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ABSTRACT

Arctic grayling *Thymallus arcticus* in 12 waters of the Tanana River drainage were sampled to estimate the age and size at sexual maturity. Of these 12 waters, Arctic grayling stocks in seven either currently have or had a minimum length limit of 305 millimeters total length (12 inches or approximately 270 millimeters fork length). Age at onset of maturity ranged from 2 years to 4 years, ranging from 4 years to 6 years at 50% maturity, and ranging from 6 years to 10 years at 99% maturity. Size at onset of maturity ranged from 192 to 265 millimeters fork length, ranging from 238 to 316 millimeters fork length at 50% maturity, and ranging from 276 to 376 millimeters fork length at 99% maturity. A minimum length limit of 305 millimeters total length appeared to allow greater than 50% of mature fish to spawn at least once in five of the seven waters with a minimum length limit. The minimum length limit regulation should be reevaluated for the remaining two waters, namely the Salcha River and Caribou Creek.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, age and size at maturity, probit analysis, minimum length limit, Chena River, Salcha River, Chatanika River, Goodpaster River, Fish Creek, Caribou Creek, Mineral Lake outlet, Piledriver Slough, Badger Slough, Fielding Lake, Tangle Lakes system, Tanana River drainage.

INTRODUCTION

Minimum length limits are one of the tools currently used to manage Arctic grayling *Thymallus arcticus* fisheries in the Tanana River drainage. One of the working hypothesis used to justify the use of a minimum length limit is that fishing mortality on a particular Arctic grayling stock should be minimized until fish are of sufficient size to have spawned at least once. However, age and size at sexual maturity have not been estimated for many of the major Arctic grayling stocks in the Tanana River drainage. To properly assess the efficacy of minimum length limits to protect the stock prior to onset of maturity, age and size at maturity were estimated for 12 Arctic grayling stocks in the Tanana River drainage.

Prior to this study, there were estimates of age and/or size at maturity available from Arctic grayling stocks in the Goodpaster River, Caribou Creek, Mineral Lake outlet, Fielding Lake, the Tangle Lakes system, and Piledriver Slough (Ridder 1989a, Ridder 1989b, Clark 1991, Ridder 1991, and Fleming 1991) that were sampled at least once during 1980 through 1991 (Figure 1). There were also estimates of age and/or size at maturity available for Arctic grayling stocks in the Chatanika River, Chena River, Goodpaster River, and Mineral Lake outlet (Schallock 1966, Van Hulle 1968, Tack 1971, 1974) from sampling prior to 1980. In addition, there were maturity data (either age or size or both) that had not been analyzed for Arctic grayling stocks at Fish Creek (Nenana River drainage), Jack Lake (Nabesna River drainage), and Badger Slough (tributary of the Chena River). There were no maturity data for the Arctic grayling stock in the Salcha River. Of these 12 systems, fisheries on the Chena, Chatanika, and Salcha rivers, Piledriver and Badger sloughs, and Mineral Lake outlet have, or have had, a minimum length limit regulation for Arctic grayling. Moreover, harvest of Arctic grayling and total fishing effort in the Goodpaster River, Caribou Creek, Mineral Lake outlet, Fielding Lake, and the Tangle Lakes system, represents approximately 50% of the annual totals for the entire Tanana River drainage.

The immediate goal of this research project was to synthesize existing maturity data and, if necessary, provide additional estimates of maturity for 12 stocks in the Tanana River drainage. In pursuit of this goal, the specific objectives of this research project were to estimate:

1) the proportion of Arctic grayling (≥ 150 mm Fork Length) that are sexually mature at age (years) in the Chena, Salcha, Chatanika, and Goodpaster rivers; Fish and Caribou creeks; Mineral Lake outlet; Piledriver and Badger sloughs; and, Fielding, Tangle, and Jack lakes; and,

2) the proportion of Arctic grayling (≥ 150 mm Fork Length) that are sexually mature at fork length (millimeters) in the Chena, Salcha, Chatanika, and Goodpaster rivers; Fish and Caribou creeks; Mineral Lake outlet; Piledriver and Badger sloughs; and, Fielding, Tangle, and Jack lakes.

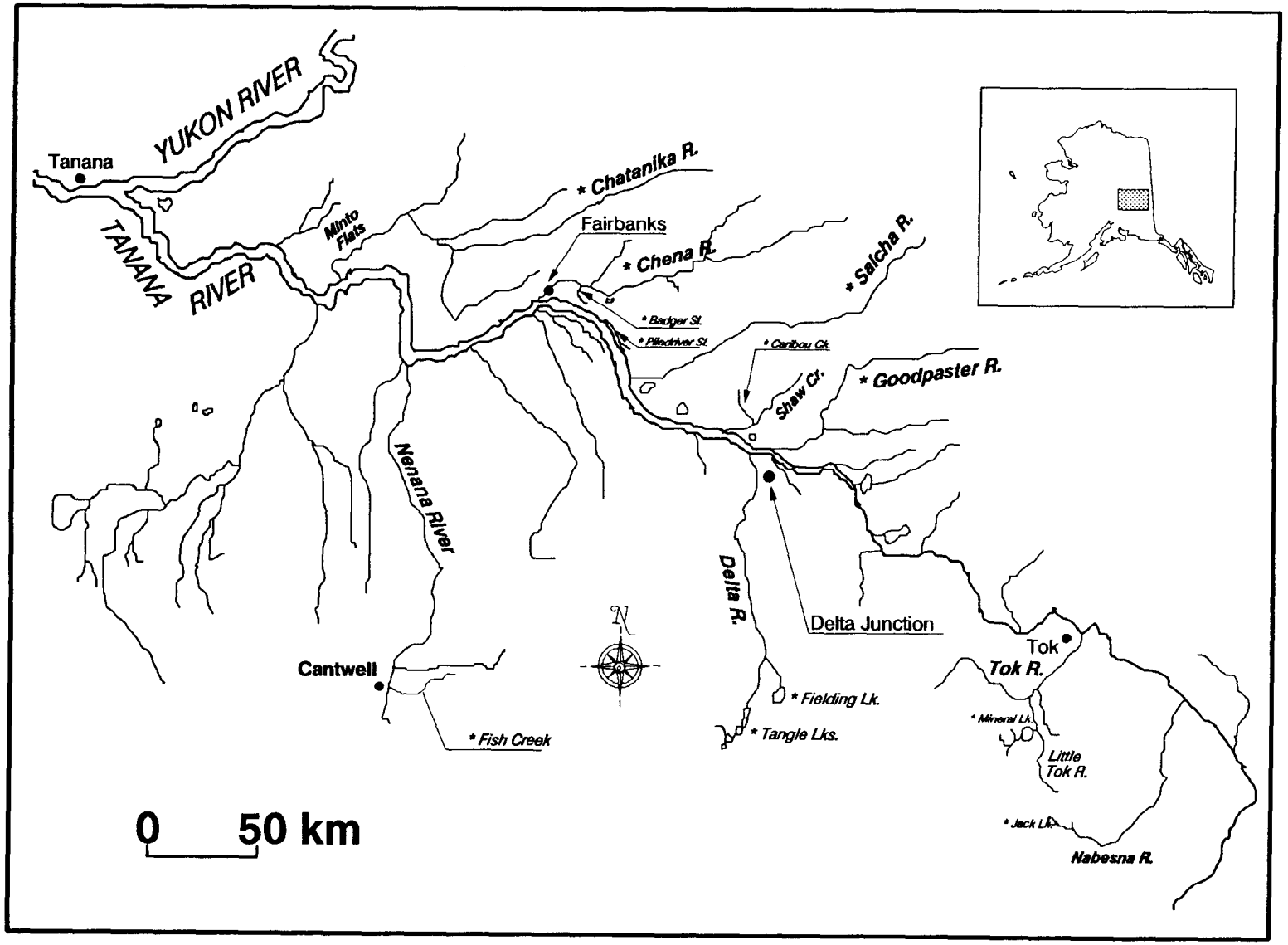

Figure 1. Geographic location of the 12 stocks of Arctic grayling from which age and size at maturity were estimated in the Tanana River drainage (asterisk denotes waters sampled).

METHODS

Methods of Capture and Handling

Arctic grayling were captured with the following gears: 1) electrofishing boat and backpack electrofisher; 2) beach seine; 3) weir; 4) weir trap; and, 5) hook and line (Table 1). Boat electrofishing was performed with standard equipment for Arctic grayling as described by Clark and Ridder (1987). Backpack electrofishing in Piledriver Slough and Mineral Lake outlet was performed as described by Fleming (1991). The weir used in Caribou Creek was described by Ridder (1984) and the weir used in Fish Creek was described by Fleming (1989). Clark (1991) described all aspects of fish collection for Fielding Lake. Sampling with hook and line gear in the Tangle Lakes system was described by Ridder (1991).

All Arctic grayling captured were handled in an identical manner in each of the 12 systems and during all sampling dates. Each fish was first measured to the nearest 1 mm of fork length (FL). Excepting data collection at Fish Creek, age was determined by removing four to six scales from an area four to six scale rows above the lateral line just posterior to the insertion of the dorsal fin. Age was not determined from fish sampled at Fish Creek in 1988. Scales were processed by cleaning in a hot solution of common dish detergent, inspected for regeneration, and then two scales from each fish 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 a single reading with the aid of a microfiche reader.

Sampling in all systems was done either immediately before, during, or immediately after the spawning period (Table 1), so that sex and maturity were determined by either sexual dimorphism or the presence of milt or eggs. Dimorphism is evident in differences in height of the dorsal fin (Bishop 1967; the male dorsal fin usually extends higher above the body than the female dorsal fin), length of the pelvic fins (Bishop 1967; males have longer and more pointed pelvic fins than females), and the swelling of the anal vent and abdomen fullness (gravid) or flaccidity (spawned out) in females (Ridder 1989b). However, some error may be associated with the use of these morphological characteristics as the sole determinant of sex. For example, small males may be classified as juveniles since their dorsal fin may not reach the adipose fin and, if recently spawned, they will not give milt (Ridder 1989b).

To assess the error associated with sexing Arctic grayling by external characteristics, an experiment was devised for sampling on the Chena River in 1991. In this experiment maturity was classified into two categories: fully mature or unknown. Fish were classified as fully mature when sex products were found, or the vent was swollen. Unknown fish were classified as those fish that showed none of the characteristics of fully mature fish. Arctic grayling classified as unknown were separated into mature and immature components by sacrificing a subsample of the unknown fish. Of 42 fish from the Chena River in 1991 that were classified as unknown, all 42 were classified as immature after dissection and examination of the gonads.

Table 1. Dates of sampling, timing of sampling, and gears used to capture Arctic grayling for determination of sexual maturity in 12 systems of the Tanana River drainage.

System	Month/Year	Timing[a]	Gear(s)
Chena River	5/91	D	Electrofishing boat
	5/92	B	Electrofishing boat
Salcha River	5 & 6/91	A	Electrofishing boat
	5 & 6/92	B,A	Electrofishing boat
Chatanika River	6/91	D	Hook and line
	6/92	A	Electrofishing boat
Goodpaster River	5/82	B	Electrofishing boat
	5/85	B	Electrofishing boat
	5/86	B	Electrofishing boat
	5/87	B	Electrofishing boat
Fish Creek	5/88	B,D	Weir, weir trap
Caribou Creek	5 & 6/85	A	Weir
	5 & 6/86	A	Weir
	5 & 6/87	A	Weir
Mineral Lake	5/88	D	Seine, backpack electrofisher
	5/90	D	Seine
Piledriver Slough	5/91	D	Backpack electrofisher
	5/92	D	Backpack electrofisher
Badger Slough	4 & 5/85	B	Weir
Fielding Lake	6/88	A	Electrofishing boat, weir trap
	6/89	A	Electrofishing boat, weir trap
	6/90	A	Electrofishing boat, weir trap
	6/91	A	Electrofishing boat, weir trap
Tangle Lakes	5 & 6/89	B,D,A	Hook and line, electrofishing boat
	5 & 6/89	B,D,A	Hook and line, electrofishing boat
Jack Lake	5/86	B	Weir trap

[a] Timing of sampling is: B = before spawning; D = during spawning; and, A = after spawning.

Estimation of Age and Size at Maturity

Age and size at maturity are a series of binomial proportions, with each age or length group (10 mm FL in this case) representing a choice between two alternatives (either mature or immature). The proportion of mature fish in each age or length group k was estimated by:

$$\hat{p}_k = \frac{m_k}{n_k} \quad (1)$$

where:

p_k = the proportion of Arctic grayling (≥ 150 mm FL) that are age or size k and are mature;
m_k = the number of Arctic grayling (≥ 150 mm FL) that are age or size k and are mature; and,
n_k = the number of Arctic grayling (≥ 150 mm FL) that are age or size k.

