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AGE, LENGTH, SEX, AND ABUNDANCE OF ARCTIC GRAYLING IN THE GOODPASTER RIVER, 1956 THROUGH 1988[1]

By

William P. Ridder

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

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ABSTRACT

Arctic grayling *Thymallus arcticus* were captured by electrofishing 48 kilometers of the lower Goodpaster River in 1988. Estimated population abundance in the section was 7,638 Arctic grayling greater than 149 millimeters fork length. Significant downstream movement of tagged fish was detected and adjusted for. The majority of the population in the section were subadult. Age 5 Arctic grayling were the predominant age class. A paucity of age 3 and 4 fish indicated that these were poor year classes. Growth parameters were estimated from both May and August samples and showed differences that indicated seasonal stratification of the population. Fifty percent of Arctic grayling in the Goodpaster River were mature at age 6.0 and 276 millimeters fork length and 90 percent were mature at age 7.2 and 308 millimeters fork length. Fecundity estimates ranged from 3,404 to 5,044 eggs per female but were considered to be biased low. All historical data on age and size compositions, harvest and effort, and population abundance from 1955 to 1987 were compared. In part, the data show recruitment to the population to be quite variable and similar to other riverine stocks of interior Alaska. Lack of whole river abundance estimates, imprecision of abundance indices, and persistent variable recruitment negated precise estimates of dynamic rates of the population.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, Goodpaster River, population abundance, age composition, size composition, maturity, fecundity, harvest, fishing effort, Relative Stock Density, electrofishing, Tanana River drainage.

INTRODUCTION

The Goodpaster River is a typical rapid runoff stream of interior Alaska. It drains an area of approximately 4,100 km^2. It originates in the Tanana Uplands and flows southwest for 224 km to its confluence with the Tanana River, 16 km north of Delta Junction (Figure 1). The river has 13 named tributaries, the largest of which are the Eisenmenger Fork (38 km long) at river kilometer 184 and the South Fork (64 km long) at river kilometer 53.

Below the confluence of the South Fork, the river can be characterized as generally shallow (< 1 m deep) but wide (60 m across), slow moving, meandering, slightly humic stained, and susceptible to rapid fluctuations in water level. Van Whye (1964) described this reach as quite low in productivity due to little aquatic vegetation and a bottom type consisting primarily of sand. He described the river above the confluence as having a predominantly coarse gravel bottom with a high density of aquatic vegetation and food organisms.

The Goodpaster River Arctic grayling *Thymallus arcticus* population has been included in twenty-five Federal Aid in Fish Restoration studies since 1955. These studies can be broken into two main categories: inter-stream migration studies from 1955 through 1966 and stock assessment studies from 1969 to the present. The migration studies presented very little data on age and size compositions of the tagged fish and instead presented quantitative data of number tagged and recovered by area. These quantitative data were partially summarized and interpreted by Reed (1961), Nagata (1963), and Roguski (1967). Generally stated, they found that the Goodpaster River served as a spawning and nursery stream for part of the summer Arctic grayling populations found in the Richardson and Delta Clearwater Rivers (Figure 1). While presenting no quantitative data, Reed (1961) stated that the majority of Goodpaster fish were tagged as two and three year olds while the recoveries of these fish in the clearwater streams were at ages five and greater. He suggested an age-size relationship for inter-stream movements. Ridder (1983) summarized the recovery data from the 7,955 fish tagged in the Goodpaster River in these studies. Of the 507 recoveries, 76% were made in the Goodpaster River and 24% in other waters, predominantly the Delta and Richardson Clearwater Rivers. He also presented stock separation data from scale analysis of age 3 fish that showed that the Goodpaster River could be the source of, at the most, 51% of the Delta Clearwater River Arctic grayling population.

Past stock assessment studies presented data on age and size compositions, population abundance (whole river and index sections), and intra-stream movements. Data on the former two parameters are included in the Appendix. Tack (1974, 1980) found and described an upstream, pre- and post-spawning movement in late May and early June followed by a mid summer period of stasis. During this stasis, the Arctic grayling population was stratified with juveniles and sub-adults occupying the lower 53 km, a mix of these groups in the middle drainage, and predominantly adults in the upper reaches above river kilometer 98.

The recreational fishery on the Goodpaster River is primarily for Arctic grayling. Most anglers are summer residents and their guests and local

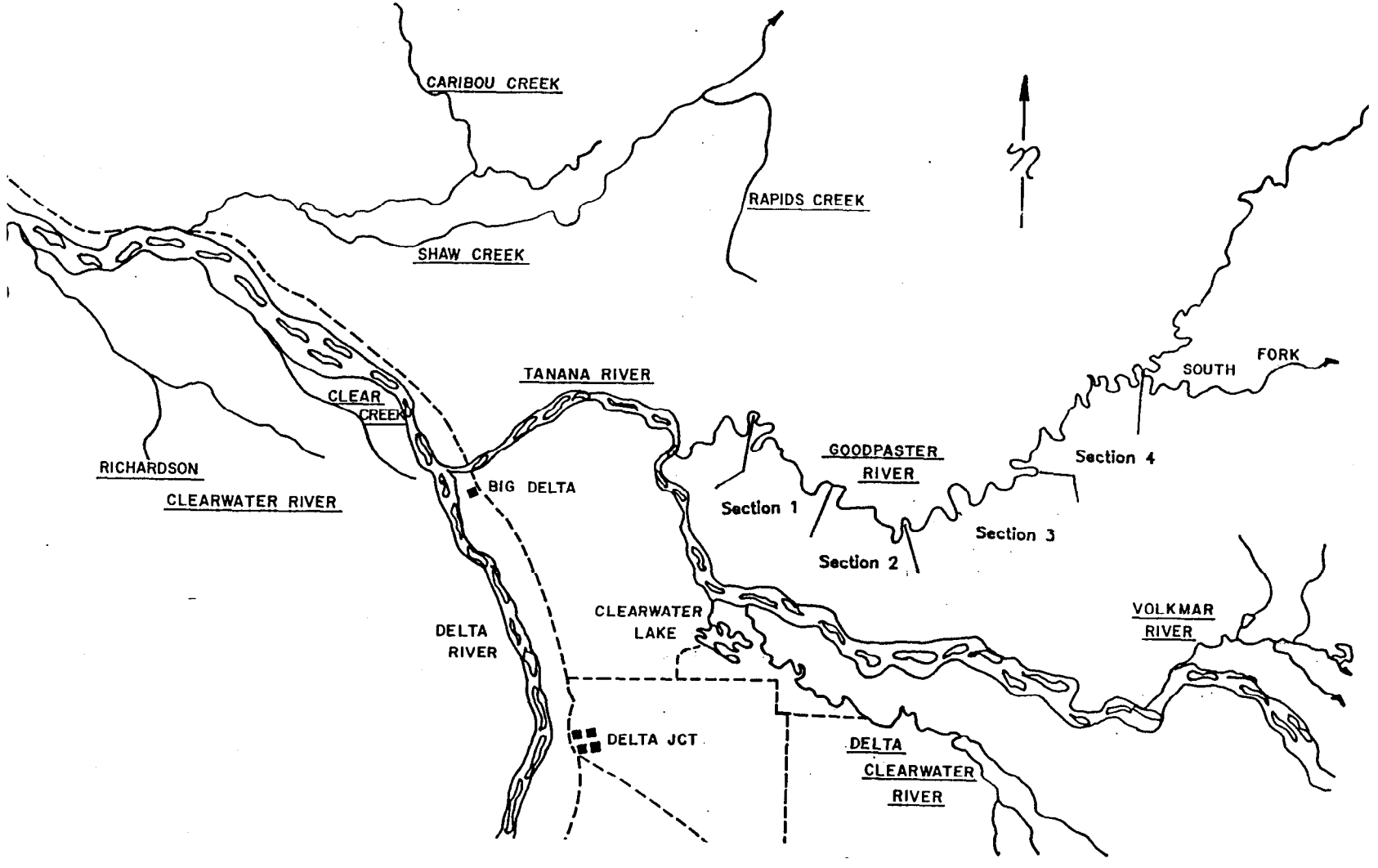

Figure 1. The middle Tanana River drainage and study sections of the Goodpaster River.

residents of the Delta Junction area. Some anglers target northern pike *Esox lucius* and burbot *Lota lota* Some round whitefish *Prosopium cylindraceum* are also harvested. While the river supports a small run of chinook salmon *Oncorhynchus tshawytscha*, the fishery is closed by regulation. The river is accessible only by riverboat or airplane. Boat launches are located 13 km downstream on the Tanana River at Big Delta and 11 km upstream via the Tanana River at Clearwater Lake (Figure 1). Riverboat access is feasible only in the lower 98 km of the river and the lower 5 km of the South Fork. Floatplane access occurs only in the lower 36 km. Landing strips are located at Central Creek at river kilometer 118 and at Tibbs Creek, a tributary of the Eisenmenger Fork. There are approximately fifty cabins on the river used by summer residents. All are located between river kilometers 11 and 48. The Fairbanks Daily News Miner (4 September 1987) reports "More than a hundred families own property in the area and transient use has grown rapidly during the past five years."

