FISHERY DATA SERIES NO. 90-1

STOCK ASSESSMENT OF ARCTIC GRAYLING IN FIELDING LAKE[1]

By

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April 1990

[1] This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-5, Job No. G-8-1b.

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ABSTRACT

During 1986 through 1989, boat electrofishing, fyke nets, seines, and gill nets were used to capture and mark 3,159 Arctic grayling *Thymallus arcticus* in Fielding Lake. The Jolly-Seber method was chosen to estimate abundance for June of 1987 and June of 1988. Mark-recapture estimates of abundance (fish greater than 199 millimeter fork length) were 4,184 fish in June of 1987 and 8,525 fish in June of 1988. Estimated annual survival rate of marked Arctic grayling was 50.3 percent between 1986 and 1987 and was 83.1 percent between 1987 and 1988. Recruitment of Arctic grayling into the defined population between 1987 and 1988 was estimated at 5,019 fish. Onset of sexual maturity of Fielding Lake Arctic grayling was at four years (fifth summer) and 260 millimeter fork length. Fifty percent were sexually mature at five years and 313 millimeter fork length. Bias in abundance and survival estimation was detected, but was not significantly different from zero.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, population abundance, age composition, size composition, Relative Stock Density, recruitment, survival, maturity, 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 eight years, anglers have taken an average 1,585 Arctic grayling and expended an average 1,526 days of fishing effort (Table 1). Although not currently a major Arctic grayling fishery in interior Alaska, road access and the availability of quality Arctic grayling fishing make Fielding Lake potentially susceptible to increased fishing pressure in the future.

Population abundance estimates of Arctic grayling in Fielding Lake were initiated in 1986 (Clark and Ridder 1987b). Prior to 1986, investigations of Arctic grayling in Fielding Lake were confined to 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).

Stock Assessment Goals and Objectives

Very little is known about lacustrine 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, recruitment, and survival. The long-term goals of stock assessment at Fielding Lake are to:

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

2) use stock status data in models that predict the consequences of regulatory actions or changes in recreational fishing pressure; and,

3) provide fishery managers with stock status data and model results, so that informed management decisions can be made.

As part of attaining the first stock assessment goal, the objectives of the 1989 research efforts were to:

