimates of survival and recruitment. Experience with single-sample mark-recapture experiments at Fielding Lake in 1986 and 1987 was frustrating. A reliable estimate of abundance was calculated in 1986, but adjustments to the mark-recapture data were needed to remove bias due to changes in vulnerability of Arctic grayling by season and to remove bias due to recruitment through growth (Clark and Ridder 1987b). Adjustment of mark-recapture data gathered in 1987 (Clark and Ridder 1988) resulted in an artificially large population estimate and correspondingly large variance. It was obvious that these single season (marking in June and recapture in August) experiments were insufficiently long to allow adequate mixing of marked and unmarked Arctic grayling while insufficiently short to reduce bias due to changes in vulnerability and permit closure of the population.

A multiple-sample design was formulated to allow adequate mixing between years and allow for recruitment and mortality during the experiment. Since marking of Arctic grayling had been performed just after ice break-up in 1986 and 1987, a design that called for marking every spring was used. Because mortality and recruitment would be occurring between sampling events, an estimator that allows for and estimates these two rates was chosen. The generalized model of Jolly (1965) and Seber (1965) was used to estimate population size of Arctic grayling greater than 199 mm FL just prior to sampling in 1987. Assumptions necessary to reliably estimating population size are (adapted from Seber 1982):

1) all Arctic grayling (marked or unmarked) in the population ($\geq$ 200 mm FL) have the same probability of being caught in the ith sample;

2) all Arctic grayling (marked or unmarked) have the same probability of surviving from the ith to the $(i + 1)$th sample;

3) all Arctic grayling caught in the ith sample have the same probability of being released alive into the population;

[1] The preferred zone for Arctic grayling is an area approximately six scale rows above the lateral line just posterior to the insertion of the dorsal fin.

4) all marked Arctic grayling do not lose their marks and all marks are reported on recovery; and,

5) all samples are instantaneous and each release is made immediately after the sample.

Assumptions 1 and 2 are interrelated because differential vulnerability to sampling gear and changes in survival rate by size (or age) of fish could not be separately detected. Both assumptions were simultaneously tested by dividing the data into two length categories: small Arctic grayling (200 through 308 mm FL) and large Arctic grayling (309 through 417 mm FL) and rerunning the calculations for population size, survival, and recruitment. If the data were not biased with respect to assumptions 1 and 2, the summed estimates from small and large Arctic grayling would equal the estimate derived from all data pooled. Assumption 3 was assumed to be valid because none of the sampling gears exhibited size selective mortality and numbers of dead or live unmarked fish were small. Assumption 4 was met by double marking of Arctic grayling with Floy tags and fin clips by sampling event (adipose fin for 1986; partial upper caudal fin for 1987; and, partial right ventral fin for 1988). Assumption 5 was met by restricting each sampling event to 10 days or less during the open water season.

The number of Arctic grayling marked in 1986 and surviving to 1987 was estimated by:

$$(1) \qquad \hat{M}_{86,87} = \frac{R_{86,88}\, M_{87}}{R_{87,88}} + R_{86,87} + D_{86,87}$$

where:

$\hat{M}_{86,87}$ = estimated number of marked Arctic grayling released alive into the population in 1986 and still alive just prior to sampling in 1987;

$R_{86,88}$ = number of Arctic grayling recaptured in 1988 that were released in 1986;

M_{87} = number of Arctic grayling released alive in 1987;

$R_{86,87}$ = number of Arctic grayling recaptured in 1987 that were released in 1986;

$R_{87,88}$ = number of Arctic grayling recaptured in 1988 that were released in 1987; and,

$D_{86,87}$ = number of Arctic grayling recaptured in 1987 and not returned to the population that were released in 1986.

Survival rate between 1986 and 1987 was then estimated as:

$$(2) \qquad \hat{S}_{86,87} = \frac{\hat{M}_{86,87}}{M_{86}}.$$

Population size just prior to sampling in 1987 was estimated as:

$$(3) \qquad \hat{N}_{87} = \frac{C_{87}\,\hat{M}_{86,87}}{R_{86,87}}$$

where:

$\hat{N}_{87}$ = estimated number of Arctic grayling (≥ 200 mm FL) in Fielding Lake just prior to sampling in 1987; and,

C_{87} = number of Arctic grayling captured during sampling in 1987.