The variance of this proportion was estimated by:

$$\hat{V}[p_k] = \frac{\hat{p}_k\,(1 - \hat{p}_k)}{n_k - 1} \quad (2)$$

A 95% confidence interval was estimated for each estimate of p_k using the technique of Goodman (1965):

$$95\%\ \text{C.I.} = \hat{p}_k \pm (\hat{V}[p_k]\ \chi^2_{(0.975,1)})^{1/2} \quad (3)$$

where:

95% C.I. = the 95% confidence interval (that number added or subtracted from p_k to produce the upper or lower 95% confidence level); and,
$\chi^2_{(0.975,1)}$ = the χ^2 value at the $(1 - \alpha/2)$ of 0.975 and 1 degree of freedom.

To estimate the age and size at 1%, 50%, and 99% mature, the age or size, number examined, and number mature were treated as the dosage, sample size, and response, respectively in a probit analysis (Finney 1971). The probit model was developed for estimating the response rate of biological assay data. Using a procedure in the Statistical Analysis System (SAS) called PROC PROBIT, maximum likelihood estimates of the parameters of the probit equation were calculated. This procedure resulted in estimates of the dosage (age or size of the fish) that results a particular proportion of the sample responding (classified as mature) to the dosage. This procedure produced estimates of the age and size at 1%, 50%, and 99% mature and their 95% fiducial limits. Age at maturity was rounded to the nearest 1 year, while size at maturity was

rounded to the nearest 1 mm. The SAS procedure also tested goodness-of-fit to the probit model with a Pearson chisquared test and likelihood-ratio test.

Sampling was performed during multiple years in nine of the 12 waters. Data were pooled between years to estimate age and size at maturity. Excepting data collected from the Goodpaster River, analyses were also performed on data collected for each year and are summarized in Appendices A1 through A19.

RESULTS

Chena River

There were a total of 759 valid ages and 898 measurements of length collected during sampling in middle to late May of 1991 and 1992. Onset of maturity was at 4 years (beginning of the fifth year of life) and between 210 and 219 mm FL (Table 2). All fish were mature at age 10 and older, and 310 mm FL and larger. Arctic grayling from the Chena River exceeded 50% maturity at age 6 and between 270 and 279 mm FL. There appeared to be an abrupt transition to maturity between ages 5 and 6 and a somewhat more gradual transition to maturity between 260 and 279 mm FL. Results from probit analyses paralleled these results; the age at 50% mature was 6 years and size at 50% maturity was 273 mm FL.

Salcha River

There were a total of 617 valid ages and 853 measurements of length collected during sampling in late May and early June of 1991 and 1992. Onset of maturity was at 3 years and between 220 and 229 mm FL (Table 3). All fish were mature at age 8 and older, and 370 mm FL and larger. Fifty percent maturity was exceeded at age 6 and between 310 and 319 mm FL. As in the Chena River data set, there was an abrupt transition to maturity between ages 5 and 6. Conversely, the Salcha River data set shows a more gradual transition to maturity with respect to size. Probit analyses estimated the age at 50% maturity as 5 years and size at 50% maturity as 304 mm FL.

Chatanika River

There were a total of 669 valid ages and 811 measurements of length collected during sampling in early June of 1991 and 1992. Onset of maturity appeared at 3 years and between 210 and 219 mm FL (Table 4). All fish in the sample were mature at age 9 and older, and 300 mm FL and larger. Arctic grayling from the upper and middle Chatanika River exceeded 50% maturity at age 6 and between 240 and 249 mm FL. The proportion of mature fish more than doubled for each intervening year between the ages of 4 and 6. Transition to maturity appeared to occur more smoothly with respect to size of fish. Results from probit analyses paralleled these results; the age at 50% maturity was 5 years and size at 50% maturity was 243 mm FL.

Table 2. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling (≥ 150 mm FL) collected from the Chena River in May of 1991 and 1992.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
2	5	0	0.00	---	150-159	2	0	0.00	---
					160-169	3	0	0.00	---
3	39	0	0.00	---	170-179	4	0	0.00	---
					180-189	8	0	0.00	---
4	170	3	0.02	0.02	190-199	16	0	0.00	---
					200-209	36	0	0.00	---
5	265	40	0.15	0.05	210-219	43	1	0.02	0.05
					220-229	70	1	0.01	0.03
6	78	57	0.73	0.11	230-239	77	1	0.01	0.03
					240-249	101	7	0.07	0.06
7	91	86	0.94	0.05	250-259	91	13	0.14	0.08
					260-269	76	20	0.26	0.11
8	79	75	0.95	0.06	270-279	63	36	0.57	0.14
					280-289	59	44	0.75	0.13
9	21	20	0.95	0.11	290-299	45	40	0.89	0.11
					300-309	30	28	0.93	0.10
10	9	9	1.00	---	310-319	37	37	1.00	---
					320-329	32	32	1.00	---
11	2	2	1.00	---	330-339	27	27	1.00	---
					340-349	36	36	1.00	---
					350-359	21	21	1.00	---
					360-369	9	9	1.00	---
					370-379	6	6	1.00	---
					380-389	5	5	1.00	---
					390-399	1	1	1.00	---

Part II. Probit analyses:

Age	Mean	Limits	Length	Mean	Limits
AM_{01}[e]	4 yr	3 to 4 yr	LM_{01}[f]	231 mm	221 to 238 mm
AM_{50}	6 yr	5 to 6 yr	LM_{50}	273 mm	268 to 278 mm
AM_{99}	8 yr	7 to 10 yr	LM_{99}	322 mm	311 to 340 mm

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_x = *x*th percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_x = *x*th percentile from probit analysis for fork length at maturity (limits are the 95% fiducial limits).

Table 3. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling (≥ 150 mm FL) collected from the Salcha River in May and June of 1991 and 1992.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
2	17	0	0.00	---	150-159	3	0	0.00	---
					160-169	4	0	0.00	---
3	119	6	0.05	0.04	170-179	11	0	0.00	---
					180-189	15	0	0.00	---
4	180	20	0.11	0.05	190-199	21	0	0.00	---
					200-209	37	0	0.00	---
5	173	46	0.27	0.07	210-219	38	0	0.00	---
					220-229	55	2	0.04	0.06
6	67	52	0.78	0.11	230-239	55	1	0.02	0.04
					240-249	75	0	0.00	---
7	36	31	0.86	0.13	250-259	67	2	0.03	0.05
					260-269	77	5	0.06	0.06
8	16	16	1.00	---	270-279	67	4	0.06	0.06
					280-289	61	12	0.20	0.11
9	9	9	1.00	---	290-299	55	18	0.33	0.14
					300-309	50	25	0.50	0.16
					310-319	35	25	0.71	0.17
					320-329	17	17	1.00	---
					330-339	18	16	0.89	0.17
					340-349	23	23	1.00	---
					350-359	22	21	0.95	0.10
					360-369	11	10	0.91	0.20
					370-379	11	11	1.00	---
					380-389	12	12	1.00	---
					390-399	7	7	1.00	---
					400-409	3	3	1.00	---
					410-419	2	2	1.00	---
					420-429	1	1	1.00	---

-continued-

Table 3. (Page 2 of 2).

Part II. Probit analyses:

Age	Mean	Limits	Length	Mean	Limits
AM_{01}[e]	3 yr	2 to 3 yr	LM_{01}[f]	245 mm	222 to 259 mm
AM_{50}	5 yr	5 to 6 yr	LM_{50}	304 mm	294 to 316 mm
AM_{99}	10 yr	8 to 18 yr	LM_{99}	376 mm	350 to 430 mm

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_x = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_x = xth percentile from probit analysis for fork length at maturity (limits are the 95% fiducial limits).

Table 4. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling (≥ 150 mm FL) collected from the upper Chatanika River in June of 1991 and the middle Chatanika River in June of 1992.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
2	5	0	0.00	---	150-159	4	0	0.00	---
					160-169	7	0	0.00	---
3	26	1	0.04	0.09	170-179	10	0	0.00	---
					180-189	5	0	0.00	---
4	75	10	0.13	0.09	190-199	22	0	0.00	---
					200-209	42	0	0.00	---
5	263	91	0.35	0.07	210-219	54	1	0.02	0.04
					220-229	97	18	0.19	0.09
6	135	108	0.80	0.08	230-239	104	37	0.36	0.11
					240-249	89	50	0.56	0.12
7	91	88	0.97	0.04	250-259	72	53	0.74	0.12
					260-269	55	47	0.85	0.11
8	59	55	0.93	0.07	270-279	46	44	0.96	0.07
					280-289	44	43	0.98	0.05
9	12	12	1.00	---	290-299	47	46	0.98	0.05
					300-309	43	43	1.00	---
10	3	2	0.67	0.75	310-319	38	38	1.00	---
					320-329	14	14	1.00	---
					330-339	11	11	1.00	---
					340-349	3	3	1.00	---
					350-359	2	2	1.00	---
					360-369	0	0	---	---
					370-379	0	0	---	---
					380-389	2	2	1.00	---

Part II. Probit analyses:

Age	Mean	Limits	Length	Mean	Limits
AM_{01}[e]	3 yr	2 to 4 yr	LM_{01}[f]	203 mm	197 to 207 mm
AM_{50}	5 yr	5 yr	LM_{50}	243 mm	240 to 245 mm
AM_{99}	8 yr	7 to 11 yr	LM_{99}	290 mm	284 to 299 mm

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_x = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_x = xth percentile from probit analysis for fork length at maturity (limits are the 95% fiducial limits).

Goodpaster River

There were a total of 945 valid ages and 1,016 measurements of length collected during sampling in early May of 1982 and early May of 1985 through 1987. Onset of maturity appeared at 5 years and between 230 and 239 mm FL (Table 5). All fish in the sample were mature at age 9 and older, and 330 mm FL and larger. There was a six-fold increase in the proportion of mature fish between the ages of 5 and 6. Transition to maturity occurred more smoothly with respect to size of fish. Probit analyses estimated the age at 50% maturity as 6 years and size at 50% maturity as 276 mm FL.

Fish Creek

There were a total of 668 measurements of length collected during sampling in May of 1988. No scales were collected during sampling. Onset of maturity appeared between 250 and 259 mm FL (Table 6). All fish were classed as mature at 330 mm FL and larger. The proportion of mature fish in each 10 mm FL group increased steadily from 0.10 mature at 250 to 259 mm FL to 0.76 mature at 280 to 289 mm FL, and then leveled off at approximately 0.85 mature between 290 and 329 mm FL. Probit analyses estimated the size at 50% maturity as 275 mm FL.

Caribou Creek

There were a total of 1,385 valid ages and 1,996 measurements of length collected during sampling in June of 1985 through 1987. Onset of maturity appeared at 4 years and between 220 and 229 mm FL (Table 7). All fish in the sample were mature at age 10 and older, and 400 mm FL and larger. However, most of the fish sampled were mature at 340 mm FL and larger. An abrupt transition to maturity with respect to age was observed in the Caribou Creek data set. Conversely, transition to maturity was much smoother with respect to changes in size. Probit analyses estimated the age at 50% maturity as 5 years and size at 50% maturity as 279 mm FL.

Mineral Lake Outlet

There were a total of 1,330 valid ages and 1,449 measurements of length collected during sampling in early May of 1988 and 1990. Onset of maturity occurred at age 3 and between 200 and 209 mm FL (Table 8). All fish in the sample were mature at age 9 and older, and 320 mm FL and longer. The proportion mature at age more than doubled between ages 4 and 5. Proportion mature at size increased from 0.20 to 0.78 between 220 and 249 mm FL. Probit analyses estimated the age at 50% maturity as 4 years and size at 50% maturity as 238 mm FL.

