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STOCK ASSESSMENT OF ARCTIC GRAYLING IN THE TANGLE LAKES AND RIVER SYSTEM, 1989[1]

By

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ABSTRACT

Results are presented for the second year of a study to assess the population parameters and mixing rates of Arctic grayling *Thymallus arcticus* among their major spawning, summer feeding, and overwintering locations in the Tangle Lakes system above the Delta River falls. Between 23 May and 29 September, a total of 3,085 Arctic grayling was sampled during three distinct time periods. A total of 204 recaptures was obtained from the population sample and from angler volunteered returns. Analysis of recapture data implied the existence of significant movement throughout the Tangle Lakes system by season. Insufficient recaptures across years and lack of 1988 spawning area samples precluded reliable estimation of mixing rates. Estimates of age and size compositions and Relative Stock Density indices are presented for samples from 14 locations and for a July harvest sample. Three spawning locations were found during spring sampling; estimates of age and size composition, and sex ratios of adult Arctic grayling are provided for these areas. Adult males were significantly larger and older than adult females. Probit analysis provided estimates of age and size at which various percentages of the population mature. Age and size compositions of Arctic grayling greater than the median length-at-maturity were combined by time period and season and compared to the samples of adult Arctic grayling. Over the course of sampling in 1989, growth recruitment of juvenile Arctic grayling into the younger age classes produced significant differences in age composition among all samples except the spring sample. Relative Stock Density did not significantly differ among all size samples except the fall sample.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, Tangle Lakes, Tangle River, Delta River, age composition, size composition, Relative Stock Density, maturity, mixing rates.

INTRODUCTION

The Tangle Lakes and River system, hereafter referred to as the Tangle System (Figure 1), supports a large population of Arctic grayling *Thymallus arcticus* and populations of lake trout *Salvelinus namaycush*, burbot *Lota lota*, round whitefish *Prosopium cylindraceum*, and longnose suckers *Catastomus catastomus*. The Tangle System has supported popular fisheries for Arctic grayling, lake trout, and burbot since the opening of the Denali Highway on 4 July 1953 (Wojcik 1953a). Prior to this time, the Tangle System was inaccessible by road and received little fishing pressure (Wojcik 1953a, 1953b, 1953c, 1953d, 1953e, 1953f, 1953g). Since 1953, the heaviest angling pressure has occurred on Upper and Round Tangle lakes and the interconnecting Tangle River (Figure 1).

The recreational fishery in the Tangle System targets Arctic grayling, lake trout, and burbot with the former comprising over 80% of the system's total harvest. From 1978 to 1988, an average of 5,818 angler-days were expended annually for all species. Arctic grayling harvests ranged from 2,467 to 9,590 fish, with an annual average of 5,623 fish (Table 1). This average annual Arctic grayling harvest is the fifth largest in Alaska (Mills 1979-1989). Lake trout and burbot harvests have averaged 988 and 109 fish per year, respectively since 1978 (Mills 1979-1989). Depressed population levels in the latter two fisheries necessitated implementation of restrictive regulations in 1987. These fisheries restrictions appear to have indirectly affected the harvest of Arctic grayling in the Tangle System. In 1987, angling pressure dropped to its lowest recorded level and harvest was reduced to 2,467 Arctic grayling (Mills 1988; Table 1). In 1988, angling pressure increased and Arctic grayling harvest almost doubled (Mills 1989).

Since 1953, numerous studies have been conducted to assess the population structure of Arctic grayling in the Tangle System (Wojcik 1953a, 1953b, 1953c, 1953d, 1953e, 1953f, 1953g; Warner 1955a, 1955b, 1956, 1957, 1958, 1959; Heckart 1965; Roguski 1967; Roguski and Winslow 1969; Roguski and Tack 1970; Schallock 1966; Peckham 1974, 1977; Holmes et al. 1986; Clark and Ridder 1987, 1988; and Baker 1988). The majority of these studies have presented limited data, quantitative or qualitative, on harvest rates, movements, location specific population estimates, and age and size compositions. As presented, these data are not comparable from year to year. However, some basic conclusions about Arctic grayling population(s) in the Tangle System can be made from these and other studies.

As with riverine populations in interior Alaska (Tack 1980), Arctic grayling are highly mobile and migrate throughout the Tangle System between spawning, summer feeding, and overwintering locations (Wojcik 1953d; Warner 1955; Schallock 1966). In spring, Arctic grayling concentrate at or near currently unidentified spawning locations. These locations are thought to be the streams of the Tangle System. After spawning (during summer), fish move to known feeding locations in the rivers, creeks, and thoroughfares between the lakes. In the fall before ice-up, the fish move back to main lakes where they overwinter. Based on the strong homing to feeding and, most likely, spawning locations found in studies of riverine populations (Tack 1980; Ridder 1983), separate populations, or stocks, of Arctic grayling may exist in the Tangle

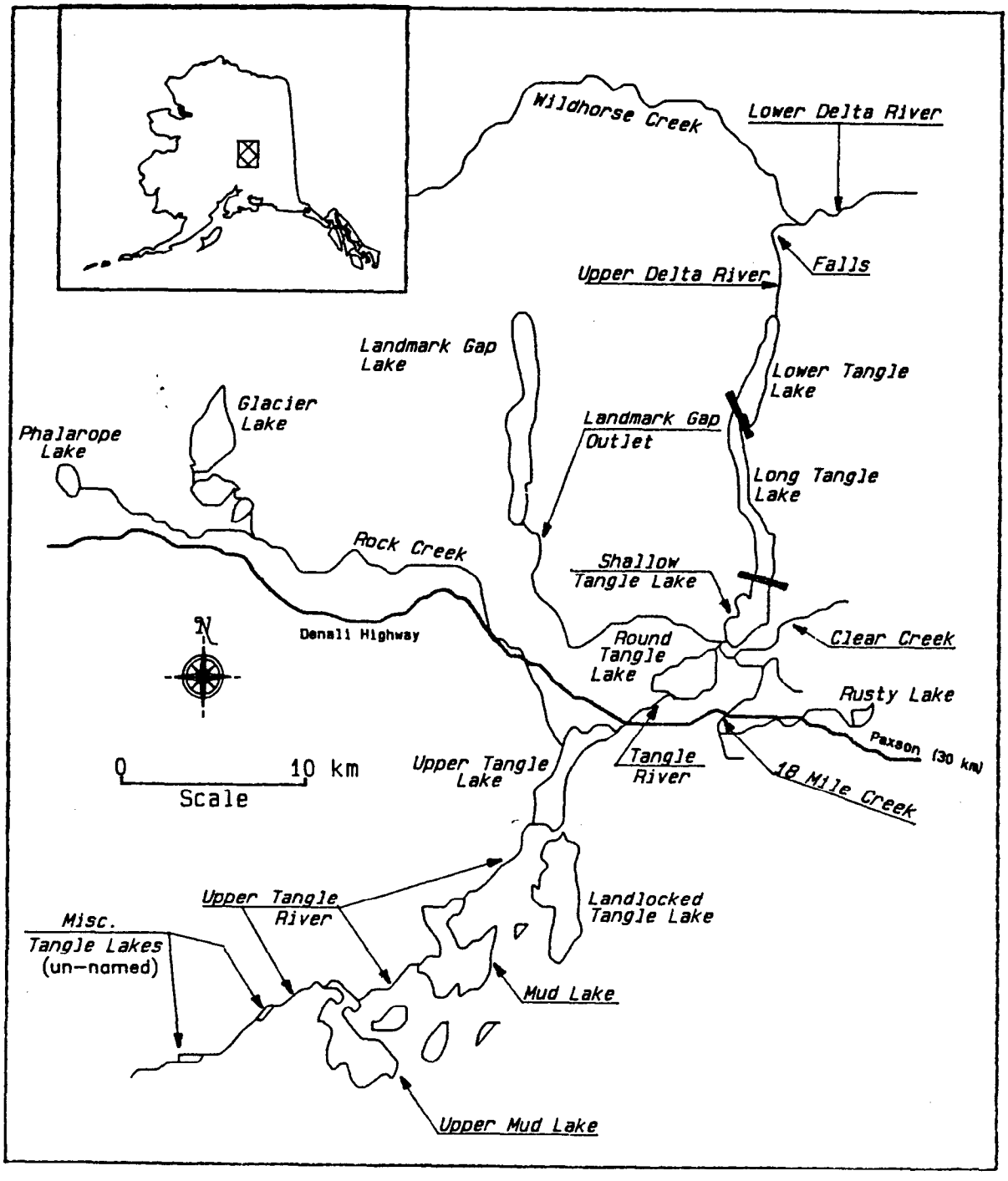

Figure 1. Map of the Tangle Lakes and River system.

Table 1. Estimated recreational harvest of Arctic grayling and total angling effort on the Tangle Lakes system, 1978 through 1988[a].

Year	Man-days[b]	Harvest	CPUE[c]
1978	7,711	5,786	0.75
1979	5,864	3,466	0.59
1980	8,198	5,522	0.67
1981	5,530	6,858	1.24
1982	9,502	9,590	1.01
1983	5,513	7,794	1.41
1984	3,954	4,829	1.22
1985	6,225	5,827	0.93
1986	5,545	5,038	0.91
1987	2,530	2,467	0.98
1988	3,456	4,675	1.35
Averages	5,818	5,623	0.97

[a] Data sources: Mills (1979 - 1989).
[b] Effort estimates includes effort expended for all species.
[c] CPUE = the number of Arctic grayling harvested per man-day.

System. The extent of mixing of spawning stocks in summer feeding locations is unknown. Differential harvest rates among feeding locations within the Tangle System could result in overexploitation of some or all of these spawning stocks.

Because no comprehensive research on stock structure had been conducted to date, a research project was initiated in 1988 to assess the stock status of Arctic grayling in the Tangle System. This report summarizes results from the second year of study (1989). The specific objectives of this research project were to estimate, within 10% of the true value 95% of the time:

1) the mixing rates of Arctic grayling among their major spawning, summer-rearing, and overwintering areas in the Tangle System;

2) the percent age composition for each age class of mature fish in the Arctic grayling population(s) in the Tangle System;

3) the percent Relative Stock Density (RSD; Gabelhouse 1984) for each of the five length categories of mature fish in the Arctic grayling population(s) in the Tangle System;

4) the mean fork length of each age class of mature fish in the Arctic grayling population(s) in the Tangle System; and,

5) the rates of return of Arctic grayling tagged with pulsed-DC electrofishing gear versus the control gears (angling and seine) in the lower Delta River.

STUDY SITE

The Tangle System is an interconnected lake-stream system located approximately 37 km west of Paxson on the Denali Highway (Figure 1). The highway bisects the system at the Tangle River between Round and Upper Tangle lakes. There are two Bureau of Land Management (BLM) campgrounds located next to the highway at the two lakes. The Tangle System is approximately 900 m in elevation and within its drainage are 12 major lakes and over 100 km of rivers and streams. The lakes range in size from 12 ha (Rusty Lake) to 304 ha (Landmark Gap Lake) and cumulatively cover a surface area of over 1,500 ha. The open-water season in the Tangle System is about four months (middle of June to the middle of October). However, some open water persists all year at the inlets and outlets of rivers and streams and the thoroughfares between lakes.

The Tangle System is composed of seven main lakes (proceeding upstream; Lower Tangle, Long Tangle, Shallow Tangle, Round Tangle, and Upper Tangle, Mud, and Upper Mud lakes) that are interconnected by the Tangle River[1]. The maximum

[1] This report refers to the Tangle River as that section connecting Upper and Round Tangle lakes. The river above Upper Tangle Lake is the Upper Tangle River. The shorter interconnecting streams below Round Tangle Lake are referred to as thoroughfares and are named by the lake at their head.

depth of the lakes is 35 m in Round Tangle Lake. The Delta River drains Lower Tangle Lake into the Tanana River. Approximately 3 km downstream of the Delta River headwaters are a series of falls that prevent upstream fish movement (Peckham 1974)[2]. At the headwaters of the Tangle System above Upper Tangle and Mud lakes, there are a series of unnamed lakes that form the headwaters of the Tangle River. Phalarope and Glacier lakes flow into Upper Tangle Lake through Rock Creek. Landmark Gap Lake flows into a thoroughfare between Round and Shallow Tangle lakes.

A portion of the Tangle System comprises a popular float trip that extends 41 km from Round Tangle Lake downstream to the Richardson Highway at Phelan Creek. It includes 28 km of the Delta River (Figure 1). The Alaska National Lands Conservation Act of 2 December 1980 established the Tangle System as The Delta National Wild and Scenic River corridor, a component of the National Wild and Scenic River System. The "scenic" portion lies above the Delta River. The "wild" portion extends from the Delta River headwaters 18.4 km to Eureka Creek, a glacial fed tributary.