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

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

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

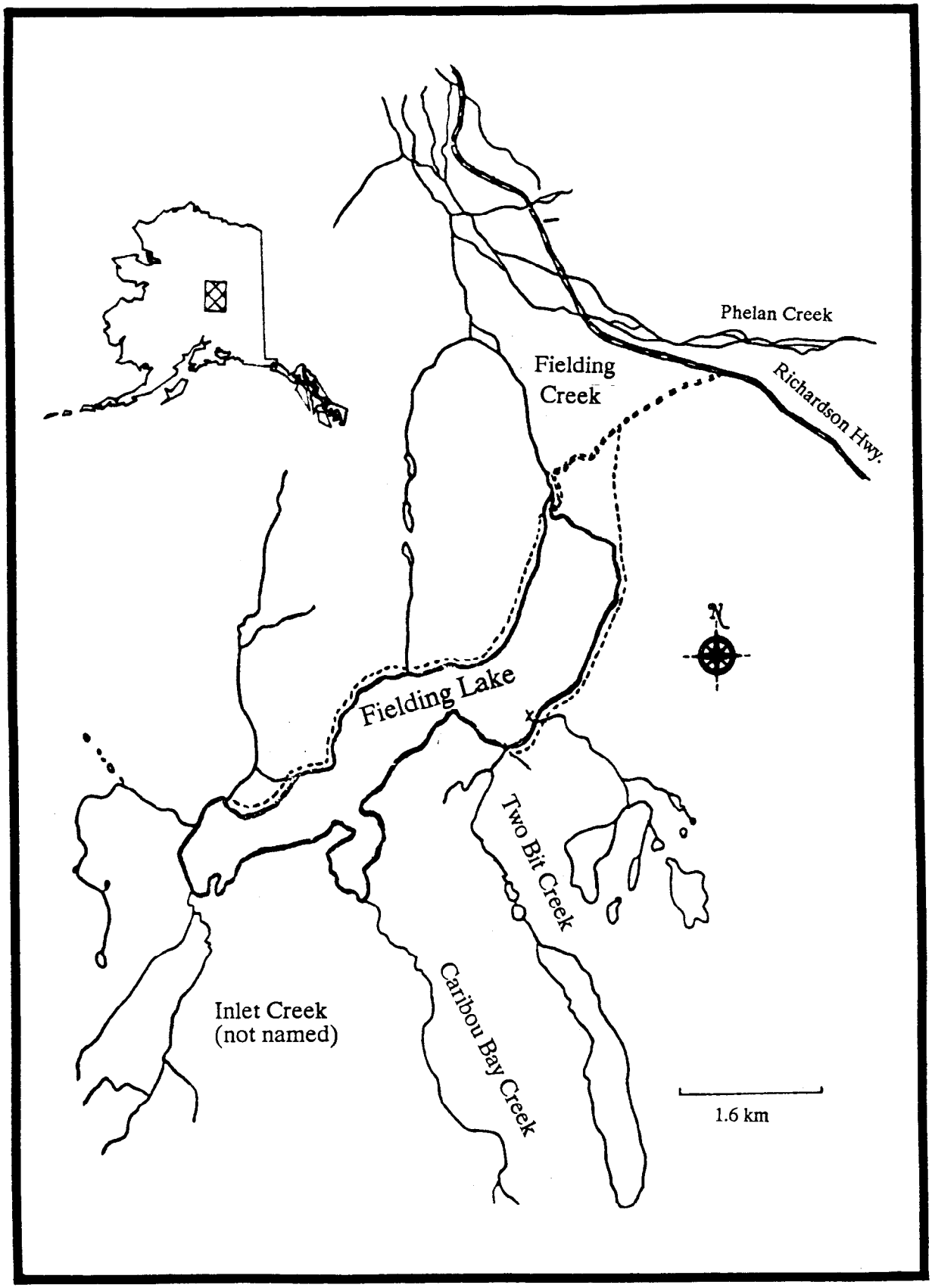

Figure 1. Fielding Lake.

Table 1. Summary of total angling effort and Arctic grayling harvest at Fielding Lake, 1981-1988[a].

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
1988	1,728	1,492
Averages	1,526	1,585

[a] Source is Mills (1982, 1983, 1984, 1985, 1986, 1987, 1988).

METHODS

Sampling Gear and Techniques

Fyke nets, seines, gill nets, and electrofishing gear were used to capture Arctic grayling in Fielding Lake from 1986 through 1989. 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 fyke nets and they were anchored along the banks 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. Arctic grayling were captured by hauling the seine downstream with the current, and then sweeping the seine towards shore. The area sampled averaged 30 m in length. In 1987, a large seine (30 m X 3 m with 25 mm mesh) was used to capture Arctic grayling in Fielding Lake proper. One end of the seine was anchored on shore and the body of the seine was pulled into the lake with a gas-powered boat. The free end of the seine was retrieved by hand. Seining was not performed in 1989.

Gill nets were used to capture lake trout in Fielding Lake in 1989. Arctic grayling were incidentally captured along with round whitefish. These nets were 30 m X 3 m with 25 mm mesh and were deployed perpendicular to the shoreline approximately 10 to 15 m from shore. Nets were checked once every hour.

Pulsed direct-current (DC) and alternating-current (AC) electrofishing boats were used to capture Arctic grayling during 1986 through 1988. Pulsed-DC electrofishing was used exclusively in 1989. 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 four 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 FL. Sex was determined by external morphology as described in Clark and Ridder (1987b) or by 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 or FD-67 internal anchor tags inserted at the base of the dorsal fin. The tip of the lower lobe of the caudal 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 were removed for ageing and comparison with the 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. Using the open population estimator of Jolly (1965) and Seber (1965), a second population estimate was calculated for 1987 with recaptures from 1988. This estimate was deemed more accurate and precise (Clark 1989) than the initial estimate of Clark and Ridder (1988). It was obvious that with single season (marking in June and recapture in August) experiments, insufficient time elapsed to allow adequate mixing of marked and unmarked Arctic grayling. Additional bias was introduced by changes over time in vulnerability to the capture gear and possible emigration by a segment 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, 1987, and 1988, 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) as modified by Buckland (1980; see also Seber 1982 p. 204) was used to estimate population size of Arctic grayling greater than 199 mm FL just prior to sampling in 1988.

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[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.

Assumptions necessary to reliably estimate population size are (adapted from Seber 1982):

1) all Arctic grayling (marked or unmarked) in the population (≥ 200 mm FL) have the same probability of being caught in the *i*th sample;

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

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

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 299 mm FL) and large Arctic grayling (300 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; partial right ventral fin for 1988; and, partial lower caudal fin for 1989). Assumption 5 was met by restricting each sampling event to 10 days or less during the open water season.

A population estimate was calculated for June of 1987 and June of 1988. First, the number of Arctic grayling marked in year *i* and surviving to year *i*+1 was estimated by:

$$\hat{M}_i = \frac{R_i \, z_i}{r_i} + m_i \qquad (1)$$

where:

R_i = the number of marked Arctic grayling released after sampling in year *i*;

z_i = the number of different Arctic grayling caught before sampling in year *i*, not seen during sampling in year *i*, but subsequently recaptured;

r_i = the number of Arctic grayling recaptured that were released in year *i* (recaptures from R_i); and,

m_i = the number of marked Arctic grayling caught during sampling in year i (recaptures).

Using estimates of the number of marked Arctic grayling in Fielding Lake in two successive years, survival rate between year i and year $i+1$ was then estimated as:

$$\hat{\phi}_i = \frac{\hat{M}_i}{M_i - m_i + R_i}. \quad (2)$$

Population size just prior to sampling in year i was estimated as:

$$\hat{N}_i = \frac{\hat{M}_i \, n_i}{m_i} \quad (3)$$

where:

n_i = the number of Arctic grayling caught during sampling in year i.