Data on the recreational fishery in the Goodpaster River are sparse. Tack (1974) conducted an on-site creel census program in 1973. A check station at river kilometer 1 was used to interview and count angler arrivals and departures with a stratified random sampling schedule. He estimated a harvest of 2,236 Arctic grayling (Table 1) with a monthly CPUE that ranged from 0.69 to 1.63 Arctic grayling harvested per hour. He reported 241 mm FL as the mean length of the sampled harvest (n = 241), that the harvest came from predominantly the lower 53 km of the river, and that the estimated 899 man-days of effort were mainly by residents of the area.

No other data were available until the statewide harvest survey (Mills 1984-1988) began to obtain estimates of harvest and effort in 1983 (Table 1). Annual harvests since then have averaged 2,036 Arctic grayling. Effort for all species has averaged 1,919 man-days for the same period.

This report summarizes all data pertinent to stock assessment work conducted on the Goodpaster River from 1955 to 1988. These data can be found in the Appendix Tables 1 - 14.

The research objectives for 1988 were to estimate:

1) abundance of Arctic grayling (≥ 150 mm fork length) in the lower 48 km of the Goodpaster River; and,

2) the age composition of the population of Arctic grayling (≥ 150 mm fork length) in the lower 48 km Goodpaster River.

METHODS

Estimation of Abundance

Population abundance was estimated in a 48 km long reach of the lower Goodpaster River. The upstream boundary is at river kilometer 53 (the confluence of the South Fork of the Goodpaster River) and the downstream boundary is at river kilometer 4.8 (300 m below Jolly's Cabins). This study

Table 1. Estimated recreational harvest of Arctic grayling and angling effort on the Goodpaster River, 1973 and 1983 - 1987[1].

	Effort					
Year	Anglers	Angler Hours	Man-days[2]	Harvest	Catch	CPUE[3]
1973	602	2,741	899	2,236	5,817	2.49
1983	---	---	1,989	3,021	---	1.52
1984	436	---	766	1,194	---	1.56
1985	939	---	2,844	2,757	---	0.97
1986	563	---	933	1,508	---	1.62
1987	742	---	3,061	1,702	---	0.57
Averages	652	2,179	1,749	2,070	5,817	1.18

[1] Data sources: 1973, Tack (1974); 1983 - 1987, Mills (1984 - 1988).
[2] Estimates of man-days from 1983 on includes effort expended for all species.
[3] CPUE = the number of Arctic grayling harvested per man-day.

area was further subdivided into four sections. Section 1 was 9.6 km long and extended from the downstream boundary to approximately river kilometer 14.4. Section 2 was 8 km long and extended to river kilometer 22.4. Section 3 was 12 km long and extended to river kilometer 34.4. Section 4, the upstream section, was 18.6 km long.

Samples were taken during two events, each four days long. The marking event ran from 8 to 11 August and the recapture event ran from 15 to 18 August. One river section was sampled each day during the events. The time interval between sampling events for each of the four study sections was seven days. Sampling started at the upstream end of a section and consisted of two electrofishing boats traveling downstream, one along each bank, collecting as many Arctic grayling as possible. Each boat had a crew of three and used a pulsed DC variable voltage pulsator with four 10 mm diameter steel cables as anodes and the unpainted bottom of the boat as the cathode. Voltages ranged from 280 to 320 volts and current ranged from 1 to 4 amperes. At the end of an approximately 30 minute run, all captured fish were measured to the nearest 1 mm of fork length (FL), and those greater than 149 mm FL were tagged with Floy FD-67 anchor tags. All tagged fish were given a left pelvic fin clip as a secondary mark to determine tag loss. The fish were then released. Data collection was segregated by section to facilitate the estimation of fish movement within the study area.

Population abundance of Arctic grayling greater than 149 mm FL was estimated with the modified Peterson formula of Bailey (1951, 1952) and the modified Peterson formula of Bernard (Bernard, pers. comm.[1]; Evenson 1988). The necessary assumptions for an accurate estimate are (from Seber 1982):

1) the grayling population in the study area must be closed;

2) no tags can be lost between samples;

3) all grayling have the same probability of capture during the first sample or during the last sample or marked grayling must completely mix with unmarked grayling between samples;

4) marking must not influence behavior between samples; and,

5) mortality is the same for both marked and unmarked fish between samples.

A Kolmogorov-Smirnov two-tailed test (Conover 1980) was unable to detect significant changes in capture probabilities of marked fish either at first capture ($D = 0.069$, $P = 0.579$) or second capture ($D = 0.052$, $P = 0.884$). Therefore, the data were not biased with respect to differing capture probabilities and assumption 3 was met. The seven day hiatus between sampling individual sections facilitated mixing of marked and unmarked fish and minimized recruitment by growth or immigration. Fin-clipping in addition to tagging, satisfied the second assumption. A chi-squared test was applied to

[1] Bernard, David. 1989. Personal Communication. ADFG, 333 Raspberry Rd., Anchorage, AK 99518.

recapture data to determine the validity of assumptions 1 and 4. The test showed significant interarea movement between events ($\chi^2 = 22.29$, df = 4, $P < 0.05$). With this evidence that Arctic grayling were moving into and out of the study area, the modified Peterson estimator of Bernard (Evenson 1988) was used to compensate for this recruitment. The additional assumptions for the accurate use of this estimator are (from Evenson 1988):

6) no Arctic grayling tagged in the midstream section migrate out of the study area; and,

7) a single process causes upstream movement and a single process causes downstream movement.

Since this estimator is built from movement between three areas, data from sections 1 and 2 were combined. This arrangement also aided in fulfilling assumption 6 by giving two large "buffer" areas of 18 km surrounding a 12 km long midstream section.

The modified Peterson estimator that accounts for movements of tagged fish is:

$$(1) \qquad \hat{N} = \frac{\{M_1(1-\hat{\theta}_d) + M_2 + M_3(1-\hat{\theta}_u)\}\{C+1\}}{R+1}$$

where:

M_x = the number of Arctic grayling marked in the first event in section x (x = 1, 2, and 3 for the downstream, midstream, and upstream sections, respectively);

$R_{..}$ = the number of Arctic grayling recaptured during the second event;

θ_z = the probability that an Arctic grayling will move out of an area in the z direction (upstream or downstream);

C = the catch from the second event; and,

N = the abundance of Arctic grayling in all areas at the start of the second event.

The probabilities of movements were estimated by:

$$(2) \qquad \hat{\theta}_d = \frac{M_2(R_{32} + R_{21})}{R_2(M_3 + M_2)} \qquad (3) \qquad \hat{\theta}_u = \frac{M_2(R_{12} + R_{23})}{R_2(M_1 + M_2)}$$

where:

R_{xy} = the number of Arctic grayling that were marked in section x during the first event and were recaptured in section y during the second event; and,

$R_{2.}$ = the number of Arctic grayling that were marked in the midstream section during the first event and were recaptured during the second event.

Variance of the abundance estimate was calculated by bootstrap analysis as described in Efron (1982) and performed in Clark and Ridder (1988). Variances of the probabilities of movements were also calculated with this procedure.

Estimation of Age and Size Composition

From all captured grayling greater than 149 mm FL, a minimum of two scales were removed from an area 4 to 6 scale rows above the lateral line just posterior to the insertion of the dorsal fin. Scales were cleaned in a hot solution of common dish detergent, inspected for regeneration, and then mounted on gummed cards. The cards were used to make impressions of the scales on 20 mil acetate film using a Carver press at 137,895 kPa heated to a temperature of 97°C. Ages were determined by replicate readings using a microfiche reader.

While electrofishing samples have been shown to exhibit bias in capturing all sizes of Arctic grayling, no significant changes in capture probabilities were detected in the mark-recapture experiment. Therefore, it was assumed that the age and size samples collected were representative of the Goodpaster River population at the time of sampling. Thus, an unbiased estimate of the proportion of Arctic grayling in each age class, p_i, was:

$$(4) \qquad \hat{p}_i = \frac{y_i}{n}$$

where:

y_i = the number of Arctic grayling of age i in the sample; and,
n = the number of Arctic grayling in the sample.

The unbiased variance of this proportion was:

$$(5) \qquad \hat{V}[p_i] = \frac{\hat{p}_i \, (1-\hat{p}_i)}{n - 1}$$

Size composition of initial captures was described with the incremental Relative Stock Density (RSD) indices of Gablehouse (1984). The RSD categories for Arctic grayling were: Stock (150 to 269 mm FL); Quality (270 to 339 mm FL); Preferred (340 to 449 mm FL); Memorable (450 to 559 mm FL); and Trophy (greater than 560 mm FL). RSD indices were estimated with equations 4 and 5, substituting the RSD categories for age classes.