METHODS

Data Collection

Sampling events were temporally stratified to target spawning, feeding, and overwintering aggregations of mature Arctic grayling. To minimize sampling during assumed inter-area movement, major sampling effort occurred during 15 May through 10 June, 2 through 23 July, and 30 August through 29 September. Although major feeding locations had been identified from past studies, locations of spawning and overwintering Arctic grayling were not. Surveys and sampling of likely spawning areas were limited due to logistical problems and poor travel conditions (weak, rotting ice, and long travel distances). Sampling of overwintering locations was constrained by lack of manpower, logistical problems, and poor gear efficiency.

Arctic grayling were captured with an electrofishing boat, seines, fyke traps, gill nets, and hook and line. The electrofishing boat was equipped with a pulsed DC variable voltage pulsator (Coffelt Model VVP-15) powered by a 3.5 KW gas generator. Anodes were four 10 mm diameter steel cables 1.5 m long arranged perpendicular to the long axis of the boat and 2.1 m forward of the bow. The unpainted bottom of the boat was the cathode. Voltages ranged from 230 to 280 volts and current ranged from 1 to 3 amperes. Duty cycle and pulse width were held constant at 40% and 80 Hz, respectively. Conductivity at Upper Tangle Lake was 230 μS (standardized to 25°C) on 9 June. Seines used were: a 6.3 mm mesh bag seine (23 m x 1.8 m) used at Upper Tangle and Tangle River; and, a 25 mm mesh purse seine (60 m x 9 m) used in Upper Tangle Lake off the mouth of Rock Creek. Gill nets were constructed from 25 mm mesh (37 m x 1.8 m) and were used at Glacier Lake. Fyke traps were constructed from 25 mm mesh and of the New Hampshire style. Optimal gear type was determined by sampling conditions and gear efficiency. During the majority of

[2] In this report, the river above the falls is called the Upper Delta River and below the falls, the Lower Delta River.

sampling, hook and line was used, with artificial flies as the primary terminal gear.

All captured Arctic grayling were measured to the nearest 1 mm in fork length (FL). Arctic grayling greater than 199 mm FL were tagged with an individually-numbered Floy internal anchor tag and given a partial clip of the left ventral fin for determination of tag loss[3]. Sex was recorded for only those adult fish sampled during the spring sampling event. Date, location, fork length, sex, finclip, tag number, gear type, and mark status were recorded for individual fish on either coin envelopes or mark-sense (optical scanning) forms. Data recorded on coin envelopes were later transcribed onto mark-sense forms. Location codes utilized were the same as those used by Baker (1989) in 1988.

For aging of sampled Arctic grayling, a minimum of two scales from all initial captures was removed from an area four to six scale rows above the lateral line just posterior to the insertion of the dorsal fin. Scales were placed in a coin envelope marked with either the above data, or the litho-code and fish number of the mark-sense form. Scales were processed by cleaning in a hot solution of common dish detergent. Scales were inspected for regeneration, and two scales from each fish were 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 97°C. Ages were determined by replicate readings of the impressions with the aid of a microfiche reader for magnification.

Sex and Maturity

Since spring sampling bracketed the assumed spawning period of Arctic grayling, sex and maturity were readily determined by either sexual dimorphism or the presence of milt or eggs. Dimorphism is evident from 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 abdomen 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 green or recently spawned, they would not have given milt. Sex ratios were presented as the ratio of the number of males to females when initially captured. The percentage of mature grayling by sex was recorded by length class and by age group. Since more than one length or age category had mature fish, probit analysis (Finney 1971) was used to estimate the length (LM_x) or age (AM_x) at which various percentages ($1\% \leq x \leq 99\%$) of the fish were mature. For estimation of age and size compositions and mixing rates, fish were considered mature at the estimated LM_{50} and AM_{50}.

[3] Arctic grayling sampled in the lower Delta River were not tagged or finclipped.

Estimation of Age and Size Composition

Estimates of age composition of Arctic grayling populations can be biased by gear selectivity, sample size, and spatial and temporal stratification of the population. To minimize these biases, three sets of age compositions are presented for the Tangle System. One set consists of all captured Arctic grayling segregated by location, time period, and gear type. The second set consists of all Arctic grayling that were captured only during the spring spawning period and classified as mature by use of external sexual characteristics. The third set consists of fish greater than or equal to LM_{50} stratified by three time periods corresponding to spring, summer, and fall. While the above biases are reduced in the latter two sets by combining samples and selecting for large sized fish, bias towards younger aged fish is introduced to the third set through growth.

The percent age composition for each age class (AC_a) was estimated as:

$$\hat{AC}_a = \frac{n_a}{n_{AC}} * 100 \qquad (1)$$

where: n_a = number of Arctic grayling sampled that are age a; and,

n_{AC} = total number of Arctic grayling sampled for which age is estimated.

The unbiased variance of this percentage $V[\hat{AC}_a]$ was estimated as:

$$\hat{V}[AC_a] = \frac{\hat{AC}_a(100-\hat{AC}_a)}{n_{AC} - 1} \qquad (2)$$

Mean fork length-at-age was estimated for Arctic grayling captured at all sample locations. Since all means are assumed to be distributed normally (according to the Central Limit Theorem), simple means and squared deviations from the mean were used to estimate mean fork length-at-age (FL_a) as:

$$\hat{\overline{FL}}_a = \frac{\sum_{i=1}^{n_{al}} FL_{ai}}{n_{al}} \qquad (3)$$

where: FL_{ai} = fork length (mm) of Arctic grayling i that is sampled and age a; and,

n_{al} = number of Arctic grayling sampled for length that are age a.

The variance of this mean $V[\hat{\overline{FL}}_a]$ was estimated as:

$$\hat{V}[\hat{\overline{FL}}_a] = \frac{\sum_{i=1}^{n_{al}} (FL_{ai} - \hat{\overline{FL}}_a)}{n_{al}(n_{al} - 1)} \quad (4)$$

RSD was estimated for Arctic grayling captured at all locations in the Tangle System. The five RSD length categories (RSD_j) were estimated as:

$$\hat{RSD}_j = \frac{n_j}{n_{RSD}} * 100 \quad (5)$$

where: n_j = number of Arctic grayling sampled that are within RSD length category j; and,

n_{RSD} = total number of Arctic grayling sampled that are greater than 149 mm FL (minimum stock size).

The unbiased variance of this percent $\hat{V}[\hat{RSD}_j]$ was estimated as:

$$\hat{V}[\hat{RSD}_j] = \frac{\hat{RSD}_j(100 - \hat{RSD}_j)}{n_{RSD} - 1} \quad (6)$$

The five RSD categories for Arctic grayling were: (1) "stock" 150 mm to 269 mm FL; (2) "quality" 270 mm to 339 mm FL; (3) "preferred" 340 mm to 449 mm FL; (4) "memorable" 450 mm to 559 mm FL; and (5) "trophy" 560 mm FL and greater.

Estimation of Mixing Rates

The release and recapture of tagged fish allows the tracking of movement. Temporal and spatial mixing rates can be estimated from the tagging information. A mixing rate is the probability that a fish tagged and released in Location A during Time B is recovered in Location C during Time D. Mixing rates can be treated as a Markov chain, such that the cell in the transition matrix is an element of a multinomial proportion:

Release Location:	Recapture Location: A	B	C
A	0.5	0.2	0.3
B	0.1	0.7	0.2
C	0.3	0.3	0.4

Information from Thompson (1987) was used to estimate how many tags must be recovered to meet the objective criteria. The number of recoveries would determine the accuracy and precision of the estimates. The number of tag

recoveries depended on the amount of sampling effort, the abundance of Arctic grayling, the effectiveness of sampling techniques, and the number of locations within the Tangle System. Based upon Thompson (1987), approximately 400 tag recoveries were needed to meet the objective criteria.

Estimation of Return Rates

Recoveries in 1989 of Arctic grayling tagged and released in the lower Delta River in 1988 were used to estimate relative return rates by gear type. These estimates of "survival" were used to test the hypothesis that: Survival of Arctic grayling is not affected by the type of sampling gear. The gears used to mark Arctic grayling in 1988 were pulsed-DC electrofishing, hook and line, and seine. Concomitant with marking of Arctic grayling in 1988, short term mortality and injury were also estimated. These results, along with return rates of Arctic grayling from the lower Delta River in 1989 will be presented in a subsequent report on injury and mortality caused by electrofishing systems.

RESULTS AND DISCUSSION

A total of 3,085 Arctic grayling was sampled from 17 locations within the Tangle System (excluding the lower Delta River) in 1989 (Table 2). The catch includes 167 fish sampled from angler creels on 2 and 3 July. Within the sample were 151 recaptures of fish marked since 1986. These included 134 tagged fish and 17 fin-clipped fish (tag losses). Tag loss estimates were not possible since the same fin-clip was used in both 1987 and 1988. A total of 2,133 fish were newly tagged and fin-clipped and included fish that had previously lost their tag.

Due to the distribution of larger Arctic grayling in areas unsuitable for other gear types, the majority of the sample was captured by hook and line (n = 2,241 fish). Seines were used to capture 571 fish, predominantly small fish from the Tangle River in late August (Table 2). A gill net was used in Glacier Lake to capture 122 Arctic grayling. An electrofishing boat captured 132 fish with 8.2 hours of effort. Electrofishing the shorelines of Upper, Round, and Shallow Tangle lakes was unproductive. However, some success was found at the southern third of Upper Tangle Lake. Eighty (80) Arctic grayling, predominantly smaller than 250 mm FL, were caught in 5.4 hours of electrofishing effort. The remaining electrofishing effort and success was expended in the three short thoroughfares below Round Tangle Lake. Fish captured in the thoroughfares were generally larger than 250 mm FL. A fyke trap set to capture upstream migrants in 18 Mile Creek upstream of the Denali Highway was fished for 10 days from 23 May through 10 June and caught 19 Arctic grayling.

Spring Sampling Summary

Sampling trips taken during spring (23 May through 10 June) resulted in a sample of 911 Arctic grayling. Concentrations of gravid, ripe, and spent fish were found in three locations: the heads of Long Tangle and Mud lakes, and in 18 Mile Creek approximately 0.8 km downstream of the Denali Highway crossing.

Table 2. Summary of Arctic grayling caught, marked, and recaptured in the Tangle Lakes system, 23 May through 29 September 1989.

Location	Location Code	Date	Catch			Number of Marks						
							Recaptures					
			Total	>199 mm	Killed	New	1986	1987	1988	1989[a]	Tag Loss	Total
Lower Delta River	060	8/22-8/25	1,496	1,490	6	0	0	0	105	0	2	107
Upper Delta River	075	7/19,7/20	394	344	0	322	0	0	18	4	2	24
Mid-Long Tangle Lake	225	6/7	6	6	0	6	0	0	0	0	0	0
Thoroughfare	"	7/12,7/18	294	208	1	193	1	0	11	1	1	14
Long Tangle Lake Head	251	5/25-6/1	264	264	3	240	0	0	2	1	1	4
Shallow Tangle Lake Thoroughfare	275	9/27	26	26	0	23	0	0	0	4	1	5
Round Tangle Lake	350	6/7	1	1	0	1	0	0	0	0	0	0
Thoroughfare	"	8/30	27	23	1	21	0	0	1	0	0	1
"	"	9/27	7	7	0	6	0	0	0	1	0	1
Landmark Gap Creek	360	7/10-7/21	335	286	3	270	0	0	13	0	2	15
"	"	8/30	26	7	0	6	0	0	1	0	0	1
Clear Creek	381	5/31	6	6	0	6	0	0	0	0	0	0
18 Mile Creek	390	5/24-6/8	257	256	4	238	1	1	8	0	3	13
"	"	7/8	15	14	0	11	0	1	1	1	0	3
Round Tangle Lake	490	6/7	2	2	0	2	0	0	0	0	0	0
"	"	9/27	10	8	1	7	0	0	0	0	0	0
Tangle River	501	6/16	4	4	0	4	0	0	0	0	0	0
"	"	8/30-8/31	307	127	3	115	0	3	8	0	0	11
Upper Tangle Lake	695	6/6-6/10	205	151	0	140	0	3	6	0	0	9
"	605	8/31	9	9	0	8	0	0	1	0	0	1
"	690	9/27	19	18	1	17	0	0	0	0	0	0
"	605	9/28,9/29	91	91	1	82	0	0	8	1	3	12
Rock Creek	610	7/5-7/7	226	188	4	171	0	2	7	4	1	14
"	"	8/29	26	3	0	3	0	0	0	0	0	0

- Continued -

Table 2. (page 2 of 2)

Location	Location Code	Date	Catch			Number of Marks						
							Recaptures					
			Total	>199 mm	Killed	New	1986	1987	1988	1989[a]	Tag Loss	Total
Glacier Lake	488	7/10-7/16	122	122	18	95	0	0	3	0	1	4
Glacier Lake Outlet	488-09	9/1	15	11	0	11	0	0	0	0	0	0
Upper Tangle River	710	6/9	131	96	1	93	0	0	2	0	1	3
"	"	6/16	48	6	0	4	0	0	0	0	0	0
"	"	8/31	3	0	0	0	0	0	0	0	0	0
Mud Lake Head	901	5/31	39	39	0	38	0	1	0	0	1	2
Harvest Sample (misc)	---	7/2-7/3	167	167	167	0	1	1	6	6	0	14
Totals:	075-901	5/24-6/16	911	821	8	765	1	5	18	1	6	31
		6/16-7/21	1,608	1,339	193	1,070	2	4	59	16	7	88
		8/29-9/29	566	330	7	298	0	3	19	6	4	32
			3,085	2,490	208	2,133	3	12	96	23	17	151
	060	8/22-8/25	1,496	1,490	6	0	0	0	105	0	2	107
			4,581	3,980	214	2,133	3	12	201	23	19	258

[a] Thirty-one recaptures made within six days of tagging and in the same location are not included.