Piledriver Slough

There were a total of 983 valid ages and 1,224 measurements of length collected during sampling in early May of 1991 and 1992. Onset of maturity occurred at age 2 and between 200 and 209 mm FL (Table 9). All fish in the sample were mature by age 9 and at 320 mm FL and larger. Similar to the other systems discussed, proportion mature at age increased rapidly between ages 3

Table 5. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling (≥ 200 mm FL) collected from the Goodpaster River in May of 1982 and May of 1985 through 1987.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
2	13	0	0.00	---	200-209	40	0	0.00	---
					210-219	51	0	0.00	---
3	104	0	0.00	---	220-229	35	0	0.00	---
					230-239	64	4	0.06	0.07
4	93	0	0.00	---	240-249	71	4	0.06	0.06
					250-259	67	10	0.15	0.10
5	199	18	0.09	0.05	260-269	80	27	0.34	0.12
					270-279	78	35	0.45	0.13
6	190	109	0.57	0.08	280-289	83	54	0.65	0.12
					290-299	74	58	0.78	0.11
7	162	134	0.83	0.07	300-309	64	57	0.89	0.09
					310-319	59	54	0.91	0.08
8	90	88	0.98	0.03	320-329	52	51	0.98	0.04
					330-339	53	53	1.00	---
9	57	57	1.00	---	340-349	30	30	1.00	---
					350-359	31	31	1.00	---
10	22	22	1.00	---	360-369	25	25	1.00	---
					370-379	15	15	1.00	---
11	10	10	1.00	---	380-389	18	18	1.00	---
					390-399	11	11	1.00	---
12	3	3	1.00	---	400-409	6	6	1.00	---
					410-419	3	3	1.00	---
13	2	2	1.00	---	420-429	1	1	1.00	---
					430-439	4	4	1.00	---
					440-449	1	1	1.00	---

Part II. Probit analyses:

Age	Mean	Limits	Length	Mean	Limits
AM_{01}[e]	4 yr	4 yr	LM_{01}[f]	227 mm	221 to 232 mm
AM_{50}	6 yr	6 yr	LM_{50}	276 mm	273 to 279 mm
AM_{99}	8 yr	8 to 9 yr	LM_{99}	335 mm	328 to 345 mm

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_x = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_x = xth percentile from probit analysis for fork length at maturity (limits are the 95% fiducial limits).

Table 6. Estimates of fork length (mm) at maturity for Arctic grayling (≥ 150 mm FL) collected from Fish Creek in May of 1988.

Part I. Number and proportion mature by age and length group.

Length Group	n[a]	m[b]	p[c]	±95% C.I.[d]
150-159	0	0	---	---
160-169	0	0	---	---
170-179	0	0	---	---
180-189	16	0	0.00	---
190-199	19	0	0.00	---
200-209	24	0	0.00	---
210-219	20	0	0.00	---
220-229	11	0	0.00	---
230-239	13	0	0.00	---
240-249	82	0	0.00	---
250-259	52	5	0.10	0.09
260-269	78	22	0.28	0.11
270-279	93	59	0.63	0.11
280-289	87	66	0.76	0.10
290-299	76	65	0.85	0.09
300-309	46	41	0.89	0.10
310-319	24	20	0.83	0.17
320-329	13	11	0.85	0.23
330-339	5	5	1.00	---
340-349	4	4	1.00	---
350-359	3	3	1.00	---
360-369	2	2	1.00	---

Part II. Probit analysis:

Age	Mean	Limits
LM_{01}[e]	233 mm	217 to 242 mm
LM_{50}	275 mm	270 to 280 mm
LM_{99}	325 mm	313 to 347 mm

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] LM_x = xth percentile from probit analysis for fork length at maturity (limits are the 95% fiducial limits).

Table 7. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling (≥ 150 mm FL) collected from Caribou Creek in June of 1985 through 1987.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
2	19	0	0.00	---	150-159	38	0	0.00	---
					160-169	26	0	0.00	---
3	208	0	0.00	---	170-179	35	0	0.00	---
					180-189	53	0	0.00	---
4	305	13	0.04	0.03	190-199	81	0	0.00	---
					200-209	81	0	0.00	---
5	285	109	0.38	0.06	210-219	119	0	0.00	---
					220-229	124	1	0.01	0.02
6	211	166	0.79	0.06	230-239	132	2	0.01	0.02
					240-249	153	4	0.03	0.03
7	217	208	0.96	0.03	250-259	141	13	0.09	0.05
					260-269	121	30	0.25	0.09
8	98	97	0.99	0.02	270-279	114	46	0.40	0.10
					280-289	117	72	0.61	0.10
9	33	32	0.97	0.07	290-299	131	117	0.89	0.06
					300-309	94	81	0.86	0.08
10	3	3	1.00	---	310-319	81	78	0.96	0.05
					320-329	76	74	0.97	0.04
11	3	3	1.00	---	330-339	77	75	0.97	0.04
					340-349	67	66	0.98	0.03
12	3	3	1.00	---	350-359	42	42	1.00	---
					360-369	35	35	1.00	---
					370-379	28	27	0.96	0.08
					380-389	15	15	1.00	---
					390-399	8	7	0.87	0.28
					400-409	3	3	1.00	---
					410-419	2	2	1.00	---
					420-429	2	2	1.00	---

-continued-

Table 7. (Page 2 of 2).

Part II. Probit analyses:

	Mean	Limits		Mean	Limits
AM_{01}[e]	4 yr	3 to 4 yr	LM_{01}[f]	232 mm	---
AM_{50}	5 yr	5 yr	LM_{50}	279 mm	---
AM_{99}	8 yr	7 to 9 yr	LM_{99}	335 mm	---

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_x = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_x = xth percentile from probit analysis for fork length at maturity (95% fiducial limits could not be calculated for these data).

Table 8. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling collected from Mineral Lake outlet in May of 1988 and 1990.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
1	105	0	0.00	---	<210	577	1	<0.01	<0.01
2	156	0	0.00	---	210-219	72	1	0.01	0.03
3	280	8	0.03	0.02	220-229	40	8	0.20	0.14
4	244	94	0.38	0.07	230-239	67	39	0.58	0.14
5	170	147	0.86	0.06	240-249	65	51	0.78	0.11
6	196	195	0.99	0.01	250-259	65	60	0.92	0.07
7	88	88	1.00	---	260-269	65	61	0.94	0.07
8	52	51	0.98	0.04	270-279	98	97	0.99	0.02
9	24	24	1.00	---	280-289	82	81	0.99	0.03
10	11	11	1.00	---	290-299	61	59	0.97	0.05
11	3	3	1.00	---	300-309	46	46	1.00	---
12	1	1	1.00	---	310-319	42	41	0.98	0.05
					>319	169	169	1.00	---

Part II. Probit analyses:

Age	Mean	Limits	Length	Mean	Limits
AM_{01}[e]	3 yr	1 to 3 yr	LM_{01}[f]	205 mm	---
AM_{50}	4 yr	3 to 5 yr	LM_{50}	238 mm	---
AM_{99}	6 yr	5 to 12 yr	LM_{99}	276 mm	---

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_X = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_X = xth percentile from probit analysis for fork length at maturity (95% fiducial limits could not be calculated).

Table 9. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling (≥ 150 mm FL) collected from Piledriver Slough in May of 1991 and 1992.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
1	1	0	0.00	---	150-159	46	0	0.00	---
					160-169	53	0	0.00	---
2	59	2	0.03	0.05	170-179	44	0	0.00	---
					180-189	58	0	0.00	---
3	154	12	0.08	0.05	190-199	63	0	0.00	---
					200-209	79	4	0.05	0.06
4	239	85	0.26	0.05	210-219	67	5	0.07	0.07
					220-229	46	5	0.11	0.10
5	268	203	0.76	0.06	230-239	76	26	0.34	0.12
					240-249	108	60	0.56	0.11
6	196	168	0.86	0.06	250-259	116	86	0.74	0.09
					260-269	127	107	0.84	0.07
7	49	45	0.92	0.09	270-279	108	98	0.91	0.06
					280-289	90	78	0.87	0.08
8	15	14	0.93	0.15	290-299	62	57	0.92	0.08
					300-309	34	33	0.97	0.07
9	2	2	1.00	---	310-319	24	23	0.96	0.09
					320-329	12	12	1.00	---
					330-339	4	4	1.00	---
					340-349	1	1	1.00	---
					350-359	2	2	1.00	---
					360-369	1	1	1.00	---
					370-379	2	2	1.00	---
					380-389	1	1	1.00	---

Part II. Probit analyses:

Age	Mean	Limits	Length	Mean	Limits
AM_{01}[e]	2 yr	1 to 3 yr	LM_{01}[f]	192 mm	186 to 197 mm
AM_{50}	4 yr	4 to 5 yr	LM_{50}	244 mm	241 to 247 mm
AM_{99}	8 yr	7 to 11 yr	LM_{99}	310 mm	303 to 318 mm

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_x = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_x = xth percentile from probit analysis for fork length at maturity (limits are the 95% fiducial limits).

and 5. Transition to maturity with respect to size occurred most rapidly between 220 and 269 mm FL. Probit analyses estimated the age at 50% maturity as 4 years and size at 50% maturity as 244 mm FL.

Badger Slough

There were a total of 837 valid ages and 962 measurements of length collected during sampling in late April and early May of 1985. Onset of maturity appeared at age 2 and between 200 and 209 mm FL (Table 10). All fish in the sample were mature by age 8. Complete maturity was observed in only the 310 to 319 mm FL size group. Probit analyses estimated the age at 50% maturity as 5 years and size at 50% maturity as 270 mm FL.

Fielding Lake

There were a total of 3,453 valid ages and 4,090 measurements of length collected during sampling in late June of 1988 through 1991. Onset of maturity occurred at age 4 and between 220 and 229 mm FL (Table 11). All fish in the sample were mature by age 10 and at 400 mm FL and larger. A rapid increase in proportion mature with respect to age was observed between ages 5 and 7. Maturity increased most rapidly between 280 and 339 mm FL. Probit analyses estimated the age at 50% maturity as 6 years and size at 50% maturity as 316 mm FL.

Tangle Lakes System

There were a total of 2,037 valid ages and 2,112 measurements of length collected during sampling in late May and early June of 1989 and 1990. Onset of maturity was observed at age 4 and between 250 and 259 mm FL (Table 12). All fish in the sample were mature by age 9 and at 370 mm FL and larger. Proportion mature with respect to age increased from 0.03 at age 4 to 0.87 by age 6. A rapid increase in maturity was observed between 270 and 319 mm FL. Probit analyses estimated the age at 50% maturity as 5 years and size at 50% maturity as 289 mm FL.

Jack Lake

There were a total of 97 valid ages and 101 measurements of length collected during sampling in late May of 1986. Of these fish, only two were classed as immature. The range of ages sampled was 3 to 10 years. The youngest mature fish was age 4 and the oldest immature fish was age 5. The range of fish sizes sampled was 198 to 410 mm FL. The smallest mature fish was 238 mm FL. The largest immature fish was 262 mm FL. No probit analyses could be performed on these data.

DISCUSSION

It is evident from the stocks of Arctic grayling investigated that there is considerable variability in age and size at maturity in the Tanana River drainage. Based on probit analyses, point estimates of age at 1% and 50% maturity differed by as many as two years, while point estimates of age at 99%

Table 10. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling (≥ 150 mm FL) collected from Badger Slough in April and May of 1985.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
1	2	0	0.00	---	150-159	54	0	0.00	---
					160-169	29	0	0.00	---
2	118	1	0.01	0.02	170-179	58	0	0.00	---
					180-189	67	0	0.00	---
3	360	8	0.02	0.02	190-199	67	0	0.00	---
					200-209	98	2	0.02	0.03
4	221	39	0.18	0.06	210-219	100	0	0.00	---
					220-229	96	0	0.00	---
5	78	39	0.50	0.13	230-239	82	1	0.01	0.03
					240-249	83	2	0.02	0.04
6	38	34	0.89	0.11	250-259	63	14	0.22	0.12
					260-269	55	26	0.47	0.15
7	15	13	0.87	0.20	270-279	35	29	0.83	0.14
					280-289	29	28	0.97	0.08
8	5	5	1.00	---	290-299	12	11	0.92	0.19
					300-309	9	8	0.89	0.25
					310-319	6	6	1.00	---
					320-329	9	8	0.89	0.25
					330-339	7	6	0.86	0.32
					340-349	3	2	0.67	0.75

Part II. Probit analyses:

Age	Mean	Limits	Length	Mean	Limits
AM_{01}[e]	3 yr	2 to 3 yr	LM_{01}[f]	223 mm	153 to 241 mm
AM_{50}	5 yr	4 to 6 yr	LM_{50}	270 mm	253 to 311 mm
AM_{99}	9 yr	7 to 23 yr	LM_{99}	325 mm	292 to 574 mm

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_x = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_x = xth percentile from probit analysis for fork length at maturity (limits are the 95% fiducial limits).