Estimation of Length at Age

Length at age information was used to characterize growth of adult Arctic grayling. Data collected from 1986 through 1988 (Clark and Ridder 1987, 1988) were used to construct a growth model. Mean lengths were calculated as the arithmetic mean fork length at each age. The von Bertalanffy growth model (Ricker 1975) was chosen to equate age with average length of each sex. The model parameters were fitted by nonlinear regression using Marquardt's compromise (Marquardt 1963). The three parameters ($L\infty$, K, and t_o) were fitted 270 times with differing initial values: 350 to 600 by 50 for $L\infty$; 0.0 to 0.4 by 0.1 for K; and -2.0 to 2.0 by 0.5 for t_o. The set of estimates with the lowest sums squared deviations was selected as the starting values for the Marquardt procedure.

Sex and Maturity

Age, length, and sex data of adult Arctic grayling were collected by AC electrofishing in the lower 16 km of the Goodpaster River during 1982 (Ridder 1983) and during egg take operations in 1985 through 1987 (office files; Holmes et al. 1986). All sampling occurred within three days of ice break-up and lasted not more than two days. Since sampling was conducted during spawning of Arctic grayling, sex and maturity were readily determined by either sexual dimorphism or the presence of milt or eggs. Dimorphism was evident in differences in length of the dorsal fin (the male dorsal fin usually extends to the adipose fin whereas the female dorsal fin is noticeably shorter) and the swelling of the anal vent and abdominal fullness (gravid) or flaccidity (spawned out) in females. Some error was associated with the use of these morphological characteristics as the sole determinant of sex. For example, at the time of sampling, small males may have been classed as juveniles since their dorsal fin may not have reached the adipose and, if recently spawned, they would not have given milt.

Sex ratios were presented as the ratio of the number of males to females. Fecundity estimates for 1985 through 1987 were calculated from the total number of eggs collected divided by the total number of females spawned. Total eggs were determined by volumetric methods, however no descriptive statistics were kept (Parks pers. comm.[2]).

The length and age at maturity for the Arctic grayling population were recorded as percent mature in 10 mm FL groups and age classes. Since more than one length group and age class had mature and immature fish, probit analysis was used to estimate the length and age at which 50 and 90% of the population was mature (LM_{50}, LM_{90}, AM_{50}, and AM_{90}; Finney 1971). The procedure PROBIT from SAS Institute Inc., Cary, NC 27511 was used for the analysis.

[2] Parks, David. 1989. Personal Communication. ADFG, PO Box 40219, Clear, AK 99704.

RESULTS

Population Abundance

Population abundance of Arctic grayling in the 48 km study area of the Goodpaster River was 8,096 fish (SE = 632), as calculated by Bailey's (1951, 1952) modification of the Peterson formula. Based on observed downstream movements of marked fish out of the sections in which they were marked, this estimate was assumed to be biased high. The modified Peterson formula to account for this movement (Evenson 1988) gave a lower estimate of 7,594 fish with a probability of downstream movement of 0.12 and of upstream movement of 0.01 (Table 2). The bootstrap procedure produced a slightly higher abundance estimate of 7,638 fish with a standard error of 582 fish (CV = 7.6%; Table 2). This later estimate results in an average density of 159 Arctic grayling per kilometer in 1988, slightly higher than the 134 fish per kilometer estimated in 1987 (Appendix Table 1).

Age 5 Arctic grayling dominated the stock in 1988, comprising 40% of a 784 fish sample taken from 8 to 10 August (Table 3). The 1983 year class (age 5) has been predominant in all August samples since 1985 (Appendix Table 2). Age 2 fish were the next most numerous with 18% of the 1988 sample. Ages 3 and 4 comprised only 7% and 11% of the sample, respectively, suggesting two consecutive year classes with poor recruitment.

Relative Stock Density (RSD) indices applied to the total initial catch of 2,011 Arctic grayling collected between 8 and 18 August showed that 60% of the lower Goodpaster River Arctic grayling were stock size (150-269 mm FL), 36% were quality size (270-339 mm FL), and 4% were of the preferred size (340 - 449 mm FL) (Table 4). There was an abrupt change in the RSD estimates between Section 3 and the uppermost Section 4, with stock size fish falling from 64% in the former to 36% in the latter section (Table 4). The estimated RSD for stock size fish was the lowest value from seventeen years of summer sampling (Appendix Table 11).

Estimates of mean length at age (Table 5) were used to calculate parameters of the von Bertalanffy growth model for two multi-year samples from the Goodpaster River collected in May and August (Table 6). The two parameter estimates were slightly different ($T^2 = 18.91$, df = 3, 2,655, $P < 0.05$) with K estimates indicating faster growth in the May sample.

Maturity

The length at which 50% of the Arctic grayling population matures (LM_{50}) in the Goodpaster River was estimated from samples taken in May (n = 1,136) at 276 mm FL with a 95% confidence interval of 273 to 279 mm (Table 7). The estimated LM_{90} was 308 mm FL with a 95% confidence interval of 304 to 313 mm. The AM_{50} (age at maturity) estimate from May samples (n = 947) was 5.97 years with a 95% confidence interval of 5.87 to 6.07 years (Table 8). The AM_{90} estimate was 7.19 years (95% CI = 7.01 to 7.41 years). These estimates indicated that the majority of the population (60%, Table 4) in the lower 53 kilometer of the river in August were sub-adults, or stock size fish.

Table 2. Population abundance estimate of Arctic grayling (≥ 150 mm FL) in a 48 km section of the Goodpaster River, 8 to 18 August 1988.

Parameter	Calculated or Known Quantity	Bootstrap Estimate
M_1	573	573
M_2	352	352
M_3	205	205
C	1,002	1,002
$R_{\cdot\cdot}$	139	139
R_{11}	69	69
R_{12}	1	1
R_{13}	0	0
R_{21}	5	5
R_{22}	43	43
R_{23}	0	0
R_{31}	4	4
R_{32}	4	4
R_{33}	13	13
θ_d	0.119	0.119
θ_u	0.008	0.008
$\hat{N}$ (Evenson 1988)	7,594	7,638
SE	Unknown	582
$\hat{N}$ (Bailey 1951, 1952)	8,096	Bootstrap not performed
SE	632	Bootstrap not performed

Table 3. Estimated proportional contribution of each age class and mean fork length at age for Arctic grayling (≥ 150 mm FL) captured in the Goodpaster River, 8 through 11 August 1988.

	Proportion			Length		
Age Class	n[1]	p[2]	SE[3]	mean	SD[4]	SE
1	1	0.001	0.001	155	---	---
2	144	0.184	0.014	187	13	1
3	58	0.074	0.009	221	14	2
4	86	0.110	0.011	243	16	2
5	317	0.404	0.018	268	17	1
6	34	0.043	0.007	296	17	3
7	67	0.085	0.010	307	20	3
8	45	0.057	0.009	321	22	3
9	20	0.026	0.006	336	33	8
10	8	0.010	0.004	352	15	6
11	3	0.004	0.002	376	33	24
12	1	0.001	0.001	391	---	---
Total	784	1.000		254	46	2

[1] n = sample size.
[2] p = proportion.
[3] SE = standard error.
[4] SD = sample standard deviation

Table 4. Relative Stock Density (RSD) indices for Arctic grayling (≥ 150 mm FL) in four study sections of the lower 48 km of the Goodpaster River, 8 through 18 August 1988.

	RSD Category[1]				
	Stock	Quality	Preferred	Memorable	Trophy
Sec. 1					
Number sampled	253	126	12	0	0
RSD	0.647	0.322	0.031	---	---
Standard Error	0.024	0.024	0.009	---	---
Sec. 2					
Number sampled	407	181	7	0	0
RSD	0.684	0.304	0.012	---	---
Standard Error	0.019	0.019	0.004	---	---
Sec. 3					
Number sampled	422	224	19	0	0
RSD	0.635	0.337	0.029	---	---
Standard Error	0.019	0.018	0.006	---	---
Sec. 4					
Number sampled	131	194	35	0	0
RSD	0.364	0.539	0.097	---	---
Standard Error	0.025	0.026	0.016	---	---
Total					
Number sampled	1,213	725	73	0	0
RSD	0.603	0.361	0.036	---	---
Standard Error	0.011	0.011	0.004	---	---

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

Table 5. Mean fork length (mm) at age for Arctic grayling sampled in the lower 53 km of the Goodpaster River, May 1982 and 1985 through 1986, and August 1986 through 1988.

	May				August			
Age Class	n[1]	Mean	SD[2]	SE[3]	n	Mean	SE	SD
1	2	96	11	11	9	167	14	5
2	13	135	22	6	277	179	16	1
3	104	182	20	2	469	198	17	1
4	93	221	14	1	277	236	15	1
5	199	252	20	1	363	267	17	1
6	190	281	24	2	112	285	21	2
7	162	304	28	2	107	301	21	2
8	90	326	26	3	59	315	23	3
9	57	352	24	3	27	341	35	7
10	22	369	27	6	9	347	19	7
11	11	386	19	6	3	376	33	24
12	3	414	26	18	1	391	---	---
13	2	416	14	14	0	---	---	---
Total	947	272	61	2	1,713	238	48	1

[1] n = sample size.
[2] SD = sample standard deviation.
[3] SE = standard error.

Table 6. Parameter estimates and standard errors of the von Bertalanffy growth model[1] for Arctic grayling from the Goodpaster River, May 1982 and 1985 through 1986, and August 1986 through 1988.