These spawning concentrations generally lacked fish less than 280 mm FL. In addition, recently spawned-out fish and immature fish were captured at the mouth of Upper Tangle River and Upper Tangle Lake (Figure 2). Adult fish sampled at the Upper Tangle River and Lake had likely spawned in upstream locations (Mud Lake or further upstream) and were moving to feeding areas. Some evidence for this movement came from the recapture of an adult fish tagged four days earlier in Mud Lake (upstream of the Upper Tangle River). Further evidence of movement was inferred from the rapid change in size composition during a five day period (Figure 3).

In contrast to sampling in these spawning locations, no fish were captured during sampling surveys of upper and lower Landmark Gap Creek (31 May and 8 June), the lower 11 km of Rock Creek (23 May, 3 June, and 9 June), Rusty Creek (28 May), 18 Mile Creek (upstream of Denali Highway, 1 June), Clear Creek (above 18 Mile Creek, 8 June), Glacier Lake outlet (3 June and 8 June), the thoroughfare at mid Long Tangle Lake (25 May), and a small creek draining from the east into the thoroughfare below Shallow Tangle Lake (7 June). In addition, juvenile fish were seen only in two of these locations. Several small (< 200 mm FL) Arctic grayling were observed in lower Landmark Gap Creek on 23 May and in the tributary to Shallow Tangle thoroughfare (7 June). During all surveys, temperatures ranged from 3.0 to 5.5°C, within the preferred temperature range of Arctic grayling spawning (Tack 1980).

Summer Sampling Summary

Sampling was performed in the summer from 16 June through 21 July and 1,608 Arctic grayling were captured. All except 48 of these fish were sampled during 2 through 21 July. The majority of the sample (n = 1,289, Table 2) came from five locations: Rock and Landmark Gap creeks, the thoroughfare in mid Long Tangle Lake, the Upper Delta River, and Glacier Lake. Rock Creek was sampled in two reaches: 1.6 km above and below the mouth of Glacier Lake outlet (upper reach), and an 8.3 km reach from the river mouth upstream to a point approximately 3.2 km above the Denali Highway crossing (lower reach). The upper reach contained few Arctic grayling. Landmark Gap Creek was also sampled in two reaches: a 3.2 km reach downstream from the headwaters and a reach extending 2 km upstream from the river mouth. The Long Tangle Lake thoroughfare and Upper Delta River were sampled in their entirety.

These feeding location samples contained a wider range of lengths than found at spawning locations. Of the five samples, the Upper Delta River and Glacier Lake samples contained the highest proportion of large Arctic grayling (Figure 4). However, differences in gear type (gill net in Glacier Lake and hook and line in the other locations) may have influenced these observations.

Fall Sampling Summary

Sampling occurred during the fall from 29 August through 1 September, and from 27 through 29 September. A total of 566 Arctic grayling was captured during these trips. Three locations produced 84% of the sample: Tangle River (seine, n = 306), the three thoroughfares below Round Tangle Lake (electrofishing, n = 62), and Upper Tangle Lake (at the mouth of Rock Creek by purse seine, n = 61; hook and line gear, n = 28; and, electrofishing the south

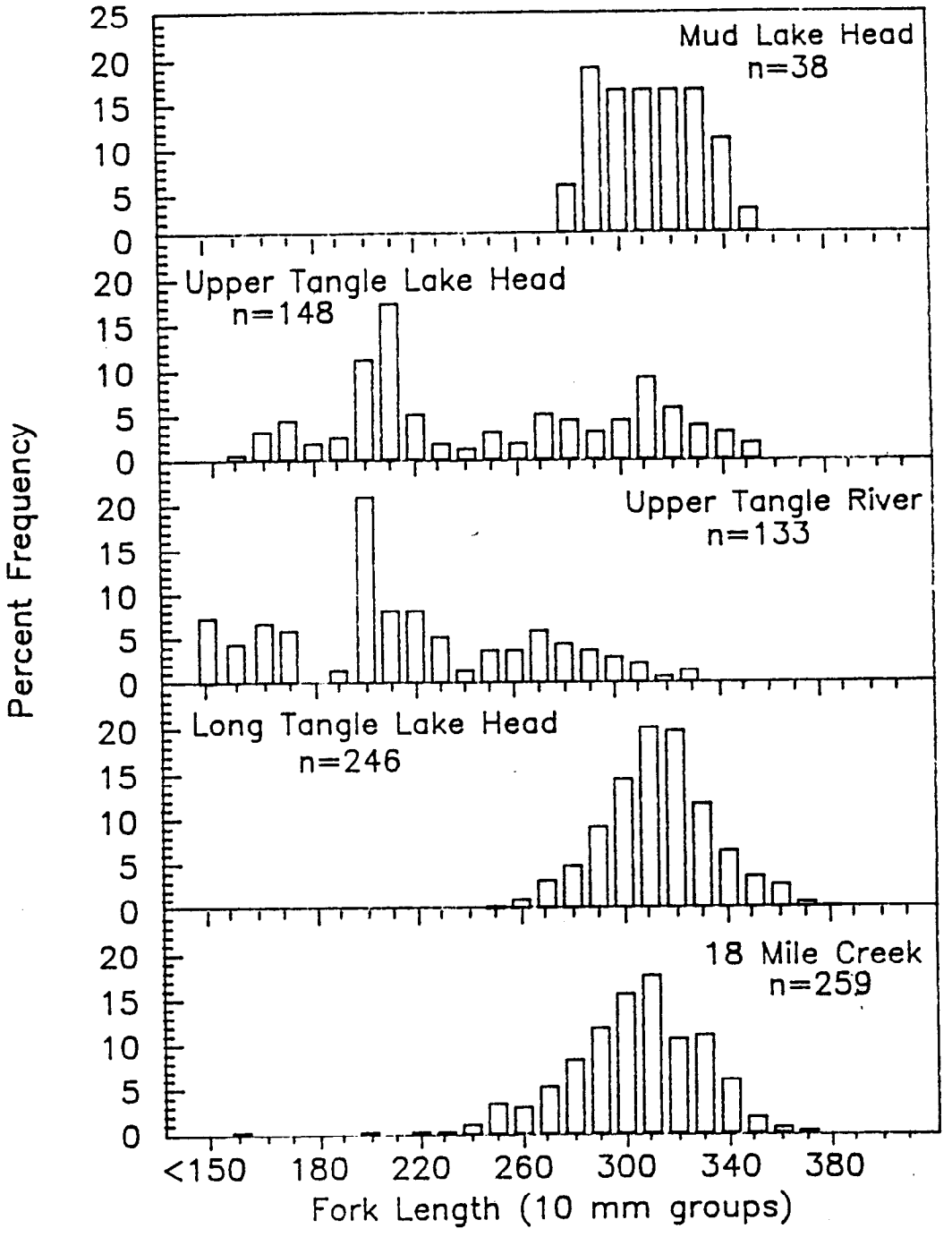

Figure 2. Comparison of length frequencies of Arctic grayling sampled from five locations in the Tangle Lakes system, 23 May through 10 June 1989.

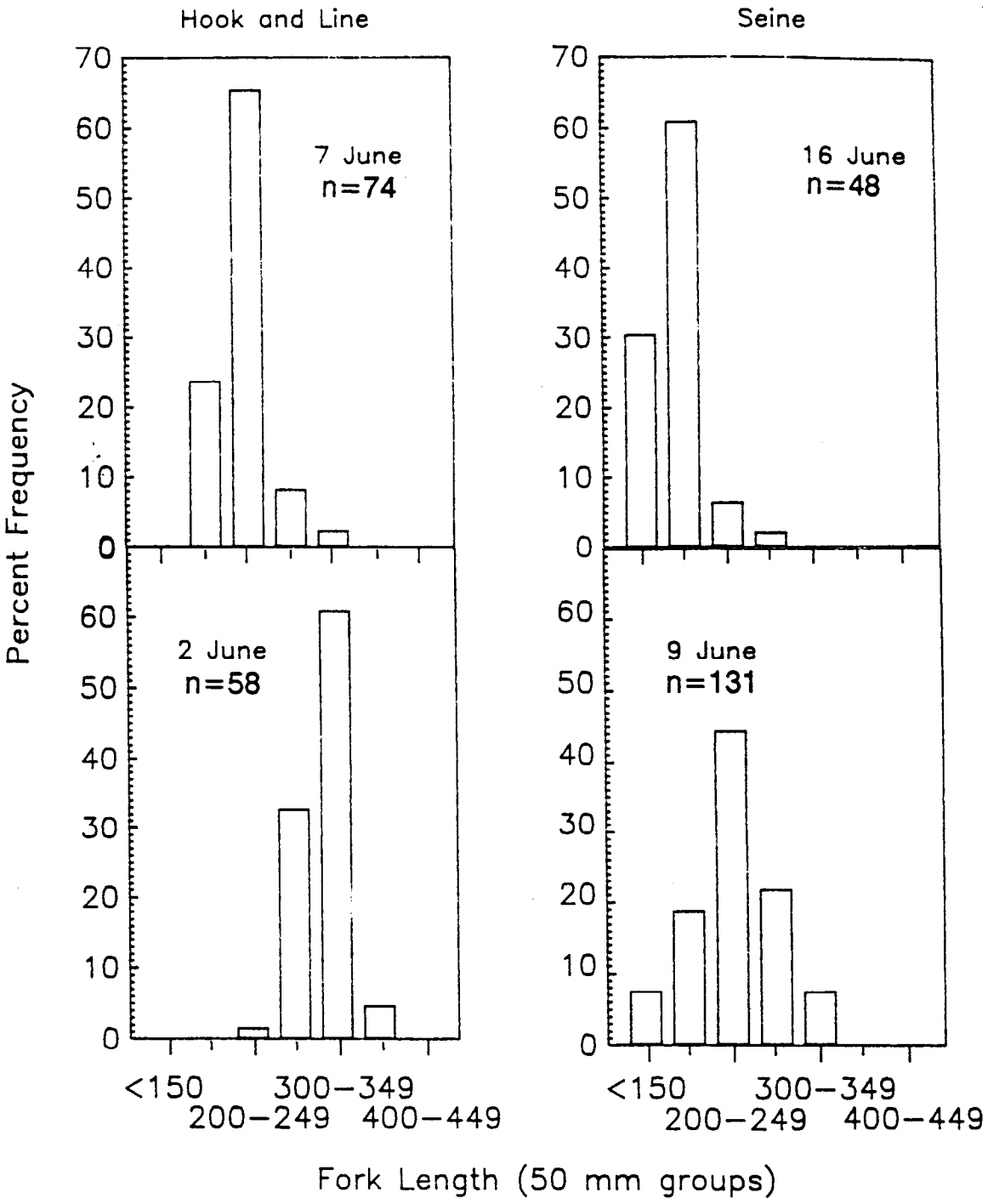

Figure 3. Comparison of length frequencies of Arctic grayling sampled by two gear types at the mouth of Upper Tangle River, 2 through 16 June 1989.