Assuming that assumption 2 applies to unmarked Arctic grayling as well as marked Arctic grayling, the number of recruits added to the population between year i and year $i+1$ and surviving to year $i+1$ was estimated as:

$$\hat{B}_i = \hat{N}_i - \hat{\phi}_i(\hat{N}_i - n_i + R_i). \quad (4)$$

Point estimates and variance of population size, survival rate, and recruitment were calculated by program RECAP (Buckland 1980). Confidence intervals were calculated by bootstrapping the Jolly-Seber estimates 400 times within program RECAP.

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 1988, estimates of age and size composition used to apportion the abundance estimate by age or size category were taken from Clark (1989). Age and size composition data were also collected during June 1989 and will be used to apportion an estimate of population size in June 1989 when sampling in 1990 is concluded.

Unadjusted age-length data were used to estimate age and size compositions for the June 1988 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 1989. Accuracy in estimation of age and size compositions for June 1989 will be assessed after sampling in June 1990. The proportion of Arctic grayling in the sample that are age j was estimated by:

$$\hat{p}_j = \frac{y_j}{n} \quad (5)$$

where: y_j = the number of age j Arctic grayling sampled; and,
n = the total number of Arctic grayling sampled.

The unbiased variance of this proportion was estimated by:

$$\hat{V}[p_j] = \frac{\hat{p}_j\,(1 - \hat{p}_j)}{n - 1}. \quad (6)$$

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

Maturity

Age and length at sexual maturity were estimated from data collected during June 1988 and 1989. All Arctic grayling greater than 199 mm FL were examined for maturity by the presence of sex products or by external methods (Clark and Ridder 1987b). The data were stratified by assigned age or 10 mm length groups. The proportion of mature fish at age j or within 10 mm length group j was estimated as:

$$\hat{q}_j = \frac{y_j}{n_j} \quad (7)$$

where:

y_j = the number of mature Arctic grayling at age or length group j; and,
n_j = the number of Arctic grayling examined for maturity at age or length group j.

The estimated proportions were used to estimate the percent mature at age or length for the population with probit analysis (SAS 1985).

Historic Data Summary

Data collected from Fielding Lake (1953 to 1989) were summarized in Appendix A. Creel census estimates, population abundance estimates, length at age estimates, age composition estimates, and a growth model 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 in Alaska from 1952-1980 were compiled by Armstrong (1982). For a worldwide reference source, Armstrong et al. (1986) have compiled a bibliography for the genus *Thymallus* to 1985.

RESULTS

A total of 3,159 Arctic grayling was marked and released between 1986 and 1989 (Table 2). Between 1987 and 1989, 219 Arctic grayling were recaptured at least once (32 recaptured in 1987; 60 recaptured in 1988; and 127 recaptured in 1989). The 1987 estimate of Arctic grayling abundance did not show appreciable bias due to differential survival and/or gear selectivity by length of fish (Table 3). The summed population estimate of 4,407 fish (SE = 1,316 fish) did not differ from the pooled estimate of 4,184 fish (SE = 998 fish; Table 4) generated from program RECAP. Similarly, the averaged survival estimate between 1986 and 1987 (Table 3) did not differ appreciably from the pooled estimate (Table 4). Survival rate between 1986 and 1987 was 0.518 (SE = 0.089) for 355 days, resulting in an annual survival rate of 0.503 (SE = 0.086). Recruitment between 1986 and 1987 was 776 fish (SE = 524 fish; Clark 1989).

However, the 1988 estimates of Arctic grayling abundance and survival did show some bias due to heterogeneous survival and/or catchability by length of fish. The summed population estimate of 10,770 fish (SE = 3,840 fish; Table 3) was larger than the pooled estimate of 8,525 fish (SE = 1,628 fish; Table 4). The difference between these estimates was not significantly different from zero (difference = 2,245 fish; SE = 4,171 fish). Similarly, the survival rate estimates for summed-by-length and pooled data sets differed by 0.188 (SE = 0.248; Table 3 and Table 4). The survival rate between 1987 and 1988 for the pooled data set was 0.838 (SE = 0.127) for 362 days, resulting in an annual survival rate of 0.831 (SE = 0.126). Recruitment between 1987 and 1988 was 5,019 fish (SE = 1,481 fish; Table 4).

Age compositions estimated from data collected from 1986 through 1989 showed that age 7 Arctic grayling were most abundant in 1986 and 1987 (Table 5). Age composition shifted towards age 5 fish in 1988 and 1989 (Table 5). Other strong year classes (over 20% of sample) were detected for age 3 and age 6 fish in 1986, age 4 fish in 1987 and 1988, and age 6 fish in 1989. These shifts in age composition were also seen in shifting RSD's (Table 6). Size composition in 1986 and 1988 favored "stock" size (200 to 270 mm FL) Arctic grayling, while "preferred" size (340 to 450 mm FL) fish dominated the sample taken in June of 1987. "Quality" size (270 to 340 mm FL) Arctic grayling were most abundant in the 1989 sample.

Maturity samples taken during June of 1988 and June of 1989 showed that 50% of Arctic grayling in Fielding Lake were sexually mature by age 5 (their sixth summer) at a fork length of 313 mm (Table 7). The onset of sexual maturity occurred at age 4 (fifth summer) and 260 mm FL. Most of the Arctic grayling population were sexually mature by eight years of age (ninth summer) and 377 mm FL. From the raw data (Table 7), 50% maturity occurred between age 5 and age 6 at a length of 300 to 349 mm FL.