	May		August	
Parameter	Estimate	Standard Error	Estimate	Standard Error
L_∞	527	17	533	121
K	0.112	0.008	0.085	0.037
t_o	-0.780	0.134	-2.825	0.871
Corr(L_∞, K)	-0.982		-0.994	
Corr(L_∞, t_o)	-0.829		-0.919	
Corr(K, t_o)	-0.912		0.956	
Sample size	947		1,713	

[1] The form of the von Bertalanffy growth model (Ricker 1975) is: $l_t = L_\infty (1 - \exp(-K (t - t_o))$. Estimation was accomplished through nonlinear regression using the Marquardt compromise (Marquardt 1963).

Table 7. Proportion of mature[1] Arctic grayling in 10 mm FL groups sampled in the lower 16 km of the Goodpaster River, May 1982 and 1985 through 1987.

10 mm Group	N[2]	Mature		
		n[3]	p[4]	SE[5]
<200	120	0	---	---
200 - 209	40	0	---	---
210 - 219	51	0	---	---
220 - 229	35	0	---	---
230 - 239	64	4	0.063	0.030
240 - 249	71	4	0.056	0.027
250 - 259	67	4	0.149	0.044
260 - 269	80	4	0.338	0.053
270 - 279	78	4	0.449	0.056
289 - 289	83	4	0.651	0.052
290 - 299	74	4	0.784	0.048
300 - 309	64	4	0.891	0.039
310 - 319	59	4	0.915	0.036
320 - 329	52	4	0.981	0.019
330 - 339	53	53	1.000	---
340 - 349	30	30	1.000	---
350 - 359	31	31	1.000	---
360 - 369	25	25	1.000	---
370 - 379	15	15	1.000	---
380 - 389	18	18	1.000	---
390 - 399	11	11	1.000	---
400 - 409	6	6	1.000	---
410 - 419	3	3	1.000	---
420 - 429	1	1	1.000	---
430 - 439	4	4	1.000	---
440 - 449	1	1	1.000	---
Totals	1,136	553	0.487	0.015

[1] Maturity determined by sexual dimorphism or sexual products.
[2] N = total catch in group.
[3] n = number mature in group.
[4] p = proportion mature in group.
[5] SE = sample standard error for the proportion.

Table 8. Proportion of mature[1] Arctic grayling in age classes sampled in the lower 16 km of the Goodpaster River, May 1982, and 1985 through 1986.

Age Class	N[2]	Mature		
		n[3]	p[4]	SE[5]
1	2	0	---	---
2	13	0	---	---
3	104	0	---	---
4	93	0	---	---
5	199	18	0.090	0.020
6	190	109	0.574	0.036
7	162	134	0.827	0.030
8	90	88	0.978	0.016
9	57	57	1.000	---
10	22	22	1.000	---
11	10	10	1.000	---
12	3	3	1.000	---
13	2	2	1.000	---
Total	947	443	0.468	0.016

[1] Maturity was determined by sexual dimorphism or sexual products.
[2] N = total catch in age class.
[3] n = number mature in age class.
[4] p = proportion mature in age class.
[5] SE = sample standard error for the proportion.

Fecundity

Historically, four estimates of fecundity of Goodpaster River Arctic grayling have been calculated. These estimates ranged from 3,404 to 5,044 eggs per female (Table 9). The weighted mean of these estimates was 4,042 eggs for a 312 mm FL Arctic grayling. Data to correlate fork length with fecundity are not available.

DISCUSSION

Population Estimation

One of the tenets of Peterson estimates is that marked fish behave like unmarked fish. The significant downstream movement of marked fish in the 1988 experiment may have been due to the capture method and not a distinct migrational behavior. Tack (1974) noted that fish captured by electrofishing were recaptured downstream of the release site in greater numbers than those initially captured by either gill net or hook and line. He considered this unusual considering they were on their spring upstream migration. Ridder (1983) noted schooling of Arctic grayling in downstream pools of the Richardson Clearwater River at the end of a mark/recapture experiment that had been conducted for 3 consecutive days on a dispersed population. Clark (1989) calculated the probability of movement of Arctic grayling downstream to be 13 times more likely than the probability of upstream movement during a mark and recapture experiment in late May on the Salcha River. Again, this is contrary to the seasonal movement patterns of Arctic grayling, which at this time of year is upstream (Tack 1980). Unless compensated for, as in this study and Clark's, estimates using electrofishing gear over a short time interval should be suspected of positive bias. Such is the case for the estimates conducted by Alaska Department of Fish and Game from 1975 through 1987, which used a sampling methodology of repetitive daily sampling for four days in two 4.8 km river sections (Ridder field notes; Clark and Ridder 1987 and 1988).

Despite the extent of the Goodpaster River data base, assessment of the Arctic grayling stock is limited to general abundance trends, determination of year class strength, and size composition. Even these are compromised to a degree by small sample sizes and changes in the timing of abundance estimates. In addition, gear bias, which was not considered in prior estimates, could also affect estimates of age and size composition. Accurate determination of dynamic rates, such as mortality and recruitment, which are needed to successfully manage the fishery, are difficult to obtain due to sampling biases, small samples and study sections, and variable year class strength. Applying the 1988 sampling methodology in coming years will provide some of the necessary data, at least for the younger age classes. Stratification of the population, with fish occupying higher reaches of the river as they mature, as well as the seasonal migration of a component of the population to other rivers, could still compromise the data set with false estimates of mortality and reproductive potential.

Table 9. Estimates of average fecundity of Arctic grayling in the Goodpaster River, May 1973, and 1985 through 1987.

Year	Sample size	Mean FL(mm)	Fecundity[1]	Source
1973	22	324	5,044	Tack 1974
1985	114	313	3,404	Holmes et al. 1986
1986	42	304	4,722	Parks et al. 1986
1987	49	---	4,494	Parks et al. 1987
Average[2]	227	312	4,042	

[1] Estimates for 1985 through 1987 were obtained by dividing total number of eggs obtained from egg takes by the number of females spawned. These estimates also included fish that were not fully ripe (Holmes et al. 1986 and field notes).

[2] Averages were calculated by weighting FL and fecundity estimates by sample size.

Maturity

The estimated age and length at maturity for the Goodpaster River population may be negatively biased if the presence of smaller and younger fish in samples are not representative of the true population. Also, if samples of these younger fish are not detected as mature (inherent in the external sexing technique), then the maturity estimates would be biased towards larger fish. The latter bias is intuitively present in the Goodpaster River maturity estimates, but is considered low due to sampling during the spawning period. The former bias is more troublesome since its extent is unknown. Ridder (1985) reported that large numbers of age 1 through 5 Arctic grayling migrate into the Delta Clearwater River in mid April. This is one month before the arrival of adult fish and about the normal spawning time for grayling in the Goodpaster River. This stratification of a population(s) creates problems in analysis of sample data. Population compositions of Arctic grayling during their major spring and fall migrations are probably not representative of the population due to the different needs and behavior of rearing, subadult and adult life stages. Thus, the best estimates of maturity would be obtained through sampling of fish up to 320 mm FL in early fall to insure maturation of gonads and eggs for positive identification during dissection.

The estimate of average fecundity, 4,020 per female (Table 9), should be considered a minimum. The gross volumetric techniques applied after field egg takes (1985 - 1987) included spawned fish that were not fully ripe (Holmes et al. 1986; field notes). In comparison, Schallock (1966) estimated an average fecundity of 5,350 eggs for 22 Arctic grayling (mean length = 315 mm) collected from four areas in interior Alaska. Tack (1971) calculated a fecundity of 6,036 eggs for 5 fish (mean length = 278 mm) collected at Mineral Lake Outlet. The estimated fecundity for Goodpaster River grayling obtained in 1973 (5,044 eggs per female) is more in line with estimates obtained from other areas, and is therefore considered the best available fecundity estimate for Goodpaster River grayling.

Growth

Arctic grayling in the Goodpaster River grow at a slower rate in the younger ages and at a faster rate in older ages than populations from two other rapid run-off systems in interior Alaska. The estimated growth parameters from May sampling (Table 6) were slightly, though significantly, different from those estimated by Clark (1989) from combined June and July samples from the Salcha River ($T^2 = 24.18$, df = 3, 2,141, $p < 0.05$). Comparison of the growth parameters from August samples between the Goodpaster River and the Chatanika River (Clark 1989) gave the same slightly significant results ($T^2 = 17.90$, df = 3, 3,177, $p < 0.05$). The estimates of the growth parameter K were smaller in the Goodpaster than either the Salcha or Chatanika Rivers (K = 0.156 and 0.189, respectively) and thus gave estimates of L_∞ that were much higher than the latter (L_∞ = 489 and 375 mm, respectively).

In comparing growth of Arctic grayling between waters, time of sampling and life history factors, i.e. population stratification, must be considered. In the Goodpaster River, different growth parameters were estimated for May and August samples (Table 6). The mean lengths at age of age 7 and older fish

were smaller in the August sample than in the May sample (Table 6). The May sample was collected during spawning and favored larger, adult fish. With the older and larger adult fish occupying the upper drainage during the summer and younger and smaller fish in the lower drainage (Tack 1974; Appendix Tables 2 and 3), different parameter estimates, i.e., t_o and K, could be expected.