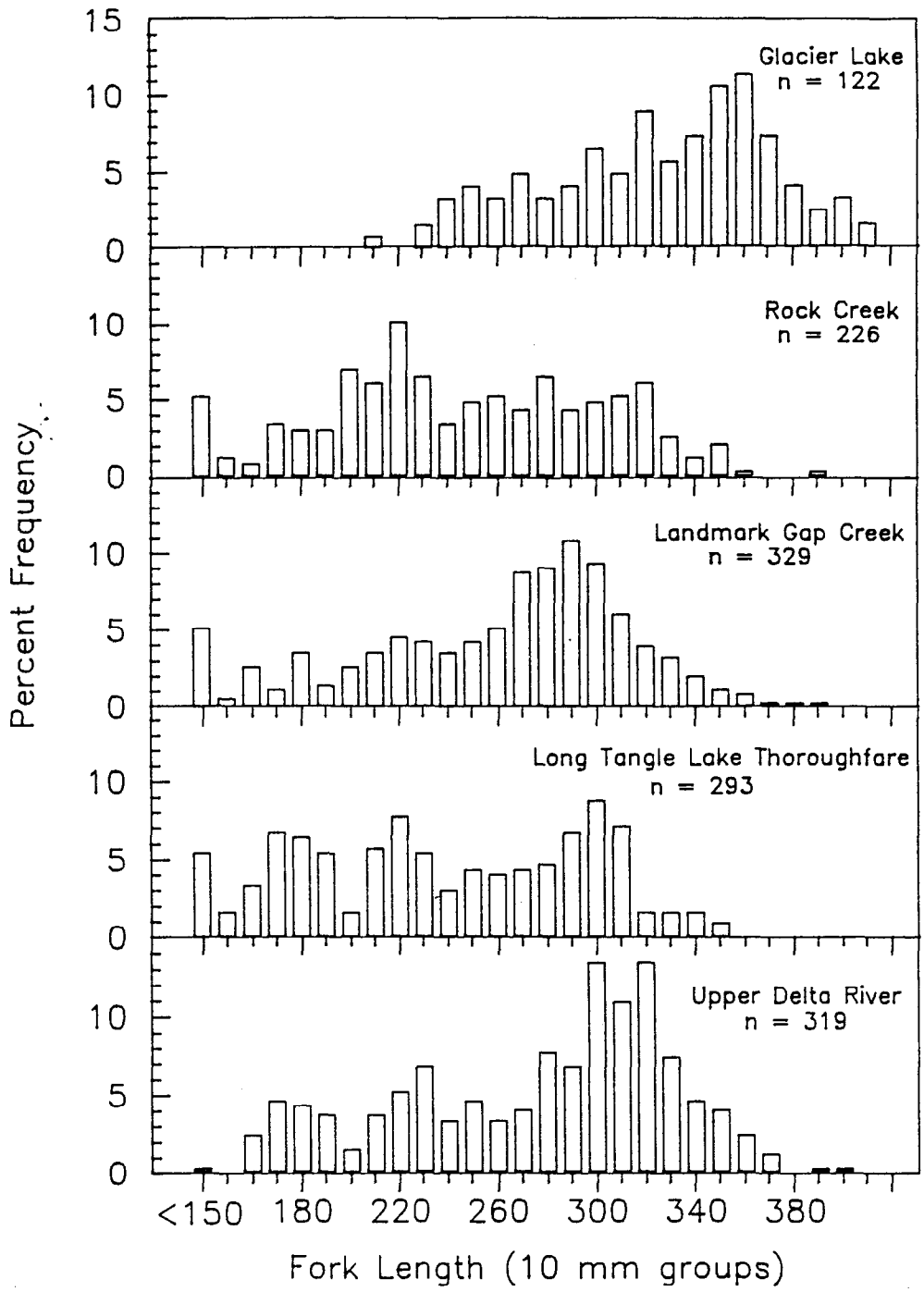

Figure 4. Comparison of length frequencies of Arctic grayling sampled from five locations in the Tangle Lakes system, July 1989

quarter of the lake, n = 19). Size composition was similar in Upper Tangle Lake and the thoroughfares, weighted towards fish greater than 270 mm FL. In contrast, the Tangle River sample was predominantly composed of fish less than 250 mm FL (Figure 5).

Sex and Maturity

A total of 890 Arctic grayling out of a total sample of 911 were examined for sex and maturity during 23 May through 10 June at four locations. A total of 516 of these fish were considered mature fish. Mature fish were first detected at lengths of 270 to 279 mm FL, and at an age of 4 years (Tables 3 and 4). All fish were classified mature above a length of 330 mm and age 8. Compared to similar data from three, lower elevation populations in the Tanana River drainage, the Tangle System fish begin maturing at a larger size and then mature quickly (Figure 6). Their maturation at age was between that of two Tanana River drainage populations (Figure 7).

The length at which 50% of the Tangle System Arctic grayling are mature (LM_{50}) was estimated to be 289 mm FL with a 95% confidence interval of 287 to 291 mm FL (Table 5). The estimated LM_{99} was 320 mm FL with a confidence interval of 316 to 326 mm FL. The AM_{50} (age at maturity) estimate was 5.2 years with a 95% confidence interval of 5.1 to 5.3 years (Table 5). The AM_{99} estimate was 6.9 years with a confidence interval of 6.6 to 7.1 years. Estimates of maturity by sex were not attempted due to the necessity of sacrificing all immature fish for examination of gonads.

The male to female sex ratio for the adult sample was 1.07:1 but ranged in the three larger samples from 0.80:1 at 18 Mile Creek, 1.32:1 at Long Tangle Lake head, to 1.64:1 at Upper Tangle Lake head.

The length frequency of males was significantly different from that of females ($\chi^2 = 37.25$, df = 8, $p < 0.05$; Figure 8) and was skewed towards larger fish. This size difference between sexes has also been found at Mineral Lake Outlet and the Goodpaster River (Ridder 1989a, 1989b).

Age Composition

The following estimates of age composition are all biased to some degree. Most are affected by small sample sizes and all, with the possible exception of the combined seasonal samples of fish of LM_{50} and greater, suffer from gear selectivity. Yet, the largest errors may stem from the inaccuracies in aging from scale patterns, especially those of the older fish.

Age Composition By Location:

From samples taken during spring (Table 6), age 6 Arctic grayling predominated in the spawning aggregations at 18 Mile Creek and Long Tangle Lake head (43% and 45%, respectively). Age 7 fish were the next most numerous (28 and 36%, respectively). Age 3 fish predominated in both the hook and line (43%) and seine (39%) samples from the area adjacent to the mouth of the Upper Tangle River. Most likely due to gear selectivity, timing, and habitat differences in the Upper Tangle River area, age 6 fish were the next most numerous in the

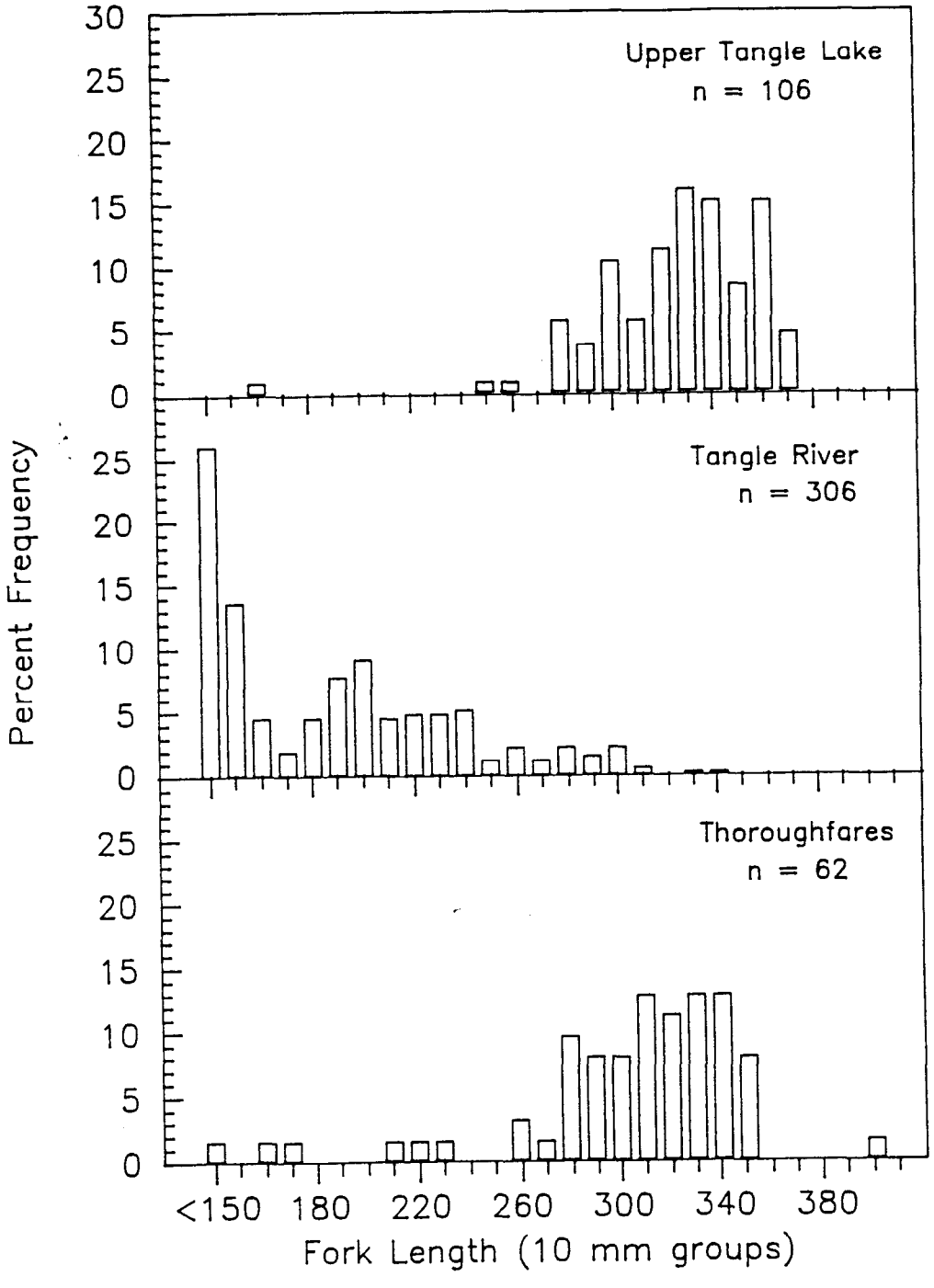

Figure 5. Comparison of length frequencies of Arctic grayling sampled from three locations in the Tangle Lakes system, 29 August through 29 September 1989.

Table 3. Percent mature[a] Arctic grayling in 10 mm FL groups sampled from five locations[b] in the Tangle Lakes system, 23 May through 10 June 1989.

10 mm Group	N[c]	Mature		
		n[d]	%[e]	SE[f]
<200	90	0	---	---
200 - 209	55	0	---	---
210 - 219	43	0	---	---
220 - 229	22	0	---	---
230 - 239	11	0	---	---
240 - 249	8	0	---	---
250 - 259	20	0	---	---
260 - 269	21	0	---	---
270 - 279	39	4	10.3	4.9
289 - 289	50	19	38.0	6.9
290 - 299	70	49	70.0	5.5
300 - 309	96	83	86.5	3.5
310 - 319	122	119	97.5	1.4
320 - 329	99	98	99.0	1.0
330 - 339	72	72	100.0	---
340 - 349	42	42	100.0	---
350 - 359	18	18	100.0	---
360 - 369	8	8	100.0	---
370 - 379	3	3	100.0	---
380 - 389	1	1	100.0	---
Totals	890	516	58.0	1.7

[a] Maturity determined by sexual dimorphism or sexual products.
[b] 18 Mile and Clear creeks, Heads of Mud, Upper Tangle, and Long Tangle lakes.
[c] N = total catch in group.
[d] n = number mature in group.
[e] % = percent mature in group.
[f] SE = sample standard error for the percentage.

Table 4. Percent mature[a] Arctic grayling in age classes sampled from five locations[b] in the Tangle Lakes system, 23 May through 10 June 1989.

Age Class	N[c]	Mature		
		n[d]	%[e]	SE[f]
1	6	0	---	---
2	65	0	---	---
3	136	0	---	---
4	40	2	5.0	3.4
5	108	31	28.7	4.4
6	274	243	88.7	1.9
7	182	181	99.5	0.5
8	28	28	100.0	---
9	7	7	100.0	---
Total	846	492	58.2	1.7

[a] Maturity determined by sexual dimorphism or sexual products.
[b] 18 Mile and Clear creeks, Heads of Mud, Upper Tangle, and Long Tangle lakes.
[c] N = total catch in age class.
[d] n = number mature in age class.
[e] % = percent mature in age class.
[f] SE = sample standard error for the percentage.