Table 11. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling (≥ 200 mm FL) collected from Fielding Lake in June of 1988 through 1991.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
2	41	0	0.00	---	200-209	89	0	0.00	---
					210-219	175	0	0.00	---
3	558	0	0.00	---	220-229	240	1	<0.01	0.01
					230-239	242	0	0.00	---
4	697	4	0.01	0.01	240-249	248	1	<0.01	0.01
					250-259	247	1	<0.01	0.01
5	733	108	0.15	0.03	260-269	267	1	<0.01	0.01
					270-279	237	4	0.02	0.02
6	640	436	0.68	0.04	280-289	263	17	0.06	0.03
					290-299	211	36	0.17	0.06
7	487	444	0.91	0.03	300-309	195	46	0.24	0.07
					310-319	174	98	0.56	0.08
8	234	228	0.97	0.02	320-329	170	117	0.69	0.08
					330-339	188	156	0.83	0.06
9	60	59	0.98	0.04	340-349	194	188	0.97	0.03
					350-359	193	182	0.94	0.04
10	3	3	1.00	---	360-369	225	217	0.96	0.03
					370-379	225	221	0.98	0.02
					380-389	137	132	0.96	0.04
					390-399	110	107	0.97	0.03
					400-409	50	50	1.00	---
					410-429	10	10	1.00	---

Part II. Probit analyses:

	Mean	Limits		Mean	Limits
AM_{01}[e]	4 yr	4 yr	LM_{01}[f]	265 mm	232 to 281 mm
AM_{50}	6 yr	6 yr	LM_{50}	316 mm	303 to 328 mm
AM_{99}	8 yr	8 yr	LM_{99}	376 mm	354 to 428 mm

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_x = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_x = xth percentile from probit analysis for fork length at maturity (limits are the 95% fiducial limits).

Table 12. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling (≥ 200 mm FL) collected from the Tangle Lakes system in May and June of 1989 and 1990.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
2	109	0	0.00	---	200-209	74	0	0.00	---
					210-219	72	0	0.00	---
3	219	0	0.00	---	220-229	50	0	0.00	---
					230-239	50	0	0.00	---
4	140	4	0.03	0.03	240-249	40	0	0.00	---
					250-259	56	1	0.02	0.04
5	223	81	0.36	0.07	260-269	58	3	0.05	0.07
					270-279	72	6	0.08	0.07
6	761	660	0.87	0.03	280-289	100	35	0.35	0.11
					290-299	189	122	0.65	0.08
7	492	475	0.96	0.02	300-309	241	201	0.83	0.05
					310-319	302	289	0.96	0.03
8	78	77	0.99	0.03	320-329	321	314	0.98	0.02
					330-339	230	228	0.99	0.01
9	15	15	1.00	---	340-349	136	135	0.99	0.02
					350-359	78	75	0.96	0.05
					360-369	29	28	0.97	0.08
					370-379	10	10	1.00	---
					380-389	2	2	1.00	---
					390-399	1	1	1.00	---
					400-409	1	1	1.00	---

Part II. Probit analyses:

Age	Mean	Limits	Length	Mean	Limits
AM_{01}[e]	4 yr	3 to 4 yr	LM_{01}[f]	252 mm	154 to 274 mm
AM_{50}	5 yr	5 yr	LM_{50}	289 mm	254 to 302 mm
AM_{99}	7 yr	7 to 8 yr	LM_{99}	332 mm	315 to 444 mm

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_x = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_x = xth percentile from probit analysis for fork length at maturity (limits are the 95% fiducial limits).

maturity differed by as many as four years between stocks (Figure 2). Of the 10 systems investigated for age at 50% maturity, 20% (or two of 10 systems) were 50% mature at age 4, 50% at age 5, and the remaining 30% at age 6. Based on a review of the literature between 1952 and 1982, Armstrong (1986) also found that most Arctic grayling stocks in interior Alaska have matured by age 4 to 6. More specifically, Van Hulle (1968) found that Arctic grayling in the Chena River were 100% mature at age 5. This study found only 15% (95% C.I. of ±5%) mature at age 5. Similarly, Tack (1974) found that 100% of age 7 fish in the Goodpaster River were mature, while this study found 83% mature (95% C.I. of ±7%). Tack (1971) found that 100% of age 6 fish from Mineral Lake outlet were mature, closely agreeing with the estimate of 99% mature (95% C.I. of ±1%) in this study.

Variability in size at maturity also occurred. Point estimates of size at 1% maturity differed by as much as 73 mm FL, by as much as 78 mm FL at 50% maturity, and by as much as 100 mm FL at 99% maturity (Figure 3). No previous studies have quantitatively related maturity with size, although Tack (1974) stated that most Arctic grayling populations in the Tanana River drainage mature at 290 to 300 mm FL. Tack (1974) also noted that fish in the Chena River and Mineral Lake outlet were mostly mature at 270 mm FL. In this study 57% (95% C.I. of ±14%) of the Chena River stock and 99% (95% C.I. of ±2%) of the Mineral Lake outlet stock were mature at 270 to 279 mm FL. Excepting the Chena River and Mineral Lake outlet, only three of the remaining nine systems (33%) were 50% mature at 290 to 300 mm FL; all other systems were greater than 50% mature at this length.

However, there are some notable similarities in maturity between the systems. Without exception there was a rapid increase in the proportion of mature fish at age occurring from the onset of maturity up to approximately 50% mature. The increase in maturity with respect to size was more gradual, but this may be accounted for by the small size range of the length groups (10 mm FL). After 50% maturity was established in each of the systems, there was a gradual increase to 100% maturity. None of the stocks investigated had mature fish (no significant difference from 0% mature; $\alpha = 0.05$) at age 2 and younger or at 210 mm FL or smaller. Excepting the Arctic grayling stock in Fielding Lake, all stocks were 100% mature (no significant difference from 100% mature) at age 8 and older or at 320 mm FL and larger.

Outside of the Tanana River drainage, Arctic grayling stocks in Saskatchewan mature between 5 and 6 years of age (Rawson 1950). Bishop (1967) also found that while 50% of fish at Great Slave Lake are mature at age 4, 100% maturity was not attained until 8 years of age. Conversely, the more southerly stocks of Arctic grayling in Montana, Wyoming, and the Canadian province of Alberta do mature sooner than those mentioned above. Ward (1951) found that stocks of Arctic grayling in the Athabaska drainage of Alberta mature at age 3. No mention was made concerning the level of maturity at age 3 (50% or 100%). Brown (1938) and Kruse (1959) also found that Arctic grayling in Montana and Wyoming, respectively matured at age 3. Early maturity in these stocks appeared to be related to total life span in these stocks. The life span of southerly stocks is 5 to 7 years (Nelson 1954, Kruse 1959, Peterman 1972, Beauchamp 1982), whereas the life span of northerly stocks is 8 to 13 years (Miller 1946, Bishop 1967, and this study).

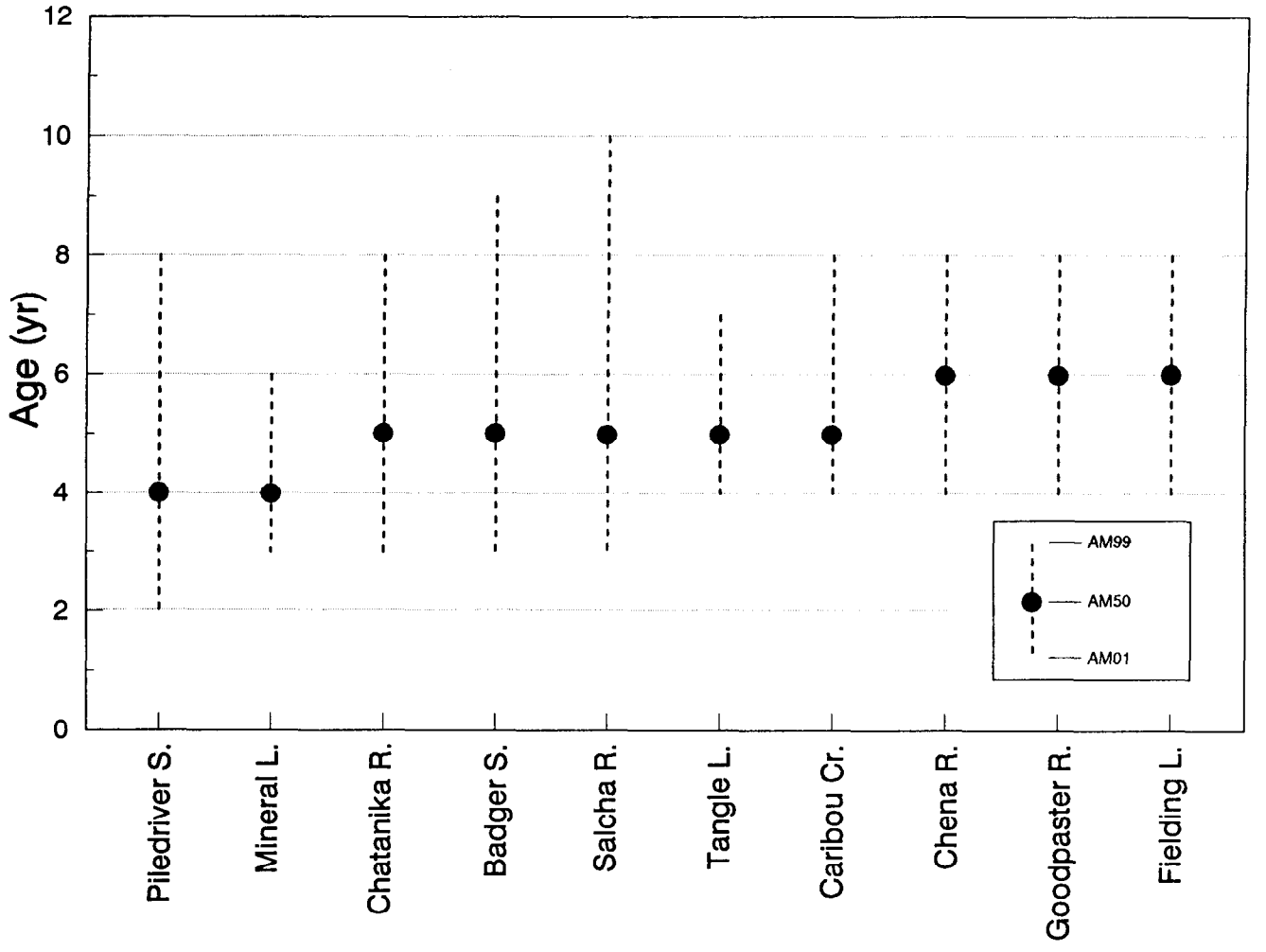

Figure 2. Estimates of the age (yr) at 1%, 50%, and 99% maturity from probit analysis of Arctic grayling sampled from 10 stocks in the Tanana River drainage.

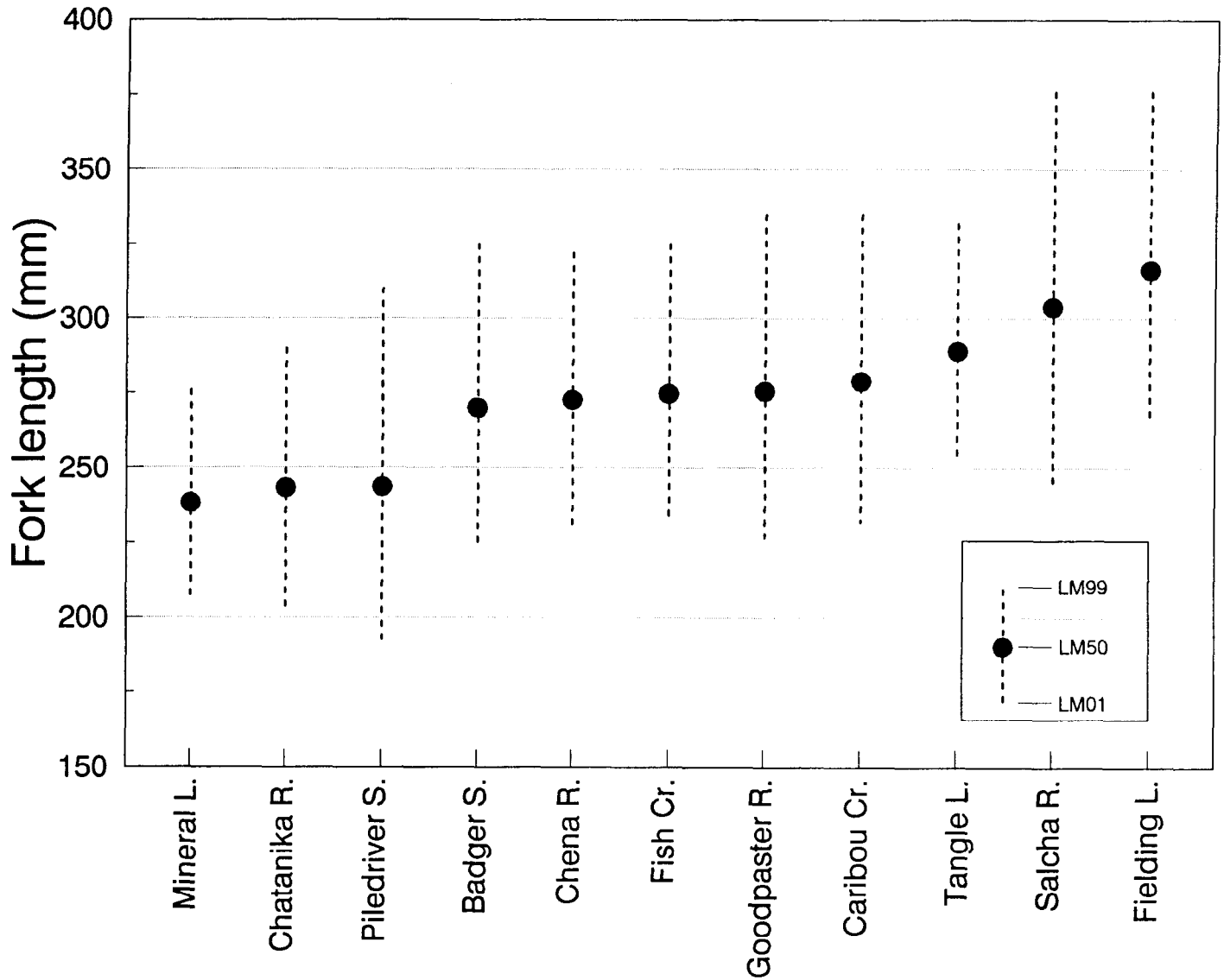

Figure 3. Estimates of fork length (mm) at 1%, 50%, and 99% maturity from probit analysis of Arctic grayling sampled from 11 stocks in the Tanana River drainage.