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APPENDIX

Appendix Table 1. Summary of population abundance estimates of Arctic grayling (≥ 150 mm FL) in the Goodpaster River, 1972 - 1988[1].

Year	Month	River km	M	C	R	Fish/km^2 N	95% CI[3]	Rel.Prec
1972	12-14 Jul	4.8 - 9.6	210	---	30	189	---	---
1973	1 Jun-30 Aug	0 - 53	2,328	1,734	122	480	411 - 590	18.6%
		53 - 98	561	680	16	322	223 - 732	79.0%
		98 - 184	415	410	19	81	57 - 164	66.1%
		0 - 184	---	---	---	241	209 - 287	16.2%
1974[4]	15-29 Jul	0 - 53	1,217	489	55	201	155 - 260	26.2%
		53 - 98	479	279	9	298	165 - 596	72.4%
		98 - 184	343	275	27	63	44 - 93	39.6%
		0 - 184	---	---	---	152	124 - 186	20.4%
1975	23-27 Jun	4.8 - 9.6	330	145	31	314	223 - 456	37.2%
		24 - 28.8	317	319	34	604	436 - 863	35.3%
		combined	647	464	65	475	374 - 603	24.1%
1976	21-24 Jun	4.8 - 9.6	155	99	9	323	178 - 646	72.4%
		24 - 28.8	202	165	18	368	238 - 597	48.9%
		combined	357	264	27	351	245 - 524	39.6%
1977	21-24 Jun	4.8 - 9.6	234	150	11	613	356-1,150	64.8%
		24 - 28.8	396	263	60	357	278 - 457	25.1%
		combined	630	413	71	377	300 - 474	23.1%
1978	20-23 Jun	4.8 - 9.6	248	167	19	434	284 - 694	47.3%
		24 - 28.8	373	212	32	502	359 - 726	36.6%
		combined	621	379	51	473	361 - 618	27.1%
1980	24-27 Jun	4.8 - 9.6	231	153	13	529	318 - 938	58.6%
		24 - 28.8	337	213	31	470	334 - 683	37.2%
		combined	568	366	44	483	362 - 658	30.7%
1982	29 Jun-2 Jul	4.8 - 9.6	79	107	9	178	98 - 356	72.4%
		24 - 28.8	214	155	39	174	128 - 242	32.9%
		combined	293	260	48	163	123 - 219	29.6%
1984	27-29 Jun	4.8 - 9.6	265	91	12	391	153 - 629	60.9%
		24 - 28.8	216	169	28	264	161 - 367	39.0%
		combined	481	260	40	352	249 - 455	29.3%

- Continued -

Appendix Table 1. Summary of population abundance estimates of Arctic grayling (≥ 150 mm FL) in the Goodpaster River, 1972 - 1988[1] (Continued).

Year	Month	River km	M	C	R	Fish/km N	.95 CI	Rel.Prec
1985	25-27 Jun	4.8 - 9.6	189	213	7	459	238 - 966	79.3%
1985	6-13 Aug	4.8 - 9.6	307	455	42	400	296 - 554	32.3%
		24 - 28.8	303	424	45	328	245 - 450	31.3%
		combined	610	879	87	364	271 - 502	31.7%
1986	11-15 Aug	4.8 - 9.6	230	312	15	403	250 - 686	54.1%
		24 - 28.8	293	389	42	256	193 - 352	31.1%
		combined	523	701	57	305	234 - 397	26.7%
1987	4-10 Aug	4.8 - 9.6	138	191	14	188	115 - 324	55.6%
		24 - 28.8	158	213	24	133	91 - 203	42.1%
		combined	274	363	35	134	97 - 191	35.1%
1988	8-18 Aug	4.8 - 53	1,130	1,002	139	158	SE= 12/km	

[1] Data sources: 1972 - 1974, Tack (1973, 1974, 1975); 1975 - 1978, 1980, Peckham (1976, 1977, 1978, 1979, 1981); 1982, 1984, Ridder (1983, 1985); 1985, Holmes et al. (1986); 1986 - 1987, Clark and Ridder (1987, 1988).

[2] Schnabel estimator in 1972, 1973, 1985 through 1987; modified Peterson (Bailey 1951) estimator in 1974 through 1984; modified Peterson (Evenson 1988) in 1988.

[3] The confidence interval is based on a Poisson distribution of recaptures (Ricker 1975). Estimate for 1988 was from bootstrap methods (Efron 1982) and a standard error (SE) is reported.

[4] Estimate was based on total marks in 1973 which were adjusted with a mortality rate of 0.46 (Tack 1975). Number of marks presented shown for 1973 do not include those applied during the final 1973 sampling event.

Appendix Table 2. Summary of age composition estimates and standard errors for Arctic grayling sampled in the lower 53 km of the Goodpaster River, summer, 1955 - 1988[1].

	1955 29 July - 15 Sept.			1956 summer			1957 11 June - 15 Aug.			1958 7 May - 25 July			1969		
Age Class	n[2]	p[3]	SE[4]	n	p	SE	n	p	SE	n	p	SE	n	p	SE
1	14	0.077	0.020	15	0.051	0.013	3	0.007	0.004	111	0.101	0.009	0	---	---
2	49	0.271	0.033	109	0.367	0.028	40	0.099	0.015	532	0.482	0.015	9	0.129	0.040
3	40	0.221	0.031	115	0.387	0.028	178	0.441	0.025	106	0.096	0.009	13	0.186	0.047
4	53	0.293	0.034	30	0.101	0.018	122	0.302	0.023	225	0.204	0.012	12	0.171	0.045
5	14	0.077	0.020	19	0.064	0.014	30	0.074	0.013	100	0.091	0.009	11	0.157	0.044
6	6	0.033	0.013	5	0.017	0.007	19	0.047	0.011	16	0.014	0.004	9	0.129	0.040
7	5	0.028	0.012	4	0.013	0.007	6	0.015	0.006	10	0.009	0.003	4	0.057	0.028
8	0	---	---	0	---	---	5	0.012	0.006	4	0.004	0.002	7	0.100	0.036
9	0	---	---	0	---	---	1	0.002	0.002	0	---	---	4	0.057	0.028
10	0	---	---	0	---	---	0	---	---	0	---	---	1	0.014	0.014
11	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
12	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
Total	181	1.000		297	1.000		404	1.000		1104	1.000		70	1.000	

- Continued -

Appendix Table 2. Summary of age composition estimates and standard errors for Arctic grayling sampled in the lower 53 km of the Goodpaster River, summer, 1955 - 1988[1] (Continued).

	1973[5] 15 June - 15 Aug.			1975 23 June - 24 June			1976 21 June - 22 June			1977 21 June - 22 June			1978 21 June - 22 June		
Age Class	n	p	SE	n	p	SE	n	p	SE	n	p	SE	n	p	SE
1	0	---	---	3	0.030	0.017	1	0.008	0.008	8	0.069	0.024	2	0.019	0.014
2	3	0.030	0.017	3	0.030	0.017	13	0.108	0.028	1	0.009	0.009	23	0.221	0.041
3	65	0.650	0.048	52	0.520	0.050	13	0.108	0.028	76	0.655	0.044	13	0.125	0.033
4	27	0.270	0.045	7	0.070	0.026	44	0.367	0.044	6	0.052	0.021	58	0.558	0.049
5	2	0.020	0.014	29	0.290	0.046	25	0.208	0.037	13	0.112	0.029	8	0.077	0.026
6	3	0.030	0.017	5	0.050	0.022	22	0.183	0.028	12	0.103	0.028	0	---	---
7	0	---	---	1	0.010	0.010	1	0.008	0.008	0	---	---	0	---	---
8	0	---	---	0	---	---	1	0.008	0.008	0	---	---	0	---	---
9	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
10	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
11	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
12	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
Total	100	1.000		100	1.000		120	1.000		116	1.000		104	1.000	

- Continued -

Appendix Table 2. Summary of age composition estimates and standard errors for Arctic grayling sampled in the lower 53 km of the Goodpaster River, summer, 1955 - 1988[1] (Continued).

	1980 24 June - 25 June			1982 29 June - 2 July			1984 27 June - 28 June			1985[5] 25 June - 26 June		
Age Class	n	p	SE	n	p	SE	n	p	SE	n	p	SE
1	5	0.052	0.023	0	---	---	7	0.070	0.026	0	---	---
2	26	0.271	0.046	8	0.082	0.028	7	0.070	0.026	3	0.015	0.008
3	19	0.198	0.041	21	0.216	0.042	17	0.170	0.038	44	0.216	0.029
4	40	0.417	0.051	43	0.443	0.051	48	0.480	0.050	33	0.162	0.026
5	6	0.063	0.025	21	0.216	0.042	11	0.110	0.031	79	0.387	0.034
6	0	---	---	4	0.041	0.020	7	0.070	0.026	25	0.123	0.023
7	0	---	---	0	---	---	3	0.030	0.017	16	0.078	0.019
8	0	---	---	0	---	---	0	---	---	4	0.020	0.010
9	0	---	---	0	---	---	0	---	---	0	---	---
10	0	---	---	0	---	---	0	---	---	0	---	---
11	0	---	---	0	---	---	0	---	---	0	---	---
12	0	---	---	0	---	---	0	---	---	0	---	---
Total	96	1.000		97	1.000		100	1.000		204	1.000	

- Continued -

Appendix Table 2. Summary of age composition estimates and standard errors for Arctic grayling sampled in the lower 53 km of the Goodpaster River, summer, 1955 - 1988[1] (Continued).