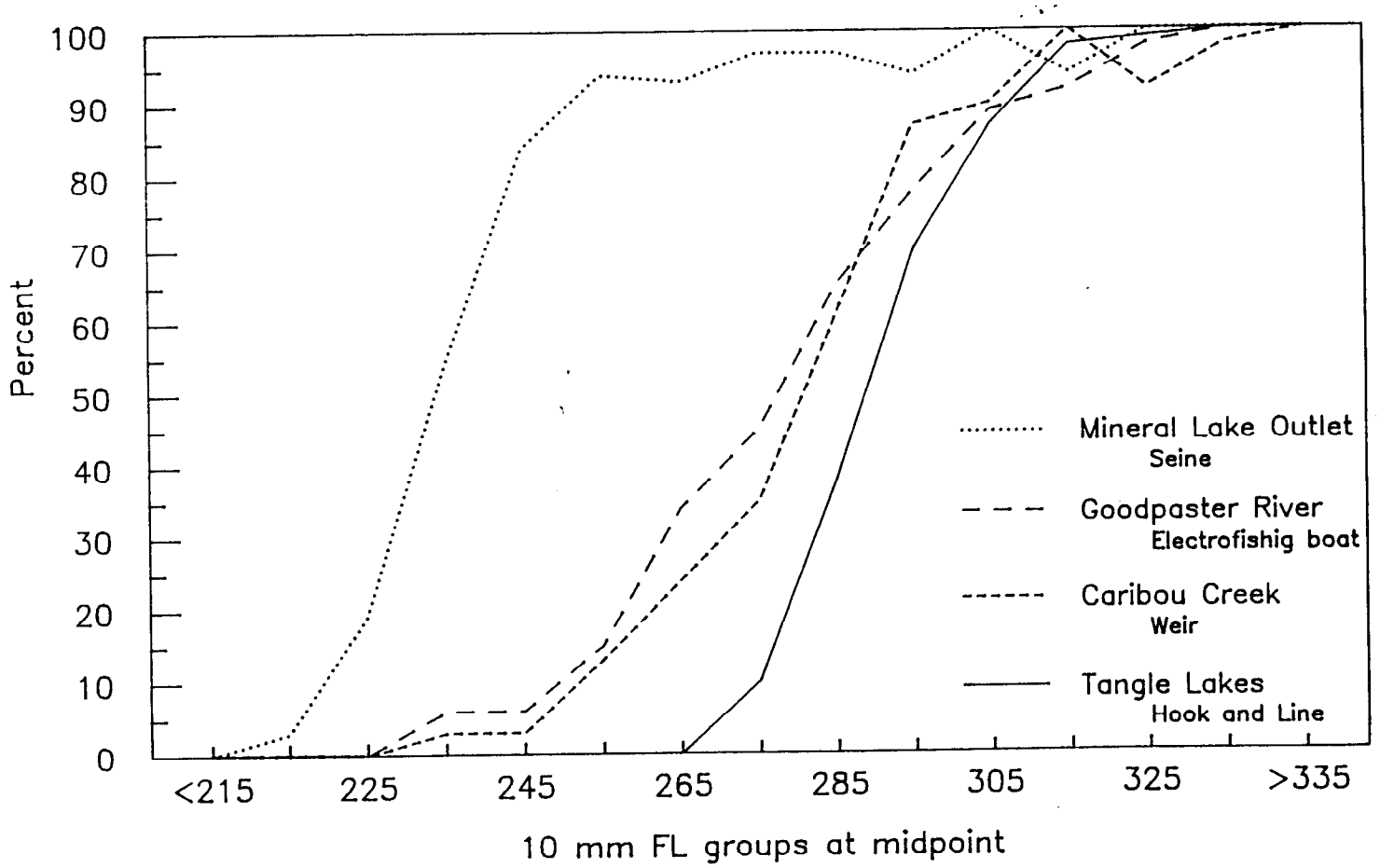

Figure 6. Comparison of the percentage of mature Arctic grayling in 10 mm FL groups sampled from four tributaries of the Tanana River drainage.

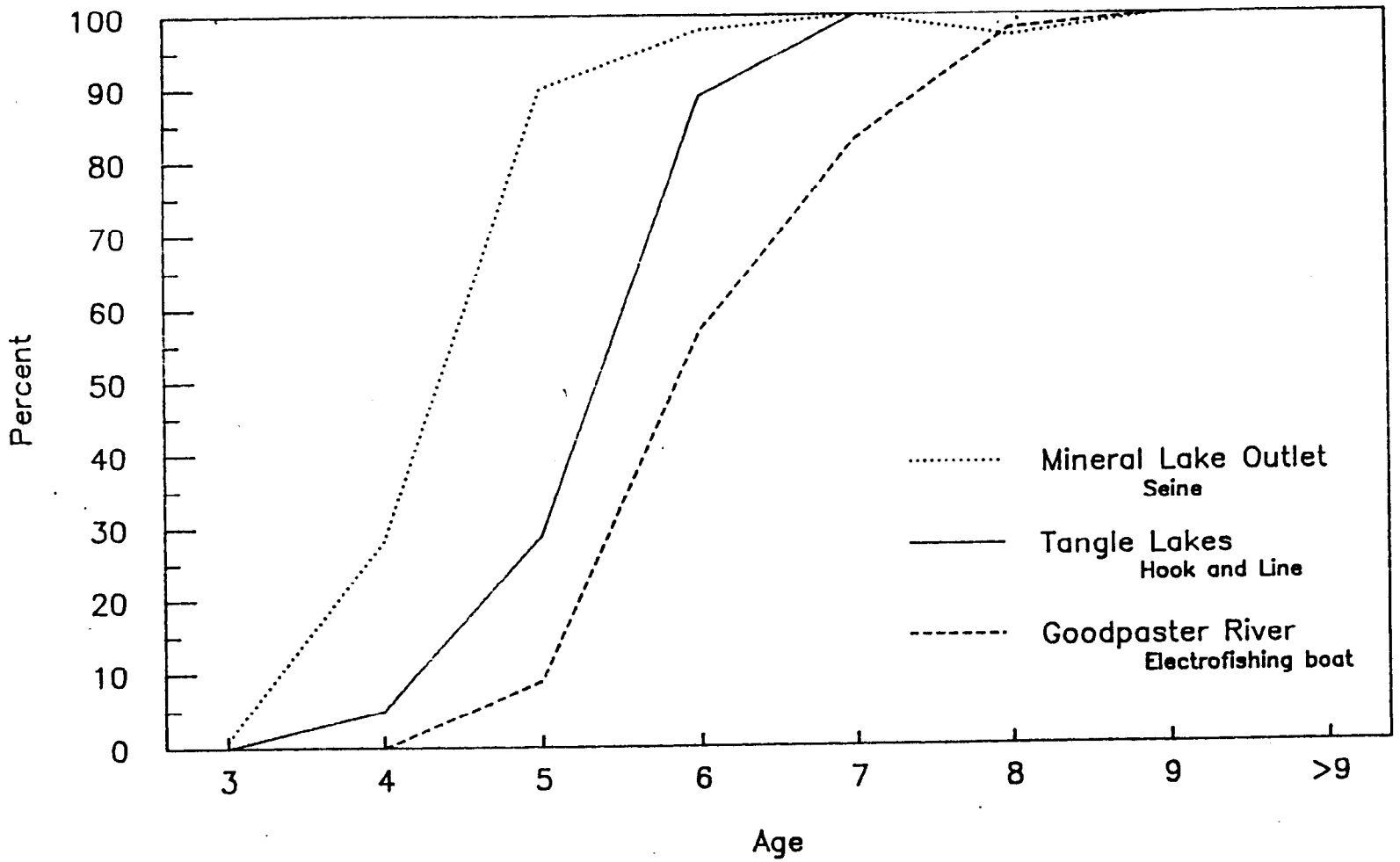

Figure 7. Comparison of the percentage of mature Arctic grayling in age classes sampled from three tributaries of the Tanana River drainage.

Table 5. Estimated lengths and ages at which various percentages (x) of Arctic grayling are mature (LM_x and AM_x)[a], Tangle Lakes system, 23 May through 10 June 1989.

Percent of Population	Length at Maturity (LM_x)		Age at Maturity (AM_x)	
	Length	95% CI[b]	Age	95% CI
1	261	255 - 266	4.0	3.8 - 4.2
5	269	264 - 273	4.3	4.1 - 4.5
25	281	277 - 283	4.9	4.7 - 5.0
50	289	287 - 291	5.2	5.1 - 5.3
90	306	303 - 309	6.1	6.0 - 6.2
95	311	308 - 315	6.3	6.2 - 6.5
99	320	316 - 326	6.9	6.7 - 7.1

[a] LM_x (AM_x) = Estimated length (age) at which x% of the population is mature (Finney 1971). Estimates from probit analysis.
[b] 95% fiducial limits.

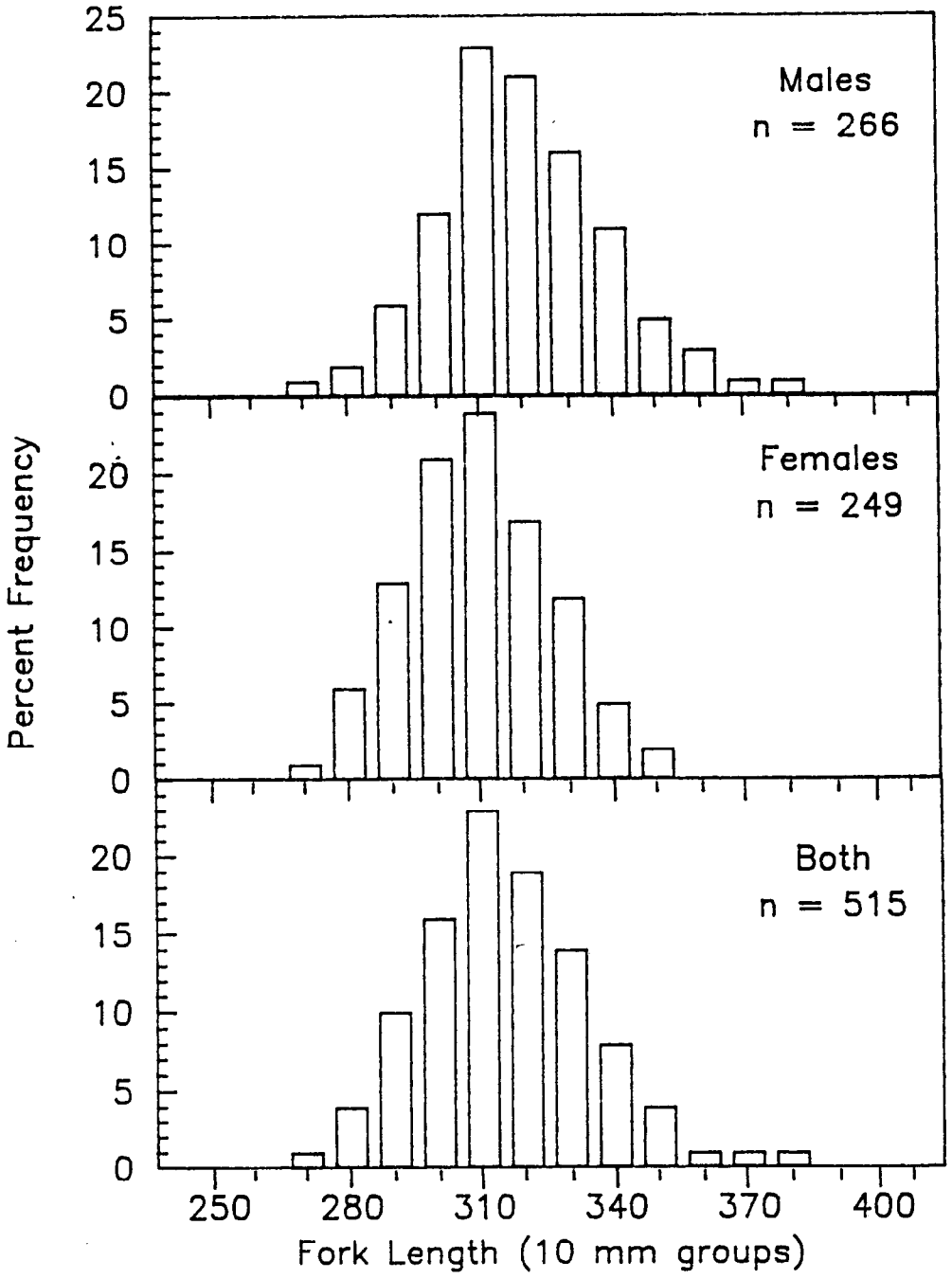

Figure 8. Comparison of length frequencies of male and female adult Arctic grayling sampled in the Tangle Lakes system, 23 May through 10 June 1989.

Table 6. Age composition estimates by gear type and location for Arctic grayling sampled from four locations in the Tangle Lakes system, 23 May through 10 June 1989.

	18 Mile Creek 23 May - 8 June Hook and Line			Long Tangle Lake Head 31 May - 10 June Hook and Line			Upper Tangle Lake Head 2 - 7 June Hook and Line			Upper Tangle River 9 June Seine		
Age Class	n[a]	%	SE[b]	n	%	SE	n	%	SE	n	%	SE
1	0	---	---	0	---	---	0	---	---	2	1.5	1.1
2	1	0.4	0.4	0	---	---	12	8.6	2.4	31	23.5	3.7
3	2	0.8	0.6	0	---	---	60	43.2	4.2	52	39.4	4.3
4	11	4.4	1.3	3	1.3	0.7	9	6.5	2.1	13	9.8	2.6
5	48	19.3	2.5	21	9.1	1.9	12	8.6	2.4	16	12.1	2.8
6	108	43.4	3.1	104	44.8	3.3	25	18.0	3.3	14	10.6	2.7
7	70	28.1	2.8	83	35.8	3.1	17	12.2	2.8	3	2.3	1.3
8	8	3.2	1.1	16	6.9	1.7	3	2.2	1.2	1	0.8	0.8
9	1	0.4	0.4	5	2.2	1.0	1	0.7	0.7	0	---	---
Total	249	100.0		232	100.0		139	100.0		132	100.0	

[a] n = sample size.