With an estimated survival rate between 1986 and 1987 and population estimates for 1986 (Clark and Ridder 1987b) and 1987, an estimate of recruitment between these two years was calculated by:

$$(4) \qquad \hat{A}_{86,87} = \hat{N}_{87} - \hat{N}_{86}\,\hat{S}_{86,87}.$$

Point estimates and variance of population size and survival rate were calculated by bootstrapping the capture histories of Arctic grayling marked in 1986 through 1988 1,000 times according to procedures in Efron (1982). Recruitment was also calculated by bootstrapping procedures, with the restriction that the 1986 population estimate was held constant at 6,578 fish (Clark and Ridder 1987b) for all 1,000 bootstrap samples.

Age and Size Composition

Collection of Arctic grayling for age-length samples was conducted in conjunction with the estimation of population size. Because the estimate of population size was germane to the time just before sampling in 1987, estimates of age and size composition used to apportion the abundance estimate by age or size category were taken from Clark and Ridder (1988). Age and size composition data were also collected during June 1988 and will be used to apportion an estimate of population size in June 1988 when sampling in 1989 is concluded.

Unadjusted age-length data were used to estimate age and size compositions for the June 1987 sample. It was assumed that bias in age-length data was minimal if assumptions 1 and 2 of the Jolly-Seber estimator were being met. In addition, unadjusted age-length data were used to calculate age and size compositions of the Arctic grayling population in June 1988. Accuracy in estimation of age and size compositions for June 1988 will be assessed after sampling in June 1989. The proportion of Arctic grayling in the sample that are age *i* was estimated by:

$$(5) \qquad \hat{p}_i = \frac{y_i}{n}$$

where: y_i = the number of age *i* Arctic grayling sampled; and,

n = the total number of Arctic grayling sampled.

The unbiased variance of this proportion was estimated by:

$$(6) \qquad \hat{V}[p_i] = \frac{\hat{p}_i (1 - \hat{p}_i)}{n - 1}.$$

Size composition of Arctic grayling in Fielding Lake was described with the incremental Relative Stock Density (RSD) indices of Gablehouse (1984). Equations 5 and 6 were used to estimate the proportion of fish in each RSD category.

Growth

Growth of Fielding Lake Arctic grayling was modelled with the von Bertalanffy growth equation (Ricker 1975). Instead of using methods described by Ricker (1975), a nonlinear least-squares approach was used. Age-length data collected between 1986 and 1988 were used to model growth. All samples were taken with electrofishing gear, seines, and fyke nets during mark-recapture experiments in the months of June and July.

Mean length at age was calculated as the arithmetic mean fork length at each age for samples taken from 1986 to 1988. Variances were calculated using the normal distribution theory. The Marquardt (1963) compromise was used to fit the three parameters of the von Bertalanffy growth equation. By allowing the parameters to range from 200 to 600 mm FL by 100 mm increments for L_∞; from 0.0 to 0.4 by 0.1 for K; and from -2.0 to 2.0 by 0.5 for t_0, the model was fitted a total of 200 times. The model with the smallest squared deviations provided the starting parameters for iterative solution of the equation.

Historic Data Summaries

Data collected from Fielding Lake (1953 to 1988) were summarized in a series of appendix tables. Creel census estimates, population abundance estimates, length at age estimates, and age composition estimates were summarized from Federal Aid in Sport Fish Restoration reports and State of Alaska Fishery Data Series reports written from 1955 to the present. When possible, estimates of precision were reported with point estimates. Precision was reported as either standard error or 95% confidence interval. Sample sizes were reported if neither of these estimates of precision were available. Research on spawning habits of Fielding Lake Arctic grayling was reported by Warner (1955b). In addition to the aforementioned state and federal reports, reports concerning Arctic grayling research from 1952-1980 were compiled by Armstrong (1982). For a worldwide reference source, Armstrong, Hop, and Triplehorn (1986) have compiled a bibliography for the genus *Thymallus* to 1985.