The mechanisms that produce differences in maturity of Arctic grayling of the Tanana River drainage are not known and an analysis of plausible mechanisms is beyond the scope of this report. Differences in the population density, level of exploitation, productivity of the water body, rate of growth, longevity of the stock (or natural mortality rate), and genetic differences between stocks could potentially influence the rate and timing of maturation of Arctic grayling in the Tanana River drainage. However, correlation analyses between one or combinations of these factors and age or size at maturity were not performed. Moreover, information on exploitation rate, productivity of the water bodies, natural mortality rates, and genetic makeup is lacking in most of these stocks. Regardless of the causes of observed differences in maturation, these results have broad implications for research and management of Arctic grayling resources in the Tanana River drainage.

One of the principal methods used to manage Arctic grayling stocks in the Tanana River drainage is the minimum length limit. Prior to 1987, the daily bag limit for Arctic grayling was five fish and there were no minimum length limit regulations. During 1987 and 1988, a minimum length limit of 305 mm total length (12 inches total length or ~270 mm FL) was enacted for several river systems[1] in the Tanana River drainage. The assumption behind this regulation was that if fishing mortality was eliminated from the juvenile portion of the stock, more mature fish would be produced and overall harvest would decrease. Implicit in this assumption was that most fish (>50%) would have spawned at least once before reaching a fork length of 270 mm. While overall harvest should decrease (given that fishing effort remains constant), the assumption that most fish have spawned at a fork length of 270 mm appears invalid for some of the stocks investigated. Of the systems that currently have or had a minimum length limit, the supposition that most fish have spawned appears valid for Badger and Piledriver sloughs, the Chatanika River and Mineral Lake outlet (Figure 4A). However, this supposition appears at least partially invalid for the Salcha River and Caribou Creek (Figure 4A). The assumption that most Arctic grayling are mature at 270 mm FL appears valid for the Chena River since 57% of the stock is mature at this length. However, if the minimum length limit were increased 25 mm (1 inch) to 330 mm total length (13 inches total length or ~300 mm FL), most Arctic grayling would be mature in all of the stocks that currently had or have a 305 mm total length limit (Figure 4B).

A secondary and implicit assumption of a minimum length limit is that natural mortality rate is sufficiently low and the juvenile stage is of short duration so that sufficient juvenile fish survive to maturity. Clark (1992) found that instantaneous natural mortality rate of Arctic grayling in the Chena River was 0.31 (approximately 22% per year). Clark (1991) also found that instantaneous natural mortality rate in Fielding Lake was 0.22 (approximately 18% per year).

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[1] From 1987 or 1988 through 1991 river systems with a 305 mm total length limit were the Chena, Salcha, Delta Clearwater, and Richardson Clearwater rivers; Piledriver and Badger sloughs; and Mineral Lake outlet. In 1992 catch-and-release regulations were enacted on the Chena River, the 305 mm total length limit was removed from Mineral Lake outlet, and the 305 mm total length limit enacted on a portion of the Chatanika River.

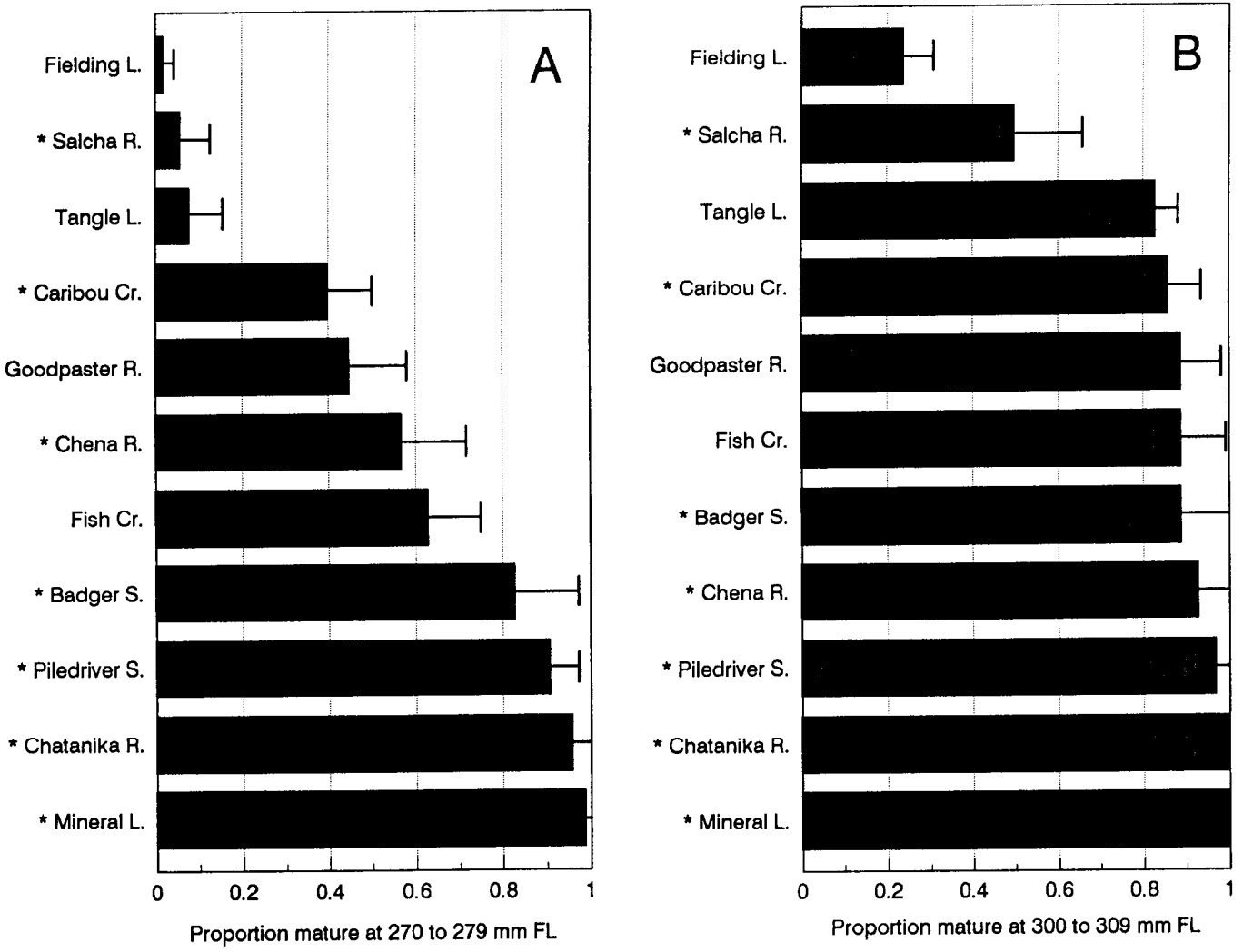

Figure 4. Estimates of the proportion and upper 95% confidence level of Arctic grayling that were classed as mature at a fork length of 270 to 279 mm (panel A) and at a fork length of 300 to 309 mm (panel B) from 11 stocks in the Tanana River drainage (stocks preceded with an asterisk have or had a minimum length limit of 305 mm total length).

Assuming that natural mortality rate is 20% per year, approximately 50% of the juveniles available at age 3 would survive to maturity at age 5 in the absence of fishing mortality (survival to maturity = $[1-0.2]^3$). If maturity is not achieved until age 6, only 40% would survive to maturity (survival to maturity = $[1-0.2]^4$). Therefore, the earlier in life that the stock achieves maturity, the more likely that a minimum length limit will achieve success in allowing more fish to attain maturity. Age at maturity data reveals that many fish in the stocks investigated are not mature at age 5 (Figure 5A). Increases in the proportion of mature fish at age 6 are substantial for most of these stocks (Figure 5B).

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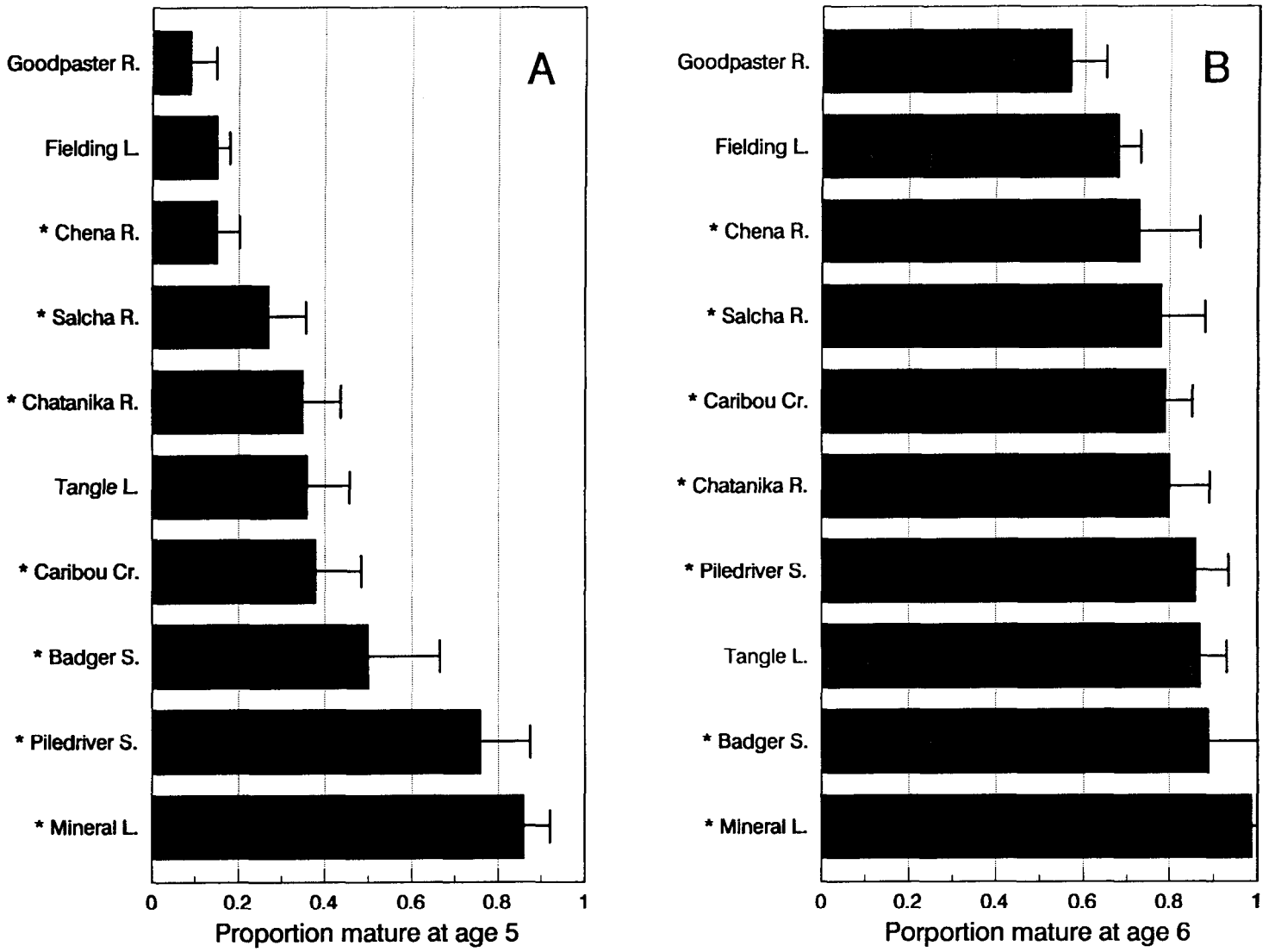

Figure 5. Estimates of the proportion and upper 95% confidence level of Arctic grayling that were classed as mature at age 5 (panel A) and at age 6 (panel B) from 10 stocks in the Tanana River drainage (stocks preceded with an asterisk have or had a minimum length limit of 305 mm total length).