	1985[5] 8 - 11 August			1986[5] 11 - 15 August			1987[5] 3 - 10 August			1988[5] 8 - 11 August		
Age Class	n	p	SE	n	p	SE	n	p	SE	n	p	SE
1	0	---	---	0	---	---	6	0.017	0.007	1	0.001	0.001
2	56	0.269	0.031	80	0.140	0.015	55	0.154	0.019	144	0.184	0.014
3	27	0.130	0.023	360	0.630	0.020	51	0.142	0.018	58	0.074	0.009
4	22	0.106	0.021	26	0.046	0.009	165	0.461	0.026	86	0.110	0.011
5	69	0.332	0.033	37	0.065	0.010	9	0.025	0.008	317	0.404	0.018
6	18	0.087	0.020	56	0.098	0.012	22	0.061	0.013	34	0.043	0.007
7	15	0.072	0.018	8	0.014	0.005	32	0.089	0.015	67	0.085	0.010
8	1	0.005	0.005	2	0.004	0.002	12	0.034	0.010	45	0.057	0.008
9	0	---	---	2	0.004	0.002	5	0.014	0.006	20	0.026	0.006
10	0	---	---	0	---	---	1	0.003	0.003	8	0.010	0.004
11	0	---	---	0	---	---	0	---	---	3	0.004	0.002
12	0	---	---	0	---	---	0	---	---	1	0.001	0.001
Total	208	1.000		571	1.000		358	1.000		784	1.000	

1 Data sources and gear type: 1955 - 1956, hook and line (H&L), Warner (1957); 1957, H&L, Warner (1958); 1958, seine, Warner (1959); 1969, electrofishing boat (EB), Roguski and Tack (1970); 1973 - 1974, EB, Tack (1973,1974); 1975 - 1980, EB, Peckham (1976, 1977, 1978, 1979, 1980, 1981); 1982 - 1984, EB, Ridder (1983, 1985); 1985, EB, Holmes et al. (1986); 1986 - 1987, EB, Clark and Ridder (1987, 1988).

2 n = sample size.

3 p = proportion.

4 SE = standard error of the proportion.

5 For Arctic grayling greater than 149 mm FL only.

Appendix Table 3. Summary of age composition estimates and standard errors for Arctic grayling sampled in the middle (53-98 km) and upper (98 - 152 km) sections of the Goodpaster River, summer, 1973 and 1979[1].

	1973[2] 15 June - 15 Aug middle			1973[2] 15 June - 15 Aug upper			1979 23 - 24 June upper		
Age Class	n[3]	p[4]	SE[5]	n	p	SE	n	p	SE
1	0	---	---	0	---	---	0	---	---
2	3	0.030	0.017	0	---	---	0	---	---
3	26	0.260	0.044	0	---	---	0	---	---
4	30	0.300	0.046	11	0.112	0.032	0	---	---
5	31	0.310	0.046	15	0.153	0.037	6	0.095	0.037
6	8	0.080	0.027	17	0.173	0.038	11	0.175	0.048
7	2	0.020	0.014	35	0.357	0.049	23	0.365	0.061
8	0	---	---	6	0.062	0.024	18	0.286	0.057
9	0	---	---	7	0.072	0.026	5	0.079	0.034
10	0	---	---	4	0.041	0.021	0	---	---
11	0	---	---	2	0.020	0.016	0	---	---
12	0	---	---	1	0.010	0.010	0	---	---
Total	100	1.000		98	1.000		63	1.000	

1 Data sources and gear type: 1973 (middle) electrofishing boat, 1973 (upper) hook and line, Tack (1973, 1974); 1979, hook and line, Peckham (1979).

2 For Arctic grayling greater than 149 mm FL only.

3 n = sample size.

4 p = proportion.

5 SE = standard error of the proportion.

Appendix Table 4. Age composition estimates[1] for Arctic grayling weighted by three area population densities, Goodpaster River, 1973 and 1974.

Age Class	1973			1974		
	n[2]	p[3]	SE[4]	n	p	SE
2	ND[5]	0.027	ND	---	---	---
3	ND	0.448	ND	ND	0.069	ND
4	ND	0.277	ND	ND	0.524	ND
5	ND	0.133	ND	ND	0.200	ND
6	ND	0.052	ND	ND	0.056	ND
7	ND	0.043	ND	ND	0.055	ND4
8	ND	0.005	ND	ND	0.008	ND
9	ND	0.006	ND	ND	0.003	ND
10	ND	0.004	ND	ND	0.003	ND
11	ND	0.003	ND	---	---	---
12	ND	0.001	ND	---	---	---
Total	ND	1.000		277	36	1

[1] Estimates developed from combining age proportions found in three river sections using the estimated population abundance in each section as a weighting factor. Data source is Tack (1974, 1975).
[2] n = sample size.
[3] p = proportion.
[4] SE = standard error of the proportion.
[5] ND = no data in citation.

Appendix Table 5. Summary of age composition estimates and standard errors for Arctic grayling sampled in the lower 16 km of the Goodpaster River, spring, 1982, 1985, and 1986[1].

	1982 15 - 16 May			1985 22 - 23 May			1986 16 - 17 May		
Age Class	n[2]	p[3]	SE[4]	n	p	SE	n	p	SE
1	2	0.009	0.006	0	---	---	0	---	---
2	4	0.018	0.009	0	---	---	9	0.027	0.009
3	26	0.117	0.022	11	0.028	0.008	67	0.200	0.022
4	30	0.135	0.023	32	0.082	0.014	31	0.093	0.016
5	29	0.131	0.023	136	0.349	0.024	34	0.101	0.016
6	45	0.203	0.027	53	0.136	0.017	92	0.275	0.024
7	29	0.131	0.023	85	0.218	0.021	48	0.143	0.019
8	33	0.149	0.024	25	0.064	0.012	32	0.096	0.016
9	16	0.072	0.017	31	0.079	0.014	10	0.030	0.009
10	7	0.032	0.012	10	0.026	0.008	5	0.015	0.007
11	1	0.005	0.004	7	0.018	0.007	2	0.006	0.004
12	0	---	---	0	---	---	3	0.009	0.005
13	0	---	---	0	---	---	2	0.006	0.004
Total	222	1.000		390	1.000		335	1.000	

1 All fish captured with an electrofishing boat. 1982 data from Ridder (1983) and Hop (1984); other data collected during an egg-take program (see Holmes et al., 1986) and are from office files.

2 n = sample size.

3 p = proportion.

4 SE = standard error of the proportion.

Appendix Table 6. Summary of age composition estimates and standard errors for adult Arctic grayling sampled in the lower 16 km of the Goodpaster River, spring, 1982, 1985, and 1986[1].

Age Class	1982 15 - 16 May n[2]	p[3]	SE[4]	1985 22 - 23 May n	p	SE	1986 16 - 17 May n	p	SE	Total n	p	SE
5	14	0.099	0.025	3	0.019	0.011	1	0.007	0.007	18	0.041	0.009
6	41	0.291	0.038	25	0.155	0.029	43	0.305	0.039	109	0.246	0.020
7	29	0.206	0.034	62	0.385	0.038	43	0.305	0.039	134	0.302	0.022
8	33	0.234	0.036	23	0.143	0.028	32	0.227	0.035	88	0.199	0.019
9	16	0.113	0.027	31	0.193	0.031	10	0.071	0.022	57	0.129	0.016
10	7	0.050	0.018	10	0.062	0.019	5	0.035	0.016	22	0.050	0.010
11	1	0.007	0.007	7	0.043	0.016	2	0.014	0.010	10	0.023	0.007
12	0	---	---	0	---	---	3	0.021	0.012	3	0.007	0.004
13	0	---	---	0	---	---	2	0.014	0.010	2	0.005	0.003
Total	141	1.000		161	1.000		141	1.000		443	1.000	

1 All fish captured with an electrofishing boat. Determination of adult fish was made by sexual dimorphism and/or reproductive products. 1982 data from Ridder (1983) and Hop (1984); other data collected during an egg-take program (see Holmes et al., 1986) and are from office files.

2 n = sample size.

3 p = proportion.

4 SE = standard error of the proportion.

Appendix Table 7. Summary of mean length at age data for Arctic grayling sampled in the Goodpaster River, summer, 1969 - 1988[1].