RESULTS

During sampling events in 1986, 1987, and 1988 a total of 1,883 Arctic grayling (≥ 200 mm FL) was marked and released (Table 2). During sampling in

Table 2. Summary of captures[1] of Arctic grayling made with fyke nets, seine, and electrofishing in Fielding Lake during spring sampling, 1986-1988.

Year	Dates	Fyke Net[2]	Seine[3]	Electrofishing[4]	Total Marks
1986	24 June to 3 July	46	208	297	551
1987	16 to 21 June	221	25	222	468
1988	13 to 20 June	50	30	784	864
Total		317	263	1,303	1,883

[1] Captures are those Arctic grayling ≥200 mm FL and released alive and bearing a Floy internal anchor tag.

[2] Fyke nets were deployed along the shoreline of Fielding Lake in 1986. In 1987 and 1988 fyke nets were deployed as weirs across Two Bit and Caribou Bay Creeks. All fyke nets were similar to the New Hampshire style and had 10 mm mesh.

[3] Seining was done with 15 m X 2 m beach seines (10 mm mesh) primarily in Fielding Lake outlet. Some beach seining in Fielding Lake proper was done in 1987 with a 60 m X 3 m seine (25 mm mesh) near Two Bit Creek.

[4] Electrofishing was performed with AC and pulsed-DC boat electrofishing units mounted on a 6.1 m riverboat.

1988 a total of 60 fish was recovered from the previous two sampling events. Bias in population estimation due to differential survival and/or gear selectivity was negligible. The summed population estimate of 3,980 fish (SE = 1,247 fish; Table 3) was not different from the pooled bootstrap estimate of 3,924 fish (SE = 751 fish; Table 4). Survival rate between 1986 and 1987 was 0.477 (SE = 0.076; Table 4) for 355 days, resulting in an annual survival rate of 0.490 (SE = 0.078). Recruitment between 1986 and 1987 was 788 fish (SE = 527 fish).

Age compositions estimated from samples taken in 1986, 1987, and 1988 indicate that age 7 fish were most abundant in 1986 and 1987 (Table 5). Age 5 fish were most abundant in 1988. Relative stock density of Arctic grayling in Fielding Lake reflected shifts in age composition over time. A high proportion of age 3 fish in 1986 and a high proportion of age 4 fish in 1988 gave correspondingly high proportions of stock size Arctic grayling in the lake (Table 5 and Table 6). Stock structure shifted to larger fish in 1987 when few age 3 fish were sampled in the stock.

The von Bertalanffy growth model was not successfully adapted to Arctic grayling collected from 1986 through 1988. The x-intercept of the model (referred to as t_o in this report and Ricker 1975) was not estimated with sufficient precision to differentiate the estimate from zero (Table 7). The model was refitted with t_o set to zero, resulting in a gain in precision in the other parameter estimates (Table 7). Sufficient sampling of all age classes was evident from the stable standard deviations of mean fork length at age (Table 8).

DISCUSSION

Utilization of the Jolly-Seber estimator for mark-recapture data collected from Fielding lake resulted in an apparently accurate estimate of Arctic grayling population size. A modified Petersen estimate (Chapman 1951) performed in 1987 by Clark and Ridder (1988) was biased. The magnitude of the bias was large (16,097 fish versus 3,924 fish) and was attributable to incomplete mixing of marked and unmarked fish between the two sampling events in 1987. The disparity between these two estimates reinforces the need to carefully examine mark-recapture data for bias due to sampling or behavior of the fish. The multi-year, multi-sample design used in 1988 allowed for mixing to occur over a long time period (355 days) and permitted mortality and recruitment to occur. Bias due to gear selectivity or differential survival was not evident between years, although Clark and Ridder (1987b) found bias in mark-recapture samples taken two months apart (June and August).

Although the multi-year design permitted accurate estimation of population size, the definition of the population led to some complications in performing age-structure analyses of abundance data. The population was defined as those Arctic grayling that were greater than 199 mm FL. The choice of this minimum length was arbitrary, but as a result the first three age classes of the defined population are only partially recruited. Examination of the age composition data and an analysis of the age at full recruitment shows that ages 2 through 4 are not fully recruited to the defined population, i.e. some

Table 3. Estimates[1] of population size and survival for small (200 through 308 mm FL) and large (> 308 mm FL) Arctic grayling in Fielding Lake in June 1987.