[b] SE = standard error of the percentage.

hook and line sample (18%) and age 2 fish in the seine sample (24%). No fish older than age 9 were present in these samples.

From samples taken during summer (Table 7), there was a wide range of ages (age 1 to age 11) in the five locations. The Glacier Lake sample ranged from age 4 to age 11 with 89% older than age 5 (gill net sample). In the four other locations (hook and line samples only), similarities in age composition estimates existed in pairs. Landmark Gap Creek and the Upper Delta River samples contained more older fish than either Rock Creek or the Lower Tangle Lake thoroughfare. In each of the former samples, age 6 predominated with over 60% of the sample at age 5 or older. In each of the latter samples, age 3 fish predominated and less than 40% were age 5 and older.

Age 6 Arctic grayling were the most numerous age class in the July harvest sample (Table 8). Eighty-two percent of the sample was age 5 or older. The sample was taken from six locations: Tangle River, n = 92; Round Tangle Lake, n = 34; Landmark gap Creek, n = 12; Upper Tangle Lake, n = 15; Rock Creek, n = 9, and; 18 Mile Creek, n = 5.

From samples taken during fall, age compositions were estimated for two locations (Table 9). Age 1 Arctic grayling predominated in the Tangle River sample and 94% were age 4 or younger. In the sample collected in Upper Tangle Lake at the mouth of Rock Creek, age 6 and 7 fish comprised 68% of the total. Ninety-eight percent of the Upper Tangle Lake sample was age 5 or older.

Age Composition Of Adults:

The majority (93%) of the adult sample was age 6 or older (Table 10). Age 6 fish were most numerous among the spawning assemblages. There was a sharp decline in relative contribution of ages after age 7 that may be partially explained by the inaccuracies of aging older Arctic grayling with scales. Males contributed slightly more to the oldest age classes than did females. Forty-nine percent of male Arctic grayling were age 7 or older as compared to 39% of female Arctic grayling.

Age Composition Inferred From Length At Maturity (LM_{50}):

Glacier Lake samples were not included in the following age composition estimates due to sampling bias that selected for the largest fish (gill net sample). Unlike other locations, the Glacier Lake sample contained equal proportions of age 4 through age 9 fish (Table 7).

Age 6 fish predominated in all three seasonal samples of Arctic grayling with lengths equal to or greater than LM_{50} (> 288 mm FL; Table 11). Recruitment into the youngest age classes, and possibly small sample size of the fall sample resulted in significant differences in the estimated compositions of the three samples ($\chi^2 = 60.50$, df = 8, $p < 0.05$). Ages 4 and 5 comprised 7%, 17%, and 26% of the spring, summer, and fall samples, respectively.

Because growth recruitment was indicated from changes in the contributions of age 4 and age 5 fish, the spring adult composition differed significantly from the summer, fall, and combined age compositions inferred from LM_{50} (for ages 4

Table 7. Age composition estimates and standard errors for Arctic grayling sampled[a] from five locations in the Tangle Lakes system, July 1989.

	Rock Creek 5 - 6 July			Glacier Lake 6 - 12 July			Landmark Gap Creek 10 - 21 July			Long Tangle Lake Thoroughfare 12 & 18 July			Upper Delta River 19 - 20 July		
Age Class	n[b]	%	SE[c]	n	%	SE	n	%	SE	n	%	SE	n	%	SE
1	7	3.3	1.2	0	---	---	4	1.4	0.7	13	4.7	1.3	1	0.3	0.3
2	32	15.2	2.5	0	---	---	16	5.7	1.4	63	22.7	2.5	50	13.7	1.8
3	51	24.3	3.0	0	---	---	45	16.0	2.2	66	23.8	2.6	59	16.2	1.9
4	47	22.4	2.9	13	11.1	2.9	31	11.0	1.9	23	8.3	1.7	28	7.7	1.4
5	25	11.9	2.2	20	17.1	3.5	72	25.5	2.6	33	11.9	1.9	50	13.7	1.8
6	30	14.3	2.4	22	18.8	3.6	87	30.9	2.8	60	21.7	2.5	98	26.8	2.3
7	14	6.7	1.7	13	11.1	2.9	23	8.2	1.6	17	6.1	1.4	64	17.5	2.0
8	3	1.4	0.8	24	20.5	3.7	2	0.7	0.5	2	0.7	0.5	13	3.6	1.0
9	1	0.5	0.5	19	16.2	3.4	1	0.4	0.4	0	---	---	2	0.5	0.4
10	0	---	---	5	4.3	1.9	1	0.4	0.4	0	---	---	0	---	---
11	0	---	---	1	0.9	0.9	0	---	---	0	---	---	0	---	---
Total	210	100.0		117	100.0		282	100.0		277	100.0		365	100.0	

[a] Gear type was hook and line except for Glacier Lake which was gill net.

[b] n = sample size.

[c] SE = standard error of the percentage.

Table 8. Age composition estimates and mean fork length at age for Arctic grayling sampled from angler creels, Tangle Lakes system, 2 and 3 July 1989.

	Proportion			Length		
Age Class	n[a]	%	SE[b]	Mean	SD[c]	SE
3	16	11.0	2.6	224	13	3
4	24	16.6	3.1	258	13	3
5	32	22.1	3.4	287	14	2
6	50	34.5	3.9	306	14	2
7	21	14.5	2.9	334	11	2
8	2	1.4	1.0	373	10	10
Total	145	100.0		287	37	3

[a] n = sample size.
[b] SE = standard error of the proportion.
[c] SD = sample standard deviation

Table 9. Age composition estimates and standard errors for Arctic grayling sampled[a] from two locations in the Tangle Lakes system, 30 August through 29 September 1989.

	Tangle River 29 - 31 August			Upper Tangle Lake 28 - 29 September		
Age Class	n[b]	%	SE[c]	n	%	SE
0	24	8.2	1.6	---	---	---
1	105	35.8	2.8	---	---	---
2	86	29.4	2.7	---	---	---
3	42	14.3	2.0	---	---	---
4	19	6.5	1.4	2	2.5	1.7
5	12	4.1	1.2	14	17.3	4.2
6	4	1.4	.7	28	34.6	5.3
7	1	0.3	.3	27	33.3	5.2
8	0	---	---	9	11.1	3.5
9	0	---	---	1	1.2	1.2
Total	293	100.0		81	100.0	

[a] Sampling by beach seine at Tangle River; by purse seine (n = 63) and hook and line (n = 28) at Upper Tangle Lake at the mouth of Rock Creek.
[b] n = sample size.
[c] SE = standard error of the percentage.

Table 10. Age composition estimates and standard errors for mature male and female Arctic grayling sampled from five locations[a] in the Tangle Lakes system, 23 May through 10 June 1989.

	Males			Females			Both		
Age Class	n[b]	%	SE[c]	n	%	SE	n	%	SE
4	1	0.4	0.4	1	0.4	0.4	2	0.4	0.3
5	12	4.8	1.3	19	7.9	1.7	31	6.3	1.1
6	115	45.8	3.1	128	53.1	3.2	243	49.4	2.3
7	99	39.4	3.1	82	34.0	3.1	181	36.8	2.2
8	19	7.6	1.7	9	3.7	1.2	28	5.7	1.0
9	5	2.0	0.9	2	0.8	0.6	7	1.4	0.5
Total	251	100.0		241	100.0		492	100.0	

a 18 Mile and Clear creeks, heads of Mud, Upper Tangle, and Long Tangle lakes.

b n = sample size.

c SE = standard error of the percentage.

Table 11. Age composition estimates and standard errors for Arctic grayling greater than 288 mm FL sampled[a] from the Tangle Lakes system, spring, summer, and fall 1989.

	23 May - 10 June			2 July - 21 July			29 August - 29 Sept			Season		
Age Class	n[b]	%	SE[c]	n	%	SE	n	%	SE	n	%	SE
4	3	0.6	0.3	6	1.1	0.5	6	4.2	1.7	15	1.3	0.3
5	33	6.6	1.1	85	15.8	1.6	31	21.8	3.5	149	12.6	1.0
6	251	49.9	2.3	282	52.5	2.2	52	36.6	4.0	585	49.5	1.5
7	181	36.0	2.1	138	25.7	1.9	39	27.5	3.7	358	30.3	1.3
8	28	5.6	1.0	21	3.9	0.8	12	8.5	2.3	61	5.2	0.6
9	7	1.4	0.5	4	0.7	0.4	2	1.4	1.0	13	1.1	0.3
10	0	---	---	1	0.2	0.2	0	---	---	1	0.1	0.1
Total	503	100.0		537	100.0		142	100.0		1,182	100.0	

a Samples from Glacier Lake not included.

b n = sample size.

c SE = standard error of the percentage.

through 9+; χ^2 = 35.26, 47.87, and 20.29, respectively, df = 5, $p < 0.05$). As expected, there was no difference between the age composition of adults and the age composition inferred from LM_{50} for spring sampling (χ^2 = 0.27, df = 8, $p > 0.05$).

Mean Length-at-Age

Mean fork lengths-at-age at each sample location were similar within seasons (Appendices A1 through A3) so all samples within each season were combined (Table 12). While mean length for ages 1 through 3 increased in each successive sampling period (spring through fall), growth of ages 4 through 7 was essentially nonexistent between the spring and summer sample. Growth was evident between the summer and fall sample for ages 4 through 7. The lack of early season growth for adult fish, especially ages 6 and 7, could be attributed to energetic recovery from spawning. Some age 4 and 5 fish would experience a lag in growth because of spawning, however, not all age 4 and 5 fish spawn. The spring sample was probably biased towards the largest age 4 and 5 fish, while the summer and fall samples were not. This bias would tend to overestimate mean length in spring and accurately represent mean length during summer and fall. If these suppositions are accurate, the maturity estimates calculated from probit analysis may also be biased and thus should be considered preliminary. If bias is present, maturity samples taken during fall (fish would be sacrificed for internal examination) could give accurate estimates of maturity.

The mean length-at-age for adult males was significantly larger than that of females for ages 6 and greater (Table 13). The male sample had a mean length of 324 mm FL (SD = 19 mm; SE = 1 mm), while females had a mean length of 314 mm FL (SD = 17 mm; SE = 1 mm). The mean length of the combined sample was 319 mm FL.

Relative Stock Density

The RSD for fifteen samples collected within the Tangle System varied depending on location and time of sampling (Figure 9; Appendix A4). Stock size fish (150 to 269 mm FL) were most numerous in the Upper Tangle and Tangle rivers, the head of Upper Tangle Lake, Rock Creek, and the thoroughfare at mid-Long Tangle Lake. Quality size fish (270 to 339 mm FL) were predominant in the samples from spawning areas, from Landmark Gap Creek, in the harvest sample, and from the lower and upper Delta River. Preferred size fish (340 to 449 mm FL) were most numerous in the Glacier Lake sample. No memorable or trophy-sized fish (minimum lengths of 450 and 560 mm FL, respectively) were present in any of the samples.

The RSD indices for adult male Arctic grayling were 80% quality and 20% preferred fish, while adult females were 93 and 7%, respectively (Appendix A5). These RSD indices were significantly different (χ^2 = 17.44, df = 1, $p < 0.05$) among the sexes.

The RSD indices for the spring adult, the spring LM_{50}, and the summer LM_{50} samples were identical and comprised two size categories: quality (86%) and preferred (14%), while the LM_{50} fall sample contained 61% and 39% of these

Table 12. Summary of mean fork length-at-age for Arctic grayling in combined seasonal samples from the Tangle Lakes system, 1989.

Age Class	Spring 23 May - 10 June			Summer 2 - 21 July			Fall 29 Aug - 29 Sept		
	n[a]	FL[b]	SD[c]	n	FL	SD	n	FL	SD
0	0	---	---	0	---	---	24	83	7
1	6	103	7	8	113	15	77	148	14
2	65	159	13	61	180	22	95	198	15
3	136	210	12	231	223	15	65	230	17
4	40	256	18	172	256	16	38	267	20
5	108	282	16	234	283	18	44	300	17
6	274	310	15	348	307	15	54	327	17
7	182	327	13	151	333	14	39	347	15
8	28	348	13	46	359	15	12	362	9
9	7	353	25	23	377	19	2	392	13
10	0	---	---	6	388	14	0	---	---
11	0	---	---	1	402	---	0	---	---
Total	846	280	58	1,281	280	51	450	227	80

[a] n = sample size.

[b] FL = mean fork length at age.

[c] SD = sample standard deviation of FL.

Table 13. Mean fork length-at-age for mature male and female Arctic grayling sampled from five locations[a] in the Tangle Lakes system, 23 May through 10 June 1989.