LITERATURE CITED

Armstrong, R. H. 1986. A review of Arctic grayling studies in Alaska, 1952-1982. Biological Papers of the University of Alaska 23:3-17.

Beauchamp, D. A. 1982. The life history, spawning behavior, and interspecific interactions of the Arctic grayling (*Thymallus arcticus*) in Upper Granite Lake. Master's thesis, University of Washington, Seattle.

Bishop, F. G. 1967. The biology of Arctic grayling, *Thymallus arcticus*, in Great Slave Lake. Master's thesis, University of Alberta, Edmonton.

Brown, C. J. D. 1938. Observations on the life-history and breeding habits of the Montana grayling. Copeia 3:132-136.

Clark, R. A. 1991. Stock assessment of Arctic grayling in Fielding Lake. Alaska Department of Fish and Game, Fishery Data Series No. 91-11, Anchorage.

_____. 1992. Influence of stream flows and stock size on recruitment of Arctic grayling (*Thymallus arcticus*) in the Chena River, Alaska. Canadian Journal of Fisheries and Aquatic Sciences 49:1027-1034.

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

Finney, D. J. 1971. Statistical methods in biological assay, second edition. Charles Griffin & Company, Ltd., London.

Fleming, D. F. 1989. Effects of spawning run delay on spawning migration of Arctic grayling. Master's thesis, University of Alaska, Fairbanks.

_____. 1991. Stock assessment of Arctic grayling in Piledriver Slough, 1991. Alaska Department of Fish and Game, Fishery Data Series No. 91-71, Anchorage.

Goodman, L. A. 1965. On simultaneous confidence intervals for multinomial proportions. Technometrics 7:247-254.

Kruse, T. E. 1959. Grayling of Grebe Lake, Yellowstone National Park, Wyoming. U.S. Fish and Wildlife Service Fishery Bulletin 59:307-351.

Miller, R. R. 1946. Notes on the Arctic grayling *Thymallus signifier* (Richardson) from Great Bear Lake. Copeia 1946, no. 4, p. 227-236.

Nelson, P. H. 1954. Life history and management of the American grayling (*Thymallus signifer tricolor*) in Montana. The Journal of Wildlife Management 18:324-342.

Peterman, L. G. 1972. The biology and population characteristics of the Arctic grayling in Lake Agnes, Montana. Master's thesis, Montana State University, Bozeman.

Rawson, D. S. 1950. The grayling (*Thymallus signifer*) in northern Saskatchewan. Canadian Fish Culturist 6:3-10.

Ridder, W. P. 1984. A study of a typical spring-fed stream in Interior Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1983-1984, Project F-9-16, 25(G-III-G), Juneau.

_____. 1989a. Age, length, sex, and abundance of Arctic grayling in the Goodpaster River, 1956 through 1988. Alaska Department of Fish and Game, Fishery Data Series No. 94, Juneau.

_____. 1989b. Age, length, sex, and abundance of Arctic grayling in Mineral Lake outlet, 1969 - 1988. Alaska Department of Fish and Game, Fishery Data Series No. 87, Juneau.

_____. 1991. Stock assessment of Arctic grayling in the Tangle lakes system. Alaska Department of Fish and Game, Fishery Data Series No. 91-47, Anchorage.

Shallock, E. D. 1966. Grayling life history related to hydroelectric development of the Chatanika River in Interior Alaska. Master's thesis, University of Alaska, Fairbanks.

Tack, S. L. 1971. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1970-1971, Project F-9-3, 12(R-I), Juneau.

_____. 1974. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1973-1974, Project F-9-6, 15(R-I), Juneau.

Van Hulle, F. 1968. Investigation of the fish populations in the Chena River. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1967-1968, Project F-5-R-9, 9(15-B), Juneau.

Ward, J. C. 1951. The biology of Arctic grayling in the southern Athabaska drainage. Master's thesis, University of Alberta, Edmonton.

APPENDIX A

Appendix A1. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling (≥ 150 mm FL) collected from the Chena River in May of 1991.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
2	4	0	0.00	---	150-159	2	0	0.00	---
					160-169	2	0	0.00	---
3	27	0	0.00	---	170-179	4	0	0.00	---
					180-189	4	0	0.00	---
4	115	3	0.03	0.03	190-199	10	0	0.00	---
					200-209	26	0	0.00	---
5	64	24	0.37	0.14	210-219	26	1	0.04	0.09
					220-229	43	1	0.02	0.05
6	45	35	0.78	0.14	230-239	28	1	0.04	0.08
					240-249	34	7	0.21	0.16
7	55	52	0.94	0.07	250-259	30	9	0.30	0.19
					260-269	30	16	0.53	0.21
8	59	55	0.93	0.07	270-279	36	29	0.81	0.15
					280-289	35	29	0.83	0.14
9	11	10	0.91	0.20	290-299	27	24	0.89	0.14
					300-309	16	15	0.94	0.14
10	6	6	1.00	---	310-319	19	19	1.00	---
					320-329	12	12	1.00	---
11	2	2	1.00	---	330-339	13	13	1.00	---
					340-349	21	21	1.00	---
					350-359	10	10	1.00	---
					360-369	7	7	1.00	---
					370-379	5	5	1.00	---
					380-389	4	4	1.00	---

Part II. Probit analyses:

	Mean	Limits		Mean	Limits
AM_{01}[e]	3 yr	3 to 4 yr	LM_{01}[f]	217 mm	208 to 224 mm
AM_{50}	5 yr	5 to 6 yr	LM_{50}	263 mm	259 to 267 mm
AM_{99}	9 yr	8 to 10 yr	LM_{99}	318 mm	308 to 331 mm

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_x = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_x = xth percentile from probit analysis for fork length at maturity (limits are the 95% fiducial limits).

Appendix A2. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling (≥ 150 mm FL) collected from the Chena River in May of 1992.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
2	1	0	0.00	---	150-159	0	0	---	---
					160-169	1	0	0.00	---
3	12	0	0.00	---	170-179	0	0	---	---
					180-189	4	0	0.00	---
41	55	0	0.00	---	190-199	6	0	0.00	---
					200-209	10	0	0.00	---
5	201	16	0.08	0.04	210-219	17	0	0.00	---
					220-229	27	0	0.00	---
6	33	22	0.67	0.19	230-239	49	0	0.00	---
					240-249	67	0	0.00	---
7	36	34	0.94	0.09	250-259	61	4	0.07	0.07
					260-269	46	4	0.09	0.09
8	20	20	1.00	---	270-279	27	7	0.26	0.19
					280-289	24	15	0.62	0.23
9	10	10	1.00	---	290-299	18	16	0.89	0.17
					300-309	14	13	0.93	0.16
10	3	3	1.00	---	310-319	18	18	1.00	---
					320-329	20	20	1.00	---
					330-339	14	14	1.00	---
					340-349	15	15	1.00	---
					350-359	11	11	1.00	---
					360-369	2	2	1.00	---
					370-379	1	1	1.00	---
					380-389	1	1	1.00	---
					390-399	1	1	1.00	---

Part II. Probit analyses:

Age	Mean	Limits	Length	Mean	Limits
AM_{01}[e]	4 yr	4 to 5 yr	LM_{01}[f]	249 mm	243 to 254 mm
AM_{50}	6 yr	6 yr	LM_{50}	281 mm	278 to 285 mm
AM_{99}	7 yr	7 to 8 yr	LM_{99}	316 mm	308 to 328 mm

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_x = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_x = xth percentile from probit analysis for fork length at maturity (limits are the 95% fiducial limits).

Appendix A3. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling (≥ 150 mm FL) collected from the Salcha River in May of 1991.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
2	8	0	0.00	---	150-159	1	0	0.00	---
					160-169	0	0	0.00	---
3	63	5	0.08	0.08	170-179	4	0	0.00	---
					180-189	9	0	0.00	---
4	131	7	0.05	0.04	190-199	10	0	0.00	---
					200-209	16	0	0.00	---
5	87	23	0.26	0.11	210-219	18	0	0.00	---
					220-229	34	1	0.03	0.07
6	39	29	0.74	0.16	230-239	29	0	0.00	---
					240-249	37	0	0.00	---
7	16	16	1.00	---	250-259	31	1	0.03	0.07
					260-269	38	1	0.03	0.06
8	9	9	1.00	---	270-279	35	3	0.09	0.11
					280-289	28	7	0.25	0.19
9	5	5	1.00	---	290-299	36	12	0.33	0.18
					300-309	29	12	0.41	0.21
					310-319	15	12	0.80	0.24
					320-329	9	9	1.00	---
					330-339	12	10	0.83	0.25
					340-349	10	10	1.00	---
					350-359	12	12	1.00	---
					360-369	6	6	1.00	---
					370-379	9	9	1.00	---
					380-389	6	6	1.00	---
					390-399	4	4	1.00	---
					400-409	1	1	1.00	---

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Part II. Probit analyses:

Age	Mean	Limits	Length	Mean	Limits
AM_{01}[e]	3 yr	2 to 4 yr	LM_{01}[f]	249 mm	217 to 264 mm
AM_{50}	5 yr	5 to 7 yr	LM_{50}	303 mm	292 to 319 mm
AM_{99}	9 yr	---	LM_{99}	368 mm	341 to 443 mm

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] $\pm$95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_x = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_x = xth percentile from probit analysis for fork length at maturity (limits are the 95% fiducial limits).

Appendix A4. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling (≥ 150 mm FL) collected from the Salcha River in May and June of 1992.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
2	9	0	0.00	---	150-159	2	0	0.00	---
					160-169	4	0	0.00	---
3	56	1	0.02	0.04	170-179	7	0	0.00	---
					180-189	6	0	0.00	---
4	149	13	0.09	0.05	190-199	11	0	0.00	---
					200-209	11	0	0.00	---
5	86	23	0.27	0.11	210-219	20	0	0.00	---
					220-229	21	1	0.05	0.11
6	28	23	0.82	0.16	230-239	26	1	0.04	0.09
					240-249	38	0	0.00	---
7	20	15	0.75	0.22	250-259	36	1	0.03	0.06
					260-269	39	4	0.10	0.11
8	7	7	1.00	---	270-279	32	1	0.03	0.07
					280-289	33	5	0.15	0.14
9	4	4	1.00	---	290-299	19	6	0.32	0.24
					300-309	21	13	0.62	0.24
					310-319	20	13	0.65	0.24
					320-329	8	8	1.00	---
					330-339	6	6	1.00	---
					340-349	13	13	1.00	---
					350-359	10	9	0.90	0.22
					360-369	5	4	0.80	0.45
					370-379	2	2	1.00	---
					380-389	6	6	1.00	---
					390-399	3	3	1.00	---
					400-409	2	2	1.00	---
					410-419	2	2	1.00	---
					420-429	1	1	1.00	---

-continued-

Part II. Probit analyses:

Age	Mean	Limits	Length	Mean	Limits
AM_{01}[e]	3 yr	3 yr	LM_{01}[f]	242 mm	221 to 255 mm
AM_{50}	5 yr	5 to 6 yr	LM_{50}	304 mm	295 to 317 mm
AM_{99}	9 yr	8 to 12 yr	LM_{99}	383 mm	356 to 436 mm

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] $\pm$95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_x = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_x = xth percentile from probit analysis for fork length at maturity (limits are the 95% fiducial limits).

Appendix A5. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling (≥ 150 mm FL) collected from the upper Chatanika River in June of 1991.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
2	3	0	0.00	---	150-159	1	0	0.00	---
					160-169	1	0	0.00	---
3	3	0	0.00	---	170-179	1	0	0.00	---
					180-189	2	0	0.00	---
4	34	6	0.18	0.15	190-199	9	0	0.00	---
					200-209	8	0	0.00	---
5	44	31	0.65	0.16	210-219	5	0	0.00	---
					220-229	22	11	0.50	0.24
6	78	67	0.86	0.09	230-239	27	17	0.63	0.21
					240-249	26	18	0.69	0.21
7	84	81	0.96	0.05	250-259	38	32	0.84	0.13
					260-269	31	27	0.87	0.14
8	40	37	0.92	0.09	270-279	31	30	0.97	0.07
					280-289	36	35	0.97	0.06
9	2	2	1.00	---	290-299	36	36	1.00	---
					300-309	32	32	1.00	---
					310-319	29	29	1.00	---
					320-329	12	12	1.00	---
					330-339	6	6	1.00	---
					340-349	1	1	1.00	---
					350-359	1	1	1.00	---

Part II. Probit analyses:

Age	Mean	Limits	Length	Mean	Limits
AM_{01}[e]	3 yr	2 to 3 yr	LM_{01}[f]	185 mm	170 to 196 mm
AM_{50}	5 yr	4 to 5 yr	LM_{50}	231 mm	225 to 236 mm
AM_{99}	8 yr	7 to 10 yr	LM_{99}	289 mm	279 to 305 mm

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_x = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_x = xth percentile from probit analysis for fork length at maturity (limits are the 95% fiducial limits).