Quantity	Small	Large	Summed[2]
M_{86}	280	271	551
M_{87}	174	294	468
M_{88}	484	380	864
$R_{86,87}$	15	17	32
$R_{86,88}$	7	13	20
$R_{87,88}$	7	33	40
$\hat{N}_{87}$	1,839	2,141	3,980
SE	1,001	743	1,247
$\hat{S}_{86,87}$	0.600	0.463	0.526
SE	0.296	0.125	0.221

[1] Estimates were calculated with the generalized Jolly-Seber model (Seber 1982) using program JOLLY model A (U.S.F.W.S., Patuxent Wildlife Research Center, Laurel, MD 20708)

[2] Summed estimates of population size and survival were obtained by adding population size for small and large fish or calculating the mean of survival for small and large fish. These summed estimates are similar to estimates calculated with all data combined (N_{87} = 3,924 and $S_{86,87}$ = 0.477).

Table 4. Summary of bootstrap[1] parameter estimates from the Jolly-Seber model applied to mark-recapture data from Fielding Lake, 1986-1988.

Parameter[2]	Estimate[3]	Standard Error	Lower Quartile	Upper Quartile	CV[4]
N_{86}	6,578	1,150	NA[5]	NA	17.5
$S_{86,87}$	0.477	0.076	0.416	0.532	15.9
M_{87}	263	45	228	297	17.1
N_{87}	3,924	751	3,370	4,326	19.1
$A_{86,87}$	788	527	401	1,106	66.9

[1] Bootstrapping was accomplished by methods described in Efron (1982).

[2] Parameter definitions are:

N_{86} = population size of Arctic grayling ≥ 200 mm FL on 29 June 1986;

$S_{86,87}$ = the proportion of marked Arctic grayling that survived from marking in 1986 to recapture in 1987 (average time at large is 355 days);

M_{87} = the number of Arctic grayling marked in 1986 that were alive just before sampling in 1987;

N_{87} = population size of Arctic grayling ≥ 200 mm FL prior to sampling in June 1987; and,

$A_{86,87}$ = the number of new Arctic grayling ≥ 200 mm FL that recruited to the population between 29 June 1986 and 19 June 1987 and were alive in June 1987.

[3] The estimate of population size in 1986 was taken from Clark and Ridder (1987b). All other estimates were calculated from bootstrapping methods.

[4] CV = the coefficient of variation of the estimate, expressed as a percentage.

[5] NA = quartile ranges not applicable to the 1986 estimate of population size.

Table 5. Summary of age composition estimates and standard errors for Arctic grayling (≥ 200 mm FL) in Fielding Lake, 1986-1988.

	1986[1]					1987[2]					1988[3]		
Age	n[4]	p[5]	SE[6]	N[7]	SE[8]	n	p	SE	N	SE	n	p	SE
2	3	0.006	0.003	38	23	0	---	---	0	---	0	---	---
3	127	0.247	0.019	1,622	301	16	0.035	0.009	138	42	30	0.037	0.007
4	50	0.097	0.013	639	137	114	0.250	0.020	981	203	201	0.246	0.015
5	31	0.060	0.013	396	96	52	0.114	0.015	447	103	229	0.281	0.016
6	111	0.216	0.018	1,418	268	90	0.197	0.019	774	165	160	0.196	0.014
7	142	0.276	0.020	1,814	333	143	0.314	0.022	1,231	250	116	0.142	0.012
8	51	0.099	0.013	651	140	35	0.077	0.012	301	75	65	0.080	0.009
9	0	---	---	0	---	6	0.013	0.005	52	23	14	0.017	0.004
10	0	---	---	0	---	0	---	---	0	---	1	0.001	0.001
Total	515	1.000	---	6,578	1,115	456	1.000	---	3,924	751	816	1.000	---

[1] Samples taken in 1986 were from seining (37.7%), fyke net (8.3%), and electrofishing (54.0%). Age composition was adjusted for gear selectivity (Clark and Ridder 1987b). Sampling dates were 24 June - 3 July.