Table 2. Summary of captures[a] of Arctic grayling with fyke, seine, and gill nets, and electrofishing gear in Fielding Lake during spring sampling, 1986-1989.

Year	Dates	Fyke Net[b]	Seine[c]	Gill Net[d]	Electro-fishing[e]	Total Marks
1986	24 June to 3 July	46	208	NU[f]	297	551
1987	16 to 21 June	221	25	NU	222	468
1988	13 to 20 June	50	30	NU	784	864
1989	22 to 26 June	33	NU	137	1,106	1,276
Total		350	263	137	2,409	3,159

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

[b] Fyke nets were deployed along the shoreline of Fielding Lake in 1986. In 1987, 1988, and 1989 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.

[c] 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.

[d] Gill nets (33 m X 3 m; 25 mm mesh) were used to capture lake trout in 1989. Arctic grayling were incidentally caught in these gill nets.

[e] Electrofishing was performed with AC and pulsed-DC boat electrofishing units mounted on a 6.1 m riverboat (1986 through 1988). Pulsed-DC was used exclusively in 1989.

[f] NU = gear type not utilized to capture Arctic grayling.

Table 3. Estimates[a] of population size and survival for small (200 through 299 mm FL) and large (> 299 mm FL) Arctic grayling in Fielding Lake, in June 1987 and June 1988.

Quantity	Small	Large	Summed[b]
R_{86}	266	285	551
R_{87}	168	300	468
R_{88}	451	413	864
R_{89}	695	581	1,276
$m_{86,87}$	10	20	30
$m_{86,88}$	3	20	23
$m_{87,88}$	4	34	38
$m_{86,89}$	3	13	16
$m_{87,89}$	5	23	28
$m_{88,89}$	34	33	67
$\hat{\phi}_{86}$	0.46	0.55	0.51
SE	0.22	0.11	0.17
$\hat{N}_{87}$	2,062	2,345	4,407
SE	1,144	650	1,316
$\hat{\phi}_{87}$	0.51	0.95	0.65
SE	0.21	0.21	0.21
$\hat{N}_{88}$	7,385	3,385	10,770
SE	3,748	835	3,840

[a] Estimates were calculated with the generalized Jolly-Seber model (Seber 1982) using program RECAP (Buckland 1980).

[b] Summed estimates of population size and survival were obtained by adding population size for small and large fish or calculating the weighted arithmetic mean of survival for small and large fish. The survival rate estimate of small fish between 1987 and 1988 was adjusted for recruitment of small fish into the large category (personal communication, David Bernard, Alaska Department of Fish and Game, 333 Raspberry Road, Anchorage, Alaska).

Table 4. Summary of bootstrap[a] parameter estimates from the Jolly-Seber model applied to mark-recapture data from Fielding Lake, 1986-1989.

Parameter[b]	Estimate	Standard Error	Lower 95% C.I.[c]	Upper 95% C.I.	CV[d]
ϕ_{86}	0.52	0.09	0.37	0.71	17.2
M_{86}	285	51	212	402	17.9
N_{87}	4,184	998	2,569	6,125	23.8
B_{87}	5,019	1,481	2,357	8,076	29.5
ϕ_{87}	0.84	0.13	0.62	1.00	15.1
M_{87}	605	87	442	762	14.4
N_{88}	8,525	1,628	5,484	11,747	19.1
$\bar{\phi}$[e]	0.67	0.14	0.40	0.93	20.9

[a] Bootstrapping was accomplished with program RECAP as described by Buckland (1980).

[b] Parameter definitions are:
- ϕ_{86} = the proportion of marked Arctic grayling that survived from marking in 1986 to recapture in 1987 (average time at large is 355 days);
- M_{86} = 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;
- B_{87} = the number of new Arctic grayling ≥ 200 mm FL that recruited to the population between 19 June 1987 and 16 June 1988 and were alive in June 1988;
- ϕ_{87} = the proportion of marked Arctic grayling that survived from marking in 1987 to recapture in 1988 (average time at large is 362 days);
- M_{87} = the number of Arctic grayling marked in 1986 and 1987 that were alive just before sampling in 1988; and,
- N_{88} = population size of Arctic grayling ≥ 200 mm FL prior to sampling in June 1988;

[c] 95% C.I. = the 95% 'minimum length' bootstrap confidence intervals calculated in program RECAP (Buckland 1980).

[d] CV = the coefficient of variation of the estimate, expressed as a percentage. Calculated as standard error/estimate x 100%.

[e] $\bar{\phi}$ = the geometric mean proportion of marked Arctic grayling that survived from marking in June of one year to June of the next year between 1986 and 1988.

Table 5. Summary of age composition estimates, abundance, and standard errors for Arctic grayling (≥ 200 mm FL) in Fielding Lake, 1986-1989.