	1969 summer			1973 15 June-15 August			1975 23-24 June			1976 21-22 June			1977 21-22 June		
Age Class	n[2]	FL[3]	SD[4]	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	0	---	---	0	---	---	3	82	ND	1	108	ND	8	98	ND
2	9	126	ND[5]	3	146	ND	3	149	ND	13	149	ND	1	151	ND
3	13	171	ND	91	181	ND	52	182	ND	13	187	ND	76	175	ND
4	12	215	ND	68	224	ND	7	207	ND	44	209	ND	6	229	ND
5	11	265	ND	48	276	ND	29	233	ND	25	240	ND	13	245	ND
6	9	297	ND	28	317	ND	5	269	ND	22	264	ND	12	273	ND
7	4	330	ND	37	343	ND	1	346	ND	1	285	ND	0	---	---
8	7	351	ND	6	368	ND	0	---	---	1	364	ND	0	---	---
9	4	362	ND	7	396	ND	0	---	---	0	---	---	0	---	---
10	1	378	ND	4	404	ND	0	---	---	0	---	---	0	---	---
11	0	---	---	3	417	ND	0	---	---	0	---	---	0	---	---
12	0	---	---	1	432	ND	0	---	---	0	---	---	0	---	---
Total	70			295			100			120			116		

- Continued -

Appendix Table 7. Summary of mean length at age data for Arctic grayling sampled in the Goodpaster River, summer, 1969 - 1988[1] (Continued).

	1978 21-22 June			1979 25-28 June			1980 24-25 June			1982 29-30 June			1984 27-28 June		
Age Class	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	2	101	ND	0	---	---	5	105	ND	0	---	---	7	92	ND
2	23	140	ND	0	---	---	26	156	ND	8	133	ND	7	161	ND
3	13	188	ND	0	---	---	19	202	ND	21	191	ND	17	204	ND
4	58	208	ND	0	---	---	40	220	ND	43	218	ND	48	219	ND
5	8	268	ND	6	281	ND	6	260	ND	21	249	ND	11	259	ND
6	0	---	---	11	320	ND	0	---	---	4	270	ND	7	258	ND
7	0	---	---	23	359	ND	0	---	---	0	---	---	3	289	ND
8	0	---	---	18	379	ND	0	---	---	0	---	---	0	---	---
9	0	---	---	5	395	ND	0	---	---	0	---	---	0	---	---
10	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
11	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
12	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
Total	104			63			96			97			100		

- Continued -

Appendix Table 7. Summary of mean length at age data for Arctic grayling sampled in the Goodpaster River, summer, 1969 - 1988[1] (Continued).

	1985[6] 25-26 June			1985[6] 6-8 August			1986[6] 11-15 August			1987[6] 3-10 August			1988[6] 8-11 August		
Age Class	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	0	---	---	0	---	---	0	---	---	6	166	17	1	155	---
2	3	160	6	56	164	15	80	164	9	55	183	15	144	187	13
3	44	190	12	27	208	10	360	193	19	51	206	14	58	221	14
4	33	224	14	22	236	14	26	235	15	165	233	13	86	243	16
5	79	245	19	69	253	17	37	261	12	9	264	15	317	268	17
6	25	269	20	18	284	13	56	281	22	22	276	14	34	296	17
7	16	284	21	15	292	20	8	305	23	32	288	17	67	307	20
8	4	323	25	1	295	---	2	301	8	12	296	17	45	321	22
9	0	---	---	0	---	---	2	387	27	5	341	34	20	336	33
10	0	---	---	0	---	---	0	---	---	1	311	---	8	352	15
11	0	---	---	0	---	---	0	---	---	0	---	---	3	376	33
12	0	---	---	0	---	---	0	---	---	0	---	---	1	391	---
Total	204	236	37	208	227	47	571	211	72	358	233	38	784	254	46

1 Data sources and gear type: 1969, electrofishing boat (EB), Roguski and Tack (1970); 1973 - 1974, EB, Tack (1973,1974); 1975 - 1980, EB, Peckham (1976, 1977, 1978, 1979, 1980, 1981); 1982 - 1984, EB, Ridder (1983, 1985); 1985, EB, Holmes et al. (1986); 1986 - 1987, EB, Clark and Ridder (1987, 1988).

2 n = sample size.

3 FL = mean fork length at age.

4 SD = sample standard deviation of FL.

5 ND = no data in citation.

6 For Arctic grayling greater than 149 mm FL only.

Appendix Table 8. Summary of mean length at age data for Arctic grayling sampled in the lower 16 km of the Goodpaster River, spring, 1982, 1985 through 1986[1].

Age Class	1982 15 - 16 May			1985 22 - 23 May			1986 16 - 17 May		
	n[2]	FL[3]	SD[4]	n	FL	SD	n	FL	SD
1	2	96	11	0	---	---	0	---	---
2	4	137	21	0	---	---	9	133	23
3	26	195	9	11	193	9	67	175	20
4	30	217	10	32	224	15	31	221	15
5	29	262	20	136	250	21	34	252	16
6	45	293	31	53	279	17	92	276	21
7	29	311	36	85	301	28	48	305	18
8	33	337	29	25	323	21	32	317	22
9	16	349	24	31	355	23	10	378	25
10	7	368	24	10	365	28	5	385	25
11	1	383	---	7	381	16	2	405	24
12	0	---	---	0	---	---	3	414	26
13	0	---	---	0	---	---	2	416	14
Total	222	278	63	390	280	48	335	259	64

1 All fish captured with an electrofishing boat. 1982 data from Ridder (1983) and Hop (1984); other data collected during an egg-take program (see Holmes et al., 1986) and are from office files.

2 n = sample size.

3 FL = mean fork length at age.

4 SD = sample standard deviation of FL.

Appendix Table 9. Summary of mean length at age data for adult male Arctic grayling sampled in the lower 16 km of the Goodpaster River, spring, 1982, 1985 through 1986[1].

	1982 15 - 16 May			1985 22 - 23 May			1986 16 - 17 May			Total		
Age Class	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
5	8	276	11	2	304	49	0	---	---	10	281	26
6	21	298	35	7	291	17	21	292	19	49	294	27
7	16	311	42	19	321	30	19	313	17	54	315	31
8	26	337	30	5	329	13	14	318	18	45	330	27
9	11	351	24	11	360	21	4	361	22	26	356	23
10	7	368	24	4	379	35	4	385	23	15	376	28
11	1	383	---	2	394	7	2	405	24	5	396	17
12	0	---	---	0	---	---	3	414	26	3	414	26
13	0	---	---	0	---	---	2	416	14	2	416	14
Total	90	322	41	50	333	39	69	325	42	209	328	42

1 All fish captured with an electrofishing boat. Determination of adult fish was made by sexual dimorphism and/or reproductive products. 1982 data from Ridder (1983) and Hop (1984); other data collected during an egg-take program (see Holmes et al., 1986) and are from office files.

2 n = sample size.

3 FL = mean fork length at age.

4 SD = sample standard deviation of FL.

Appendix Table 10. Summary of mean length at age data for adult female Arctic grayling sampled in the lower 16 km of the Goodpaster River, spring, 1982, 1985 through 1986[1].

	1982 15 - 16 May			1985 22 - 23 May			1986 16 - 17 May			Total		
Age Class	n[2]	FL[3]	SD[4]	n	FL	SD	n	FL	SD	n	FL	SD
5	6	280	11	1	248	---	1	253	---	8	273	16
6	20	296	24	18	283	18	22	287	22	60	289	22
7	13	310	25	43	301	26	24	302	16	80	302	24
8	7	334	23	18	322	23	18	317	24	43	322	24
9	5	345	25	20	352	24	6	344	24	31	349	24
10	0	---	---	6	356	17	1	351	---	7	355	16
11	0	---	---	5	376	16	0	---	---	5	376	16
Total	51	307	30	111	316	37	72	304	27	234	309	33

1 All fish captured with an electrofishing boat. Determination of adult fish was made by sexual dimorphism and/or reproductive products. 1982 data from Ridder (1983) and Hop (1984); other data collected during an egg-take program (see Holmes et al., 1986) and are from office files.

2 n = sample size.

3 FL = mean fork length at age.

4 SD = sample standard deviation of FL.

Appendix Table 11. Summary of Relative Stock Density (RSD) estimates for Arctic grayling (≥ 150 mm FL) in the lower Goodpaster River, 1955 - 1988[1].