[2] Samples taken in 1987 were from seining (5.3%), fyke weir (47.2%), and electrofishing (47.4%). Age composition did not need adjustment for length selectivity (Clark and Ridder 1988). Sampling dates were 16 June - 21 June.

[3] Samples taken in 1988 were from seining (3.5%), fyke weir (5.8%), and electrofishing (90.7%), but were not adjusted for length selectivity. Sampling dates were 13 June - 20 June.

[4] n = sample size.

[5] p = estimated proportion of sample at age.

[6] SE = estimated standard error of p.

[7] N = estimated population size at age.

[8] SE = estimated standard error of N.

Table 6. Summary of Relative Stock Density (RSD) indices of Arctic grayling (≥ 200 mm FL) captured in Fielding Lake, 1986-1988 (sampling dates in parentheses).

	RSD Category[1]				
	Stock	Quality	Preferred	Memorable	Trophy
1986 (24 June through 3 July)					
Number sampled	218	144	189	0	0
RSD	0.396	0.261	0.343	0.000	0.000
Standard Error	0.021	0.019	0.020	0.000	0.000
1987 (16 through 21 June)					
Number sampled	134	120	217	0	0
RSD	0.285	0.255	0.461	0.000	0.000
Standard Error	0.021	0.020	0.023	0.000	0.000
1988 (13 through 20 June)					
Number sampled	344	225	295	0	0
RSD	0.398	0.260	0.341	0.000	0.000
Standard Error	0.017	0.015	0.016	0.000	0.000

[1] Minimum lengths for RSD categories are (Gablehouse 1984): Stock - 150 mm FL; Quality - 270 mm FL; Preferred - 340 mm FL; Memorable - 450 mm FL; and, Trophy - 560 mm FL.

Table 7. Parameter estimates and standard errors of the von Bertalanffy growth model[1], and for the same model with t_0 omitted[2], for Arctic grayling from Fielding Lake, 1986-1988.

Parameter	Estimate	Standard Error	Coefficient of variation
von Bertalanffy			
L_∞	552	69	12.5%
K	0.147	0.036	24.5%
t_0	0.029	0.259	893.1%
$Corr(L_\infty, K)$	-0.987	---	---
$Corr(L_\infty, t_0)$	-0.768	---	---
$Corr(K, t_0)$	0.848	---	---
von Bertalanffy without t_0			
L_∞	558	42	7.5%
K	0.143	0.017	11.9%
$Corr(L_\infty, K)$	-0.988	---	---
Sample size	2,267		

[1] The form of the von Bertalanffy growth model (Ricker 1975) is as follows: $l_t = L_\infty (1 - exp(-K (t - t_0)))$. The parameters of this model were estimated with data collected during 1986 through 1988. Estimation was accomplished through weighted nonlinear regression using the Marquardt compromise (Marquardt 1963).

[2] The von Bertalanffy growth model without t_0 is as follows: $l_t = L_\infty (1 - exp(-Kt))$.

Table 8. Mean fork length (mm) at age of Arctic grayling from Fielding Lake, 1986-1988.

Age	n[1]	FL[2]	SD[3]	SE[4]
1	21	80	11	2
2	130	143	23	2
3	465	186	25	1
4	446	237	22	1
5	339	283	28	2
6	349	337	28	1
7	361	360	21	1
8	136	377	17	1
9	20	386	12	3
Totals	2,267	271	79	2

[1] n is the total number of fish aged from samples taken in 1986, 1987, and 1988.
[2] FL is the arithmetic mean fork length in millimeters.
[3] SD is the estimated population standard deviation of FL.
[4] SE is the estimated standard error of FL.

age 2 through 4 Arctic grayling were not at least 200 mm FL at the time of the population estimate. If recruitment is to be estimated from age composition data, age 5 would have to be the age of full recruitment. If the population was redefined to be "fish greater than 149 mm FL", then the age of full recruitment would be four years. In this case, partial recruitment would occur for only two age classes and a larger proportion of the population would be fully recruited.