Appendix A6. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling (≥ 150 mm FL) collected from the middle Chatanika River in June of 1992.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
2	2	0	0.00	---	150-159	3	0	0.00	---
					160-169	6	0	0.00	---
3	23	1	0.04	0.10	170-179	9	0	0.00	---
					180-189	3	0	0.00	---
4	42	4	0.09	0.10	190-199	13	0	0.00	---
					200-209	36	0	0.00	---
5	219	60	0.27	0.07	210-219	49	1	0.02	0.05
					220-229	75	7	0.09	0.08
6	57	41	0.72	0.13	230-239	77	20	0.26	0.11
					240-249	63	32	0.51	0.14
7	7	7	1.00	---	250-259	34	21	0.62	0.19
					260-269	24	20	0.83	0.17
8	19	18	0.95	0.12	270-279	15	14	0.93	0.15
					280-289	8	8	1.00	---
9	10	10	1.00	---	290-299	11	10	0.91	0.20
					300-309	11	11	1.00	---
10	3	2	0.67	0.75	310-319	9	9	1.00	---
					320-329	2	2	1.00	---
					330-339	5	5	1.00	---
					340-349	2	2	1.00	---
					350-359	1	1	1.00	---
					360-369	0	0	---	---
					370-379	0	0	---	---
					380-389	2	2	1.00	---

Part II. Probit analyses:

Age	Mean	Limits	Length	Mean	Limits
AM_{01}[e]	3 yr	2 to 4 yr	LM_{01}[f]	208 mm	200 to 213 mm
AM_{50}	5 yr	5 to 6 yr	LM_{50}	247 mm	244 to 251 mm
AM_{99}	9 yr	7 to 16 yr	LM_{99}	294 mm	285 to 308 mm

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_x = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_x = xth percentile from probit analysis for fork length at maturity (limits are the 95% fiducial limits).

Appendix A7. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling (≥ 150 mm FL) collected from Caribou Creek in June of 1985.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
2	9	0	0.00	---	150-159	18	0	0.00	---
					160-169	20	0	0.00	---
3	40	0	0.00	---	170-179	14	0	0.00	---
					180-189	8	0	0.00	---
4	42	7	0.17	0.13	190-199	19	0	0.00	---
					200-209	12	0	0.00	---
5	93	37	0.40	0.11	210-219	6	0	0.00	---
					220-229	13	0	0.00	---
6	76	61	0.80	0.10	230-239	12	0	0.00	---
					240-249	22	1	0.04	0.10
7	34	33	0.97	0.07	250-259	25	1	0.04	0.09
					260-269	33	8	0.24	0.17
8	7	7	1.00	---	270-279	38	19	0.50	0.18
					280-289	43	33	0.77	0.15
9	1	1	1.00	---	290-299	35	31	0.88	0.12
					300-309	22	21	0.95	0.10
10	1	1	1.00	---	310-319	14	14	1.00	---
					320-329	14	14	1.00	---
					330-339	7	7	1.00	---
					340-349	1	1	1.00	---
					350-359	4	4	1.00	---
					360-369	1	1	1.00	---
					370-379	0	0	---	---
					380-389	3	3	1.00	---

Part II. Probit analyses:

Age	Mean	Limits	Length	Mean	Limits
AM_{01}[e]	3 yr	3 to 4 yr	LM_{01}[f]	242 mm	233 to 248
AM_{50}	5 yr	5 yr	LM_{50}	275 mm	272 to 278
AM_{99}	8 yr	7 to 9 yr	LM_{99}	313 mm	305 to 324

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_X = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_X = xth percentile from probit analysis for fork length at maturity (limits are the 95% fiducial limits).

Appendix A8. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling (≥ 150 mm FL) collected from Caribou Creek in June of 1986.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
2	7	0	0.00	---	150-159	9	0	0.00	---
					160-169	5	0	0.00	---
3	160	0	0.00	---	170-179	12	0	0.00	---
					180-189	26	0	0.00	---
4	163	2	0.01	0.02	190-199	30	0	0.00	---
					200-209	34	0	0.00	---
5	90	33	0.37	0.11	210-219	64	0	0.00	---
					220-229	63	1	0.01	0.04
6	89	72	0.81	0.09	230-239	49	0	0.00	---
					240-249	59	1	0.02	0.04
7	103	98	0.95	0.05	250-259	40	2	0.05	0.08
					260-269	34	9	0.26	0.17
8	62	61	0.98	0.04	270-279	33	12	0.36	0.19
					280-289	36	16	0.44	0.19
9	11	11	1.00	---	290-299	51	47	0.92	0.08
					300-309	42	33	0.78	0.14
10	6	6	1.00	---	310-319	33	30	0.91	0.11
					320-329	37	37	1.00	---
11	1	1	1.00	---	330-339	29	28	0.96	0.08
					340-349	39	38	0.97	0.06
					350-359	23	23	1.00	---
					360-369	20	20	1.00	---
					370-379	15	14	0.93	0.15
					380-389	4	4	1.00	---
					390-399	4	3	0.75	0.56
					400-409	1	1	1.00	---

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Part II. Probit analyses:

Age	Mean	Limits	Length	Mean	Limits
AM_{01}[e]	4 yr	3 to 4 yr	LM_{01}[f]	230 mm	---
AM_{50}	5 yr	5 yr	LM_{50}	282 mm	---
AM_{99}	7 yr	7 to 8 yr	LM_{99}	347 mm	---

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_x = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_x = xth percentile from probit analysis for fork length at maturity (95% fiducial limits could not be calculated for these data).

Appendix A9. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling (≥ 150 mm FL) collected from Caribou Creek in June of 1987.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
2	3	0	0.00	---	150-159	11	0	0.00	---
					160-169	1	0	0.00	---
3	8	0	0.00	---	170-179	9	0	0.00	---
					180-189	19	0	0.00	---
4	100	4	0.04	0.04	190-199	32	0	0.00	---
					200-209	35	0	0.00	---
5	102	39	0.38	0.11	210-219	49	0	0.00	---
					220-229	48	0	0.00	---
6	46	33	0.72	0.15	230-239	71	2	0.03	0.04
					240-249	72	2	0.03	0.04
7	80	77	0.96	0.05	250-259	76	10	0.13	0.09
					260-269	54	13	0.24	0.13
8	29	29	1.00	---	270-279	43	15	0.35	0.16
					280-289	38	23	0.60	0.18
9	21	20	0.95	0.11	290-299	45	39	0.87	0.11
					300-309	30	27	0.90	0.12
10	9	9	1.00	---	310-319	34	34	1.00	---
					320-329	25	23	0.92	0.12
11	2	2	1.00	---	330-339	41	40	0.97	0.05
					340-349	27	27	1.00	---
12	3	3	1.00	---	350-359	15	15	1.00	---
					360-369	14	14	1.00	---
					370-379	13	13	1.00	---
					380-389	8	8	1.00	---
					390-399	4	4	1.00	---
					400-409	2	2	1.00	---
					410-419	2	2	1.00	---
					420-429	2	2	1.00	---

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Part II. Probit analyses:

Age	Mean	Limits	Length	Mean	Limits
AM_{01}[e]	3 yr	3 to 4 yr	LM_{01}[f]	234 mm	227 to 239
AM_{50}	5 yr	5 to 6 yr	LM_{50}	278 mm	275 to 282
AM_{99}	8 yr	7 to 10 yr	LM_{99}	332 mm	324 to 343

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_x = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_x = xth percentile from probit analysis for fork length at maturity (limits are the 95% fiducial limits).

Appendix A10. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling collected from Mineral Lake outlet in May of 1988.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
1	102	0	0.00	---	<210	402	0	0.00	---
2	79	0	0.00	---	210-219	39	1	0.03	0.06
3	182	1	<0.01	0.01	220-229	31	6	0.19	0.16
4	139	39	0.28	0.09	230-239	41	22	0.54	0.18
5	96	86	0.90	0.07	240-249	32	27	0.84	0.15
6	60	59	0.98	0.04	250-259	31	29	0.93	0.10
7	39	39	1.00	---	260-269	29	27	0.93	0.11
8	29	28	0.97	0.08	270-279	37	36	0.97	0.06
9	10	10	1.00	---	280-289	37	36	0.97	0.06
10	4	4	1.00	---	290-299	16	15	0.94	0.14
11	1	1	1.00	---	300-309	25	25	1.00	---
12	1	1	1.00	---	310-319	18	17	0.94	0.12
					>319	76	76	1.00	---

Part II. Probit analyses:

Age	Mean	Limits	Length	Mean	Limits
AM_{01}[e]	3 yr	---	LM_{01}[f]	204 mm	---
AM_{50}	4 yr	---	LM_{50}	239 mm	---
AM_{99}	6 yr	---	LM_{99}	279 mm	---

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_x = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (95% fiducial limits could not be calculated).
[f] LM_x = xth percentile from probit analysis for fork length at maturity (95% fiducial limits could not be calculated).

Appendix A11. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling (≥ 150 mm FL) collected from Mineral Lake outlet in May of 1990.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
1	3	0	0.00	---	150-159	19	0	0.00	---
					160-169	19	0	0.00	---
2	77	0	0.00	---	170-179	30	0	0.00	---
					180-189	39	0	0.00	---
3	98	7	0.07	0.06	190-199	27	0	0.00	---
					200-209	41	1	0.02	0.05
4	105	55	0.52	0.11	210-219	33	0	0.00	---
					220-229	19	2	0.10	0.16
5	74	61	0.82	0.10	230-239	26	17	0.65	0.21
					240-249	33	24	0.73	0.18
6	136	136	1.00	---	250-259	34	31	0.91	0.11
					260-269	36	34	0.94	0.09
7	49	49	1.00	---	270-279	61	61	1.00	---
					280-289	45	45	1.00	---
8	23	23	1.00	---	290-299	45	44	0.98	0.05
					300-309	21	21	1.00	---
9	14	14	1.00	---	310-319	24	24	1.00	---
					320-329	24	24	1.00	---
10	7	7	1.00	---	330-339	20	20	1.00	---
					340-349	14	14	1.00	---
11	2	2	1.00	---	350-359	11	11	1.00	---
					360-369	12	12	1.00	---
					370-379	5	5	1.00	---
					380-389	5	5	1.00	---
					390-399	2	2	1.00	---

Part II. Probit analyses:

Age	Mean	Limits	Length	Mean	Limits
AM_{01}[e]	3 yr	2 to 3 yr	LM_{01}[f]	203 mm	185 to 213 mm
AM_{50}	4 yr	4 yr	LM_{50}	236 mm	229 to 243 mm
AM_{99}	6 yr	6 to 7 yr	LM_{99}	275 mm	263 to 297 mm

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_x = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_x = xth percentile from probit analysis for fork length at maturity (limits are the 95% fiducial limits).

Appendix A12. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling (≥ 150 mm FL) collected from Piledriver Slough in May of 1991.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
2	11	0	0.00	---	150-159	23	0	0.00	---
					160-169	30	0	0.00	---
3	89	0	0.00	---	170-179	34	0	0.00	---
					180-189	44	0	0.00	---
4	89	8	0.09	0.07	190-199	48	0	0.00	---
					200-209	48	3	0.06	0.08
5	53	21	0.40	0.15	210-219	23	4	0.17	0.18
					220-229	12	3	0.25	0.29
6	14	9	0.64	0.30	230-239	9	6	0.67	0.37
					240-249	8	6	0.75	0.37
7	11	11	1.00	---	250-259	9	8	0.89	0.25
					260-269	8	8	1.00	---
8	5	5	1.00	---	270-279	10	10	1.00	---
					280-289	6	6	1.00	---
					290-299	7	7	1.00	---
					300-309	4	4	1.00	---
					310-319	2	2	1.00	---
					320-329	2	2	1.00	---

Part II. Probit analyses:

Age	Mean	Limits	Length	Mean	Limits
AM_{01}[e]	3 yr	3 to 4 yr	LM_{01}[f]	196 mm	187 to 202 mm
AM_{50}	5 yr	5 to 6 yr	LM_{50}	231 mm	226 to 237 mm
AM_{99}	8 yr	7 to 10 yr	LM_{99}	272 mm	260 to 292 mm

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_X = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_X = xth percentile from probit analysis for fork length at maturity (limits are the 95% fiducial limits).