	1986[a]					1987[b]					1988[c]					1989[d]		
Age	n[e]	p[f]	SE[g]	N[h]	SE[i]	n	p	SE	N	SE	n	p	SE	N	SE	n	p	SE
2	3	0.01	<0.01	38	23	0	---	---	0	---	0	---	---	0	---	0	---	---
3	127	0.25	0.02	1,622	301	16	0.04	0.01	147	50	30	0.04	0.01	313	81	68	0.07	0.01
4	50	0.10	0.01	639	137	114	0.25	0.02	1,046	263	201	0.25	0.02	2,100	420	131	0.14	0.01
5	31	0.06	0.01	396	96	52	0.11	0.02	477	129	229	0.28	0.02	2,392	475	327	0.34	0.02
6	111	0.22	0.02	1,418	268	90	0.20	0.02	826	211	160	0.20	0.01	1,672	340	235	0.24	0.02
7	142	0.28	0.02	1,814	333	143	0.31	0.02	1,312	325	116	0.14	0.01	1,212	253	114	0.12	0.01
8	51	0.10	0.01	651	140	35	0.08	0.01	321	92	65	0.08	0.01	679	152	71	0.07	0.01
9	0	---	---	0	---	6	0.01	0.01	55	25	14	0.02	0.00	146	47	26	0.03	0.01
10	0	---	---	0	---	0	---	---	0	---	1	<0.01	<0.01	10	10	0	---	---
Total	515	1.00	---	6,578	1,115	456	1.00	---	4,184	998	816	1.00	---	8,525	1,628	972	1.00	---

[a] 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.

[b] 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.

[c] 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.

[d] Samples taken in 1989 were from fyke weir (2.6%),electrofishing (86.7%), and gill net (10.7%) and were not adjusted for length selectivity. Sampling dates were 22 June - 26 June.

[e] n = sample size.

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

[g] SE = estimated standard error of p.

[h] N = estimated population size at age.

[i] 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, 1986-1989[a].

	RSD Category[b]				
	Stock	Quality	Preferred	Memorable	Trophy
1986 (24 June through 3 July)					
Number sampled	218	144	189	0	0
RSD	0.40	0.26	0.34	0.00	0.00
Standard Error	0.02	0.02	0.02	0.00	0.00
1987 (16 through 21 June)					
Number sampled	134	120	217	0	0
RSD	0.29	0.26	0.46	0.00	0.00
Standard Error	0.02	0.02	0.02	0.00	0.00
1988 (13 through 20 June)					
Number sampled	344	225	295	0	0
RSD	0.40	0.26	0.34	0.00	0.00
Standard Error	0.02	0.02	0.02	0.00	0.00
1989 (22 through 26 June)					
Number sampled	379	604	301	0	0
RSD	0.30	0.47	0.23	0.00	0.00
Standard Error	0.01	0.01	0.01	0.00	0.00

[a] Sampling dates are in parentheses.
[b] Minimum lengths for RSD categories are (Gabelhouse 1984):
Stock - 150 mm FL; Quality - 270 mm FL; Preferred - 340 mm FL;
Memorable - 450 mm FL; and, Trophy - 560 mm FL.

Table 7. Age (years) and fork length (mm) at maturity estimates for Arctic grayling (≥ 200 mm FL) collected from Fielding Lake, June 1988 and June 1989.

Age	Number Examined	Number Mature	Length Group	Number Examined	Number Mature
Raw data:					
3	96	0	200-224	147	0
4	326	0	225-249	277	0
5	547	67	250-274	359	0
6	387	255	275-299	368	47
7	224	208	300-324	268	127
8	133	132	325-349	228	204
9	40	39	350-374	280	269
10	1	1	375-399	189	182
			400-424	28	28

Summary statistics:					
AM_{01}[a]	4 yrs	3 to 5 yrs	LM_{01}[b]	260 mm	244 to 271 mm
AM_{50}	6 yrs	5 to 6 yrs	LM_{50}	313 mm	306 to 321 mm
AM_{99}	8 yrs	7 to 10 yrs	LM_{99}	377 mm	361 to 403 mm

[a] AM_x = xth percentile for age at maturity rounded to the nearest 1 year (ranges are the 95% fiducial limits).

[b] LM_x = xth percentile for fork length at maturity (ranges are the 95% fiducial limits).

DISCUSSION

Two estimates of Arctic grayling abundance and survival have been calculated from data collected during 1986 through 1989. The 1987 estimate of abundance appears to be accurate and has changed little from the previous estimate of 3,924 fish (Clark 1989).

Analysis of accuracy of the 1988 estimate of abundance and survival is more ambiguous than the 1987 estimate. Although the 1987 abundance estimate appears to be biased low (Table 3 and Table 4), the bias is not significantly different from 0 bias. The unusually high survival rate between 1987 and 1988 also warrants concern for accuracy. Length frequencies of Arctic grayling captured in 1987 and 1988 indicate considerable recruitment of fish into the defined population (≥ 200 mm FL; Figure 2). Examining only large Arctic grayling, recruitment appears to be occurring at the smaller sizes of fish greater than 299 mm FL. This is the phenomenon one would expect to see if recruitment had actually occurred. In contrast, recruitment into the small fish category appears over the entire range of sizes less than 300 mm FL. Two interrelated processes could offer an explanation for the gross change in length frequency of small Arctic grayling between 1987 and 1988. These two processes are seasonal growth characteristics and year class strength.