Precision of estimates generated from the Jolly-Seber model was generally high, but could be improved with additional marking each year. If the survival rate averages 50% per year and population size is between 4,000 and 6,500 fish, then approximately 1,000 Arctic grayling would have to marked each year to estimate population size with high precision (Robson and Regier 1964). This level of marking would have to continue for at least four years beyond 1988 to significantly affect precision of the 1989 estimate of population size. Based on recommendations by Thompson (1987), a sample of 1,000 fish would allow precise estimation of multinomial proportions such as age and size composition.

ACKNOWLEDGEMENTS

The author wishes to thank William Ridder, Mark Ross, James Harrild, Tim Viavant, and James Chumbley for their expertise in the field. Special thanks go to William Ridder for introducing me to Fielding Lake Arctic grayling research and stressing the need for stock assessment work in lakes of the Interior. Without the generosity of Cy Clausen, field operations at the lake would have been much less enjoyable. Thanks also go to David Bernard for aid in the development of statistical procedures that are exposed in this report. John H. Clark and Rolland Holmes are to be commended for their supervisory and coordination roles that provided the structure necessary for a successful field season and reporting process. This project and report were made possible by partial funding provided by the U.S. Fish and Wildlife Service through the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K under project F-10-4, Job Number G-8-4.

LITERATURE CITED

Armstrong, R. H. 1982. Arctic grayling studies in Alaska. Alaska Cooperative Fisheries Research Unit and the Alaska Department of Fish and Game, Fairbanks, Alaska. 1,593 pp.

_____., H. Hop, and J. H. Triplehorn. 1986. Indexed bibliography of the holarctic genus *Thymallus* (grayling) to 1985. Biological Papers of the University of Alaska No. 23, Fairbanks, Alaska.

Baker, T. T. 1988. Creel censuses in interior Alaska in 1987. Alaska Department of Fish and Game. Fishery Data Series No. 64, Juneau, Alaska. 138 pp.

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological censuses. University of California Publications in Statistics 1: 131-160.

Clark, R. A. and W. P. Ridder. 1987a. Tanana drainage creel census and harvest surveys, 1986. Alaska Department of Fish and Game. Fishery Data Series No. 12, Juneau, Alaska. 91 pp.

_____. and W. P. Ridder. 1987b. Abundance and length composition of selected grayling stocks in the Tanana drainage during 1986. Alaska Department of Fish and Game. Fishery Data Series No. 26, Juneau, Alaska. 55 pp.

_____. and W. P. Ridder. 1988. Stock assessment of Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Fishery Data Series No. 54, Juneau, Alaska. 79 pp.

Efron, B. 1982. The jackknife, the bootstrap, and other resampling plans. Society for Industrial and Applied Mathematics, Monograph 38, CBMS-NSF, Philadelphia.

Gablehouse, D. W. 1984. A length-categorization system to assess fish stocks. North American Journal of Fisheries Management 4:273-285.

Holmes, R. A., W. P. Ridder, and R. A. Clark. 1986. Population structure and dynamics of Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1985-1986, Project F-10-1, 27(G-8-1). 68 pp.

Jolly, G. M. 1965. Explicit estimates from capture-recapture data with both death and immigration-stochastic model. Biometrika 52: 225-247.

Marquardt, D. W. 1963. An algorithm least-squares estimation of nonlinear parameters. Journal for the Society of Industrial and Applied Mathematics 11:431-441.

Mills, M. J. 1982. Alaska statewide sport fish harvest studies (1981). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1981-1982, Project F-9-14, 23(SW-I-A). 115 pp.

_____. 1983. Alaska statewide sport fish harvest studies (1982). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1982-1983, Project F-9-15, 24(SW-I-A). 118 pp.

_____. 1984. Alaska statewide sport fish harvest studies (1983). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1983-1984, Project F-9-16, 25(SW-I-A). 123 pp.

_____. 1985. Alaska statewide sport fish harvest studies (1984). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1984-1985, Project F-9-17, 26(SW-I-A). 137 pp.

_____. 1986. Alaska statewide sport fish harvest studies (1985). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1985-1986, Project F-10-1, 27(RT-2). 137 pp.