Appendix A13. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling (≥ 150 mm FL) collected from Piledriver Slough in May of 1992.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
1	1	0	0.00	---	150-159	23	0	0.00	---
					160-169	23	0	0.00	---
2	48	2	0.04	0.06	170-179	10	0	0.00	---
					180-189	14	0	0.00	---
3	65	4	0.06	0.07	190-199	15	0	0.00	---
					200-209	31	1	0.03	0.07
4	186	64	0.34	0.08	210-219	44	1	0.02	0.05
					220-229	34	2	0.06	0.04
5	254	194	0.76	0.06	230-239	67	20	0.30	0.13
					240-249	100	54	0.54	0.11
6	185	157	0.85	0.06	250-259	107	78	0.73	0.10
					260-269	119	99	0.83	0.08
7	44	40	0.91	0.10	270-279	98	88	0.90	0.07
					280-289	84	72	0.86	0.09
8	15	14	0.93	0.15	290-299	55	50	0.91	0.09
					300-309	30	29	0.97	0.07
9	2	2	1.00	---	310-319	22	21	0.95	0.10
					320-329	10	10	1.00	---
					330-339	4	4	1.00	---
					340-349	1	1	1.00	---
					350-359	2	2	1.00	---
					360-369	1	1	1.00	---
					370-379	2	2	1.00	---
					380-389	1	1	1.00	---

Part II. Probit analyses:

Age	Mean	Limits	Length	Mean	Limits
AM_{01}[e]	2 yr	1 to 3 yr	LM_{01}[f]	194 mm	184 to 202 mm
AM_{50}	4 yr	4 to 5 yr	LM_{50}	246 mm	242 to 249 mm
AM_{99}	9 yr	7 to 12 yr	LM_{99}	311 mm	302 to 324 mm

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_x = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_x = xth percentile from probit analysis for fork length at maturity (limits are the 95% fiducial limits).

Appendix A14. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling (≥ 200 mm FL) collected from Fielding Lake in June of 1988.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
2	0	0	---	---	200-209	27	0	0.00	---
					210-219	37	0	0.00	---
3	30	0	0.00	---	220-229	49	0	0.00	---
					230-239	49	0	0.00	---
4	201	2	0.01	0.02	240-249	67	0	0.00	---
					250-259	61	1	0.02	0.04
5	229	18	0.08	0.04	260-269	58	1	0.02	0.04
					270-279	41	1	0.02	0.05
6	160	117	0.73	0.08	280-289	40	1	0.02	0.06
					290-299	27	2	0.06	0.11
7	116	108	0.93	0.05	300-309	36	4	0.11	0.12
					310-319	22	10	0.45	0.24
8	65	64	0.98	0.03	320-329	28	19	0.68	0.20
					330-339	33	25	0.76	0.17
9	14	14	1.00	---	340-349	44	42	0.95	0.07
					350-359	54	50	0.93	0.08
10	1	1	1.00	---	360-369	62	60	0.97	0.05
					370-379	59	59	1.00	---
					380-389	41	40	0.98	0.05
					390-399	25	24	0.96	0.09
					400-409	12	12	1.00	---
					410-429	2	2	1.00	---

Part II. Probit analyses:

Age	Mean	Limits	Length	Mean	Limits
AM_{01}[e]	4 yr	4 to 5 yr	LM_{01}[f]	259 mm	245 to 269 mm
AM_{50}	6 yr	5 to 6 yr	LM_{50}	309 mm	302 to 316 mm
AM_{99}	8 yr	7 to 9 yr	LM_{99}	369 mm	356 to 387 mm

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_x = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_x = xth percentile from probit analysis for fork length at maturity (limits are the 95% fiducial limits).

Appendix A15. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling (≥ 200 mm FL) collected from Fielding Lake in June of 1989.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
2	0	0	---	---	200-209	12	0	0.00	---
					210-219	27	0	0.00	---
3	66	0	0.00	---	220-229	45	0	0.00	---
					230-239	54	0	0.00	---
4	126	0	0.00	---	240-249	56	0	0.00	---
					250-259	80	0	0.00	---
5	320	50	0.16	0.05	260-269	104	0	0.00	---
					270-279	98	3	0.03	0.04
6	230	141	0.61	0.07	280-289	124	12	0.10	0.06
					290-299	98	29	0.30	0.10
7	110	102	0.93	0.06	300-309	83	24	0.29	0.11
					310-319	85	60	0.71	0.11
8	68	68	1.00	---	320-329	56	44	0.79	0.12
					330-339	56	51	0.91	0.09
9	26	25	0.96	0.09	340-349	55	54	0.98	0.04
					350-359	50	49	0.98	0.04
10	0	0	---	---	360-369	57	56	0.98	0.04
					370-379	53	51	0.96	0.06
					380-389	30	28	0.93	0.10
					390-399	40	38	0.95	0.08
					400-409	9	9	1.00	---
					410-429	5	5	1.00	---

Part II. Probit analyses:

Age	Mean	Limits	Length	Mean	Limits
AM_{01}[e]	4 yr	3 to 5 yr	LM_{01}[f]	261 mm	237 to 274 mm
AM_{50}	6 yr	5 to 6 yr	LM_{50}	311 mm	301 to 321 mm
AM_{99}	8 yr	7 to 11 yr	LM_{99}	370 mm	350 to 412 mm

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_X = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_X = xth percentile from probit analysis for fork length at maturity (limits are the 95% fiducial limits).

Appendix A16. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling (≥ 200 mm FL) collected from Fielding Lake in June of 1990.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
2	0	0	---	---	200-209	27	0	0.00	---
					210-219	69	0	0.00	---
3	225	0	0.00	---	220-229	72	0	0.00	---
					230-239	79	0	0.00	---
4	180	1	0.01	0.01	240-249	66	1	0.01	0.03
					250-259	55	1	0.02	0.04
5	104	6	0.06	0.05	260-269	60	0	0.00	---
					270-279	48	1	0.02	0.05
6	149	92	0.62	0.09	280-289	54	0	0.00	---
					290-299	55	3	0.05	0.07
7	177	160	0.90	0.05	300-309	56	14	0.25	0.13
					310-319	45	16	0.36	0.16
8	66	64	0.97	0.05	320-329	61	39	0.64	0.14
					330-339	54	43	0.80	0.12
9	11	11	1.00	---	340-349	51	50	0.98	0.04
					350-359	49	47	0.96	0.06
10	1	1	1.00	---	360-369	63	62	0.98	0.04
					370-379	62	61	0.98	0.04
					380-389	42	42	1.00	---
					390-399	30	30	1.00	---
					400-409	17	17	1.00	---
					410-429	2	2	1.00	---

Part II. Probit analyses:

Age	Mean	Limits	Length	Mean	Limits
AM_{01}[e]	4 yr	4 yr	LM_{01}[f]	273 mm	201 to 294 mm
AM_{50}	6 yr	6 yr	LM_{50}	318 mm	297 to 339 mm
AM_{99}	8 yr	8 yr	LM_{99}	371 mm	345 to 497 mm

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_X = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_X = xth percentile from probit analysis for fork length at maturity (limits are the 95% fiducial limits).

Appendix A17. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling (≥ 200 mm FL) collected from Fielding Lake in June of 1991.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
2	5	0	0.00	---	200-209	23	0	0.00	---
					210-219	44	0	0.00	---
3	196	0	0.00	---	220-229	73	1	0.01	0.03
					230-239	58	0	0.00	---
4	189	3	0.02	0.02	240-249	57	0	0.00	---
					250-259	49	0	0.00	---
5	82	35	0.43	0.12	260-269	46	1	0.02	0.05
					270-279	51	0	0.00	---
6	103	88	0.85	0.08	280-289	43	4	0.09	0.10
					290-299	30	2	0.07	0.10
7	86	76	0.88	0.08	300-309	20	4	0.20	0.21
					310-319	23	13	0.56	0.24
8	35	32	0.91	0.11	320-329	25	16	0.64	0.22
					330-339	44	37	0.84	0.12
9	9	9	1.00	---	340-349	45	43	0.96	0.07
					350-359	41	37	0.90	0.10
10	1	1	1.00	---	360-369	42	40	0.95	0.07
					370-379	51	50	0.98	0.04
					380-389	23	21	0.91	0.13
					390-399	14	14	1.00	---
					400-409	12	12	1.00	---
					410-429	1	1	1.00	---

Part II. Probit analyses:

Age	Mean	Limits	Length	Mean	Limits
AM_{01}[e]	4 yr	3 to 4 yr	LM_{01}[f]	261 mm	90 to 293 mm
AM_{50}	5 yr	5 to 6 yr	LM_{50}	316 mm	263 to 363 mm
AM_{99}	8 yr	7 to 10 yr	LM_{99}	384 mm	345 to 997 mm

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_x = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_x = xth percentile from probit analysis for fork length at maturity (limits are the 95% fiducial limits).

Appendix A18. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling (≥ 200 mm FL) collected from the Tangle Lakes system in May and June of 1989.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
2	65	0	0.00	---	200-209	55	0	0.00	---
					210-219	43	0	0.00	---
3	136	0	0.00	---	220-229	22	0	0.00	---
					230-239	11	0	0.00	---
4	40	2	0.05	0.08	240-249	8	0	0.00	---
					250-259	20	0	0.00	---
5	108	31	0.29	0.10	260-269	21	0	0.00	---
					270-279	39	4	0.10	0.11
6	274	243	0.89	0.04	280-289	50	19	0.38	0.15
					290-299	70	49	0.70	0.12
7	182	181	0.99	0.01	300-309	96	83	0.86	0.08
					310-319	122	119	0.97	0.03
8	28	28	1.00	---	320-329	99	98	0.99	0.02
					330-339	72	72	1.00	---
9	7	7	1.00	---	340-349	42	42	1.00	---
					350-359	18	18	1.00	---
					360-369	8	8	1.00	---
					370-379	3	3	1.00	---
					380-389	1	1	1.00	---

Part II. Probit analyses:

Age	Mean	Limits	Length	Mean	Limits
AM_{01}[e]	4 yr	4 yr	LM_{01}[f]	261 mm	255 to 266 mm
AM_{50}	5 yr	5 yr	LM_{50}	289 mm	289 to 293 mm
AM_{99}	7 yr	7 yr	LM_{99}	321 mm	317 to 326 mm

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_X = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_X = xth percentile from probit analysis for fork length at maturity (limits are the 95% fiducial limits).

Appendix A19. Estimates of age (years) and fork length (mm) at maturity for Arctic grayling (≥ 200 mm FL) collected from the Tangle Lakes system in May and June of 1990.

Part I. Number and proportion mature by age and length group.

Age	n[a]	m[b]	p[c]	±95% C.I.[d]	Length Group	n	m	p	±95% C.I.
2	44	0	0.00	---	200-209	19	0	0.00	---
					210-219	29	0	0.00	---
3	83	0	0.00	---	220-229	28	0	0.00	---
					230-239	39	0	0.00	---
4	100	2	0.02	0.03	240-249	32	0	0.00	---
					250-259	36	1	0.03	0.06
5	115	50	0.43	0.10	260-269	37	3	0.08	0.10
					270-279	33	2	0.06	0.09
6	487	417	0.86	0.04	280-289	50	16	0.32	0.15
					290-299	119	73	0.61	0.10
7	310	294	0.95	0.03	300-309	145	118	0.81	0.07
					310-319	180	170	0.94	0.04
8	50	49	0.98	0.04	320-329	222	216	0.97	0.02
					330-339	158	156	0.99	0.02
9	8	8	1.00	---	340-349	94	93	0.99	0.02
					350-359	60	57	0.95	0.06
					360-369	21	20	0.95	0.11
					370-379	7	7	1.00	---
					380-389	1	1	1.00	---
					390-399	1	1	1.00	---
					400-409	1	1	1.00	---

Part II. Probit analyses:

Age	Mean	Limits	Length	Mean	Limits
AM_{01}[e]	4 yr	3 to 4 yr	LM_{01}[f]	249 mm	198 to 268 mm
AM_{50}	5 yr	5 yr	LM_{50}	290 mm	270 to 300 mm
AM_{99}	7 yr	7 to 8 yr	LM_{99}	337 mm	322 to 384 mm

[a] n is the number of fish examined for sexual maturity.
[b] m is the number of fish that were sexually mature.
[c] p is the proportion of fish in the sample that were sexually mature.
[d] ±95% C.I. is the 95% confidence interval for the binomial (Goodman 1965).
[e] AM_x = xth percentile from probit analysis (Finney 1971) for age at maturity rounded to the nearest 1 year (limits are the 95% fiducial limits).
[f] LM_x = xth percentile from probit analysis for fork length at maturity (limits are the 95% fiducial limits).