Clark (1989) found that growth of Arctic grayling in Fielding Lake was approximately 50 mm per year from age 1 through age 5 (see also Appendix A5). In addition, Clark and Ridder (1988) found that most of the annual growth increment was accumulated between June and late August. It is quite possible that many fish less than 200 mm FL in June of 1987 were as large as 250 mm FL by August of 1987. If a certain year class were comprised of mostly prerecruited fish (< 200 mm FL) in June, but were very abundant, they could appear in fully recruited (≥ 200 mm FL) by August.

For example, if there was a strong age 3 cohort in Fielding Lake during June of 1987, these fish would have not been completely recruited to the 200 mm FL and greater segment of the population (i.e., they would not have been tagged in 1987; see Appendix A4). By June of 1988, these prerecruited fish would not only be greater than 200 mm FL, they might be as large as 250 mm FL. Clark and Ridder (1988) found evidence for this occurrence while sampling Fielding Lake in August of 1987. The August 1987 sample was weighted heavily towards smaller Arctic grayling than the June 1987 sample, but the August 1987 sample was unbiased with respect to fish marked in June of 1987 (Figure 3; Clark and Ridder 1988). The distribution of lengths of Arctic grayling captured in August of 1987 is more similar to that of June 1988 than that of June 1987.

Regardless of the biological arguments supporting the accuracy of these estimates, further marking and recovery of tagged Arctic grayling in Fielding Lake is needed. If the estimates calculated for June of 1988 are not accurate, additional recaptures of this marking cohort will reduce bias and increase precision. If the estimates are valid, then additional recaptures will confirm their accuracy and increase precision. It is recommended that the 1988 estimate of abundance, survival and recruitment be regarded with caution until sampling and analysis of data collected in 1990 is concluded.

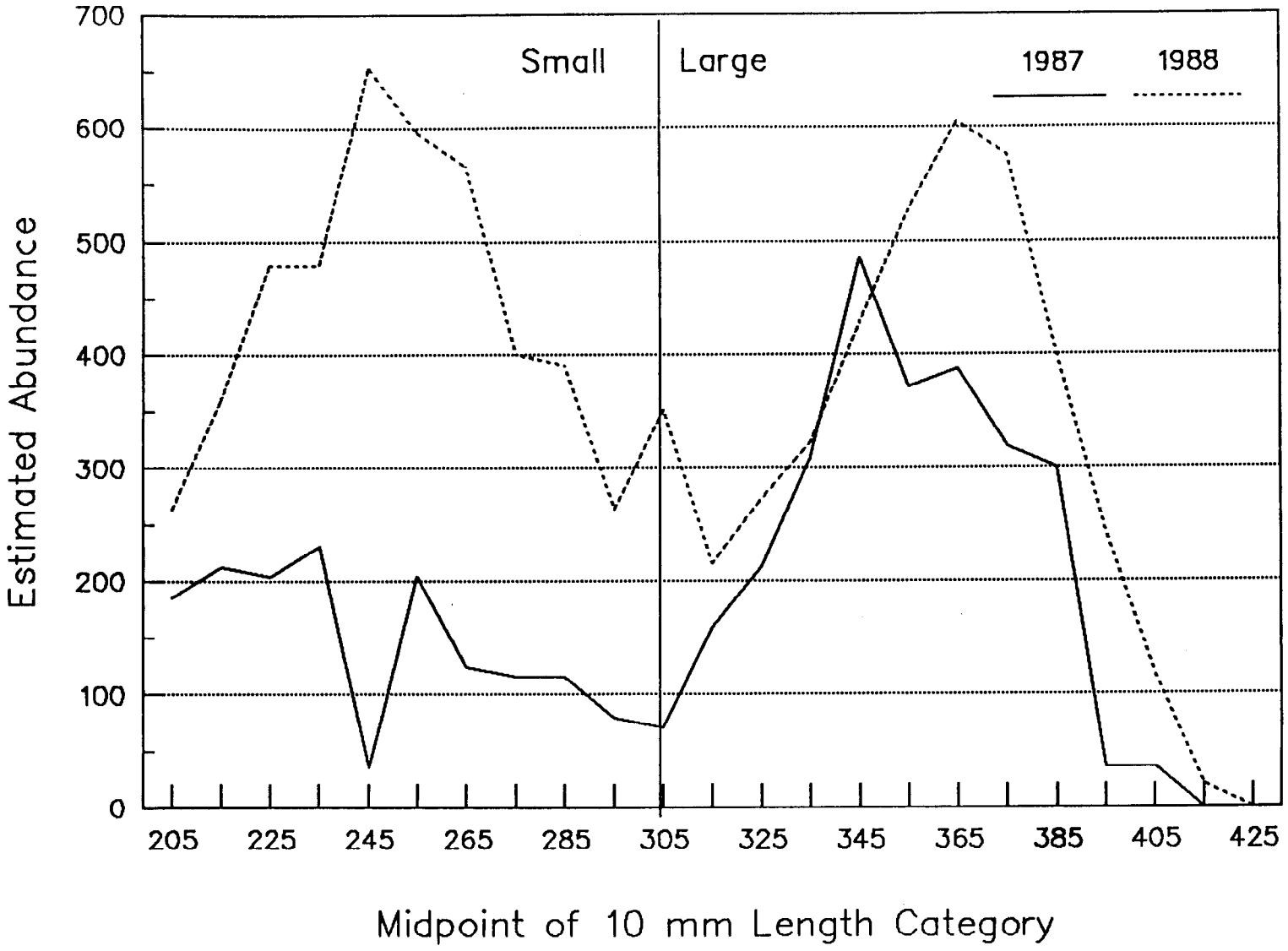

Figure 2. Length frequency distributions of Arctic grayling captured in June of 1987 and 1988.