_____. 1987. Alaska statewide sport fisheries harvest report (1986). Alaska Department of Fish and Game. Fishery Data Series No. 2. Juneau, Alaska. 140 pp.

_____. 1988. Alaska statewide sport fisheries harvest report (1987). Alaska Department of Fish and Game. Fishery Data Series No. 52. Juneau, Alaska. 142 pp.

Peckham, R. 1977. Evaluation of interior Alaska waters and sport fish with emphasis on managed waters, Delta District. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1976-1977, Project F-9-9, 18(G-III-I): 88-105.

_____. 1983. Evaluation of interior Alaska waters and sport fish with emphasis on managed waters, Delta District. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1982-1983, Project F-9-15, 24(G-III-I): 1-38.

_____. 1984. Evaluation of interior Alaska waters and sport fish with emphasis on managed waters, Delta District. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1983-1984, Project F-9-16, 25(G-III-I): 1-25.

_____. 1985. Evaluation of interior Alaska waters and sport fish with emphasis on managed waters, Delta District. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1984-1985, Project F-9-17, 26(G-III-I): 27-66.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada No. 191. 382 pp.

Robson, D. S. and H. A. Regier. 1964. Sample size in Petersen mark-recapture experiments. Transactions of the American Fisheries Society 93: 215-226.

Seber, G. A. F. 1965. A note on the multiple recapture census. Biometrika 52: 249-259.

_____. 1982. The estimation of animal abundance and related parameters. Charles Griffin and Co., Ltd. London, U.K. 654 pp.

Thompson, S. K. 1987. Sample size for estimating multinomial proportions. The American Statistician 41(1): 42-46.

Warner, G. 1955a. Dynamics of fish populations in waters of interior Alaska. U.S. Fish and Wildlife Service, Federal Aid in Fish Restoration, Quarterly Progress Report. Project F-1-R-5, Work Plan C, Job No. 3: 15-20.

_____. 1955b. Spawning habits of grayling in interior Alaska. U.S. Fish and Wildlife Service, Federal Aid in Fish Restoration, Quarterly Progress Report. Project F-1-R-5, Work Plan E, Job No. 1. 10 pp.

_____. 1959. Catch distribution, age and size composition sport fish in Fairbanks area. U.S. Fish and Wildlife Service, Federal Aid in Fish Restoration, Quarterly Progress Report. Project F-1-R-8, Work Plan A, Job 3c, 8(3). 7 pp.

APPENDIX

Appendix Table 1. Summary of Arctic grayling creel censuses at Fielding Lake, 1953-1988[1].

Year	Dates	Angler Interviews	Angler hours	Harvest Rate GR/hr	Mean length (mm)
1953	ND[2]	200	1,077	0.50	---
1954	ND	250	1,493	0.49	---
1955[3]	ND	72	277	0.62	348
1956[3]	ND	158	1,073	0.49	348
1957[3]	ND	96	388	0.69	257
1958[3]	ND	75	579	0.34	249
1976	6/15 - 9/4	143	508	0.38	---
1982	7/4 - 9/5	95	288	0.43	336
1983	ND	ND	ND	0.55	325
1984	6/10 - 8/11	43	136	0.46	318
1985	6/30 - 8/25	181	ND	0.34	318
1986	6/24 - 8/31	173	2,374	0.34	304
1987	6/15 - 8/31	162	1,609	0.49	300

[1] Sources are: 1953-1958 from Warner (1959); 1976 from Peckham (1977); 1982 from Peckham (1983); 1983 from Peckham (1984); 1984 from Peckham (1985); 1985 from Holmes et al. (1986); 1986 from Clark and Ridder (1987a); and, 1987 from Baker (1988).

[2] ND = data not available from source document.

[3] A spring closure (closed until 1 July) of the fishery was in effect during these years.

Appendix Table 2. Summary of population estimates of Arctic grayling (≥ 200 mm FL) in Fielding Lake, 1986 and 1987.