		RSD Category[2]				
		Stock	Quality	Preferred	Memorable	Trophy
1955	Number sampled	118	45	10	0	0
Jul-	RSD	0.682	0.260	0.058	---	---
Sept	Standard Error	0.035	0.033	0.018	---	---
1956	Number sampled	204	31	4	0	0
Jun-	RSD	0.854	0.130	0.017	---	---
Aug	Standard Error	0.023	0.022	0.008	---	---
1970	Number sampled	802	42	0	0	0
Aug	RSD	0.950	0.050	---	---	---
	Standard Error	0.007	0.007	---	---	---
1972	Number sampled	163	9	0	0	0
Jun	RSD	0.948	0.052	---	---	---
	Standard Error	0.017	0.017	---	---	---
1972	Number sampled	120	2	0	0	0
Aug	RSD	0.984	0.016	---	---	---
	Standard Error	0.011	0.011	---	---	---
1975	Number sampled	636	12	1	0	0
Jun	RSD	0.980	0.018	0.002	---	---
	Standard Error	0.002	0.005	0.002	---	---
1976	Number sampled	337	18	2	0	0
Jun	RSD	0.944	0.050	0.006	---	---
	Standard Error	0.012	0.012	0.004	---	---
1977	Number sampled	633	15	1	0	0
Jun	RSD	0.975	0.023	0.002	---	---
	Standard Error	0.006	0.006	0.002	---	---
1978	Number sampled	603	17	0	0	0
Jun	RSD	0.973	0.027	---	---	---
	Standard Error	0.007	0.007	---	---	---
1980	Number sampled	588	12	0	0	0
Jun	RSD	0.980	0.020	---	---	---
	Standard Error	0.006	0.006	---	---	---

- Continued -

Appendix Table 11. Summary of Relative Stock Density (RSD) estimates for Arctic grayling (≥ 150 mm FL) in the lower Goodpaster River, 1955 - 1988[1] (Continued).

		RSD Category[2]				
		Stock	Quality	Preferred	Memorable	Trophy
1982	Number sampled	112	102	37	0	0
May	RSD	0.446	0.406	0.147	---	---
	Standard Error	0.031	0.031	0.022	---	---
1982	Number sampled	314	11	0	0	0
Jun	RSD	0.966	0.034	---	---	---
	Standard Error	0.010	0.010	---	---	---
1984	Number sampled	443	39	0	0	0
Jun	RSD	0.919	0.081	---	---	---
	Standard Error	0.012	0.012	---	---	---
1985	Number sampled	217	210	80	0	0
May	RSD	0.428	0.414	0.158	---	---
	Standard Error	0.022	0.022	0.016	---	---
1985	Number sampled	169	35	1	0	0
Jun	RSD	0.824	0.171	0.005	---	---
	Standard Error	0.027	0.026	0.005	---	---
1985	Number sampled	322	60	0	0	0
Aug	RSD	0.843	0.157	---	---	---
	Standard Error	0.019	0.019	---	---	---
1986	Number sampled	167	151	28	0	0
May	RSD	0.483	0.436	0.081	---	---
	Standard Error	0.027	0.027	0.015	---	---
1986	Number sampled	560	80	6	0	0
Aug	RSD	0.867	0.124	0.009	---	---
	Standard Error	0.013	0.013	0.004	---	---
1987	Number sampled	58	128	130	1	0
May	RSD	0.183	0.404	0.410	0.003	---
	Standard Error	0.022	0.028	0.028	0.003	---
1987	Number sampled	290	66	2	0	0
Aug	RSD	0.810	0.184	0.006	---	---
	Standard Error	0.021	0.020	0.004	---	---

- Continued -

Appendix Table 11. Summary of Relative Stock Density (RSD) estimates for Arctic grayling (≥ 150 mm FL) in the lower Goodpaster River, 1955 - 1988[1] (Continued).

		RSD Category[2]				
		Stock	Quality	Preferred	Memorable	Trophy
1988	Number sampled	1,213	725	73	0	0
Aug	RSD	0.603	0.361	0.036	---	---
	Standard Error	0.011	0.011	0.004	---	---

[1] Data Sources: 1955-1956, Warner (1957); 1970, 1972, Tack (1971, 1973); 1975- 1982 (June), Peckham (1976, 1977, 1978, 1979, 1983); 1984, Ridder (1985); 1982 (May), 1985, 1986, 1987 (May), Office files; 1987 (Aug), Clark and Ridder (1988).

[2] Minimum lengths (FL) for RSD categories are (Gablehouse 1984):

Stock - 150 mm
Quality - 270 mm
Preferred - 340 mm
Memorable - 450 mm
Trophy - 560 mm

Appendix Table 12. Summary of Relative Stock Density (RSD) estimates for adult Arctic grayling (≥ 150 mm FL) in the lower 16 km of the Goodpaster River, spring, 1982 and 1985 through 1987.

		RSD Category[1]				
		Stock	Quality	Preferred	Memorable	Trophy
1982	Number sampled	17	99	37	0	0
	RSD	0.111	0.647	0.242	---	---
	Standard Error	0.025	0.039	0.035	---	---
1985	Number sampled	20	141	80	0	0
	RSD	0.083	0.585	0.332	---	---
	Standard Error	0.018	0.019	0.030	---	---
1986	Number sampled	8	109	24	0	0
	RSD	0.057	0.773	0.170	---	---
	Standard Error	0.019	0.035	0.032	---	---
1987	Number sampled	1	108	130	1	0
	RSD	0.004	0.450	0.542	0.004	---
	Standard Error	0.004	0.032	0.032	0.004	---
Total	Number sampled	46	457	271	1	0
	RSD	0.059	0.590	0.350	0.001	---
	Standard Error	0.008	0.018	0.017	0.001	---

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

Appendix Table 13. Summary of Relative Stock Density (RSD) indices for adult Arctic grayling (≥ 150 mm FL) by sex in the lower 16 km of the Goodpaster River, spring, 1982 and 1985 through 1987.

		RSD Category[1]				
		Stock	Quality	Preferred	Memorable	Trophy
1982	Males:					
	Number sampled	10	51	30	0	0
	RSD	0.110	0.560	0.330	---	---
	Standard Error	0.033	0.052	0.049	---	---
1982	Females:					
	Number sampled	7	48	7	0	0
	RSD	0.113	0.774	0.113	---	---
	Standard Error	0.040	0.053	0.040	---	---
1985	Males:					
	Number sampled	4	39	44	0	0
	RSD	0.046	0.448	0.506	---	---
	Standard Error	0.022	0.053	0.054	---	---
1985	Females:					
	Number sampled	16	102	36	0	0
	RSD	0.104	0.662	0.234	---	---
	Standard Error	0.025	0.038	0.034	---	---
1986	Males:					
	Number sampled	2	56	20	0	0
	RSD	0.026	0.718	0.256	---	---
	Standard Error	0.018	0.051	0.049	---	---
1986	Females:					
	Number sampled	7	66	8	0	0
	RSD	0.086	0.815	0.099	---	---
	Standard Error	0.031	0.043	0.033	---	---
1987	Males:					
	Number sampled	1	68	110	1	0
	RSD	0.006	0.378	0.611	0.006	---
	Standard Error	0.006	0.036	0.036	0.006	---
1987	Females:					
	Number sampled	0	40	20	0	0
	RSD	---	0.667	0.333	---	---
	Standard Error	---	0.061	0.061	---	---

- Continued -

Appendix Table 13. Summary of Relative Stock Density (RSD) indices for adult Arctic grayling (≥ 150 mm FL) by sex in the lower 16 km of the Goodpaster River, spring, 1982 and 1985 through 1987 (Continued).

	RSD Category				
	Stock	Quality	Preferred	Memorable	Trophy
Total Males:					
Number sampled	17	214	204	1	0
RSD	0.039	0.491	0.468	0.002	---
Standard Error	0.009	0.024	0.024	0.002	---
Total Females:					
Number sampled	30	256	71	0	0
RSD	0.084	0.717	0.199	---	---
Standard Error	0.015	0.024	0.021	---	---

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

Appendix Table 14. Arctic grayling abundance, harvest, and angler exploitation estimates for the Goodpaster River, 1972 through 1988.

		Abundance[1]			Angler exploitation[2]	
Year	Month	0-53km	0-152km	Harvest	0-53	0-152
1972	JUNE	10,017	20,034	ND[3]	---	---
1973	JUNE	25,440	44,955	2,236	0.09	0.05
1974	JUNE	10,649	27,441	ND	---	---
1975	JUNE	25,166	50,332	ND	---	---
1976	JUNE	18,654	37,307	ND	---	---
1977	JUNE	19,999	39,998	ND	---	---
1978	JUNE	25,054	50,108	ND	---	---
1979	JUNE	ND	ND	ND	---	---
1980	JUNE	25,574	51,149	ND	---	---
1981	JUNE	ND	ND	ND	---	---
1982	JUNE	8,616	17,232	ND	---	---
1983	JUNE	ND	ND	3,021	---	---
1984	JUNE	18,656	37,312	1,194	0.06	0.03
1985	AUGUST	19,292	38,584	2,757	0.13[4]	0.07[4]
1986	AUGUST	16,165	32,330	1,508	0.09[4]	0.05[4]
1987	AUGUST	7,102	14,204	1,702	0.19[4]	0.11[4]
1988	AUGUST	8,374	16,748	(2,070)[5]	0.20[4]	0.11[4]
Averages:		17,054	34,108	2,070	0.13	0.07

[1] Abundance in the lower 53 km for 1972 and 1975 through 1988 was extrapolated from fish per km estimates (Appendix Table 1). Abundance for 0 - 152 km for the same years is twice the estimate for the lower 53 km based on the average ratio between the sections estimated in 1973 and 1974 (Appendix Table 1).

[2] Exploitation rate is harvest divided by abundance.

[3] ND = no data.

[4] Harvests were added to abundance estimates to give an approximation of abundance at start of season prior to calculating exploitation rates.

[5] Average harvest was used in order to obtain exploitation estimates.