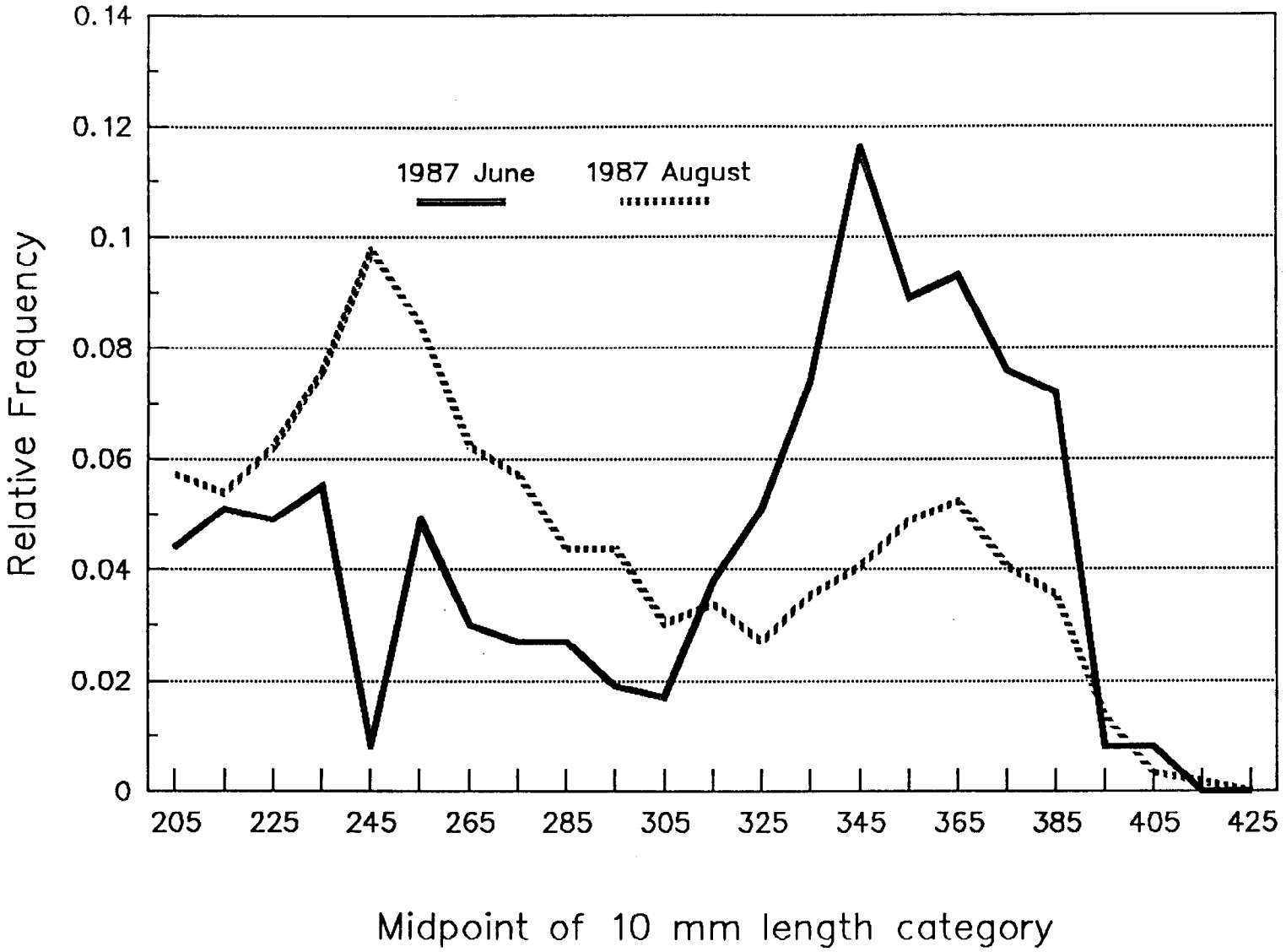

Figure 3. Relative length frequency distributions of Arctic grayling captured in June of 1987 and August of 1987.

From the estimates of abundance and mortality for 1986 (Clark and Ridder 1987b) and 1987, sustained yield can be calculated. However, uncertainty in the survival rate estimate between 1987 and 1988 would probably bias calculation of sustained yield from these data. When reliable estimates of abundance and survival are calculated for 1987 and 1988, sustained yield calculations can be made. Using only one estimate of abundance and survival (the 1986 and 1987 data) to calculate sustained yield might not give an accurate picture of a sustainable harvest level for Arctic grayling in Fielding Lake.