Date	Estimator[1]	Estimate	SE
3 July 1986	Petersen[2]	6,578	1,150
16 June 1987	Jolly-Seber[3]	3,924	751

[1] Petersen = the Petersen estimator as modified by Chapman (1951); and, Jolly-Seber = the estimator of Jolly (1965) and Seber (1965).
[2] Source is Clark and Ridder (1987b).
[3] Source is this report. This estimate supercedes the previous estimate of Clark and Ridder (1988) of 16,097 fish (SE = 3,780 fish).

Appendix Table 3. Mean fork length (mm) at age of Arctic grayling sampled from Fielding Lake, 1953-1988[1].

	Age																			
	1		2		3		4		5		6		7		8		9		10	
Year	n[2]	FL[3]	n	FL	n	FL	n	FL	n	FL	n	FL	n	FL	n	FL	n	FL	n	FL
1953[4]	0	---	11	159	23	204	16	245	22	320	30	356	13	347	5	379	0	---	0	---
1982[4]	0	---	0	---	5	247	8	293	25	328	22	358	8	383	2	400	0	---	0	---
1982[5]	ND[6]	124	ND	190	ND	253	ND	312	ND	343	ND	359	0	---	0	---	0	---	0	---
1984[4]	0	---	0	---	4	243	6	275	7	353	4	373	1	385	0	---	0	---	0	---
1985[5]	89	126	75	176	35	217	12	262	9	320	4	341	0	---	2	400	0	---	0	---
1986[4]	0	---	0	---	8	210	14	273	22	301	44	335	16	362	8	381	0	---	0	---
1986[5]	0	---	229	142	409	183	115	240	58	295	99	337	102	362	36	383	0	---	0	---
1987[4]	0	---	1	200	13	237	49	259	18	300	14	347	19	370	7	388	4	396	0	---
1987[5]	21	80	37	121	147	169	129	230	52	291	90	336	143	357	35	377	6	387	0	---
1988[5]	0	---	15	150	62	198	206	236	229	278	160	338	116	360	65	375	14	385	1	370

[1] Sources are: Warner (1955a) for 1953; Peckham (1983) for 1982; Peckham (1985) for 1984; Holmes et al. (1986) for 1985; Clark and Ridder (1987a, 1987b) for 1986; Baker (1988) and Clark and Ridder (1988) for 1987; and this report for 1988.

[2] n = number sampled at age.

[3] FL = mean fork length in mm.

[4] Collected from harvest sample.

[5] Collected from population sample.

[6] ND = data not available from source document.

Appendix Table 4. Estimates of age composition of Arctic grayling harvested in the sport fishery from Fielding Lake, 1953-1988[1]

	Age																			
	1		2		3		4		5		6		7		8		9		10	
Year	n[2]	p[3]	n	p	n	p	n	p	n	p	n	p	n	p	n	p	n	p	n	p
1953	0	0.00	11	0.09	23	0.19	16	0.13	22	0.18	30	0.25	13	0.11	5	0.04	0	0.00	0	0.00
1954	1	0.00	1	0.00	12	0.03	14	0.04	30	0.08	122	0.34	104	0.29	59	0.17	12	0.03	2	0.00
1982	0	0.00	0	0.00	5	0.07	8	0.11	25	0.36	22	0.31	8	0.11	2	0.03	0	0.00	0	0.00
1984	0	0.00	0	0.00	4	0.18	6	0.27	7	0.32	4	0.18	1	0.05	0	0.00	0	0.00	0	0.00
1985	0	0.00	5	0.04	11	0.09	9	0.07	34	0.27	33	0.26	26	0.20	6	0.05	3	0.02	0	0.00
1986	0	0.00	0	0.00	8	0.07	14	0.13	22	0.20	44	0.39	16	0.14	8	0.07	0	0.00	0	0.00
1987	0	0.00	1	0.01	13	0.10	49	0.39	18	0.14	14	0.11	19	0.15	7	0.06	4	0.03	0	0.00

[1] Sources are: Warner (1955a) for 1953 and 1954; Peckham (1983) for 1982; Peckham (1985) for 1984; Holmes et al. (1986) for 1985; Clark and Ridder (1987a) for 1986; and, Baker (1988) for 1987.

[2] n = number sampled at age.

[3] p = proportion of sample at age.