Age Class	Males			Females			Both		
	n[b]	FL[c]	SD[d]	n	FL	SD	n	FL	SD
4	1	297	---	1	303	---	2	300	3
5	12	301	12	19	294	14	31	297	13
6	115	316	15	128	309	12	243	312	14
7	99	330	12	82	324	14	181	327	13
8	19	355	11	9	335	6	28	348	13
9	5	365	10	2	322	24	7	353	25
Total	251	324	19	241	314	17	492	319	18

a 18 Mile and Clear creeks, heads of Mud, Upper Tangle, and Long Tangle lakes.

b n = sample size.

c FL = mean fork length at age in millimeters

d SD = sample standard deviation of FL.

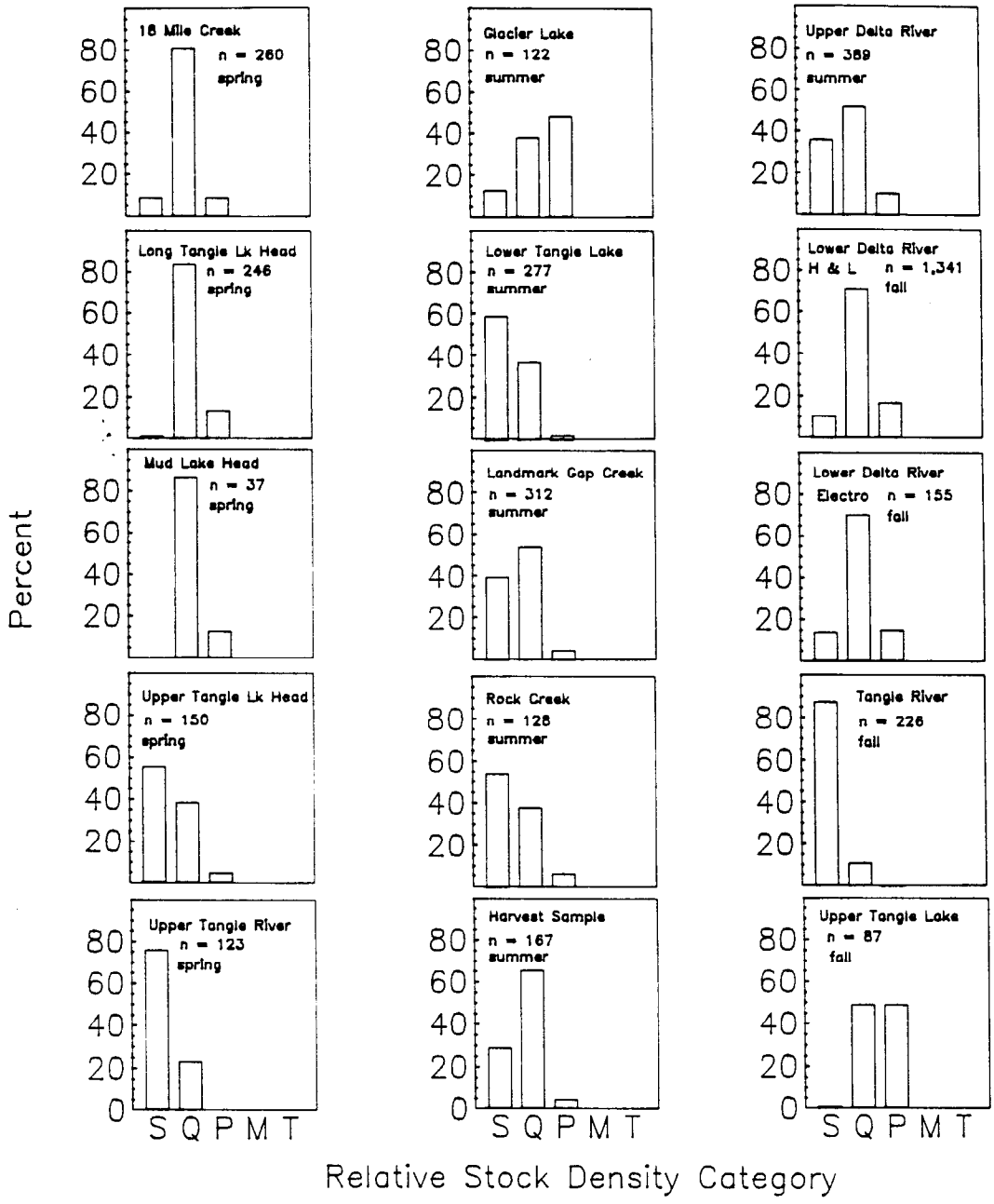

Figure 9. Comparison of Relative Stock Density (RSD) indices for Arctic grayling from fifteen samples in the Tangle Lakes system, 23 May through 29 September 1989.

categories, respectively (Figure 10; Appendix A5). There was no significant difference between RSD indices from the adult sample and the combined LM_{50} samples ($\chi^2 = 2.75$, df = 1, $p > 0.05$; Appendix A5).

1989 Recaptures

Population sampling recovered 134 tagged Arctic grayling, 5.4% of the total sample for 1989 (≥ 200 mm FL). These recoveries were augmented by 70 recoveries of tagged fish by anglers who reported a specific location of recovery[4]. A simplification of spatial and temporal aspects of marks and recaptures (a summary matrix of recaptures) implied significant movements both upstream and downstream from tagging locations (Table 14). The largest proportion of recaptures in six of the 10 locations came from fish tagged and released at the same location from which they were recovered (no movement). Exceptions to this observation were for fish tagged in Clear and 18 Mile creeks, Round Tangle Lake, and areas above Upper Tangle Lake. Of those fish tagged at locations in the middle of the Tangle System, approximately equal numbers of fish were recovered both upstream and downstream. The recovery in Glacier Lake of four fish tagged in Rock Creek, exactly one year after tagging, suggests more effort be directed in Glacier Lake and the inlet to Glacier Lake. This location may support spawning Arctic grayling.

Mixing Rates

An estimate of mixing rates of Arctic grayling among their major spawning, summer feeding, and overwintering areas was not generated due to an insufficient number of tag recoveries and a lack of tagged fish released during spring and fall. A total of 5,686 Arctic grayling have been tagged and released in the Tangle System above the Delta River falls since 1986 (Appendix A6). Sampling and angler returns in 1988 and 1989 have produced 321 recaptures[5] (Appendix A7). Spawning areas were not located and sampled until 1989. The sampling of these three areas (heads of Mud and Long Tangle lakes and 18 Mile Creek) yielded only 13 recaptures (2.3% of 559 fish ≥ 200 mm FL sampled; Table 2). Sixty-six percent of all fall tagging has been in only two areas, the Tangle and upper Delta rivers. These early September samples are likely not indicative of overwintering areas. Also, the fact that immature fish were almost totally absent from the spawning areas (Figure 2) indicates that movements and mixing rates of immature and adult fish may be different. This differential movement needs quantification and, if valid, will require stratification of the mixing rate estimate and require a greater number of recaptures. Extrapolation from recapture rates (Appendix A7) and a similar 1989 sample size, indicates that sampling efforts in 1990 should produce a minimum of 340 recaptures. Also, Clark and Ridder (1988) reported 45 recaptures of 1986 and 1987 tags that have yet to be used for analysis of mixing rates. Thus, approximately 700 recaptures will probably be available

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[4] Anglers returned a total of 82 tags including 7 tags from the lower Delta River.

[5] Includes 204 recoveries made in 1989 and 117 recoveries made in 1988. The 1988 recoveries differ from those reported in Baker (1989) since recoveries made within seven days of release and in the same location have been excluded.

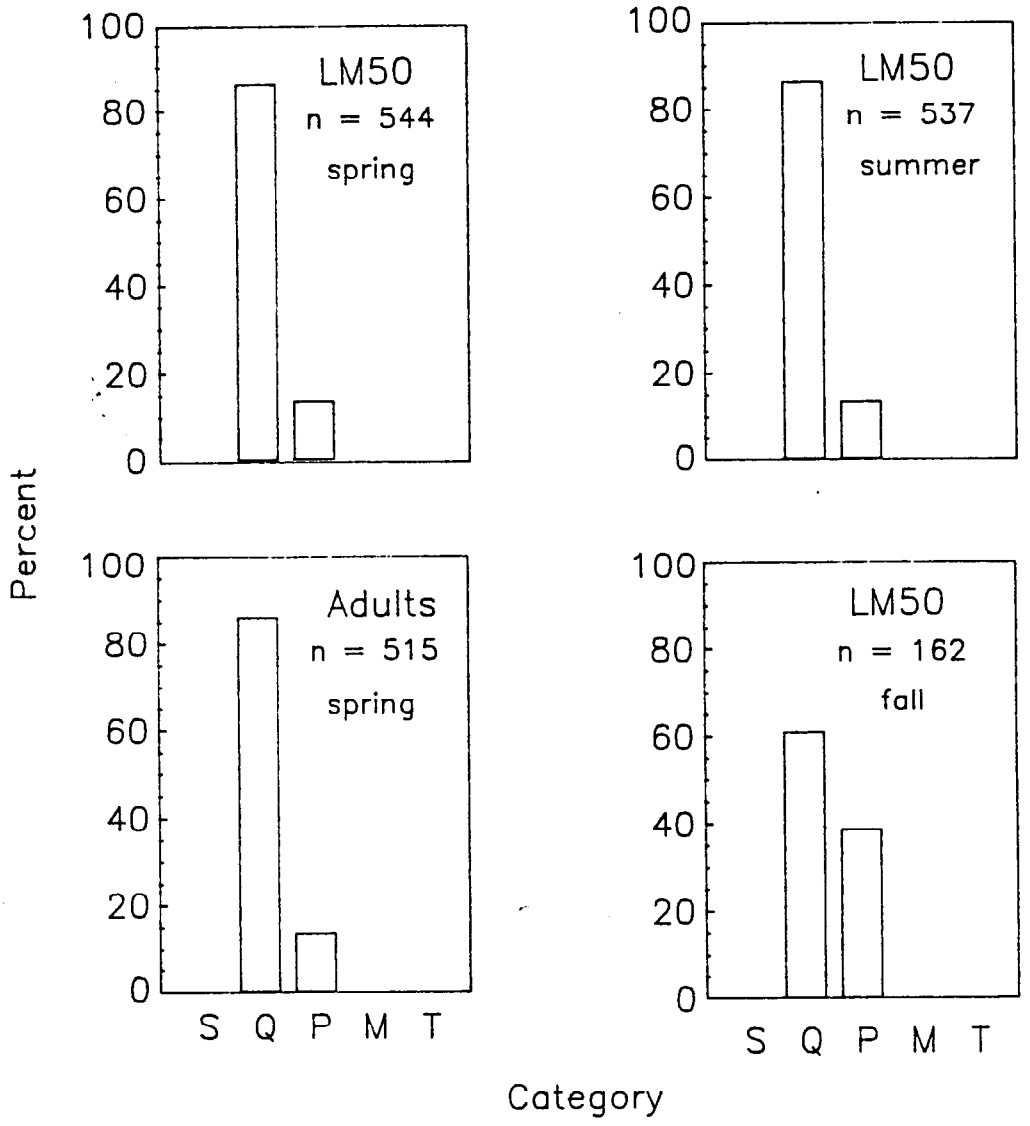

Figure 10. Comparison of Relative Stock Density (RSD) indices for mature Arctic grayling as determined by sexual characteristics and LM_{50} criteria in the Tangle Lakes system during 1989.

Table 14. Summary matrix of 1989 recapture locations of Arctic grayling tagged in the Tangle Lakes system from 1986 through 1989.

Tagging Location	Location Codes	Number of Recaptures: 1986	1987	1988	1989[a]	Total	Recapture Locations: 1	2	3	4	5	6	7	8	9	10
1 Upper Delta River-Long Tangle Lake	075 - 250	0	0	41	2	43	29	2	4	-	1	4	2	1	-	-
2 Shallow Tangle Lake	251 - 325	0	2	1	7	10	2	5	1	-	-	1	1	-	-	-
3 Clear & 18 Mile creeks	380 - 395	0	0	6	12	18	2	1	3	6	4	1	1	-	-	-
4 Landmark Gap Lake & Creek	360 - 375	0	0	10	6	16	-	-	2	8	2	1	-	2	1	-
5 Round Tangle Lake	400 - 490, 350	0	2	3	0	5	1	-	1	1	-	1	-	1	-	-
6 Tangle River	500 - 502	3	18	23	1	45	1	-	4	2	1	29	1	5	2	-
7 Upper Tangle Lake	600 - 605, 690	0	0	29	2	31	1	-	-	2	2	8	9	6	3	-
8 Upper Tangle River & Lakes	695 - 901	0	0	7	13	20	2	-	-	1	1	6	2	2	6	-
9 Rock Creek	610 - 640	0	0	10	6	16	-	-	-	-	-	-	1	1	10	4
10 Glacier Lake	488	0	0	0	0	0	-	-	-	-	-	-	-	-	-	-
Totals		3	22	130	49	204	38	8	15	20	11	51	17	18	22	4

[a] Recaptures of 1989 tags made within 6 days of tagging and in same location not included (n = 31). Also includes 70 recaptures reported by anglers.

for analysis with 420 being immature fish (< LM_{50}) and 280 being mature fish (> LM_{50}).