ACKNOWLEDGEMENTS

The author wishes to thank Bill Ridder, Mark D. Ross, James Harrild, Tim Viavant, George Schisler, John Burr, and Tim McKinley for their expertise in the field. The bulk of scale mounting was performed by David Davenport. Special thanks go to Bill 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 Dave Bernard for aid in the development of statistical procedures that are exposed in this report. John H. Clark, Peggy Merritt, and Rocky Holmes are to be commended for their supervisory and coordination roles that provided the structure necessary for a successful field season and reporting process. Special thanks goes to Kerri Clark for editing and final publication of this report. 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-10-5, Job Number G-8-1b.

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APPENDIX A

Appendix A1. Summary of Arctic grayling creel censuses at Fielding Lake, 1953-1989[a].

Year	Dates	Angler Interviews	Angler Hours	Harvest Rate GR/hr	Mean Length (mm)
1953	ND[b]	200	1,077	0.50	---
1954	ND	250	1,493	0.49	---
1955[c]	ND	72	277	0.62	348
1956[c]	ND	158	1,073	0.49	348
1957[c]	ND	96	388	0.69	257
1958[c]	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

[a] 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).

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

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

Appendix A2. Summary of population estimates of Arctic grayling (≥ 200 mm FL) in Fielding Lake, 1986 through 1988.

Date	Estimator[a]	Estimate	SE
3 July 1986	Petersen[b]	6,578	1,150
16 June 1987	Jolly-Seber[c]	4,184	998
13 June 1988	Jolly-Seber[d]	8,525	1,628

[a] Petersen = the Petersen estimator as modified by Chapman (1951); and, Jolly-Seber = the estimator of Jolly (1965) and Seber (1965).
[b] Source is Clark and Ridder (1987b).
[c] Source is this report. This estimate supercedes the previous estimates of Clark and Ridder (1988) of 16,097 fish (SE = 3,780 fish) and Clark (1989) of 3,924 (SE = 751).
[d] Source is this report.

Appendix A3. Estimates of age composition of Arctic grayling harvested in the sport fishery from Fielding Lake, 1953-1989[a].

	Age																	
	1		2		3		4		5		6		7		8		9		10	
Year	n[b]	p[c]	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

[a] 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.

[b] n = number sampled at age.

[c] p = proportion of sample at age.

Appendix A4. Mean fork length (mm) at age of Arctic grayling sampled from Fielding Lake, 1953-1988[a].

	Age																			
	1		2		3		4		5		6		7		8		9		10	
Year	n[b]	FL[c]	n	FL	n	FL	n	FL	n	FL	n	FL	n	FL	n	FL	n	FL	n	FL
1953[d]	0	---	11	159	23	204	16	245	22	320	30	356	13	347	5	379	0	---	0	---
1982[d]	0	---	0	---	5	247	8	293	25	328	22	358	8	383	2	400	0	---	0	---
1982[e]	ND[f]	124	ND	190	ND	253	ND	312	ND	343	ND	359	0	---	0	---	0	---	0	---
1984[d]	0	---	0	---	4	243	6	275	7	353	4	373	1	385	0	---	0	---	0	---
1985[e]	89	126	75	176	35	217	12	262	9	320	4	341	0	---	2	400	0	---	0	---
1986[d]	0	---	0	---	8	210	14	273	22	301	44	335	16	362	8	381	0	---	0	---
1986[e]	0	---	229	142	409	183	115	240	58	295	99	337	102	362	36	383	0	---	0	---
1987[d]	0	---	1	200	13	237	49	259	18	300	14	347	19	370	7	388	4	396	0	---
1987[e]	21	80	37	121	147	169	129	230	52	291	90	336	143	357	35	377	6	387	0	---
1988[e]	0	---	15	150	62	198	206	236	229	278	160	338	116	360	65	375	14	385	1	370
1989[e]	0	---	50	155	102	208	132	247	327	284	235	315	114	357	71	369	26	384	0	---

[a] 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; Clark (1989) for 1988; and this report for 1989.

[b] n = number sampled at age.

[c] FL = mean fork length in mm.

[d] Collected from harvest sample.

[e] Collected from population sample.

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

Appendix A5. Parameter estimates and standard errors of the von Bertalanffy growth model with t_o omitted[a] for Arctic grayling from Fielding Lake, 1986-1988[b].

Parameter	Estimate	Standard Error	Coefficient Of Variation
von Bertalanffy without t_o			
L_∞[c]	558	42	7.5%
K[d]	0.14	0.02	11.9%
$Corr(L_\infty,K)$[e]	-0.99	---	---
Sample size	2,267		

[a] The von Bertalanffy growth model (Ricker 1975) without t_o is as follows: $l_t = L_\infty\ (1 - exp(-Kt))$. The applicable range of ages for this model are 1 through 9 years. This model was fitted to the data by nonlinear regression (SAS 1985) utilizing the Marquardt compromise (Marquardt 1963).

[b] From Clark 1989.

[c] L_∞ is the length a fish would achieve if it continued to live and grow indefinitely (Ricker 1975).

[d] K is a constant that determines the rate of increase of growth increments (Ricker 1975).

[e] $Corr(L_\infty,K)$ is the correlation of parameter estimates (SAS 1985).