To estimate a mixing rate, sampling in 1990 should concentrate on spawning and overwintering areas. Spring sampling effort should be increased in the Upper Tangle River. Other potential spawning areas such as the inlets to Glacier and Landmark Gap lakes, the head of Lower Tangle Lake, and the upper Delta River should also be sampled. Sampling of overwintering areas should commence on 15 September and continue until freeze-up and employ purse seines, gill nets, and electrofishing. Sampling of feeding areas should be expanded to include all of Rock and Landmark Gap creeks.

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APPENDIX A

Appendix A1. Mean fork length at age for Arctic grayling sampled from four locations in the Tangle Lakes system, 23 May through 10 June 1989.

	18 Mile Creek 23 May - 8 June Hook and Line			Long Tangle Lake Head 31 May - 10 June Hook and Line			Upper Tangle Lake Head 2 - 7 June Hook and Line			Upper Tangle River 9 June Seine		
Age Class	n[a]	FL[b]	SD[c]	n	FL	SD	n	FL	SD	n	FL	SD
1	0	---	---	0	---	---	0	---	---	2	107	3
2	1	158	10	0	---	---	12	170	7	31	158	15
3	2	213	14	0	---	---	60	211	13	52	211	9
4	11	258	16	3	268	10	9	254	13	13	244	11
5	48	280	15	21	288	15	12	281	8	16	274	11
6	108	309	14	104	311	14	25	311	15	14	297	12
7	70	328	14	83	326	13	17	327	9	3	321	9
8	8	342	14	16	352	12	3	352	3	1	337	---
9	1	398	---	5	365	10	1	346	---	0	---	---
Total	249	306	28	232	318	22	139	255	56	132	220	51

[a] n = sample size.
[b] FL = mean fork length-at-age.
[c] SD = sample standard deviation of FL.

Appendix A2. Mean fork length at age for Arctic grayling sampled[a] from five locations in the Tangle Lakes system, July 1989.

	Rock Creek 5 - 6 July			Glacier Lake 6 - 12 July			Landmark Gap Creek 10 - 21 July			Long Tangle Lake Thoroughfare 12 & 18 July			Upper Delta River 19 - 20 July		
Age Class	n[b]	FL[c]	SD[d]	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	7	113	14	0	---	---	4	118	13	13	125	12	1	141	---
2	32	178	22	0	---	---	16	176	20	63	177	13	50	182	13
3	51	217	19	0	---	---	45	221	15	66	223	13	59	227	13
4	47	251	16	13	250	15	31	261	22	23	257	14	28	260	10
5	25	291	17	20	283	19	72	275	19	33	285	15	50	288	12
6	30	312	13	22	317	14	87	305	19	60	301	13	98	311	13
7	14	330	10	13	339	12	23	329	19	17	330	14	64	334	13
8	3	356	3	24	358	16	2	347	10	2	350	3	13	361	16
9	1	393	---	19	375	19	1	380	---	0	---	---	2	388	16
10	0	---	---	5	387	14	1	394	---	0	---	---	0	---	---
11	0	---	---	1	402	---	0	---	---	0	---	---	0	---	---
Total	210	249	58	117	329	45	282	263	57	277	242	58	365	280	55

a Gear type was hook and line except for Glacier Lake which was gill net.

b n = sample size.

c FL = mean fork length-at-age.

d SD = sample standard deviation of FL.

Appendix A3. Mean fork length at age for Arctic grayling sampled[a] from two locations in the Tangle Lakes system, 30 August through 29 September 1989.

Age Class	Tangle River 29 - 31 August				Upper Tangle Lake 28 - 29 September			
	n[b]	Mean	SD[c]	SE[d]	n	Mean	SD	SE
0	24	83	7	1	---	---	---	---
1	105	148	11	1	---	---	---	---
2	86	198	16	2	---	---	---	---
3	42	233	15	2	---	---	---	---
4	19	262	19	4	2	269	19	19
5	12	295	15	4	14	306	13	4
6	4	306	24	14	28	332	13	3
7	1	314	---	---	27	351	13	3
8	0	---	---	---	9	366	7	2
9	0	---	---	---	1	379	---	---
Total	293	187	56	3	81	337	25	3

[a] Sampling by beach seine at Tangle River; by purse seine (n = 63) and hook and line (n = 28) at Upper Tangle Lake at the mouth of Rock Creek.
[b] n = sample size.
[c] SD = sample standard deviation.
[d] SE = standard error.

Appendix A4. Summary of Relative Stock Density (RSD) indices for Arctic grayling (≥ 150 mm FL) sampled from the Tangle Lakes system by area, date, and gear type during 1989.

		RSD Category[a]				
		Stock	Quality	Preferred	Memorable	Trophy
18 Mile Creek:						
23 May - 8 June						
H&L[b]	n[c]	24	212	24	0	0
	%[d]	9.2	81.5	9.2	---	---
	SE[e]	1.8	2.4	1.8	---	---
Long Tangle Lake Head:						
31 May - 10 June						
H&L	n	4	207	35	0	0
	%	1.6	84.1	14.2	---	---
	SE	0.8	2.3	2.2	---	---
Mud Lake Head:						
31 May						
H&L	n	0	33	4	0	0
	%	---	86.8	13.2	---	---
	SE	---	5.5	5.5	---	---
Upper Tangle Lake Head:						
2 June, 7 June						
H&L	n	84	58	8	0	0
	%	56.0	38.7	5.3	---	---
	SE	4.1	4.0	1.8	---	---
Upper Tangle River:						
9 June						
Seine	n	94	29	0	0	0
	%	76.4	23.6	---	---	---
	SE	3.8	3.8	---	---	---
Harvest Sample[f]:						
2 July - 3 July						
H&L	n	49	110	8	0	0
	%	29.3	65.9	4.8	---	---
	SE	3.5	3.7	1.7	---	---

- Continued -

		RSD Category[a]				
		Stock	Quality	Preferred	Memorable	Trophy
Rock Creek:						
5 July - 7 July						
H&L	n	70	49	9	0	0
	%	54.7	38.3	7.0	---	---
	SE	4.4	4.3	2.3	---	---
Glacier Lake:						
6 July - 12 July						
Gill net	n	16	47	59	0	0
	%	13.1	38.4	48.4	---	---
	SE	3.1	4.4	4.5	---	---
Landmark Gap Creek:						
10 July - 23 July						
H&L	n	125	170	17	0	0
	%	40.1	54.5	5.4	---	---
	SE	2.8	2.8	1.3	---	---
Long Tangle Lake[s]:						
12 July, 18 July						
H&L	n	165	104	8	0	0
	%	59.6	37.5	2.9	---	---
	SE	2.9	2.9	1.0	---	---
Upper Delta River:						
19 July - 20 July						
H&L	n	142	205	42	0	0
	%	36.4	52.6	10.8	---	---
	SE	2.4	2.5	1.6	---	---
Tangle River:						
30 August - 31 August						
Seine	n	199	26	1	0	0
	%	88.1	11.5	0.4	---	---
	SE	2.2	2.1	0.4	---	---

- Continued -

		RSD Category[a]				
		Stock	Quality	Preferred	Memorable	Trophy
Upper Tangle Lake[h]:						
28 Sept. - 29 Sept.						
H&L, seine	n	1	43	43	0	0
	%	1.1	49.4	49.4	---	---
	SE	1.1	5.4	5.4	---	---
Lower Delta River:						
22 Aug. - 25 Aug.						
H&L	n	191	946	204	0	0
	%	14.2	70.5	15.2	---	---
	SE	1.0	1.2	1.0	---	---
Lower Delta River:						
22 Aug. - 25 Aug.						
electrofishing	n	17	111	27	0	0
	%	11.0	71.6	17.4	---	---
	SE	2.5	3.6	3.0	---	---

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

[b] H&L = hook and line.

[c] n = sample size in RSD category.

[d] % = percent of RSD category in total sample.

[e] SE = standard error of percentage.

[f] Harvest sample from miscellaneous locations.

[g] Exact location is thoroughfare in middle of lake.

[h] Exact location is at mouth of Rock Creek.

Appendix A5. Summary of Relative Stock Density (RSD) indices for mature Arctic grayling as determined by sexual characteristics and LM_{50} criteria in the Tangle Lakes system during 1989.

		RSD Category[a]				
		Stock	Quality	Preferred	Memorable	Trophy
Adults[b]:						
23 May - 10 June	n[c]	0	444	71	0	0
	%[d]	---	86.2	13.8	---	---
	SE[e]	---	1.5	1.5	---	---
Males[b]:						
23 May - 10 June	n	0	213	53	0	0
	%	---	80.1	19.9	---	---
	SE	---	2.4	2.4	---	---
Females[b]:						
23 May - 10 June	n	0	231	18	0	0
	%	---	92.8	7.2	---	---
	SE	---	1.6	1.6	---	---
LM50[f]:						
23 May - 10 June	n	0	469	75	0	0
	%	---	86.2	13.8	---	---
	SE	---	1.5	1.5	---	---
LM50:						
2 July - 21 July	n	0	464	73	0	0
	%	---	86.4	13.6	---	---
	SE	---	1.5	1.5	---	---
LM50:						
30 Aug. - 29 Sept.	n	0	99	63	0	0
	%	---	61.1	38.9	---	---
	SE	---	3.8	3.1	---	---

- Continued -

Appendix A5. (page 2 of 2)

		RSD Category[a]				
		Stock	Quality	Preferred	Memorable	Trophy
LM50:						
Season	n	0	1,032	211	0	0
	%	---	83.0	17.0	---	---
	SE	---	1.1	1.1	---	---

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

[b] Determined by sexual dimorphism or presence of sex products.

[c] n = sample size in RSD category.

[d] % = percent of RSD category in total sample.

[e] SE = standard error of percentage.

[f] Fish greater than 288 mm FL.

Appendix A6. Summary of numbers of Arctic grayling tagged by year, season, and location in the Tangle Lakes system from 1986 through 1989.

Tagging Location	Location Codes	Number of Tags														
		1986			1987			1988			1989			Total		
		sp[a]	s[a]	f[a]	sp	s	f	sp	s	f	sp	s	f	sp	s	f
1 Upper Delta River-Long Tangle Lake	075 - 250	0	0	0	0	0	0	0	583	407	6	512	0	6	1,095	407
2 Shallow Tangle Lake	251 - 325	0	0	0	0	75	0	0	67	6	241	0	22	241	142	28
3 Clear & 18 Mile creeks	380 - 395	0	0	0	0	2	0	0	77	0	246	11	0	246	90	0
4 Landmark Gap Lake & Creek	360 - 375	0	0	0	0	0	0	0	292	0	0	267	6	0	559	6
5 Round Tangle Lake	400 - 490, 350	0	0	26	0	23	10	0	138	0	2	1	34	2	162	70
6 Tangle River	500 - 502	0	0	181	0	159	309	0	28	240	0	4	114	0	191	845
7 Upper Tangle Lake	600 - 605, 690	0	0	11	0	17	0	348	67	14	22	0	103	370	84	132
8 Upper Tangle River & Lakes	695 - 901	0	0	0	0	0	0	23	19	163	251	8	0	271	27	163
9 Rock Creek	610 - 640	0	0	0	0	0	0	0	32	220	0	172	3	0	204	223
10 Glacier Lake	488	0	0	0	0	0	0	0	0	0	0	95	11	0	95	11
Totals:	All	0	0	218	0	276	319	371	1,303	1,050	765	1,070	293	1,136	2,649	1,885
	< 289 mm FL	0	0	209	0	274	311	212	739	599	255	535	155	467	1,548	1,276
	> 288 mm FL	0	0	9	0	2	8	159	564	451	510	535	139	669	1,101	609

[a] Sp = spring, 15 May through 15 June; s = summer, 16 June through 15 August; f = fall, 16 August through 15 October.

Appendix A7. Summary of 1988 and 1989 recaptures[a], total number marked, and recapture rates[b] of Arctic grayling (≥ 200 mm FL) sampled from the Tangle Lakes system[c] by season[d], 1986 through 1989.

	Tags				Recaptures				
Year	Spring	Summer	Fall	Total	Spring	Summer	Fall	Total	R/M
1986	0	0	218	218	3	4	2	9	4.1%
1987	0	276	319	595	22	34	13	69	11.6%
1988	371	1,303	1,050	2,724	29	112	53	194	7.1%
1989	765	1,070	298	2,133	2	29	18	49	2.3%
Totals:	1,136	2,649	1,885	5,670	56	179	86	321	5.7%
<289 mm:	467	1,548	1,276	3,291	36	111	47	194	5.9%
>288 mm:	669	1,101	609	2,379	20	68	39	127	5.3%

[a] Recaptures include voluntary angler returns.
[b] Recapture rate = recaptures divided by number marked times 100.
[c] Excludes lower Delta River.
[d] Spring, 15 May through 15 June; summer, 16 June though 15 August; fall, 16 August through 15 October.